

General Equilibrium Models for the Chilean Economy

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GENERAL EQUILIBRIUM MODELS: AN OVERVIEW

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The development of general equilibrium models (GEMs) goes back a long way in economics, both at a theoretical level and as a tool for empirical analysis. General equilibrium theory and modeling have proved to be relevant and useful for understanding economic interactions between markets and agents in complex modern economies and the determination of prices and quantities as a result of the latter interactions. Applied GEMs have been developed and used to address a wide range of theoretical questions and empirical/policy issues, in the fields of macroeconomics, international trade, public finance, and environmental analysis, among others. GEMs are used for many purposes, including simulation of policy changes and response to exogenous shocks, as well as forecasting (mostly macroeconomic) variables.

Following international experience, general equilibrium analysis and modeling are increasingly applied as tools that assist in better understanding the Chilean economy. GEMs are developed and used in Chile on a wide range of policy questions and areas, including macroeconomic, trade, environmental, and tax policy. The purpose of this book—the first of its kind in Chile—is to publish a representative collection of recent GEM research and

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applications that illustrate the usefulness and relevance of frontier general equilibrium tools to better understand the aggregate structure and policy response of the Chilean economy. They should be of interest to academics and policymakers in Chile and elsewhere, for several reasons.

First, Chile is known for implementing bold and innovative economic policies. Chile's political bodies, its leaders, and its society at large, have seriously considered policy reforms proposed by economists. The profession has returned this trust by providing careful assessments of policies, formalizing and quantifying their potential effects by using the types of models presented in this book.

Second, this volume publishes a variety of methodological choices that are available to address key issues. The thoughtful combination of empirical and theoretical considerations informs the user about model strengths and weaknesses and the types of questions that they are able to tackle.

Third, the volume also presents some novel methodological contributions to the empirical and theoretical literature on general equilibrium models. Issues such as how to better characterize the dynamic interactions of agents or how to combine theoretical and econometric models, along with a presentation of the limitations of some of the modeling choices available, are of interest to a wide readership with academic and applied interests.

Finally, by putting together a broad sample of frontier GEM research and applications on policy issues, we expect to motivate future research on these issues and new policy areas, and questions not previously subjected to general equilibrium modeling.

What is a GEM and where are the boundaries between a GEM and a non-general equilibrium model? We limit our review to models that deal with interactions between and outcomes of economic decisions by different aggregations of agents and in different markets, representing a dominant part of an economy. However, these limits are diffuse in practice and therefore our decisions about inclusion or exclusion of particular models in this review may be disputed.

The next section provides a brief overview of the development and application of three families of GEMs that are of relevance to this book. We then refer selectively to GEMs developed previously for Chile. Against this historical background, we summarize the scope and main results of the GEMs presented in each of the chapters of this book. We close with concluding remarks.

1. GENERAL EQUILIBRIUM MODELING

General equilibrium analysis marks an old tradition in economics that started in the nineteenth century. General equilibrium modeling was developed in the interwar period and was spurred by mathematical and computational advances since the 1960s. Next we describe the international development of three important families of models: macroeconomic GEMs, computable general equilibrium (CGE) models, and overlapping generations (OLG) models. Also here we note that the boundaries between families of models—and our decision about including or excluding particular models—can be arbitrary.¹

1.1 Macroeconomic GEMs

Analyzing aggregate economic phenomena from a general equilibrium perspective began with Walras's publication of *Eléments* in the late nineteenth century (Walras, 1874). However, it was not until Keynes's *General Theory* that general equilibrium analysis was first developed to understand macroeconomic fluctuations in general and the Great Depression in particular (Keynes, [1936] 1964). Modeling goods, financial, and labor markets allowed for a unified treatment of short and medium-term effects of macroeconomic policies on output, providing a cornerstone of the ongoing debate between different schools of macroeconomic thought.²

1. For example, a multi-sector dynamic stochastic model with nominal, real, and financial variables, together with households disaggregated by overlapping age groups, could be included in any family. Our minimum requirement for a macroeconometric model is the inclusion of endogenous real (and typically also nominal) variables with (at least) an equilibrium condition for aggregate goods markets. Behavioral models of macroeconometric models are typically validated by econometric estimation from time-series data but at times calibrated to time-series data or estimated from cross-section data. Macroeconomic models that focus either on aggregate output or on aggregate prices or wages do not qualify for inclusion. Our minimum requirement for a CGE model is a multi-sector specification with endogenous general-equilibrium determination of sector-level and aggregate quantities and prices. Our minimum requirement for an OLG model is a multi-cohort specification with endogenous general-equilibrium determination of cohort-level and aggregate quantities and prices. Behavioral equations in CGE and OLG models may be empirically validated by econometric estimation, calibration from input-output matrices or household surveys, or econometrically estimated from time-series or cross-section data.

2. Blanchard (2000) and Morishima (2003) provide recent overviews of the development of macroeconomic and general-equilibrium modeling.

Keynes's qualitative framework triggered a new generation of ideas and literature that aimed at providing structure and formality to macroeconomic general equilibrium analysis. Hicks (1936) made a major contribution in specifying a system of simultaneous equations for different markets. The first treatment of dynamic general equilibrium analysis can be traced back to Hicks's subsequent work (1939), as well as La Volpe's (1936) study, in which current behavior is influenced by backward- and forward-looking expectations. Arrow and Debreu (1954) made path-breaking progress in the treatment of uncertainty in general equilibrium analysis, by modeling contingent asset claims required for market completion.

Patinkin (1956) further formalized macroeconomic general equilibrium models, by explicitly deriving demand and supply equations from microeconomic fundamentals, embedded in value and firm theory, respectively. Tinbergen's (1939) pioneering model building, extending from the 1930s through the 1960s, and the Cowles Commission's support for modeling contributed to huge advances in the development of applied macroeconometric models for forecasting and policy analysis. Parallel progress in computing power led to the building and use of large-scale simultaneous-equation macroeconomic models, often comprising hundreds of equations. A paramount example is the Federal Reserve Bank-MIT-Penn model for the United States (Zellner, 1969). This class of Keynesian models, which saw their heyday in the 1960s and 1970s, was widely used for macroeconomic analysis and projections.

The two-gap models for open developing economies represent another strand of Keynesian models, which generalize the Harrod-Domar growth model. Under fixed prices, a binding foreign resource constraint restricts growth either through investment or imports (Chenery and Bruno, 1962; McKinnon, 1964; Chenery and Strout, 1966). A large number of both macroeconometric and multi-sector planning models built for developing countries from the 1960s through the 1980s had the two-gap model at their core.

An extreme strand of Keynesian macroeconomic modeling based on price rigidities and unemployment are the GEMs of market disequilibrium (Barro and Grossman, 1971; Benassy, 1982). This mostly theoretical—and largely abandoned—literature takes price rigidity to the limit, deriving the spillover effects of disequilibrium from one market to other in a Walrasian multi-market framework.

Financial programming models developed at the IMF in the 1960s represent a quite different approach to macroeconomic general

equilibrium modeling. The core of the latter models is comprised by flow budget constraints for the government and the external sector (the balance-of-payments restriction), a goods-markets (saving-investment) equilibrium condition, a money supply equation, and a few behavioral equations. Financial programming models are applied still to date for budgetary and monetary programming purposes by some countries and in country work at the IMF.

The families of Keynesian macroeconomic models—and the financial programming models as well—generally lacked microeconomic foundations, were not consistent with intra- and inter-temporal budget constraints, did not treat expectations in a satisfactory way, and had no well-defined steady-state equilibrium. With hindsight, they were severely affected by the Lucas's (1976) critique, implying that their specification was not useful for analyzing the effects of policy changes, as forward-looking agents would modify their behavior as a response to them.

A paradigmatic shift in macroeconomics—and hence in macroeconomic general equilibrium modeling—came with the rational expectations revolution. Based on Muth's (1961) insightful but long-neglected notion, Lucas (1972) and Sargent (1973) stress that in dynamic environments with forward-looking agents, the mechanism through which expectations are formed has to be explicitly stated. Lucas's (1976) critique to econometric policy evaluation and Lucas and Sargent's (1981) manifesto sealed the fate of the once-powerful traditional large-scale macroeconomic models in favor of internally consistent and micro-founded macroeconomic models. These advances fostered research on theoretical tools needed to understand and characterize the equilibrium outcomes of new models and to develop numerical techniques necessary to solve, simulate, and estimate them. Technological progress and the accessibility of cheaper and faster computational methods have also played an important role in characterizing key properties of increasingly complex structures.

Consideration of a stochastic environment, microeconomic foundations, and rational expectations gave rise to the new literature on real-business cycle (RBC) models, pioneered by Kydland and Prescott (1982) and Long and Plosser (1983). RBC models developed explanations for short-term fluctuations driven largely by technological shocks.

The New Keynesian literature incorporated rational expectations into macroeconomic models with nominal rigidities, such as staggered wage contracts (Taylor, 1981), staggered prices (Calvo, 1983), menu

costs (Mankiw, 1985), efficiency wages (Shapiro and Stiglitz, 1984), or other real rigidities to account for short-term deviations from full employment (Clarida, Galí, and Gertler, 1999).

Obstfeld and Rogoff's (1995) *Redux* model paved the way for the quick development of micro-founded rational-expectations models for open economies—what came to be known as the new open economy macroeconomics (Lane, 2001).

A major disadvantage of many empirical structural models based only on microeconomic fundamentals—reflected in a sparse specification that avoids ad hoc variable inclusion—is their poor tracking of short-run dynamics and their unsatisfactory short-term predictive ability. This (and Sims's 1980 critique of large-scale macroeconometric models) has led to the development of non- (and semi-) structural vector autoregression models (VARs), based on statistically observed dynamic relations among a small number of key macroeconomic variables. VARs are popularly used for generating impulse responses to temporary shocks, variance decompositions, and short-term projections, but because they lack behavioral structure, they are not useful for understanding structural relations, generating long-term projections, or simulating permanent changes in predetermined variables. Hence, VARs are empirically useful but not more than complementary tools to structural general equilibrium models for empirical analysis.

Recent progress in macroeconomic general equilibrium modeling is represented by mid-sized open economy models that combine a rich stochastic structure with rational expectations and microeconomic foundations. Some of them also include imperfect competition in goods, labor, asset, and financial markets, with nominal or real rigidities (or both) in the short run. Examples of this so-called new neoclassical synthesis with Keynesian elements include Smets and Wouters (2003) and Laxton and Pesenti (2003).

1.2 Computable General Equilibrium Models

Beyond macroeconomics, a family of models termed computable general equilibrium (CGE) models focuses on issues related to resource allocation across different supply sectors, relative prices of goods and factors of production, and welfare levels of different income groups. Economy-wide planning models—developed between the 1950s and 1970s—were predecessors to CGE models. Planning models—used in countries with a large government role in determining sector

prices and quantities—combined macroeconomic (and particularly fiscal) policy analysis with aggregate and sector-level budgeting and planning. Multisector planning models were based on social-accounting matrices, integrating fiscal, balance-of-payments and national accounts. Many planning models for developing countries embedded two-gap models for a binding foreign resource constraint. Planning models typically lacked microeconomic foundations at the level of economic agents and endogenous price determination, but some were based on explicit optimization of a central-planning objective function.³

CGE models with endogenous prices grew out of the multisector planning models of the 1960s.⁴ Johansen (1960) developed the first empirical model with a multi-sector structure and endogenous prices to analyze economic growth in Norway. Harberger (1962) followed suit, providing the first numerical application to tax policy analysis in a two-sector model. Scarf (1967) contributed advances in the development of algorithms for solving increasingly complex models. Since then, the development of CGE models has grown exponentially. Their fields of application include fiscal policy and optimal taxation (for example, Slemrod, 1983), trade policy (Devarajan and Rodrik, 1989), income distribution (Bandara, 1991), sector development (such as Robinson and others, 1993, for agriculture), and environmental issues (Kokoski and Smith, 1987).

More recent CGE models on trade issues have provided measurements of the effects of lower bilateral and multilateral tariffs stemming from regional free-trade agreements, particularly within the European Union. These models allow the assessment not only of aggregate trade, productivity, and output effects of trade integration, but also of welfare, transfer, and labor mobility effects, both across sectors and across workers with different skills (for example, Rollo and Smith, 1993; Keuschnigg and Kohler, 2000). CGEs on environmental issues include measurements of intergenerational and multisector effects of policies such as cutting tolerated toxic emissions levels, raising contamination (green) taxes, and levying mining extraction (Bohringer and Rutherford, 1996; Rutherford, 2000; Jensen, 2000).

3. Blitzer, Clark, and Taylor (1975) review a representative sample of economy-wide planning models.

4. Shoven and Whalley (1984) review the development of CGEs through the early 1980s. Devarajan and Robinson (2002) provide a recent survey of CGE models.

Standard CGE models disaggregate by supply sectors, industries, regions, and countries, providing a system of sector demand and supply equations. Sector equilibrium conditions, with appropriate treatment of interdependence and aggregate consistency, determine the economy's general equilibrium. Once a base-case solution is found and numerically determined, the effects of particular policy changes on equilibrium prices and quantities—and on welfare levels of different population groups—can be assessed. As in the case of all GEM families, CGE models have progressed significantly in their theoretical foundations and computational complexity over the last three decades. Micro-founded behavior has been embodied in the systems of supply and demand equations of CGEs since the late 1970s. This Walrasian characterization of an economy that considers micro-founded interactions of goods and factor markets can be traced back to contributions like De Melo's (1977) application to trade policy analysis. More recently, CGE development has shifted from traditional static to truly dynamic models consistent with intertemporal optimization (for example, Harrison and others, 2000; Dixon and Rimmer, 2002; Bell, Devarajan, and Gersbach, 2003).

1.3 Overlapping Generations Models

Another family of GEMs encompasses overlapping generations (OLG) models, which analyze the general equilibrium properties and growth dynamics of economies inhabited by finitely lived population cohorts that differ in age. OLG models started with Samuelson's (1958) and Diamond's (1965) path-breaking theoretical work on two-cohort OLG models. Feldstein (1974) provided valuable insights on fiscal policy by analyzing intergenerational transfers and long-run effects of alternative fiscal policies in his simplified framework. Auerbach and Kotlikoff (1987) extended the basic OLG framework to consider a realistic setting of fifty-five annual overlapping generations and a more developed specification of preferences and technology.

The latter OLG model and its extensions are still the tool of choice for quantifying dynamic macroeconomic effects of fiscal policy, demographic change, and pension systems. In the realm of fiscal policy, an important application of OLG models is generational accounting, an OLG variant used in assessing the fiscal sustainability and intergenerational income and welfare effects of different government programs. Following the initial work by Auerbach, Gokhale, and Kotlikoff (1994), generational accounting has been applied to assess

fiscal policies in a large number of countries (Kotlikoff and Raffelhüschen, 1999). Since the 1990s OLG applications have been developed to assess the dynamic effects of pension systems and reforms for a large number of countries (for example, Huang, Imrohoroglu, and Sargent, 1997). The major progress in software development and computational power has facilitated the application of increasingly complex OLG country models.

1.4 GEMs Today and into the Future

Today's dynamic general equilibrium models provide a powerful tool for analyzing the impact of different policies in increasingly complex representations of real-world economies. The wide array of models available today offers different combinations of key desirable features, including treatment of dynamics, overlapping generations, heterogeneous agents, multiple sectors, and adequate treatment of uncertainty and expectations. The field still has plenty of room for progress, for example with regard to expectations formation, learning mechanisms, and the treatment of misspecified models.

The huge theoretical and technological progress in general equilibrium theory and applications since the mid-twentieth century has reaped key insights that would not have been possible to grasp by means of simpler models and their limited treatment of dynamics, agent heterogeneity, uncertainty, expectations, sector complexity, and multiple generations. GEMs have provided a framework to conduct a rich intellectual discussion of nonevident dangers and potentials of policy reforms and appear to be the twenty-first century's indispensable toolkit for evaluating, quantifying, and deciding economic policy alternatives.

2. GENERAL EQUILIBRIUM MODELING FOR CHILE

2.1 Macroeconomic GEMs

Macroeconomic modeling started in Chile in the 1960s, although its focus was almost exclusively on the country's historical macroeconomic policy concern: high inflation. The best minds of the day concentrated on explaining inflation as a structural or monetary phenomenon or, eclectically, as a result of combined structural, cost-push, and demand factors. Most empirical studies centered on either

one reduced-form equation for inflation or a system of equations for aggregate inflation, sector inflation measures, and close inflation determinants, but they were not general equilibrium models (see, for example, Harberger, 1963; García, 1964; Lüders, 1968; Cauas, 1970; Behrman, 1973).

Vittorio Corbo and Jere Behrman developed two major macroeconometric models in the Keynes-Tinbergen-Klein tradition around 1970.

Corbo's econometric study of Chilean inflation represents a major general equilibrium macroeconometric model for Chile (Corbo, 1971, 1974). His 70-equation model, estimated on quarterly data for the 1960s, comprises aggregate supply and demand equations for goods, labor, and money markets, as well as auxiliary conditions and identities. The full model was used to simulate the macroeconomic effects of counterfactual wage, monetary, and investment policies during the 1960s.

Behrman's involvement with Chile during the 1960s and 1970s was reflected in many publications on multi-sector and macroeconometric models.⁵ His 172-equation macroeconometric model for Chile includes nine production sectors, aggregate demand components, endogenous money and inflation, as well as fiscal, monetary, and trade policy instruments. The model, estimated on 1945-65 data, was used to simulate the effects of fiscal, monetary, foreign-sector, and labor and income policies (Behrman, 1976, 1977).

Lira (1975a, 1975b) developed a two-sector (copper and non-copper) macroeconometric model for aggregate demand components, output, money, and inflation. The model was applied to simulate counter-factual changes in copper market conditions and domestic policies in Chile during 1956-1968.

Schmidt-Hebbel (1978) developed a two-sector (traded and non-traded goods) model, based on the Salter-Swan-Corden dependent economy model, with sluggish non-traded goods prices. The model was estimated on 1928-1932 data to explain the behavior of output and relative goods prices during the Great Depression in Chile.

Vial (1981) derived a macroeconometric model for a closed economy, with specification of aggregate demand components, labor supply and demand, output, inflation, and wages and estimated on

5. In addition to his two books on Chile, Behrman published parts of his models and related work on Chile's production sectors and macroeconomy in major international journals (Behrman, 1971, 1972a, 1972b, 1972c).

1960-1976 data. The model was used to simulate counter-factual fiscal, monetary, and exchange rate polices during 1965-1970. The latter model was extended by Vial in several directions, including an open-economy version, and used for forecasting purposes as part of Project Link at the University of Pennsylvania. The properties and simulation results of several variants of this model for Chile were compared to similar models developed for other countries (Foxley and Vial, 1986; Vial, 1988; Adams and Vial, 1991). In the tradition of two-gap models, Vial and Le Fort (1986) estimated small models for output growth and aggregate demand components for Chile and other Latin American countries and applied them to simulate the restrictions on prospective 1985-1990 growth imposed by binding foreign-resource constraints.

Corbo (1985) developed a compact model based on a two-sector dependent-economy structure with Keynesian mark-up, an inflation-augmented Philips curve, and purchasing power parity (PPP) deviations of tradable goods prices, extending the Scandinavian model. The model focuses on price and wage dynamics in Chile.

Further progress was made in the 1990s toward developing macroeconomic GEMs for Chile and applying them to policy-relevant questions. Servén and Solimano (1991) developed an empirical macroeconometric model for Chile—with consistent budget constraints and equilibrium conditions for goods and labor markets—that simulate the dynamic path of inflation, the real exchange rate, and domestic and foreign debt in response to several shocks. Corbo and Solimano (1991) developed a similar macroeconometric model and applied it to simulate actual and counter-factual policies, including money-based stabilization in the mid-1970s, exchange-rate-based stabilization in 1978-82, and exchange rate depreciation in the mid-1980s.

Quiroz (1991), one of the first open economy dynamic stochastic general equilibrium (DSGE) models published worldwide, developed a multisector model with adjustment costs in the labor market to account for the dynamic properties of the Chilean real exchange rate. Subsequent DSGE models include Quiroz and others (1991) and Bergoeing and others (2002). Schmidt-Hebbel and Servén (1995, 1996) derived a dynamic deterministic general equilibrium model based on intertemporal optimization and short-term wage and price rigidities, which they used to simulate the dynamic macroeconomic effects of monetary and fiscal policy changes.

The Central Bank's structural model, termed MEP (*Modelo Estructural de Proyecciones*), is the Bank's current workhorse for

macroeconomic projections (Central Bank of Chile, 2003). This quarterly model provides a rich dynamic structure for goods, labor, and financial markets, including a monetary policy reaction function, and Chile's integration into the world's goods and financial markets. The model is in the tradition of neo-Keynesian monetary policy models à la Clarida, Galí, and Gertler (1999), with rigidities in goods and labor markets that allow one to account for short- and medium-term deviations from full-capacity employment and production. However, it lacks microeconomic foundations, consistent stock-flow relationships, and an endogenous steady state.⁶

2.2 Computable General Equilibrium Models

Chile's National Planning Office (Odeplan) and the Center for International Studies at MIT carried out from 1968 to 1970 a joint project of policy-oriented research.⁷ A substantial focus of this project was on the development of a multisector linear programming model for Chile, based on Chile's input-output matrix and national accounts. The model is static and prices are exogenous. It is characterized by different combinations of binding foreign exchange, domestic saving, and foreign investment constraints (in the tradition of the gap models) and is solved by linear-programming maximization of private consumption or GDP. The model was developed at Odeplan and subsequently at Ceplan and Cieplan in several variants and used for policy evaluation and projection purposes. Clark and Foxley (1970a, 1970b, 1973), Clark, Foxley, and Jul (1973), and Foxley (1970, 1972, 1975) presented and used the multi-sector programming model. Applications included derivation of optimal growth paths, simulation of alternative development and trade strategies, simulation of income and consumption redistribution, macroeconomic projection, and investment project evaluation.

Taylor (1973a), also as part of the Odeplan-MIT project, developed the first CGE model for Chile, for two sectors of

6. The development of a dynamic stochastic GEM for Chile is currently underway at the Central Bank of Chile. It combines short-term rigidities and monopolistic competition in goods and labor markets with micro-founded behavioral equations, consistent stock-flow relationships based on intertemporal budget constraints, rational expectations under uncertainty, and convergence to an endogenous steady-state equilibrium.

7. The volume by Eckaus and Rosenstein-Rodan (1973) comprises a significant part of the work that grew out of the Odeplan-MIT project.

production, three sectors of consumption, two types of capital, and labor, and with a binding foreign-resource constraint. The model, based on static preferences and technology, is used for simulating the dynamic (30-year) response of the Chilean economy to trade reform and relaxation of foreign resource constraints. Using a variant of the preceding CGE model, Taylor (1973b) projected Chile's needs of foreign exchange.

Juan E. Coeymans developed in the mid-1970s a large CGE model for Chile, with eighteen production sectors and labor markets. Among other applications, the model was used to assess the effects of trade and pension reforms on resource allocation, relative prices, and employment (Coeymans, 1978, 1980). Schmidt-Hebbel (1988) developed a four-sector dependent-economy CGE model to analyze the general-equilibrium effects of terms-of-trade shocks under a binding foreign resource constraint in Chile. Coeymans and Mundlak (1993) developed a five-sector CGE model with goods and factor markets to analyze sectoral growth in Chile during 1962-82 and its sensitivity to changes in policies and external conditions. Coeymans and Larraín (1994) used a CGE model to simulate the growth effects of a potential free-trade agreement with the United States.

2.3 Overlapping Generations Models

The first OLG model for Chile was developed by Arrau (1991)—one of the first empirical OLG models to assess pension reform for any country in the world. Following Auerbach and Kotlikoff (1987), Arrau incorporated micro-founded equations, intertemporal consumption optimization, and a well-defined steady-state equilibrium for fifty-five cohorts. He calibrated the model to Chile and then used it to analyze the dynamic effects of Chile's pension reform on output and welfare.

Cifuentes (1994) used the Auerbach-Kotlikoff model, calibrated to Chile, to estimate intergenerational redistribution effects of the 1979 parametric reform (rise in retirement ages and changes in financing) of the then existing pay-as-you-go pension system. Subsequently, Cifuentes (1995), also using the Auerbach-Kotlikoff model, simulated the dynamic and steady-state macroeconomic and welfare effects of implementing the pay-as-you-go system in Chile and its subsequent replacement by the new fully-funded scheme.

3. OVERVIEW OF BOOK CHAPTERS

This volume compiles twelve GEMs for Chile, developed for and applied to a variety of questions and fields. Seven chapters assess macroeconomic policy changes and external shocks making use of macroeconomic GEMs. Of the latter, the first two chapters develop macroeconometric models that are flexible enough to characterize short- and medium-term dynamics. The next five chapters introduce (deterministic or stochastic) dynamic GEMs grounded on microeconomic foundations.

The subsequent three chapters develop multi-sector CGE models. Of these, the first two assess changes in trade policy and the third analyzes a fuel tax increase. The book's two final chapters assess the general-equilibrium effects of labor taxation (based on a dynamic GEM) and of tax incentives to voluntary retirement savings (using an OLG model).

3.1 Macroeconomic GEMs

Corbo and Tessada develop a small-open-economy macroeconomic model for the output gap, the monetary policy rate, inflation, and the real exchange rate. The model, estimated on quarterly data, is used to simulate the dynamic response of endogenous variables to external shocks and inflation shocks. The results show that adverse foreign output and foreign capital inflow shocks have negative effects on domestic output and inflation, which are much stronger in the case of the capital inflow shock; these effects are partly offset by the central bank's endogenous monetary easing. A positive inflation shock, which triggers a contractionary monetary response, is more persistent and has larger output costs the larger (smaller) is the backward-looking (forward-looking) root of inflation.

García, García, Magendzo and Restrepo develop a seventy-two equation macroeconomic forecasting model that extends the Central Bank's MEP model (Central Bank of Chile, 2003). Their framework comprises a detailed specification of goods markets (including individual aggregate demand and supply components and inflation components), financial and monetary markets (including a monetary policy rule), labor markets, and auxiliary equations and identities. The model includes steady-state conditions and is estimated on quarterly data. The chapter also discusses the main stylized facts of Chile's economy and the transmission mechanisms of monetary policy

reflected by the model. The model is applied to report simulations of the main macroeconomic variables to a temporary monetary shock, which are compared to the impulse responses of a VAR model. The chapter reports simulations of the dynamic response to permanent shocks to government spending and international prices.

Gallego, Schmidt-Hebbel, and Servén develop a dynamic deterministic open economy macroeconometric model to simulate the effects of external shocks and policy changes. The model is based on intertemporal consumption and production optimization, five types of assets (including money), heterogeneous consumers and firms, short-run nominal price and wage rigidities that allow for short-term unemployment, and an endogenous full-employment steady-state equilibrium. The thirty-two equation model is calibrated on plausible parameter values and econometric estimations based on quarterly data. The simulation results report the dynamic response of endogenous variables to the combination of adverse external shocks, expansionary fiscal policy, and contractionary monetary policy observed in 1997–99, which contributed to Chile's 1998–99 recession.

Chumacero and Fuentes combine time series and DSGE models to evaluate the determinants of Chile's growth process since 1960. Their DSGE model incorporates the relative price of investment with respect to consumption goods, terms of trade, and distortionary taxes, and they use it to replicate impulse response functions found in the data. In particular, their simulations suggest that distortionary fiscal policies may offset the benefits of improvements in the quality of capital and increase the economy's volatility.

Duncan develops a DSGE model to replicate several features of the Chilean economy since 1986. The open economy model is based on intertemporal optimization by representative agents, with money included as an argument in household utility. Calibration of the model is based on plausible parameter values and macroeconomic time series estimates. The model is used to provide an explanation for what has been termed the price puzzle—that is, the positive comovement between the interest rate and inflation. The simulations, which support the price puzzle, suggest that this relationship is caused by the dominance of the Fisher effect, strengthened by the presence of a Taylor rule that depends positively on inflation deviations. Impulse responses from a VAR reasonably match the simulations based on the structural DSGE model.

Bergoeing and Soto consider several DSGE models and evaluate the empirical relevance of nominal rigidities and macroeconomic

policies for the behavior of consumption, investment, inflation, and factor market prices. The models share several features, including intertemporal optimization by representative agents in a closed economy. They differ in the extent of technology shocks, the existence of real rigidities (namely, labor market rigidities and government expenditure), the inclusion of money (through a cash-in-advance constraint), and the existence of nominal rigidities. The authors compare the models' ability to match the business cycle features of the Chilean economy: the economy with government expenditure and labor indivisibility best fits the data.

Chumacero presents a small economy DSGE model that can be used to assess the effects of alternative monetary and fiscal policies. A constructive methodology for comparing alternative theoretical models is presented, and the parameters of the model are chosen so as to replicate the estimates of an identified VAR model for the Chilean economy. Several novel methodological aspects concerning the link between theoretical and empirical modeling are discussed. The paper also shows that impulse response functions obtained with VARs can be misleading. A distinguishing feature of this model is that it explicitly introduces foreign investors and solves their optimization problem.

3.2 Computable General Equilibrium Models for Trade Policy and Environmental Taxation

Harrison, Rutherford, and Tarr develop a twenty-four sector, eleven region CGE model for the world economy populated by Chile and its ten main trading partners, based on a previous world CGE model of similar structure but without Chile as one of the world regions (Harrison, Rutherford, and Tarr, 1997). Model equations are derived from static consumer and producer optimization. The model is calibrated to 1996 world data from the Global Trade Analysis Project (GTAP), but it allows for different values for the elasticity of substitution between imports from Chile and other countries. The model is applied to quantify changes in consumer welfare caused by a large number of trade reforms in Chile and at the regional and world levels. Calculations are based on trade creation gains, trade deviation losses, and (in the case of trade agreements) market access gains, with different replacement taxes. The results show that Chile's strategy of additive regionalism (in which it enters successive regional trade and free trade agreements) dominates unilateral trade opening, that joining Nafta dominates joining Mercosur, and that its losses

from joining Mercosur at moderate uniform tariffs become small gains at a lower uniform tariff.

O’Ryan, De Miguel, and Miller apply their CGE model (termed Ecogem) to evaluate the aggregate and sector effects of increasing fuel taxes. Ecogem (O’Ryan, Miller, and De Miguel, 2003) is a multi-sector model based on static optimization by households and firms, with heterogeneous consumers divided into income classes, heterogeneous labor, complex production, several taxes and transfers, and endogenous foreign trade. The model also considers environmental damage (air pollution) stemming from the emission of various pollutants by energy-using production sectors (with no effect on household utility). The version of Ecogem used here, based on Chile’s 1996 social-accounting matrix, comprises seventeen production sectors, two classes of labor, and five household sectors. The authors use the model to simulate the effects of an environmental policy in the form of higher fuel taxes, with the increased government revenue either financing higher investment or reducing trade tariffs. The results show a major decline in air pollution in Santiago; a reduction in GDP, income, and welfare of all households; and changes in resource allocation and household income distribution. The latter effects are ameliorated when the increased fuel tax revenue is offset by lower trade tariffs.

Holland, Figueroa, Álvarez and Gilbert develop a CGE model to quantify the aggregate and sectoral effects of eliminating price bands and tariffs on agricultural products. This multisector model is based on static optimization by households and firms. There are differences between urban and rural households and unemployment levels that give rise to urban-rural migration under conditions of imperfect labor mobility. The model used here encompasses fifty production sectors and is calibrated according to the international GTAP4 (1995 version) and Chile’s 1996 Casen Survey databases. The model is applied to simulate the effects of removing price bands on wheat, sugar, and oils (which protect domestic production of the latter commodities) and of full elimination of agricultural tariffs. Removing the three price bands is shown to lead to a small welfare gain and major changes in production and imports of the three affected sectors. However, according to their model, elimination of all agricultural tariffs leads to lower welfare, which reflects the negative influence of non-removable distortions (such as urban unemployment and imperfect labor mobility), which more than offsets the efficiency gains of tariff reduction.

3.3 GEMs for Labor Taxes and Retirement Incentives

Bergoeing, Morandé, and Piguillem derive a dynamic deterministic GEM to explain the changes in contributions of capital, labor, and total factor productivity (TFP) to growth that were observed in 1981–2002, with a focus on the recent 1998–2002 sub-period. The model is based on a representative agent with intertemporal consumption and leisure optimization (nesting static profit maximization by a representative firm) in a closed full-employment economy with taxation of labor and capital. Model calibration is based on historical data and plausible values for deep parameters. The paper reports five simulation exercises, based on different combinations of labor and capital tax rates and TFP growth rates. An increase in labor taxes, interpreted as the combination of higher minimum wages and anticipated larger hiring costs, best matches the contributions of growth determinants—particularly employment—to growth in 1998–2002.

Finally, Cifuentes develops an OLG model to evaluate the general equilibrium effects of Chile's tax incentives for voluntary retirement savings, which have been in place since 1981 but were extended in 2002. His model, based on Cifuentes and Valdés-Prieto (1997), extends the standard Auerbach and Kotlikoff (1987) framework by introducing sixty overlapping cohorts, heterogeneous households that differ in subjective discount rates and education (and thus income) levels, and differences in marginal income tax rates—which are all key features for realistically assessing voluntary retirement savings. Model calibration is based on relevant data from macroeconomic and microeconomic databases and previous studies. Partial equilibrium, steady-state general equilibrium, and dynamic transition general equilibrium results are reported for different model calibration choices. Voluntary retirement savings are shown to raise voluntary (and mandatory) pension fund savings, capital, income, and welfare in the new steady state (that is, in the very long term). The dynamic transition simulation results also show that voluntary retirement savings cause a monotonic rise in retirement savings and capital. Given the higher value-added taxes required to offset lower income taxes in the first decades, however, the welfare of the transition cohorts—particularly the low-income groups that do not benefit from voluntary retirement savings—declines.

4. CONCLUDING REMARKS

The broad scope of the issues covered and the wide spectrum of methodological choices presented in this volume show how active the profession is in providing a better characterization of the Chilean economy and more precise evaluation of policy reforms. Vigorous contrast of different perspectives and rigorous academic debate of these topics are invaluable for taking more informed policy decisions.

Models are useful if they can accurately describe the problem at hand and if they can explain why variables of interest respond in a given way to a disturbance. Purely empirical models sometimes provide a good statistical characterization of the data, but they are usually silent regarding the economic structure that governs data processes. On the other hand, stylized theoretical models may be rich in structure but poor in accommodating observed behavior. We believe that the use of GEMs that combine both dimensions is important. The profession requires tools that not only conform to the data, but are also able to explain the causal relations behind the data. This volume shows a sample of the best tools currently available.

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RESPONSE TO EXTERNAL AND INFLATION SHOCKS IN A SMALL OPEN ECONOMY

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Monetary policy design has experienced major changes over the last twenty years. These changes had their origin in changes in macroeconomic theory, a better understanding of the importance of achieving and maintaining low inflation, and the abandonment of fixed pegs in favor of floating exchange rate regimes. The new macroeconomic models emphasize the role of microeconomic foundations and expectations and highlight the need to develop and strengthen institutions. One of the key consequences of this process is the recognition that stabilization policies cannot achieve permanent gains in output or employment.

The emphasis on credibility and the incorporation of explicit forward-looking expectations have similarly contributed to the recognition that monetary policy must have a forward-looking design. Given the lags between policy decisions and their effect on the real economy, it is necessary to contemplate not only the current values of relevant variables, but also forecast values in the right horizon. The need to generate forecasts of economic variables has led the institutions in charge of monetary policy to develop macroeconomic models

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appropriate for forecasting the relevant variables that condition the monetary policy design. The available options are very wide, ranging from simple one-equation models of the most relevant variables to elaborate and microeconomic-founded models featuring rational expectations and a large number of estimated or calibrated relations that incorporate uncertainty in the solution, generating not only a point forecast but also a range for the key endogenous variables with a probability distribution.¹ Another important use of these models is the evaluation of the impact of different economic policy options; the clearest example is the analysis of the future evolution of inflation when central banks are deciding whether to change the interest rate or whatever variable they use as instrument.

Within this wide range, semistructural and small models have found an increasing role in macroeconomic analysis and policy design. These models incorporate reduced-form equations that can be obtained from the explicit solution of microeconomic-founded models. Although these models are not immune to the Lucas critique, they are robust enough to deal with monetary policy changes and related shocks. The use of small models reduces the level of detail, but such models have important advantages in terms of relatively easy and fast solution and intuition. Many small models are currently available, some of which have evolved from traditional models by incorporating new theoretical and empirical features.²

In this paper we present a small macroeconomic model for the Chilean economy. We start by explaining its structure and then present simulations of the dynamic response of the economy to some shocks that are of particular interest for Chile. The paper is organized as follows. The first section discusses macroeconomic models and monetary policy analysis in general, together with a brief review of recent macroeconomic models of the Chilean economy. The second section describes the model used in the rest of the paper, a model that is based on the traditional small open economy or dependent economy model. The third section analyzes the simulations and its results. The final section presents our main conclusions.

1. Good examples include the models used to elaborate monetary policy reports by most central banks that operate under an inflation-targeting framework. See, for example, the Central Bank of Chile's Monetary Policy Reports (available at www.bcentral.cl) and Bank of England (1999) for a description of the wide range of models they use.

2. In Taylor (1999), several models of this type are used to analyze issues related to monetary policy reaction functions. Walsh (2003) also reviews some of these models.

1. MACROECONOMIC MODELS FOR MONETARY POLICY ANALYSIS IN CHILE

To provide a simple organizing framework for thinking about macroeconomic models, we briefly summarize the current state of macroeconomic models and some recent applications for Chile. Most of the recent work on macroeconomic models has been generated under what is called the new Keynesian synthesis, an important research effort to provide an updated and consistent framework for economic analysis that incorporates the macroeconomic developments of the last fifteen years.³

1.1 Macroeconomic Models and Monetary Policy: A Brief Explanation

Modern macroeconomic models for monetary policy analysis build on the tradition of the IS-LM-AS models, but with several important modifications that incorporate recent theoretical advances and important changes in the way economic policy is implemented.⁴ The models are quite heterogeneous, however. Not all are clearly derived from explicit microeconomic foundations, and they do not necessarily incorporate rational expectations or impose all the cross-equation restrictions that are obtained from first-order conditions of optimizing decisions. Which model is most appropriate depends on the question the analyst is interested in exploring.

Macroeconomic models for studying the effects of policies and shocks on the trajectory of key macroeconomic variables are usually of three varieties: large-scale structural macroeconomic models; small models consistent with macroeconomic theory and forward-looking expectations; and small nonstructural models based on vector autoregressions (VAR).⁵ Models in the first class are usually derived from first principles and incorporate a lot of detail, including explicit budget constraints and first-order conditions; rational expectations

3. Good examples of this orientation can be found in Kerr and King (1996), Clarida, Gali, and Gertler (1999), McCallum and Nelson (1999), and McCallum (2001).

4. The increasingly common use of interest rates as an instrument of monetary policy has led some researchers to change the traditional IS-LM specification for a new specification that Romer (2000) calls an IS-MP model.

5. Another important differentiation would be the explicit inclusion of uncertainty, but our main focus here is on the size and foundations of the models.

are used in simulations. One of the main advantages of these models is that because they are derived from first principles, all the parameter restrictions are imposed, expectations are derived consistently within the model, and the results are robust to the Lucas critique. The parameters in structural models have to be invariant to policy changes, and the models must therefore be derived from microeconomic foundations and have forward-looking expectations (McCallum, 2001). The main disadvantage of this type of model is the poor tracking of short-run dynamics.⁶ An important example of this class is the real business cycle (RBC) model. RBC models are not designed to track the short-run evolution of the economy, but they have been applied to match correlations and other regularities of Chilean business cycles. As in most developing countries, however, the use of RBC models has been limited, and only recently has research increased in this area.

Another type of large-scale structural model that has been important in research is not derived from first principles, but is built using several empirical relationships that incorporate ad hoc specifications. These models closely track the movements in some macroeconomic aggregates. While most of the modifications are not explicitly founded on microeconomics, the models do describe a large number of variables that are then used to compute aggregate variables. Their main advantage is the possibility of incorporating a lot of detail about the interaction of several sectors and variables without loosing the ability to track the evolution of the aggregate variables. They are very useful for policy purposes, but their size is a disadvantage when the analyst needs quick answers to specific questions or when simple answers are sufficient.

The second type of model—namely, small models consistent with macroeconomic theory and forward-looking expectations—has proved to be very useful for monetary policy analysis. These models capture the main elements of an economy yet are simple enough to allow researchers and policymakers to answer simple questions without having to deal with an excessively detailed specification. Some of the models have been derived from simple first-order conditions of optimization problems faced by firms and consumers, but in general no cross-equation restrictions are imposed on the parameter for

6. See King (2000) and Woodford (2003) for reviews of the core structure of this type of model. Lane (2001) reviews the basic structure of the new open economy macroeconomic models; a seminal contribution in this area is Obstfeld and Rogoff (1995).

estimation purposes. Calibrated models can be easily constructed, however, so as to reflect results for different choices of deep behavioral parameters.⁷ The models, which are usually interpreted as the result of dynamic neo-Keynesian models, incorporate rational expectations and generally also emphasize the explicit role of (the expected values of) forward-looking variables. Clarida, Gali, and Gertler (1999) analyze monetary policy using a simple model of this type as their framework; this widely cited work shows the basis of the research in this area.

The basic structure of these models generally comprises a single-equation description of aggregate demand (an open economy IS equation), a pricing or aggregate supply equation (originally an expectations-augmented Phillips curve), and an equation or a block describing monetary policy decisions. The choice of an IS equation for describing aggregate demand generally is not questioned, and while specific issues regarding timing and the inclusion of forward-looking variables have important theoretical considerations, empirical works tend to choose according to goodness of fit more than strict theoretical underpinnings. Regarding the monetary policy specification, these models, like most research on monetary policy since Taylor (1993), usually include a Taylor reaction function describing the behavior of monetary authorities.⁸

The most important and controversial element is the pricing or aggregate supply equation. Economists do not question the characteristics of the long-run supply curve, but issues involving the short-run specification are not clear. The first problem relates to the long-standing debate between neoclassical and neo-Keynesian specifications, which we do not expect to solve here.⁹ The second important issue arises from the empirical fact that the inflation rate exhibits significant inertia, whereas traditional models derive only price-level inertia and not inflation inertia. This is not a minor issue in that inflation inertia is closely related to the idea that disinflation processes are costly in terms of output and employment. Different approaches have been tried, yet there is no consensus on a clear theoretical solution. Fuhrer and Moore (1995) present an early

7. Walsh (2003) presents some of the models in this class that are currently in use.

8. One of the main uses of these simple models is to analyze robustness of different policy rule specifications under different parameterizations of the model.

9. Recent reviews of these models can be found in Rosende (2000), Woodford (2003), and Walsh (2003).

approach, and Mankiw and Reis (2002) develop an interesting approach related to early work by Fischer (1977).

The third type of model—that is, the small nonstructural VAR models—is increasingly used to analyze the effects on key endogenous variables (such as output, inflation, and unemployment) of unexpected or unsystematic shocks to policy or exogenous variables. The popularity of these models increased after Sims (1980) critiqued the ad hoc specifications of the models then in use. Their main characteristic is the absolute lack of predetermined structure. All the relations are derived from the time series specification, which can be used to derive simple and very intuitive results such as impulse responses and variance decomposition figures.¹⁰ The models' simplicity explains both their advantages and disadvantages. When used wisely, VAR models can provide very useful insights into dynamic properties and a simple description of comovements between different economic series.

1.2 A Brief Survey for Chile

The literature on economic policy and economic performance has become one of the most active in Chile over the last fifteen years. The fact that Chile was an early reformer led most think tanks and similar institutions to study the country to develop a general framework for guiding reform efforts in other developing countries. Questions about the role played by monetary, exchange, and fiscal policy in the rapid recovery and stabilization of the country after the severe crises of the 1970s and 1980s were initially at the center of the macroeconomic research. Several new issues have since come to the forefront of economic research, but the one that interest us is monetary policy analysis. As early as 1991, Chile adopted an inflation-targeting framework for the implementation of monetary policy. Initially understood as a simple forecast, the projection soon became a target for monetary policy; it was not the only objective, but it was the most important one.¹¹ New questions emerged following the abandonment

10. For a review of this methodology, see Stock and Watson (2001) and Hamilton (1994).

11. For a review of monetary policy and the Chilean economy in the late 1970s and 1980s see Corbo and Fischer (1994). Reviews of monetary policy in the 1990s can be found in Massad (1998), Corbo (1998), Morandé (2001), Corbo and Tessada (2002), and Schmidt-Hebbel and Tapia (2002). More comprehensive reviews of the Chilean economy can be found in Bosworth, Dornbusch, and Labán (1994) and Larraín and Vergara (2000).

of the exchange rate band after the Russian and Brazilian crises and the achievement of a low inflation level in 1999. The increasing integration in international financial markets and the already high dependency on the evolution of commodity markets make the country very vulnerable to external shocks. The need to assess the effect of these shocks and other issues related to the design of monetary policy has motivated researchers and policymakers to construct useful models for economic policy analysis. The available literature on the topic is growing very fast, which precludes compiling an exhaustive survey in a brief section. We thus review six papers: Bergoeing and others (2002), García and others (in this volume), Corbo and Schmidt-Hebbel (2001), Corbo and Tessada (2002), Valdés (1998), Cabrera and Lagos (2002), and Mies, Morandé, and Tapia (2002).¹²

Bergoeing and others (2002) present a calibrated growth model, which is used to explain differences between Chile and Mexico after the debt crisis. They use the model to account for possible alternative explanations and to explore the role played by static and dynamic inefficiencies in the evolution of both economies. They find evidence supporting their hypothesis that reforms are at the center of the differences. Instead of the traditional reforms claimed by most authors, however, they identify banking and bankruptcy laws as key elements explaining the different patterns.

García and others (in this volume) construct a large-scale model for monetary policy analysis at the Central Bank of Chile. Using calibrated and estimated equations, the model is built in blocks, each of which describes a different sector of the economy. The blocks are then aggregated and used to model different monetary policy transmission channels. Not all the equations are derived from first principles, and almost no cross-equation restrictions are placed on the parameters. The two main features of the model are a very detailed external sector, justified by its great influence on the evolution of the Chilean economy, and a production block built according to a Cobb-Douglas production function, which captures the stable factor shares observed during the period under analysis. The model is simulated to compute the dynamic response of the economy to several transitory

12. Duncan (in this volume) presents a detailed review of RBC models calibrated for the Chilean economy since 1990. Cabrera and Lagos (2002), Mies, Morandé, and Tapia (2002), and Chumacero (in this volume) discuss papers that use a VAR methodology. Gallego, Servén, and Schmidt-Hebbel (in this volume) describe large-scale dynamic macroeconomic models derived from first principles; a mixture of estimated and calibrated formulas is used for simulation.

and permanent shocks. When possible, the responses are contrasted with those obtained from a simpler model and a VAR model. The results are relatively similar, but the model accounts for the responses with greater detail and supports the analysis of shocks that might affect the steady-state values, a feature that is not present in any of the other models presented by the authors.

Corbo and Schmidt-Hebbel (2001) and Corbo and Tessada (2002) present similar models to answer different questions. The model is a reduced version of the Salter-Swan-Dornbusch small open economy model, and it tests and imposes homogeneity in nominal variables in the price and wage equations to ensure a vertical long-run Phillips curve. Corbo and Schmidt-Hebbel (2001) simulate the model under counterfactual scenarios to try to shed some light on the role of credibility and the inflation target in the sustained reduction of inflation experienced by Chile in the 1990s. The authors find that the introduction of the target helped anchor expectations and that the gradual approach allowed the authorities to reduce inflation without the large cost associated with a cold-turkey approach. They do not explicitly model the steady state, so they cannot answer questions related to shocks or policy changes that might affect the real equilibrium of the economy in the long run. In fact, the underlying assumption in the analysis is that any change in the inflationary regime or the monetary policy framework does not cause a significant change to the long-run output level.

Corbo and Tessada (2002) use a very similar model with some slight modifications, together with a nonstructural VAR, to assess the importance of different factors that might account for the 1998–1999 slowdown of the Chilean economy. The nonstructural VAR is used to forecast the effects of different shocks on the trajectory of the main macroeconomic aggregates. The more structured model is then simulated to generate counterfactual scenarios for the crisis periods to inspect the role played by different factors, including the monetary policy response, in the subsequent slowdown of activity in the Chilean economy. Their main conclusion is that part of the monetary policy response can be justified as an attempt to defend the inflation target for the following year. Part of the slowdown, however, can be blamed on a severe anti-inflationary attitude on the part of the Central Bank, even after taking into consideration the external factors.

Valdés (1998) estimates a semistructural VAR model in which he makes assumptions that allow him to identify the monetary policy shocks without adding more structure to the VAR, so that the rest of

the shocks are not studied in the paper. After reviewing the previous literature on VAR models, the author presents his own results based on a modification relative to previous work: he argues that monetary policy affects the gap between the inflation rate and the target, rather than the inflation rate itself. When using the modified specification, he finds that monetary policy has significant effects on both the inflation gap and the monthly activity index (Imacec).¹³

Cabrera and Lagos (2002) use structural VAR models to compare alternative hypotheses about monetary policy transmission mechanisms. The analysis is carried out by estimating a different VAR model for each of the competing hypotheses. The authors conclude that there is weak evidence of a price puzzle result in Chile, and that spending and output do not respond significantly to the interest rate. Instead, they show significant responses to nominal money supply. They interpret this as raising doubts on the selection of the monetary policy instrument. However, the results presented in the paper are not robust to different structural identifying assumptions or to changes in the specification of the VAR model. Moreover, the results range from finding negative and significant effects of monetary policy on inflation to finding evidence of a possible price puzzle.

Finally, Mies, Morandé, and Tapia (2002) employ single-equation and VAR models to analyze the effectiveness of monetary policy in the 1990s. The single-equation analysis estimates an equation relating the twelve-month rate of change of a monthly activity index as a function of its own lag and a lagged measure of a monetary policy shock, where the latter variable is identified as the residual from the estimation of a monetary policy function. They find evidence of a change in the effectiveness of monetary policy, identified as the coefficient of the monetary shock in the regression. When they look at the nonsystematic part of monetary policy, however, the systematic portion of monetary policy movements is left out of the analysis, so they cannot address its effect.¹⁴ They then move to the analysis

13. A counterintuitive aspect of his approach is that he uses forecasts published by a private forecaster to extend the data on the target for the 1980s, which by their own nature cannot be considered to play the same role as the inflation target in the economy. Corbo and Schmidt-Hebbel (2001) follow a different approach: they show that when the inflation target is included in a nonstructural VAR model, the dynamic forecasts are closer to the forecasts published by Consensus Forecasts for the corresponding periods; they interpret this as evidence of the target as an anchor for inflation expectations.

14. See Bernanke, Gertler, and Watson (1997) on the importance of the systematic component of monetary policy in the case of the United States.

using VAR models, estimating different specifications with different samples and finding significant differences in the estimated monetary policy elasticities of inflation and output. The major innovation of the paper is the use of different monthly sectoral indicators. They estimate VAR models to study the effect of monetary policy on different economic sectors, showing that the construction and manufacturing sectors are the most affected by the monetary policy shocks, with the construction sector experiencing an effect that is about twice as large as for the aggregate economy.

2. THE MODEL

As explained above, a variety of models have been used to analyze different questions about the Chilean economy since the 1980s.¹⁵ Our model is related to most of the literature dealing with macroeconomic analysis of the country, in particular several papers that address issues associated with monetary, exchange rate, and disinflation policies since the early experiments of the late 1970s. Many papers issued over the last five years explore monetary policy considerations under an inflation-targeting framework. Most of these present small empirical models based on ad hoc specifications in order to capture empirical regularities observed in the Chilean economy. Their theoretical underpinnings lie in the traditional small open economy models of Salter, Swan, Dornbusch, and Corden, but they expand their models to incorporate new elements based on recent empirical and theoretical developments. Examples of this model include Edwards (1993), Corbo (1985), Corbo and Fisher (1994), Corbo and Schmidt-Hebbel (2001), and Corbo and Tessada (2002).

Our interest in building this model is to capture the relevant macroeconomic features of the economy for short- and medium-run analysis of the effects of exogenous shocks, including the endogenous response of monetary policy. García and others (in this volume) identify seven stylized facts about the Chilean economy, of which we directly model two: the sensitivity of the domestic cycle to external conditions and the combination of inflation rate, inflation targets, and economic cycle. The other five are not explicitly modeled because of our focus on the short run and our assumption that the long-run equilibrium is

15. The papers presented in this volume are a good example of the diversity of the research during the recent years.

exogenous to our model.¹⁶ We hold that these two facts are the main elements for short-run analysis. Most of the other characteristics, as important as they are, will not change the general properties of the model; the gain in detail would be at the cost of a larger, more complicated model.¹⁷

The model's main equations consist of an IS equation explaining the evolution of the domestic output gap, a transition equation linking the evolution of real exchange rate deviations to other exogenous and endogenous variables, an inflation equation that can be related to the Fuhrer and Moore (1995) specification of a pricing equation in the United States, and a Taylor rule describing monetary policy. We estimated each equation separately to avoid spillover effects from specification errors in a particular equation to the estimation of other equations in the model.

The first equation in the model is a simple version of an open economy IS equation relating the domestic output gap (y) to internal and external demand factors.¹⁸ External factors play an important role: the coefficients for the output gap of the main trade partners (y^* , henceforth, the foreign output gap), the real exchange rate (RER), and capital inflows ($CAPFLOWS$) are statistically significant, and the impact effects are of a relevant magnitude. Since capital inflows could be endogenous to the output gap, we use a measure of the availability of flows to the Chilean economy instead of capital inflows. This measure is constructed by adding up the supply of external funds from the euro area, Japan, and the United States and then dividing the sum by the total output of the three regions, a measure that can be considered exogenous. The importance of capital flows in the evolution of the domestic output gap can be linked to the "sudden stop" hypothesis—in particular, with Caballero's argument that the connection between developing countries and capital flows is through quantities more than through interest rates (Caballero, 2002). This evidence does not represent a careful analysis of the hypothesis, but it sheds some light on the

16. This assumption may seem overly heroic, but it is very useful when analyzing responses to transitory shocks. It does, however, restrict the size of the transitory shocks, because in some general equilibrium models for small open economy models, the evolution of the net foreign assets might lead to permanent effects of transitory shocks (see Lane, 2001).

17. García and others (in this volume) contrast their results with results derived from a VAR model and a smaller structural model.

18. Potential output was computed according to the methodology presented in Contreras and García (2002).

problem.¹⁹ We are not estimating a neo-Keynesian version of the IS equation because the expected future level is not included as an explanatory variable, a condition that is derived from intertemporal optimization.

The only internal variable considered in the specification is the real monetary policy rate (*RMPR*), expressed as a deviation from an equilibrium value that is not restricted to being constant over time.²⁰ This value also corresponds to the steady-state equilibrium of the monetary policy rate, so it can be interpreted as the natural interest rate. We do not differentiate between short and long interest rates; this simplification allows us to keep the model very simple at the cost of detail on the effect of short rates on long rates and on real activity. We also estimated an alternative specification in which we included the terms of trade as an additional explanatory variable (instead of the real exchange rate), but this did not generate significant changes in the results. Equation (1) shows the estimated open economy IS equation for the Chilean economy:

$$\begin{aligned} y_t = & -0.002 + 0.512 \overset{*}{y_{t-2}} + 0.079 RER_{t-3} + 1.151 CAPFLOWS_{t-1} \\ & (0.114) \quad (0.256) \quad (0.036) \quad (0.259) \\ & -0.276 RMPR_{t-2} + 0.737 y_{t-1}, \\ & (0.086) \quad (0.057) \end{aligned} \quad (1)$$

where the estimation method is ordinary least squares (OLS); Newey-West robust standard errors are reported in parenthesis; *R* squared equals 0.91; the LM test (1) is 0.276 (with a *p* value of 0.601); and the sample runs from the first quarter of 1987 through the fourth quarter of 2002.

The next equation in the model corresponds to the monetary policy reaction function. The dependent variable (*RMPR*) is expressed as a deviation from an equilibrium value, which also corresponds to the steady-state equilibrium of the interest rate in the model. As explained above, this value is not assumed to be constant over time.²¹

Estimating an equation like equation (2), as explained in Clarida, Gali, and Gertler (1998) and Corbo (2002), is complicated because two right-hand-side variables depend on the observed values of the interest

19. This is an interesting topic that needs more attention from an empirical point of view.

20. Calderón and Gallego (2002) discuss the natural interest rate for the case of Chile.

21. The equilibrium value was calculated by computing moving averages of the observed policy interest rate or by applying a Hodrick-Prescott (HP) filter to the original series. The results are not very sensitive to the procedure used. The version of equation (2) presented in the paper corresponds to the deviation computed using the HP filter.

rate. Following previous work on the issue, we use generalized method of moments (GMM) to solve the problem.²² We introduced a change in our definition of the policy rate used by the Central Bank of Chile. Here, following Valdés (1998), instead of using the real rate of the ninety-day Central Bank adjustable bills (the PRBC-90), we use a hybrid variable called policy rate, which consists of the PRBC-90 up to April 1995 and thereafter the monetary policy rate (*tasa de instancia*). However, as shown in Corbo and Tessada (2002), this rate was not a clear indicator of the true monetary policy stance in several specific months in 1998.²³ We therefore replaced these values with the PRBC-90 rate and then proceeded to compute the quarterly averages. For the period when the monetary policy rate was announced as a nominal rate, we subtracted the inflation target to get the implicit real rate.

Some previous papers on the topic estimate the policy function for the 1990s with the current account as an alternative target for the Central Bank, as was explicitly recognized by the authorities at the time.²⁴ The orientation of monetary policy changed after 1998, however, so we modified the specification by including the output gap (y) as the other variable. The results are relatively satisfactory, but it is too soon to derive hard conclusions about the new structure of the policy function.²⁵

$$RMPR_t = 0.539 \left(\frac{\pi - TAR}{(0.102)} \right)_{t+3} + 0.067 \left(\frac{y_t}{(0.019)} \right) - 0.561 \left(\frac{RMPR_{t-1}}{(0.059)} \right), \quad (2)$$

where π is inflation and TAR is the inflation target; the estimation method is generalized method of moments (GMM); the weighting matrix is robust to heteroskedasticity and autocorrelation; robust standard errors are shown in parenthesis; and the instruments are lags of the right-hand-side variables and of external inflation. R^2 squared equals 0.855, and the sample runs from the first quarter of 1995 through the first quarter of 2002.

22. For a review of generalized method of moments, see Hamilton (1994), Greene (2002), and Mátyás (1998). For a review of previous works on estimating monetary policy reaction functions, see Clarida, Galí, and Gertler (1998) in the case of developed countries and Corbo (2002) in the case of Latin American countries.

23. The months with this problem are January, August, September, October, and November of 1998.

24. See Massad (1998). See also Corbo (2002) and Corbo and Tessada (2002) for previous estimations of monetary policy reaction functions for the 1990s.

25. The model was estimated using only the inflation gap as an explanatory variable. It must be emphasized that obtaining a statistically significant coefficient for the output gap in the right-hand side of the equation does not imply this variable is another objective for the Central Bank.

The model includes core inflation as the relevant measure of inflation. In our specification, we identify four different variables affecting the dynamics of core inflation, π : external inflation (reflected in the real exchange rate misalignment, RER), internal inflationary pressures (summarized in the output gap, y), forward looking expectations (incorporated through market expectations or through leads of core inflation), and persistence in the inflation rate (owing to indexation or measurement).²⁶ Growing evidence indicates that exchange rate pass-through is not constant over the cycle and likely depends on more variables. We do not, however, explore major deviations from our simple linear specification here because our initial explorations did not identify any interaction or nonlinearity in the specification that could be associated with a nonconstant pass-through.²⁷ Other authors find such effects in the Chilean economy under different specifications and with different purposes (see García and Restrepo, 2001; Schmidt-Hebbel and Tapia, 2002).

We modeled the forward-looking component of the inflation equation in two different ways. Our first version incorporates as a forward-looking variable the expected inflation computed from the difference between nominal and indexed interest rates of the same maturity (90 to 360 days). This variable is intended to measure market expectations without further restrictions about model consistency, and it is modeled in a way that simply reflects a slow adjustment of expectations.²⁸ The second version assumes rational expectations, and we use the effective future inflation rate (with the corresponding leads matching the timing of the previous version) as a proxy for expected inflation. Under rational expectations, we can use GMM and estimate the equation using as instruments known variables that are useful for forecasting purposes. This specification includes model-consistent expectations. We incorporated two lags of inflation, which

26. Our dependent variable is the four-quarter rate of change of the core price index (the IPCX in the Central Bank's nomenclature).

27. Taylor (2000) explains how to rationalize a correlation between lower inflation variability and lower exchange rate pass-through. Choudhri and Hakura (2001) test the implications derived by Taylor (2000) for a comprehensive set of countries for the period 1979–2000. They confirm the existence of a positive relation between the pass-through and the average inflation level, which is related to Taylor's idea about permanent and transitory effects (see Taylor, 2000). Goldfajn and Werlang (2000) present a comprehensive study analyzing possible determinants of the magnitude of the pass-through.

28. This variable is explained using a simple equation that relates it to leads of the inflation target and lagged core inflation.

were selected to avoid autocorrelation of the residuals. The first version of the equation is the following:

$$\pi_t = 0.068 RER_{t-1} + 0.096 y_{t-1} + 0.175 E_{t-1}^M (\pi_{t+1}) + 1.117 \pi_{t-1} - 0.292 \pi_{t-2} \quad (3)$$

where the estimation method is OLS; Newey-West robust standard errors are reported in parenthesis; R squared equals 0.96; the LM test (1) is 2.13 (with a p value of 0.15); and the sample runs from the first quarter of 1991 through the fourth quarter of 2002. The second version, with rational expectations, is specified as follows:

$$\pi_t = 0.058 RER_{t-1} + 0.044 y_{t-1} + 0.210 \pi_{t+1} + 1.061 \pi_{t-1} - 0.271 \pi_{t-2} , \quad (3')$$

where the estimation method is two-stage least squares (2SLS); Newey-West robust standard errors are reported in parenthesis; and the instruments are lags of the right-hand-side variables, lags of core inflation, lags of the inflation target, and lags of external inflation. R squared equals 0.98, the LM test (1) is 2.23 (with a p value of 0.14), and the sample runs from the first quarter of 1991 through the first quarter of 2002.

The only puzzling element is that replacing the market expectation with the observed rate causes a significant change in the value of the parameter that measures the effect of the cycle. The change cannot be blamed on an endogeneity problem because the parameter value does not significantly differ when equation (3') is estimated using 2SLS versus OLS. One possible explanation might be a feedback from the right-hand-side variables into expectations or into leads of the inflation rate; an additional explanation might be a problem with the instruments in the 2SLS estimation. Despite the rational expectations alternative, the main version of the model used in the simulations incorporates equation (3) as the relevant pricing equation, complemented by a simple equation for inflation expectations.

We now turn to the main variable that connects the external sector with the evolution of domestic variables: the real exchange rate. The model defines the real exchange rate relative to Chile's main industrial trade partners, namely, Canada, the members of the euro area, Japan, the United Kingdom, and the United States. The real exchange rate is the main variable reflecting the evolution of the external sector; the selected specification includes the domestic output gap (y) and lagged values of the real exchange rate deviation (RER) as explanatory variables of the gap between the observed real

exchange rate and a long-run value.²⁹ Alternative specifications include the difference between the domestic output gap and the foreign output gap, as well as the terms of trade (as the log deviation from a long-run value), but the results do not change significantly. A different approach is to impose interest rate parity and include additional variables, but the use of very detailed and specific capital controls—which changed in the 1990s—implies that the imposition of interest rate parity might be misleading unless the right effect of the capital controls is taken into account.³⁰

$$RER_t = 0.639 RER_{t-1} - 0.403 RER_{t-2} + 0.418 RER_{t-3} - 0.229 y_t , \quad (4)$$

where the estimation method is 2SLS; Newey-West robust standard errors are reported in parenthesis; and the instruments are lags of the right-hand-side variables, lags of the real exchange rate gap, and lags of the foreign output gap and capital flows. *R* squared equals 0.45, the LM test (1) is 0.82 (with a *p* value of 0.37), the LM test (4) is 1.18 (with a *p* value of 0.88), and the sample runs from the first quarter of 1986 through the fourth quarter of 2002.

The short-run specification of the real exchange rate must be interpreted carefully because we do not include any of the nominal variables that are known to be important when forecasting the real exchange rate in the short run.³¹ As in most of the literature on macroeconomic models for Chile, the short-run evolution of the real exchange rate follows an ad hoc specification; our definition intends to capture movements of the real exchange rate that are associated with medium-run deviations and that do not necessarily follow short-run volatility from the exchange rate market.³² This assumption is relevant for the interpretation of the simulations presented in the

29. This long-run value is also the steady-state equilibrium of the real exchange rate in this model.

30. Two recent reviews of the Chilean experience with capital controls are Gallego, Hernández, and Schmidt-Hebbel (2002) and De Gregorio, Edwards, and Valdés (2000).

31. Three recent papers on the topic for Chile are Gallego, Hernández, and Schmidt-Hebbel (2002), Calderón and Massad (2003), and Cerdá, Donoso, and Lema (2003).

32. We here understand the medium run as a period long enough for real variables to be important for explaining real exchange rate fluctuations, but not necessarily as long as the half-life of purchasing power parity (PPP) shocks. For different approaches, see García and others (in this volume), García, Herrera, and Valdés (2002), Gallego, Servén, and Schmidt-Hebbel (in this volume), and Corbo and Tessada (2002).

next section. The focus on more permanent movements of the real exchange rate means that in our model, changes associated with short-run volatility will not generate a response in either the output gap or the inflation rate, and these short-run fluctuations are not even modeled in this paper. We thus assume that transitory deviations do not imply an acceleration of inflation, whereas in real situations the effect of an observed change is not clear until economic agents can identify whether it is transitory or volatile.

Blanchard (2004) postulates a different approach.³³ Under certain assumptions about imperfect capital mobility, he obtains an expanded parity condition that allows for a slightly different specification with respect to the traditional uncovered interest rate parity. He thereby explicitly incorporates the sovereign risk premium without imposing more conditions on the value of the equation's parameters.

The four equations presented above constitute the core block of the model. In addition, all the exogenous (external) variables can be modeled using autoregressive processes (possibly a multivariate autoregressive process) capturing any cyclical behavior in the different shocks. Any simulation can be implemented with or without these time series processes.

3. SIMULATION EXERCISES

This section uses the model just presented to explore the impact of external shocks on the Chilean economy. This has been an issue in the policy and academic economic debate in recent years. Although the external cycle is known to have a strong impact on domestic output, the dynamic effects have only recently been clearly characterized.³⁴ Another interesting area for analysis involves the dynamic response of the economy to internal shocks, especially inflation shocks resulting from changes in regulated prices or other exogenous changes. Our model presents a simple, easy-to-use alternative for this purpose to the extent that it captures most of the short-run issues in a very simple framework.³⁵

33. Favero and Giavazzi (2003) use this equation to study the effects of non-Ricardian fiscal policies in Brazil.

34. The papers summarized in section 1 provide fairly good coverage of the current state of research on this topic.

35. García and Valdés (2003) build a very similar model to illustrate the interaction of money and inflation under the inflation-targeting framework currently in use in Chile. They do not present estimations of their model, however.

We analyze three different shocks to the Chilean economy: an inflation shock, a foreign output gap shock, and a capital inflow shock. These three shocks reflect most of the variables that are currently relevant for monetary policy in Chile. We compare the evolution of three variables for each shock: the inflation rate, the policy rate, and the domestic gap. In the particular case of the inflation rate shock, we analyze the evolution of these three variables under two different scenarios. The first is based on the model as presented in the previous section and incorporating equation (3) for the inflation rate; the second replaces equation (3) with a calibrated relation that changes the weights on the forward-looking and backward-looking elements, most notably changing the coefficient of expected inflation to 0.7 while lowering the coefficient of lagged inflation to 0.3.

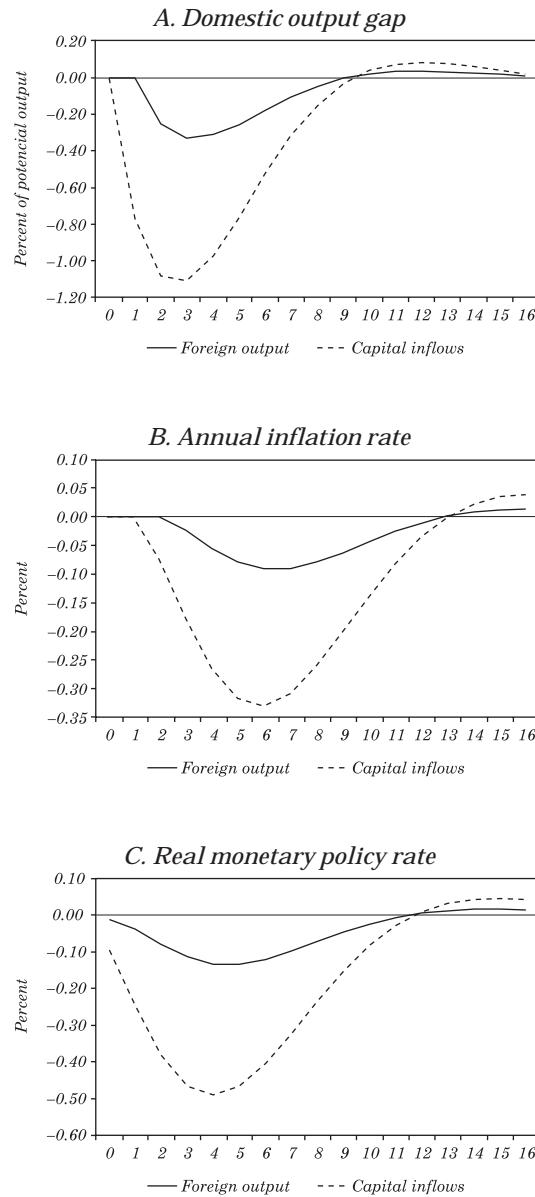
The structure of the simulation is as follows. We started by setting the initial values for all the endogenous and exogenous variables (and the market inflation expectations when used) equal to their 2001–2002 average values and then simulating the model forward using simple autoregressive processes for the exogenous variables; this simulation gives us the benchmark for comparing the effect of all the shocks.³⁶ We then ran the simulation again, this time incorporating the shocks in the model. In particular, the inflation rate shock is defined as a 0.5 percent higher inflation rate in the initial period. The shocks to the foreign output gap and the capital inflows are defined as a reduction equivalent to one standard deviation computed using the entire sample, which implies a shock equal to 0.5 percent for the foreign output gap and 0.67 percent for the capital inflows. All the shocks are defined as transitory, and we only report the effects when the shocks are allowed to show persistence or autocorrelation. The results are qualitatively similar, with significantly lower persistence if we do not incorporate the autoregressive specifications for the external variables in the model.³⁷

We now turn to the description of our results. The effect of the external shocks resembles the traditional dynamic effects of an aggregate demand shock, lowering both the domestic output gap and the inflation rate (see figure 1). Monetary policy endogenously

36. A more traditional way to simulate the model is to assume that the model is in the steady state and then apply the shocks; given the structure of the model, the solutions do not differ significantly. Another alternative would be to calibrate some of the equations so as to set a particular period as the steady state and then compute the evolution of the model starting from this steady state; this is the approach followed by Gallego, Servén, and Schmidt-Hebbel (in this volume).

37. The results for these simulations are available on request from the authors. The specification used does not incorporate cross-correlation between the shocks; all the time series processes are assumed to be univariate.

Figure 1. External Shocks: Quarterly Deviation from the Base Scenario



Source: Authors' own calculations. See the text for details.

responds to both effects and shows a significant reduction. Comparatively, the effect of foreign output is of a reduced magnitude with respect to the capital flow shock, something that could be inferred by simple inspection of the coefficients in the IS equation. The propagation mechanism appears in the graphs with the external variables affecting first the output gap and then the inflation rate; monetary policy reacts to both effects by lowering the real rate in response to reduced domestic activity and taking advantage of the room created by the low inflationary pressures.

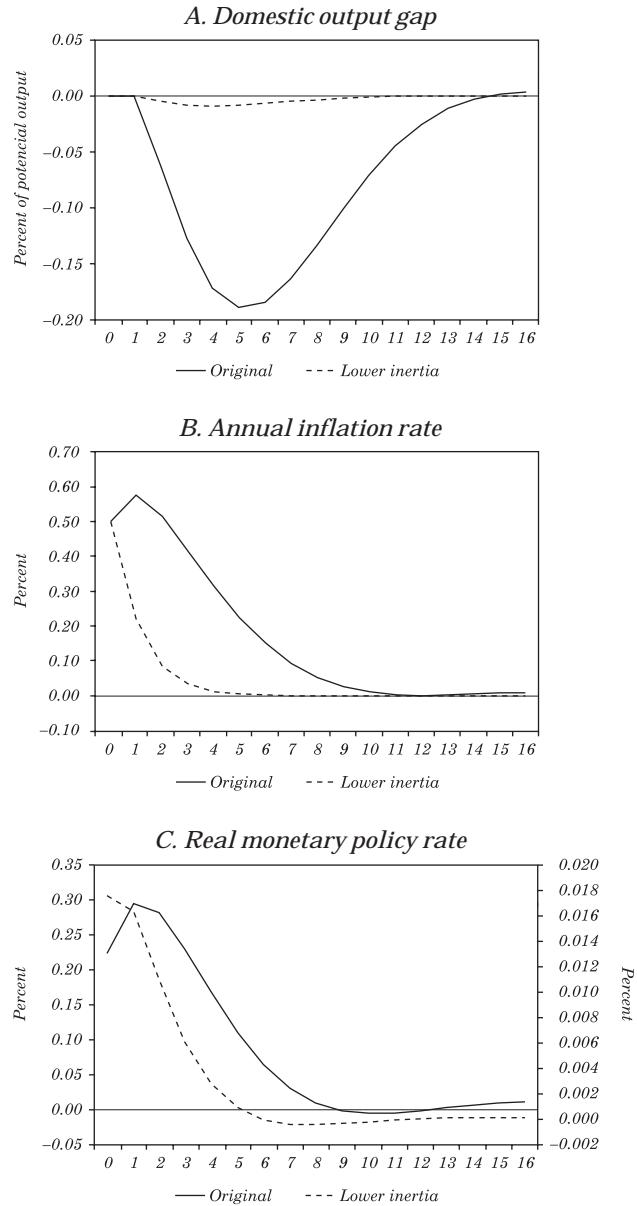
The effects are relatively important. Panel A of figure 1 illustrates that after three quarters the effect of the capital flow shock on the domestic output gap is 1.1 percent of potential output, while the maximum effect in the case of the foreign output gap is 0.32 percent (reached three quarters after the shock). For the inflation rate, the maximum effects are observed six quarters after the shocks, reflecting the propagation from output to inflation of these aggregate demand shocks (panel B).

Monetary policy turns out to be the most endogenous of all the variables under analysis. It initially responds to the reduction in the domestic output gap, but it is only when the inflation rate starts to fall that monetary policy effectively reacts with an aggressive reduction in the real rate, a result that probably generated a more precipitated recovery in domestic activity. The maximum reductions in the real interest rate are observed four to five quarters after the shock, but the response started to build immediately after the shock occurred, which emphasizes the forward-looking behavior of monetary policy (panel C).

All in all, the dynamic responses derived from the model confirm the important role that external factors play in the evolution of the Chilean macroeconomy. Even in a very simple model like the one presented in this paper, the results reflect a fact that is common knowledge among policymakers and other researchers in Chile.

Figure 2 depicts the simulation results for the case of the inflation rate shock. The series labeled *Original* corresponds to the solution when the 0.5 percent shock is simulated using equation (3). Panel B in the figure indicates that the inflation rate reaches its peak two quarters after the shock. The subsequent evolution reflects the important inflationary inertia found in the specification and also the parsimonious response of monetary policy to the shock. The effect disappears seven to nine quarters after the shock, but about half of the effect has already disappeared by the fourth or fifth quarter.

Figure 2. Inflation Rate Shock: Quarterly Deviation from the Base Scenario



Source: Authors' calculations.

Inflation expectations play a key role by anchoring the evolution of the observed inflation rate to the Central Bank's target rate, assumed to be 3 percent for the simulations.

Panel A of figure 2 shows that the domestic output gap suffers a significant slowdown after the inflation shock is observed, reaching its lowest value five quarters after the shock. This reduction in domestic activity must occur because of the increase in the interest rate, since there is no direct connection from the shock to aggregate demand. In fact, this effect on output vanishes if we simulate the same shock replacing equation (2) with a simple time series process that does not allow for an endogenous response of monetary policy to the inflation rate.³⁸

As usual, monetary policy reflects the evolution of future inflation with a small influence from the possible output costs of any increase in the policy rate (see equation (2)). The dynamics are straightforward: monetary policy reacts in advance so as to slow the acceleration in the inflation rate through its effect on domestic output.³⁹

To explore the relevance of inflation inertia in the dynamics of the economy, we construct a counterfactual exercise in which we replace equation (3) with a calibrated relation that changes the weights on the forward- and backward-looking (inertia) components of the inflation equation. The new weights are 0.7 for the expectation component and 0.3 for the lag of inflation. The simulation follows the same procedure as before, and the shock is of the same magnitude. The new results are shown in the corresponding panels of figure 2. The inflation rate shows exactly the same impact effect, but its persistence is significantly lower and is almost zero after two or three quarters. Of course, this difference implies significant differences for the rest of the variables. With the reduced endogenous persistence in inflation, monetary policy shows a very mild response that looks similar to the original simulations, but on a scale about 15 times smaller. In this case, a short-lived response of about a couple of basis points corresponds to the peak on the policy rate. The mapping into the output gap is obvious, with a very low inflation inertia, and the small

38. This comes from the implicit structure of the markup assumed in the pricing equation estimated in the model. This result is no longer valid if we allow for cost pressures on the production decision.

39. Given that we could not find an interest rate effect on the real exchange rate and that we did not impose interest rate parity in the exchange rate equation, we are ignoring a more immediate channel from monetary policy to inflation through an exchange rate pass-through.

reaction by the monetary authorities means that the domestic output gap shows almost no effect. Hence, the results are as expected, meaning that inertia increases the output cost of any anti-inflationary policy. Additional simulations show that the results are qualitatively the same if the model is simulated using equation (3') instead of our base specification with market expectations, such that our results are not a particular feature of our specification for the inflation equation.

4. CONCLUSIONS

We have built a small macroeconomic model of the Chilean economy to analyze the dependence of the evolution of economic activity on the external environment. Two main findings emerge from the simulation results. First, the counterfactual exercises confirm the Chilean economy's strong dependence on the external environment. Each shock analyzed generates nonnegligible effects on the economy. Relatively modest reductions in capital inflows and external activity can generate relatively significant effects in the output level, with the effect of capital inflows seeming to be particularly important. This dependence is to be expected given the high degree of openness of the Chilean economy, in that international trade and external financing are important relative to the size of the economy.

Second, with regard to the role of monetary policy in the adjustment to the shocks, we find that forward-looking behavior and a high credibility of monetary policy allows the authorities to deal with important shocks that can have significant transitory effects. In fact, simulations of the effects of an inflation shock highlight the importance of both forward-looking behavior and credibility on the inflation target, as the target anchors market expectations and thus affects the path of inflation and the rest of the variables. The degree of inertia in the inflation process is also a source of rigidities, however. The simulations show that it generates important variation in the side effects of the shocks, particularly in the cost of inflation stabilization after an inflation rate shock. This result is standard in the type of models analyzed in our paper.

Possible areas for further research include an empirical study of the effects of capital inflows on aggregate demand, together with an analysis of the change in monetary policy after nominalization and the abandonment of the exchange rate band.

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THE MONETARY TRANSMISSION MECHANISM IN CHILE: A MEDIUM-SIZED MACROECONOMETRIC MODEL

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The objective in building and specifying macroeconomic models is to reflect the main characteristics of an economy in a stylized way. This article describes a macroeconometric model for the Chilean economy. The aim of the model is to forecast the main macroeconomic variables, along with policy exercises and simulations. The different model equations describe both short-term movements within the economy and the long-term equilibrium. It is in this latter sense that the model can be described as structural. The main area interest in this kind of model involves the different dynamics of the variables, which can provide insight, for example, on the lags and magnitude of monetary policy transmission mechanisms. Their estimation is no substitute, however, for ensuring

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a medium-term equilibrium point toward which the economy must necessarily converge. We therefore use cointegration and error correction techniques for estimating the parameters. We also calibrate relations where necessary.

The model includes the main components of aggregate demand and external accounts. It also incorporates an aggregate supply block based on a standard production function, an equation for asset prices, and a wage, labor, margin, and price block. The key relative prices in the steady state, such as the real long-term interest rate, the real exchange rate, and the sovereign premium, are determined endogenously. We use the model to analyze and quantify the influence of monetary policy over inflation and the transmission mechanisms. The results are compared with those from a small macroeconomic model and several vector autoregressive (VAR) models, based on Phillips curves. Although these models are simpler and easier to manage, they provide less information.

This model was developed out of a need to answer more questions than a simpler gap model can address, by increasing the number of endogenous variables and dealing with the different transmission mechanisms in greater detail. It also reflects the need for a wider variety of possibilities for analyzing economic policy, together with the fact that the simulation process is dynamic in itself, so that models are constantly being revised.

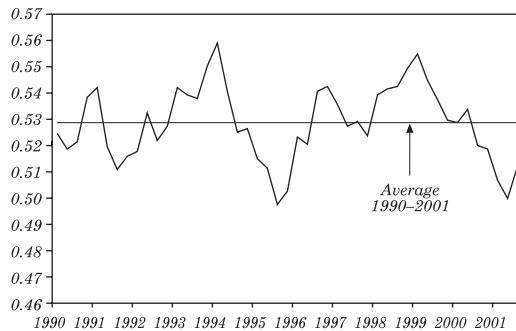
The next section highlights a series of stylized facts about the Chilean economy that must necessarily be reflected in the model. We then describe the model, in terms of both its steady state and behavioral equations. The concluding section explores the empirical properties of the model using impulse response exercises.

1. SOME STYLIZED FACTS ABOUT THE CHILEAN ECONOMY

The stylized facts presented in this section allow us to define some of the characteristics that a macroeconometric model must contain in order to simulate the Chilean economy.

1.1 Stable Factoral Distribution of Income

The labor factor's share (α_N) of nominal gross domestic product (GDP) fluctuated around 53 percent during the period under analysis (1990–2001). We estimated it by dividing the wage bill by nominal

Figure 1. Labor Income as a Share of GDP

Source: Authors' calculations based on National Institute of Statistics and Central Bank of Chile data.

GDP (YN), with different weights for wage-earning employees and self-employed workers.¹

Labor's stable share of GDP over time, as figure 1 indicates, suggests that long-term employment to real wages and employment to output elasticities equal one. Because real wages tended to rise throughout this period, labor's stable share of GDP reflects the fact that average labor productivity also rose by a similar amount, on average.²

1.2 Sensitivity to the World Cycle

Chile is a small, open economy that is affected by fluctuations in the world economy. Shifts in world demand directly affect the prices of Chile's main exports and may also affect volumes. Fiscal and monetary policies in the main economies influence financial conditions at the global level. Together with changing sentiment in financial markets, these determine capital flows to emerging economies, including Chile. During the past

1. When calculating the wage bill, different types of workers must be weighted, according to whether they are employees (NW) or self-employed (NSE). The first contribute to social security, so their share of GDP is measured through labor costs (CL). The second, in contrast, do not have access to this benefit and therefore their wages are considered to be a percentage of average nominal wages in the economy. This is assumed to be 60 percent.

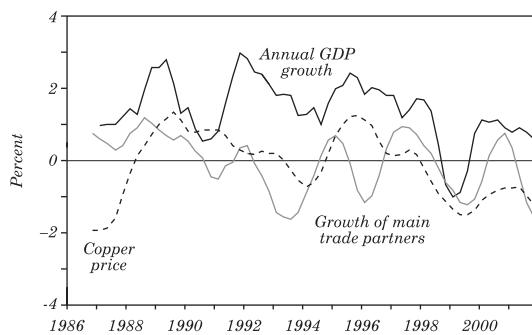
2. When labor income's share of output is calculated from 1986 the variable seems to show a different tendency. In a regression, however, the coefficient accompanying this trend reaches 0.001 which, while statistically different from zero, is of little enough magnitude to assume that labor's share is constant.

decade and a half, Chile demonstrated a rather close association between external indicators and domestic economic growth (see figure 2).

1.3 Unemployment and Private Consumption

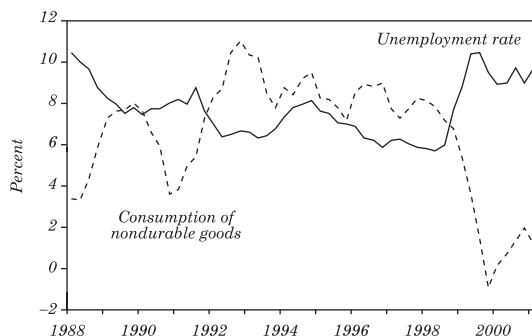
The Chilean economy exhibits a negative correlation between consumption and unemployment. This inverse relationship is apparent in figure 3. Higher employment rates coincide with slower annual growth in spending on nondurable consumer goods. The unemployment rate can be understood as an indicator of the level of

Figure 2. Economic Growth and External Conditions



Source: Central Bank of Chile.

Figure 3. Annual Growth in Consumption and Unemployment



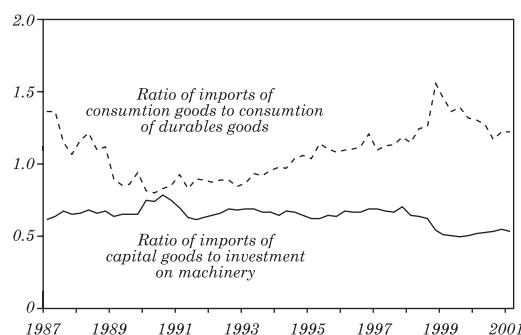
Source: Authors' calculations and Central Bank of Chile.

household uncertainty and expectations. This means that the higher unemployment, the more households reduce their consumption, probably out of caution. Moreover, high unemployment implies reduced household income, and this liquidity restriction translates into reduced spending on consumption. Consequently, growth in aggregate consumption, far from behaving at random, is highly correlated with the economic cycle.

1.4 Importance of the Imported Component of Domestic Expenditure

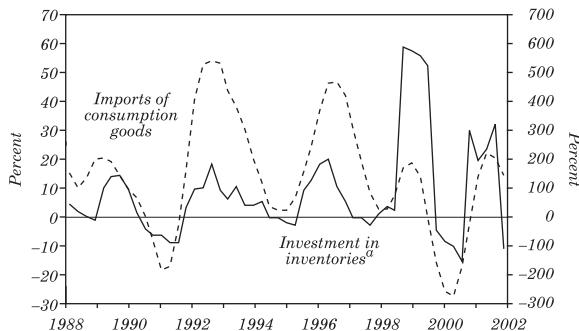
By being open to foreign trade, a small economy such as Chile resorts to international markets to meet some of its domestic demand requirements. This means that, for example, imports of capital goods account for almost all investment in machinery. Indeed, virtually all durable goods purchases involve imports. Figure 4 reveals not only the relevance of import volumes for some components of domestic demand, but also the stability of this relationship over time. Furthermore, the discrepancies between spending on durable consumer goods and imports of these goods largely reflect inventory accumulation. Figure 5 shows that rising imports of consumer goods and changes in investment in inventories (both on average for four moving quarters) are closely related. The importance of foreign trade to the different components of domestic demand also means that the real exchange rate is an important variable that influences domestic spending decisions.

Figure 4. Imports and Domestic Expenditure



Source: Authors' calculations and Central Bank of Chile.

Figure 5. Imports and Inventories
Quarterly growth (4 quarters moving average)



Source: Central Bank of Chile.

a. Secondary y axis.

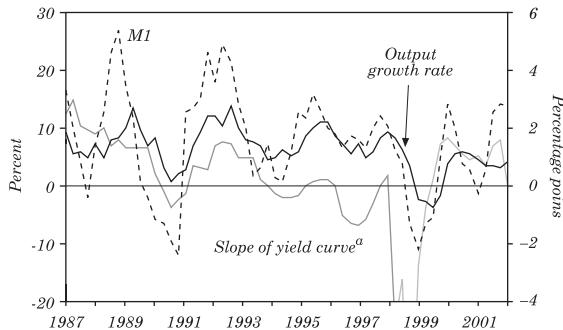
1.5 Financial Markets throughout the Economic Cycle

The relationship between monetary aggregates, interest rates, and output has been the subject of many studies.³ These monetary aggregates, particularly real M1A, and the structure of interest rates generally led economic activity in recent decades. Output growth, M1, and the difference between long-run interest rates (based on the Central Bank's eight-year adjustable bond, or *PRC8*) and short-run interest rates (*MPR*) are depicted in figure 6. In the structural models presented below, money is not a transmission channel for monetary policy, whereas interest rates are, because money does not add information beyond that contained in other explanatory variables. Money has not proved useful for predicting inflation or any of the other variables included in the model.

1.6 Factors Determining the Surcharge on External Financing

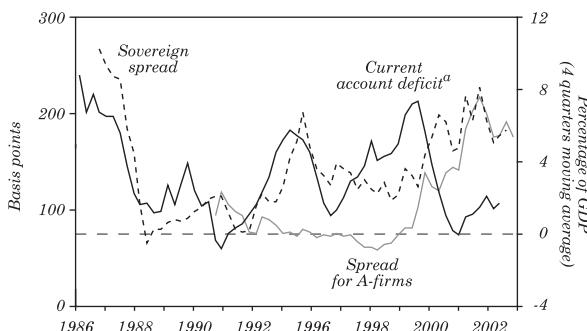
A key variable for expenditure decisions within the economy, both directly and indirectly, is the financing surcharge that domestic agents must pay on external debt, because of its impact on domestic interest rates. Although there are no measurements of this surcharge over a long period of time, it is possible to construct

3. See for example Herrera and Rosende (1991); Rojas (1993); Herrera and Magendzo (1997); Bravo and Franken (2002); Belaisch and Soto (1998).

Figure 6. Annual GDP Growth and Financial Variables

Source: Authors' calculations and Central Bank of Chile.

a. Secondary y axis.

Figure 7. Determinants of the Cost of External Financing

Source: Central Bank of Chile.

a. Secondary y axis.

approximations. As figure 7 indicates, trends in the external financing surcharge are consistent with a world in which solvency and liquidity are important. Until 1997, periods of high deficits in Chile's current account were accompanied by relatively significant increases in its spread, which may indicate that external financing became more costly as demand grew relative to the size of the economy.⁴ This relationship seems to break down after the Asian crisis and financial turbulence in Russia and other economies.

4. See Bernanke, Gertler, and Gilchrist (1996).

Evidence also shows, however, that the financial surcharge in Chile is associated with the financial surcharge paid by companies in similar risk categories in the United States.⁵ This surcharge has risen significantly since 1997.

We refer to the premium surcharge or spread affecting agents who issue debt abroad as the external financing surcharge (*REXF*). These costs are based on the risk level implicit in buying the debt of a specific country. They can be estimated by looking at sovereign spreads or surcharges required by bonds issued by a given government compared to the return on nominal U.S. Treasury notes (that is, the T-note with a similar maturity).

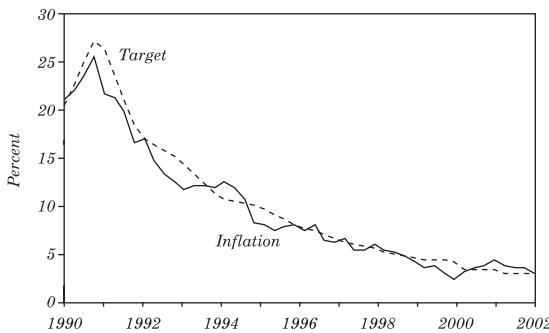
1.7 Inflation, Inflation Targeting, and the Economic Cycle

The Central Bank's use of inflation targeting since the beginning of the 1990s has proved successful in terms of coordinating agents' expectations. Annual inflation tended to fall following a gradual reduction in inflation targets (figure 8). Although factors associated with indexation can introduce inertia in the inflationary process, inflation expectations and, in particular, the Central Bank's credibility in terms of achieving the target do affect inflation itself. Demand conditions in goods and factor markets also influence inflation. Simple measurements of output can be empirically associated with changes in inflation over the past fifteen years. The relation between these two variables has weakened since 1996, but this can be associated first with the peso appreciation and later with its depreciation (figure 9).

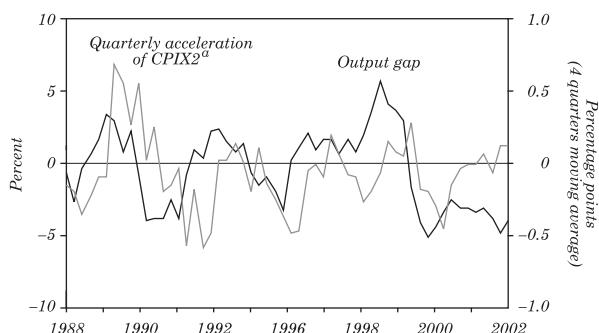
2. STRUCTURAL FORECAST MODEL (MEP2)

As mentioned in the introduction, the different equations in the model describe both short-term movements in the economy and long-term equilibrium. It is in the latter sense that the model can be labeled as structural. The techniques used to estimate parameters for the different equations are therefore consistent with being able to distinguish short-term from long-term effects (that is, cointegration). These methods, as with all econometric methodology, are subject to important degrees of uncertainty. This uncertainty largely stems from the sensibility of the estimated parameters to the deep structure of

5. See the Central Bank's Monetary Policy Report of January 2001.

Figure 8. Inflation and Inflation Target

Source: Central Bank of Chile.

Figure 9. Inflation and the Output Gap

Source: Central Bank of Chile.
a. Secondary y axis.

the economy, which cannot be directly observed. To deal with situations in which the empirical estimation is poor, in which there are well-founded indications of structural changes in different relationships, or in which economic theory itself has important relationships that must be addressed, we opted for calibrating specific parameters, even though the calibrated value may be rejected using standard statistical methods.⁶ This calibration process is the second reason for calling these models structural.

6. By calibration we mean that in some equations, the constant and occasionally the slope parameters were restricted, in order to keep the equation consistent with the long-term equilibrium of an economy with a Cobb-Douglas production function.

A third reason, associated with the above, has to do with the many different legal restrictions on determining certain prices within the economy, particularly public utility charges. The Central Bank cannot ignore these facts, and they are explicitly incorporated into the modeling of the inflationary process.

To date, two structural forecast models are being developed at the Central Bank of Chile, known as MEP1 and MEP2. Qualitatively speaking, they share the characteristics described above. One of the main differences between MEP1 and MEP2 has to do with the degree of macroeconomic variable aggregation. MEP2 consists of aggregate demand, aggregate supply, and an equation that relates prices and economic activity. MEP2 expands MEP1 by estimating the different components of aggregate demand. It also incorporates the estimated evolution of the capital stock into the forecast of potential output. In addition to estimating aggregate demand and supply, MEP2 estimates the current account of the balance of payments (and, by definition, internal demand) and the *REXF*.

2.1 The Steady State in MEP1 and MEP2

The steady state refers to balanced growth trends within the economy, incorporating demand and supply conditions in goods and factor markets that are consistent with full employment of resources and constant relative prices. The main variables within the steady state are determined endogenously in MEP2. The following equations summarize the conditions of the steady state first for MEP1, which encompasses only inflation, GDP, and financial market variables, and then for MEP2.

MEP1 steady state

$$Y = \bar{Y},$$

$$INF4 = 3\%,$$

$$PRC8 = \bar{PCR8},$$

$$MPR = \bar{MPR}, \text{ and}$$

$$RER = \bar{RER}.$$

MEP2 steady state: aggregate supply

$$Y = A \cdot N^{\alpha_N} K_{\text{CONSTR}}^{\alpha_K_{\text{CONSTR}}} K_{\text{MACH}}^{1-\alpha_N-\alpha_K_{\text{CONSTR}}} ,$$

$$\alpha_N = \frac{[(1+\tau)\lambda + (1-\lambda)W]}{YN} ,$$

$$\frac{K_{\text{CONSTR}}}{Y} = \alpha_{K_{\text{CONSTR}}} CK_{\text{CONSTR}}^{-1} , \text{ and}$$

$$\frac{K_{\text{MACH}}}{Y} = \alpha_{K_{\text{MACH}}} CK_{\text{MACH}}^{-1} .$$

Aggregate demand and the external sector

$$\frac{PC_H}{DPY} = \phi_{C_H} ,$$

$$\frac{K_D}{C_H} = \phi_{K_{D0}} \cdot CKD^{-\phi_{KD1}} ,$$

$$\frac{QM_C}{C_D} = \phi_{QM_C} ,$$

$$\frac{QM_K}{GFK_{\text{MACH}}} = \phi_{QM_K} ,$$

$$\frac{QM_{NLF}}{Y} = \phi_{QM_{NPL0}} \cdot RER^{-\phi_{QM_{NPL1}}} , \text{ and}$$

$$\frac{QX_{\text{OTHER}}}{Y} = \phi_{QX_{\text{OTHER}0}} \cdot YEX^{-\phi_{QX_{\text{OTHER}1}}} \cdot Y^{-\phi_{QX_{\text{OTHER}1}}} \cdot RER^{-\phi_{QX_{\text{OTHER}1}}} .$$

Prices and costs

$$INF4 = 3\% ,$$

$$CPI = (MG - \phi_{MG}) CLU^{0.68} \cdot GW^{0.16} \cdot CIMP,$$

$$CLU = \frac{PW}{Y/N} (1 + VAT),$$

$$CIMP = EXPI \cdot NER(1 + VAT)(1 + TAR), \text{ and}$$

$$W = PW^{0.83} \cdot GW^{0.17}.$$

Financial markets

$$PRC8 = REX_{LT} + RISK_{LT},$$

$$MPR = PRC8 - \rho, \text{ and}$$

$$RER = RER_{+1}.$$

The steady state of MEP2 is consistent with a Cobb-Douglas production function, while inflation and prices remain neutral. Potential output at each point in time therefore depends on the accumulated capital stock and normal resource utilization. Technical change is also exogenous and is reflected in total factor productivity (TFP) and the natural unemployment rate.

The accumulation of each type of capital depends on the cost of capital utilization, which is set by investment financing costs, that is, the long-term interest rate plus the respective depreciation rate, plus the price of capital measured as output units. The depreciation rate for each type of capital is assumed to be constant, but both interest rates and the relative price of capital in MEP2 are endogenous variables. Long-term interest rates are determined by conditions of international arbitrage using uncovered interest rate parity corrected for risk premiums and imposing a constant equilibrium real exchange rate. In the case of machinery and equipment, the relative price is directly affected by the real exchange rate, while the level of wages is more important for the relative price of construction.

As a result, the parity condition is key for determining interest rates in MEP2. The link with the rest of the model comes from the equilibrium between saving and investment. The sovereign risk premium is assumed to depend on the current account deficit as a

percentage of GDP, which reflects imperfections in international capital markets. The dynamics of domestic expenditure affect financing conditions.

Private consumption of nondurable goods converges to a constant fraction of private disposable income, while the purchase of durable goods is corrected to reach the desired stock of durable goods, which depends on the cost of durable versus nondurable consumption goods. Thus, in the steady state, purchases of durable goods are such that they allow us to keep the ratio of durable stock to nondurable consumption constant.

The public sector affects the model through its income and expenditure policies, in the context of achieving a structural surplus set at 1 percent of GDP. This leads to a rule for the behavior of capital and current public expenditure. Revenues are a function of cyclical conditions that affect activity and expenditure, but include an underlying tendency.

The external accounts depend on expenditure decisions. The volumes of imported consumption and capital goods approach a constant fraction of durable purchases and gross capital formation in machinery. In this sense, the equilibrium real exchange rate indirectly affects these expenditure components by affecting the capital costs of durable consumption goods and of machinery and equipment. Similarly, imports of intermediate nonfuel goods tend toward a constant fraction of GDP, which depends on the real exchange rate. The import volumes of intermediate nonfuel goods evolve according to simple rules. A simple rule is also used for the evolution of imports of nonfactoral services. Altogether, the main exports are forecast using sector-specific information regarding production plans. An econometric approximation is used solely for products other than major exports, which depend on the growth of the country's main trading partners and the real exchange rate.

The block including prices, wages, and the labor market reflects the neutrality of monetary policy in the long term. Growth in the cost of labor in real terms is equal to growth in average labor productivity. As a result, the increase in nominal wages is equal to growth in real wages plus inflation, which is stable and equal to the steady-state target. This ensures that the model remains consistent with the Cobb-Douglas production function, as does our treatment of the factorial distribution of income, which remains constant. This means that in the long-term, the elasticity of employment to real wages and the elasticity of employment to output have a value of one.

Although there is ample international evidence relating unemployment to the level of real wages, in this case the natural unemployment rate is assumed to be exogenous.

Finally, in the long run the policy rule for the monetary policy rate tends toward a neutral monetary policy position, which is consistent with full employment of productive resources and inflation in line with the target. This “neutral” monetary policy rate is given externally in MEP1, while in MEP2 it results from an interest rate structure consistent with a stable real exchange rate.

2.2 The Functioning of Financial Markets

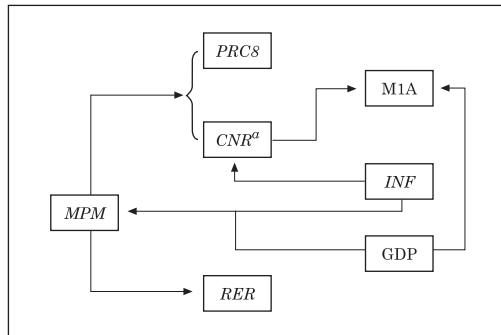
Both models (MEP1 and MEP2) share a block that describes the functioning of financial markets in Chile. This block includes three ingredients: first, the way movements in the monetary policy rate are transferred in the short term to other market interest rates and the real exchange rate; second, how private sector demand for money is determined; third, the rule that determines monetary policy rate movements.

With regard to the first point, when markets are functioning normally, long-term rates (*PRC8*) reflect arbitrage conditions affecting investment alternatives, particularly short-term instruments, so the expected behavior and level of the monetary policy rate and inflation (*INF*) influence the value of these long-term instruments. The same happens with other short-term instruments, such as nonindexed thirty- to eighty-nine-day deposit rates. Nominalizing the monetary policy rate reduced its impact on inflation, which makes it necessary to suitably correct econometric estimates for any simulation or forecast exercise.

Another sphere in which arbitrage conditions should be expected is the foreign currency exchange, particularly under the floating exchange rate system in effect in Chile. The foreseeable performance of interest rate differentials affects the financial cost associated with holding positions in one currency or another, thus affecting the value of the exchange rate. The empirical evidence regarding the validity of the uncovered interest rate parity is extremely weak. It does, however, offer a theoretical framework consistent with rational expectations and market arbitrage, so in general some version of this theory is applied to carry out forecasts and simulations.

The actual level of economic activity, represented by the gross domestic product (*Y*), is typically associated with the volume of

Figure 10. Monetary Policy Transmisssion to Financial Markets



Source: Authors' elaboration.

a. CNR^a is the medium-term nominal market interest rate.

transactions within the economy. Thus, the demand for real balances to carry out these transactions depends on Y along with the alternative cost of money, reflected in the nonindexed short-term deposit rate.

Finally, because the operational instrument used by the Central Bank is a target for the nominal interbank rate, some behavioral rule for this variable must be introduced. This is no minor point, because if we don't apply a reasonable policy rule, the model's growth and inflation forecasts will diverge in the presence of surprises on the aggregate demand side. If faced, for example, with an unexpected increase in economic growth, expected inflation will also rise. With a constant monetary policy rate, real ex ante rates in the economy fall, which in turn further increases the aggregate demand impulse and generates more inflationary pressures.

A considerable amount of literature deals with monetary policy rules.⁷ The next section contains a more detailed discussion of this point. In any case, evaluating different kinds of policy rules is not the central objective of this paper. In practice, to carry out official growth and inflation forecasts, the Central Bank uses the assumption that the monetary policy rate will remain constant over an eight-quarter horizon. It is enough to emphasize the importance of specifying a response from monetary policy to inflation deviations from the target to be able to complete macroeconomic models and use them to carry out simulations, such as those presented below.

7. For a comprehensive review of the relevant literature, see Taylor (1993) and Clarida, Gali, and Gertler (1999).

Demand for Money

Chile's Central Bank uses the interest rate as its monetary policy instrument. As a result, demand for money is determined in a residual fashion within the monetary policy stance. Broad money's performance thus depends on output and the nominal interest rate, and it serves to forecast the quantity of money that the economy will require. The Central Bank has no target for the evolution of these aggregates.

The cointegration vector relates the behavior of the (logarithm of the) seasonally adjusted real money ($\log M1$);⁸ the seasonally adjusted GDP ($\log Y$) and a transformation of the nonindexed thirty- to ninety-day deposit rate (RND). A dummy variable is included for the third quarter of 1988. The OLS results are as follows:

$$\begin{aligned} \log M1 = & -9.34 + 1.06 \log Y - 0.13 \log \left(\frac{RND}{1+RND} \right) \\ & - 0.60 \left[\log M1_{-1} + 9.34 - 1.06 \log Y_{-1} + 0.13 \log \left(\frac{RND}{1+RND} \right)_{-1} \right] \quad (1) \\ & + \sum_{i=1}^2 c_i \Delta \log Y_i + \sum_{i=1}^2 d_i \Delta \log \left(\frac{RND}{1+RND} \right)_i + D883, \end{aligned}$$

where the numbers in parentheses are Newey-West corrected t statistics, the adjusted R squared is 0.99, and the average quadratic error is 2.0 percent. The LM serial correlation test (four lags) resulted in $F = 0.227$ (with a p value of 0.922); the Jarque-Bera normality test resulted in $\chi^2 = 3.654$ (with a p value of 0.161); and the White heteroskedasticity test resulted in $N \cdot R^2 = 0.449$ (with a p value of 0.970). The estimation period is 1986:4 to 2001:1. Both the magnitudes of interest rate and income elasticities are in line with previous findings.⁹

Uncovered Interest Parity Condition

The exchange rate is a key relative price for a small, open economy like Chile. To model this variable, we use uncovered interest rate parity. We assume that the expected real exchange rate involves three

8. All seasonal adjustments have been made using the standard X12-ARIMA method.

9. See Mies and Soto (2000), and Restrepo (2002).

factors: the future exchange rate consistent with the model's own forecast; inertial expectations, which only consider the lagged exchange rate; and expectations associated with the long-term real exchange rate ($\log RER_{LT}$). For the estimation, we impose the restriction that the sum of the coefficients of these three variables is one. The interest rate spread is calculated in real terms, taking the difference between the foreign interest rate (REX) and the real monetary policy rate ($RMPR$). The foreign interest rate is constructed using the real London interbank offered rate (LIBOR), the LIBOR spread, and the reserve requirement. The following instruments were used for the lead of the real exchange rate: lags of the (log) real exchange rate, lags and differences in real money, the difference between inflation and the target, the relative position of the exchange rate within the band, the output gap, lags of the monetary policy rate, lags of the nominal exchange rate, and lags of the multilateral exchange rate. The results of the two-stage least squares (2SLS) regression are as follows:

$$\begin{aligned} \log RER = & 0.20 \log RER_{-1} + 0.63 \log RER_{+1} \\ & (2.52) \quad (10.33) \\ & + 0.17 \log RER_{LT} + (REX - RMPR), \end{aligned} \quad (2)$$

where the numbers in parentheses are Newey-West corrected t statistics, the adjusted R squared is 0.90, and the average quadratic error is 3.52 percent. The LM serial correlation test (four lags) resulted in $F = 1.433$ (with a p value of 0.000); the Jarque-Bera normality test resulted in $\chi^2 = 67.109$ (with a p value of 0.161); and the White heteroskedasticity test resulted in $N \cdot R^2 = 54.120$ (with a p value of 0.000). The estimation period is 1986:4 to 2001:3.

The theory of uncovered interest rate parity cannot be empirically validated in Chile, as is the case using international evidence.¹⁰ It has therefore been imposed. This restriction introduces some problems in the regression, however, which also occurs in the case of residue normality. In fact, the Jarque-Bera test allows us to conclude that the distribution of error is not normal.

Because Chile trades with a wide range of countries besides the United States, the real exchange rate affecting the competitiveness of Chilean products is the multilateral real exchange rate ($\log MRER$). That is, the weighted sum, by trading share, of bilateral real exchange

10. See Engel (1995); Flood and Taylor (1996); Isard (1995); McDonald and Taylor (1992); Lewis (1994).

rates. The difference between the bilateral and the multilateral real exchange rate is reduced to the difference in the index of external prices relevant to Chile ($\log EXPI$) and the U.S. consumer price index (CPI) ($\log CPI_{US}$):¹¹

$$\log MRER = \log RER + \log EXPI - \log CPI_{US} . \quad (3)$$

To explain the behavior of the external financing surcharge (REXF), an equation was estimated by 2SLS. The external financing surcharge is an endogenous variable of the model. Explanatory variables are the current account deficit (CAD) and the spread affecting category A firms from the United States (RAM). The instruments used for this estimation were the changes in the terms of trade, the residuals from durable and nondurable consumption equations, and investment (construction and machinery). The resulting parameters are the following:

$$REXF = \phi + 0.13CAD + 0.89RAM . \quad (4)$$

The hypothesis that the parameter for the surcharge on category A firms is one cannot be rejected. This result is reasonable given that Chile's sovereign debt enjoys the same rating.

Long-term Real Exchange Rate

In the long term, there is a relationship between the exchange rate, the terms of trade, public expenditure, and net international assets. The variables that are important for estimating the long-term exchange rate are the logarithm of the real exchange rate ($\log RER$), net international assets as a percentage of GDP (IA), the logarithm for the terms of trade ($\log TOT$), and total factor productivity (TFP). In its steady state, however, a constant exchange rate is imposed in this model, so that the nominal exchange rate behaves according to the differential between local and foreign inflation.

Monetary Policy Rule

For the purposes of our simulation exercises, we specify a reaction function for Central Bank policy that leaves some degree of freedom of choice in the parameters. We use a linear specification

11. Feliú (1992) describes the methodology for building an external price index.

for the sake of simplicity. The policy rule associates the nominal monetary policy rate (*MPR*) with expected inflation, the output gap, and the lagged and expected gap between expected inflation and target inflation. A constant reflects the neutral instance for monetary policy.

Monetary policy reacts to expected inflation, not only because of deviations from the target, but also because expected inflation affects real ex ante rates within the economy, which are those that ultimately influence consumption and investment decisions. We also include the output gap in this policy rule, not necessarily because full employment is one of the Central Bank objectives, but rather because this is one of the main variables affecting medium-term inflationary pressures.¹² In addition, monetary policy may experience some inertia over time, which makes sharp movements in interest rates are generally undesirable owing to the volatility they could potentially introduce into financial markets. Furthermore, some analysts argue that a gradualist monetary policy is best in the face of uncertainty.¹³

Similarly, alternative policy rules can incorporate other arguments, such as the current account of the balance of payments, or possess nonlinearities, the result of the existence of a target range rather than a target point. These considerations can lead to monetary policy being more aggressive in one direction or another. The monetary policy rule proposed here is of the following form:¹⁴

$$MPR = INF4^E + \phi_{R_0} + \phi_{R_1} (INF4^E - 3\%) + \phi_{R_2} GAP + \phi_{R_3} MPR. \quad (5)$$

This policy rule is appropriate for the current nominal scheme. Nonetheless, most of the estimations carried out in this and other sections of the paper include the period during which the *MPR* was set in indexed terms. To be able to use these models to forecast within the current stance, we use the Fischer equation, which indicates that the real ex ante rate (*RMPR*) is equal to the nominal rate minus expected

12. Svensson (1997) and Agénor (2002) emphasize this point. For Chile, the same argument can be found in García, Herrera, and Valdés (2002).

13. Woodford (1999).

14. Morandé (2002) argues that for part of the 1990s, the current account deficit was associated with monetary policy issues. Medina and Valdés (2002b) reveal the implications of this type of policy rule in terms of how interest rates respond to inflation and the capacity gap. Medina and Valdés (2002a) study the implications of nonlinearities in inflation targeting, including the target range, with regard to the aggressiveness of monetary policy.

annual inflation:

$$RMPR = MPR - INF4^E. \quad (6)$$

Market Interest Rates

Monetary policy is transmitted to other interest rates because of the natural arbitrage inherent in Chile's financial markets. Short-term deposit rates affect the demand for real balances, as do long-term indexed rates, which play a decisive role in economic agents' spending decisions.

Demand for monetary balances depends on their alternative cost, which is associated with the short-term nominal deposit rate. This reacts to movements over time in the *MPR* and a margin associated with the cost of funds to the banking system:

$$RND = \phi_{CAP} + +0.18 RND_{+1} + 0.82 MPR - 1.83 D981 - 1.37 D983, \quad (7)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.93, and the average quadratic error is 8.7 percent. The LM serial correlation test (four lags) resulted in *F* = 0.354 (with a *p* value of 0.838); the Jarque-Bera normality test resulted in $\chi^2 = 3.125$ (with a *p* value of 0.797); and the White heteroskedasticity test resulted in $N \cdot R^2 = 2.609$ (with a *p* value of 0.047). The estimation period is 1994:3 to 2001:2.

With regard to real long-term rates, the yield curve reflects arbitrage conditions between short- and long-term rates, represented by a version of the expectation hypothesis. This indicates that the difference between long-term Central Bank indexed bond (*PRC8*) rates and the short-term rate (*RMPR*) reflect expectations of capital losses or gains associated with holding these bonds. This can be translated in the long-term bond rate as a weighted average of the expected value of this rate and the short-term rate, where the weighting factor depends on the long-term bond's duration.¹⁵ As in the uncovered parity equation, we assume that expectations about the long-term rate depend on lags and leads of the same variable. The estimation therefore relies on instrumental variables.

The instruments used are the difference between the CPI and the

15. Campbell, Lo, and McKinlay (1997) provide a detailed analysis of the expectation hypothesis, while Blanchard (1984) and Blanchard and Fischer (1989) apply this theory in a simple macroeconomic model.

target, the real exchange rate and its difference, the exchange rate's position within the exchange rate band, the misalignment of the real exchange rate compared to trend value, long-term and deposit rate lags, the monetary policy rate and its lag, and the output lag gap:

$$PRC8 = \phi_{PRC8} + 0.43 PRC8_{-1} + 0.53 PRC8_{+1} + 0.04 (RMPR), \quad (8)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.89, and the average quadratic error is 0.25 percent. The LM serial correlation test (four lags) resulted in *F* = 0.944 (with a *p* value of 0.448); the Jarque-Bera normality test resulted in $\chi^2 = 2.885$ (with a *p* value of 0.236); and the White heteroskedasticity test resulted in $N \cdot R^2 = 26.061$ (with a *p* value of 0.000). The estimation period is 1990:1 to 2001:2.

We cannot reject the hypothesis that the sum of the coefficients accompanying the lags and leads in the *PRC8*, plus the *RMPR*, add up to one. Moreover, a constant is incorporated to reflect the existence of a premium for long-term maturity.

2.3 Aggregate Demand

The effect of the monetary policy rate is transmitted to aggregate demand via the functioning of financial markets. MEP1 uses a direct approximation of this problem, in which it models GDP excluding sectors associated with natural resources, such as fishing, mining, electricity, gas, and water (*YRA*). This provides the general impact of interest rates and the exchange rate on activity, but it is unable to identify precisely in which expenditure component these effects are produced. In MEP2, financial conditions affect different components of expenditure separately, which allows us to identify monetary policy transmission channels more accurately.

Aggregate demand (*AD*) is the sum of five components:

$$AD = PC + I + CG + X - M, \quad (9)$$

where *PC* denotes total private consumption, *I* denotes total investment, *GC* denotes government expenditure on final consumption goods, *X* total exports of nonfinancial goods and services and *M* total imports of nonfinancial goods and services, all expressed in constant 1986 pesos. In what follows we provide details on the estimation of each of these components.

Private consumption

Total private consumption (PC) can be broken down as follows:

$$PC = PC_D + PC_H, \quad (10)$$

where PC_D denotes private purchases of durable goods¹⁶ and PC_H denotes private consumption of nondurable or habitual goods. For the long term, it is assumed that the ratio of nondurable goods to disposable private income (DPY) is constant. Disposable private income is calculated as disposable domestic income minus public sector income. Disposable domestic income is obtained from GDP, corrected for net external income and the changes in the terms of trade. The short-term dynamic includes unemployment (U) as an indicator of household perception of uncertainty and expectations. The equation for the short-term dynamic, including error correction, is as follows:

$$\begin{aligned} \Delta \log PC_H = & \phi_{PC_{H_0}} - 0.11 \left(\log PC_{H_{-1}} - \log DPY_{-1} - \phi_{PC_{H_1}} \right) \\ & - 1.04 \cdot \frac{1}{2} \sum_{i=0}^1 U_{-i} - 1.59 \cdot \frac{1}{3} \sum_{i=0}^2 PRC8_{-i} \\ & + 0.26 \cdot \frac{1}{2} \sum_{i=1}^2 (PRC8_{-i} - MPR_{-i}) - 0.53 \Delta \log PC_{H_{-1}} \\ & - 0.49 \Delta \log PC_{H_{-2}} - 0.28 \Delta \log PC_{H_{-3}} \\ & + 0.09 \Delta \log DPY + 0.04 D894 + 0.05 D984, \end{aligned} \quad (11)$$

where the numbers in parentheses are Newey-West corrected t statistics, the adjusted R squared is 0.63, and the average quadratic error is 1.1 percent. The LM serial correlation test (four lags) resulted in $F = 0.196$ (with a p value of 0.660); the Jarque-Bera normality test resulted in $\chi^2 = 0.985$ (with a p value of 0.611); and the White heteroskedasticity test resulted in $N \cdot R^2 = 19.919$ (with a p value of 0.867). The estimation period is 1987:2 to 2000:4.

16. The purchase and stock of durable goods are constructed using the methodology proposed by Gallego and Soto (2000).

The error correction term indicates a half-life of deviations from the long-term value totaling a little over three quarters. Changes in growth rates for disposable private income affect consumption of nondurable goods in the short term. This is consistent with assuming that at least part of the population makes consumption decisions based on current rather than permanent income.¹⁷ Thus, a 1 percent increase in disposable private income translates into a 0.09 percent increase in private expenditure on nondurable consumption goods. Also, a 1 percent increase in unemployment (or, to be more precise, in the moving two-quarter average introduced here) is associated with a 1 percent reduction in consumption of nondurable goods. Changes in long- and short-term interest rates also affect consumption in the short term. An average one-point increase during the current quarter and the last two quarters of the eight-year adjustable bond (*PCR8*) reduces nondurable consumption by 1.6 percent, while a similar increase in the average short-term rate (*MPR*) over the previous two quarters produces a 0.3 percent decline in nondurable consumption.

For the purchase of durable goods, we assume that in the long term the ratio of the consumption of durable goods over the consumption of nondurable goods depends on the cost of use of durable goods (CK_D). The cost of use is calculated as the relative price, corrected for depreciation and the relevant interest rate.¹⁸ Moreover, we assume that the consumption of durable goods (which is different from the purchase of these goods) is a percentage of the stock of these goods (K_D) and therefore can be approximated using this last variable. The equation for the demand of durable goods in the short term is denoted by:

$$\begin{aligned} \Delta \log PC_D = & \phi_{CD_0} - 0.14 \left(\log K_{D_{-1}} - \log PC_{H_{-1}} + \log CK_{D_{-1}} \right) \\ & - 4.69 PRC8_{-1} - 0.75 \Delta \log PC_H + 2.69 \left(PRC8_{-1} - MPR_{-1} \right) \\ & - 1.40 \Delta (\log CPI_{DK} - \log CPI_{HK}) \\ & - 0.26 \Delta \log PC_{D_{-4}} + 0.16 D912 - 0.10 D913, \end{aligned} \quad (12)$$

17. This type of assumption is explained in detail and tested by Campbell and Mankiw (1989). For the case of the United States, the authors find that consumers who consume based on their current income account for about 50 percent of national income.

18. Both the cost of use of durable goods and the long-term relationship are first-order conditions for a model that deals with nondurable and durable goods. For more detail, see Obstfeld and Rogoff (1996).

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.73, and the average quadratic error is 5.1 percent. The LM serial correlation test resulted in $F = 0.402$ (with a *p* value of 0.671); the Jarque-Bera normality test resulted in $\chi^2 = 2.371$ (with a *p* value of 0.306); and the White heteroskedasticity test resulted in $N \cdot R^2 = 19.020$ (with a *p* value of 0.836). The estimation period is 1987:2 to 2001:1.

The equation shows that long-term deviations have a half-life of just under three quarters. The long-term interest rate negatively affects the purchase of durable goods in the short term. At the same time, some substitution occurs between durable and nondurable goods in the short term. When spending on nondurable goods rises by one percentage point, the growth rate for the purchase of durable goods falls by 0.8 points. A 1 percent increase in this rate (when the slope of the yield curve remains constant) reduces durable goods purchases by 4.7 percent one quarter later. Meanwhile, and also with a one-quarter lag, a 1 percent reduction in the spread between the long-term rate (*PRC8*) and the short-term rate (*MPR*) reduces durable goods purchases by 2.7 percent. Finally, a 1 percent increase in the comparative price resulting from the ratio of the durable goods CPI (CPI_{DK}) over the nondurable goods CPI (CPI_{HK}) reduces durable goods purchases by 1.4 percent in the short term.

Investment

Total investment consists of the formation of fixed capital and inventory changes. Investment in fixed capital breaks down into gross formation in machinery (GFK_{MACH}) and gross formation in construction (GFK_{CONSTR}), which are estimated separately. In both cases we assume that the ratio of the stock of each type of capital (K_{MACH} and K_{CONSTR} , respectively) to GDP in the long term depends inversely on the cost of use of capital (CK_{MACH} and CK_{CONSTR} , respectively). This means that the ratio of gross formation of each kind of capital to the respective stock is constant in the long run. This ratio must be equal to the long-term growth rate of the economy plus the replacement of depreciated capital.¹⁹ Both long-term relations have been included in short-term estimations. In the case

19. For more detail on deriving long-term relationships, see Bustos, Engel, and Galetovic (2000) and Bravo and Restrepo (2002).

of machinery investment, the estimated equation is as follows:

$$\begin{aligned}
 \Delta \log GFK_{MACH} = & \phi_{FBM_0} - 0.71 \left(\begin{array}{l} \log K_{MACH_{-2}} - \log Y_{-1} \\ + \log CK_{MACH_{-1}} - \phi_{GFK_{MACH_1}} \end{array} \right) \\
 & - 0.33 \left(\log GFK_{MACH_{-1}} - \log K_{MACH_{-2}} - \phi_{GFK_{MACH_2}} \right) \\
 & - 0.27 \Delta \log GFK_{MACH_{-1}} + 1.19 \Delta \log Y_{-3} - 0.53 \Delta \log CK_{MACH} \quad (13) \\
 & - 2.29 \cdot \frac{1}{2} \sum_{i=1}^2 PRC8_{-i} + 1.19 \cdot \frac{1}{2} \sum_{i=1}^2 (PRC8_{-i} - MPR_{-i}) \\
 & - 0.18 D944 - 0.15 D961,
 \end{aligned}$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.58, and the average quadratic error is 5.1 percent. The LM serial correlation test resulted in *F* = 0.805 (with a *p* value of 0.375); the Jarque-Bera normality test resulted in $\chi^2 = 1.814$ (with a *p* value of 0.404); and the White heteroskedasticity test resulted in $N \cdot R^2 = 24.636$ (with a *p* value of 0.648). The estimation period is 1987:3 to 2000:4.

The long-term price elasticity has been calibrated at 1.0, as dictated by the theory. Results show that deviations in the long-term relationship between capital stock, GDP, and the cost of use have a half-life of almost half a quarter. Meanwhile, deviations in the ratio of gross formation of stock over long-term levels, represented by $\phi_{GFK_{MACH_2}}$, have a half-life of just over one and a half quarters. Furthermore, with a three quarter lag, a change in GDP growth of 1 percentage point increases gross formation in machinery by 1.2 percent in the short term, revealing the procyclical behavior of these investments in the short term. Investment in machinery has also proved to be relatively sensitive to movements in long- and short-term interest rates. Given the slope of the yield curve, a 1 percent increase in the long-term interest rate, as a moving average over the previous two quarters, reduces growth of investment in machinery by 2.3 percent. Meanwhile, an average 1 percent increase over the previous two quarters in the slope of the yield curve reduces growth of gross formation in machinery by 1.2 percent. Finally, the cost of use of this

kind of capital has both short- and long-term effects. Thus, an increase of one percentage point in the growth of the cost per use of machinery reduces this kind of capital by 0.5 percent.

The equation for the short-term dynamic of gross formation in construction is expressed as

$$\begin{aligned}
 \Delta \log GFK_{\text{CONSTR}} = & \phi_{FBC_0} - 0.13 \left(\begin{array}{l} \log K_{\text{CONSTR}_{-3}} - \log Y_{-2} \\ + \log CK_{\text{CONSTR}_{-2}} - \phi_{FBC_1} \end{array} \right) \\
 & - 0.14 \left(\begin{array}{l} \log GFK_{\text{CONSTR}_{-2}} - \log K_{\text{CONSTR}_{-3}} - \phi_{GFK_{\text{CONSTR}_2}} \end{array} \right) \\
 & + 0.60 \Delta \log Y_{-1} - 0.33 \Delta \log GFK_{\text{CONSTR}_{-1}} \quad (14) \\
 & + 0.21 \Delta \log GFK_{\text{CONSTR}_{-3}} - 2.38 \cdot \frac{1}{2} \sum_{i=3}^4 \text{PRC8}_{-i} \\
 & + 0.04 \Delta LIG_{-1} - 0.10 D881 + 0.06 D924,
 \end{aligned}$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.69, and the average quadratic error is 2.1 percent. The LM serial correlation test resulted in *F* = 0.338 (with a *p* value of 0.564); the Jarque-Bera normality test resulted in $\chi^2 = 1.518$ (with a *p* value of 0.468); and the White heteroskedasticity test resulted in $N \cdot R^2 = 10.141$ (with a *p* value of 0.996). The estimation period is 1987:3 to 2000:4.

In this case, corrections to deviations from the long-term steady state are significant with a two-quarter delay, because investment accounting in construction is closely tied to building permits. Deviations from the long-term steady state influence building permits and affect investment with some lag. Error correction for the relationship between capital stock, GDP, and the cost of use, as well as the ratio of gross formation in construction to construction stock over the long term, has a half-life of a little over two quarters. Gross formation in machinery also behaves procyclically. In the short term, an increase in GDP growth of one percentage point raises gross capital formation in construction by 0.6 percent, with a one-quarter lag. Interest rates also affect this type of capital, although with somewhat more of a delay than in the case of machinery. An increase in the eight-year adjustable bond (average for the third and fourth lag) of one percentage point leads to a fall in investment in machinery of 2.4 percent.

Meanwhile, we found no robust relationship between the slope of the yield curve and investment in construction. We also observed that an increase in the growth rate of public investment (*GI*) of 1 percentage point increased growth in total investment in construction by 0.04 percent. Although the relationship is weak, part of investment in construction denotes investment carried out by the public sector.

Finally, the short-term behavior of inventory changes or investment in inventory (*IINV*) should also be estimated. To do so, we assume that the inventory-to-GDP ratio remains constant in the long term. Given the long-term growth rate for GDP, this suggests that the ratio of investment in inventories to GDP is also constant in the long term. The short-term dynamic is therefore expressed by the following equation:

$$\Delta \frac{IINV}{Y} = \phi_{INV_0} - 0.48 \left(\frac{IINV_{-1}}{Y_{-1}} - \phi_{INV_1} \right) - 0.27 \Delta \frac{IINV_{-1}}{Y_{-1}} + 0.22 \Delta \log M + 0.10 \Delta \log M_{-1} - 0.06 D894 + 0.05 D901, \quad (15)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.70, and the average quadratic error is 1.6 percent. The LM serial correlation test resulted in *F* = 0.818 (with a *p* value of 0.447); the Jarque-Bera normality test resulted in χ^2 = 0.677 (with a *p* value of 0.713); and the White heteroskedasticity test resulted in $N \cdot R^2$ = 21.064 (with a *p* value of 0.176). The estimation period is 1987:1 to 2000:4.

The half-life of deviations in the long-term relationship is almost one quarter. For the short term, a relationship was found between changes in imports of goods and nonfinancial services (*M*) and investment in inventory. Thus, an increase in the growth rate of imports of one percentage point increased the ratio of the change of investment in inventories to GDP by 0.2 points with a one-quarter lag and 0.1 points with a two-quarter lag. This reflects that fact, as mentioned above, that an important portion of inventories comes from abroad.

Public Sector

Total public sector tax revenues including income from pension deductions (*TT*) have risen somewhat more quickly than gross domestic product. Econometric estimations show that a reasonable assumption for the short run is

$$\Delta \log TT = 1.05 \Delta \log Y . \quad (16)$$

This elasticity between domestic output and tax revenues reflects the increase in the taxable base as GDP rises and is the same as that used by the Finance Ministry to calculate structural expenditure.²⁰ This elasticity is assumed to converge to 1.0 in the long run for the model to have a well-defined steady state. Estimates show that government income from copper (GY_{CU}) is about 7 percent of total copper exports, a ratio that is relatively stable over time. Thus,

$$GY_{CU} = 0.07 (PCU \cdot QCU \cdot NER) . \quad (17)$$

This allows us to calculate total government expenditure ($GEXP_{TOT}$) using a formula similar to that used by the national budget office to calculate the structural deficit, which must amount to one percent of potential GDP (YE). This formula represents variations in a logarithmic linearization, expressed as

$$\begin{aligned} \Delta \log GEXP_{TOT} &= \phi_{GEXP_{TOT_1}} \left(\begin{array}{l} \Delta \log TT_{-1} + 1.05 \Delta \log YE \\ -1.05 \Delta \log Y_{-1} \end{array} \right) \\ &\quad + \phi_{GEXP_{TOT_2}} \Delta \log GY_{CU} - 0.01 \phi_{GEXP_{TOT_3}} \Delta \log YE, \end{aligned} \quad (18)$$

where

$$\phi_{GEXP_{TOT_1}} = \frac{TT_{-1} (YE_{-1} / Y_{-1})^{1.05}}{GEXP_{TOT_{-1}}} , \quad (19)$$

$$\phi_{GEXP_{TOT_2}} = \frac{GY_{CU_{-1}}}{GEXP_{TOT_{-1}}} , \text{ and} \quad (20)$$

$$\phi_{GEXP_{TOT_3}} = \frac{YE_{-1}}{GEXP_{TOT_{-1}}} . \quad (21)$$

Based on total government expenditure, current expenditure ($GEXP_{CUR}$) can be estimated as

$$GEXP_{CUR} = 0.82 GEXP_{TOT} . \quad (22)$$

20. See the Budget Office's *Dirección de Presupuestos* for 2001.

Current income (GY_{CUR}), meanwhile, is the sum of tax revenues and income from copper (GY_{CU}) and other sales (GY_{OTHER}). The latter account for about 23 percent of current income:

$$GY_{CUR} = GY_{CU} + TT + GY_{OTHER} = \frac{GY_{CU} + TT}{0.77}. \quad (23)$$

The difference between current income and current expenditures corresponds to government saving. By adding this to government consumption expenditure, we obtain the part of disposable national income corresponding to government revenue:

$$GY = GC + GY_{CUR} - GEXP_{CUR}. \quad (24)$$

This income, GY , allows us to calculate disposable private income. The government's expenditure on consumption, calculated by the National Accounts department, is forecast according to the following assumption:²¹

$$\Delta \log GC = \phi_{GC}, \quad (25)$$

in which the constant is calibrated according to the information available on changes in the main government expenditures. The calculation considers personnel and goods and services expenditures, which account for a little over half the government's expenditure on consumption. In recent years this variable has risen by around 35 percent per year.

Government investment, which is part of gross capital formation, is obtained as a residue starting from the following identity:

$$GEXP_{TOT} = GC + GI + GEXP_{OTHER}, \quad (26)$$

that is, total government expenditure can be broken down into consumption expenditure, investment expenditure, and other expenditure, where it is assumed that $GEXP_{OTHER}$ grows at the same rate as total government expenditure. With this assumption, we use the calculation for total government expenditure presented above and the forecast for government consumption to obtain a forecast for government investment.

External sector

The external sector can be divided into exports and imports of goods, nonfinancial services, and financial services. Variables for

exports and imports are estimated using volumes based on 1986 dollars. The volume for total exports (QX_{GROSS}) can be calculated as the following sum of components:

$$QX_{\text{GROSS}} = QX_{\text{PRINC}} + QX_{\text{OTHER}}, \quad (27)$$

where QX_{PRINC} denotes exports of principal goods (copper and noncopper) and QX_{OTHER} denotes exports of other goods. The exports of principal goods are not forecast using econometric techniques, because the information regarding investment and production plans in these sectors is trustworthy enough to make econometric forecasts unnecessary. An econometric approximation is used, however, for the exports of other goods.

Total exports of goods in constant 1986 pesos (XG_{TOT}) are calculated using forecast quantum figures, by applying the following:

$$XG_{\text{TOT}} = QX_{\text{GROSS}} \cdot NER86 = (QX_{\text{PRINC}} + QX_{\text{OTHER}}) NER86, \quad (28)$$

where $NER86$, is the average observed exchange rate in 1986.

We assume that the quantity of other, nonprincipal, exports is determined in the long run by both Chile's GDP and the GDP of the main trading partners (YEX), which is consistent with the applied theory of gravity for international trade. Long-term quantities also depend on the real exchange rate. The short-term dynamic is expressed by the following equation:

$$\Delta \log QX_{\text{OTHER}} = \phi_{QX_{\text{OTHER}0}} - 0.86 \begin{pmatrix} \log QX_{\text{OTHER}_1} - 1.30 \log Y_1 \\ -1.49 \log YEX_1 - 0.38 \log RER_1 \\ -\phi_{QX_{\text{OTHER}1}} \end{pmatrix} + 0.53 \Delta \log RER_{-1} + 0.59 \Delta \log RER_{-2} + 1.57 \Delta \log Y - 1.33 \Delta \log Y_{-1}, \quad (29)$$

where the numbers in parentheses are Newey-West corrected t statistics, the adjusted R squared is 0.71, and the average quadratic error is 2.9 percent. The LM serial correlation test resulted in $F = 1.305$ (with a p value of 0.287); the Jarque-Bera normality test resulted in $\chi^2 = 0.784$ (with a p value of 0.676); and the White

heteroskedasticity test resulted in $N \cdot R^2 = 12.987$ (with a p value of 0.674). The estimation period is 1991:2 to 2000:4.

In the long term, a 1 percent rise in the GDP of Chile's main trading partners increases the exports analyzed here by 1.5 percent. The long-term elasticity associated with Chile's GDP is 1.3 and the price elasticity associated with the real exchange rate is 0.4. The correction of deviations from the long-term relationship has a half-life of about one-fifth of a quarter. In the short term, a 1 percent rise in Chile's GDP increases minor exports by 1.6 percent, an effect that is partially reverted a quarter later. Meanwhile, an increase of one point in the real exchange rate increases short-term expansion of minor exports by 0.5 percent with a one-quarter lag and 0.6 percent with a two-quarter lag.

The quantity of total goods imports (QM_{GROSS}) can be broken down as the sum of the following components:

$$QM_{GROSS} = QM_C + QM_K + QM_{INTERM} = QM_C + QM_K + QM_{FL} + QM_{NFL}, \quad (30)$$

where QM_C denotes imports of consumption goods, QM_K denotes imports of capital goods, and QM_{INTERM} denotes imports of intermediate goods. The latter can be broken down into fuel (QM_{FL}) and nonfuel (QM_{NFL}). As with exports of goods, imports of goods are expressed in constant 1986 pesos using the following:

$$\begin{aligned} MG_{TOT} &= QM_{GROSS} \cdot NER86 \\ &= (QM_C + QM_K + QM_{FL} + QM_{NFL}) NER86 \end{aligned} \quad (31)$$

For reasons similar to those provided for the exports of principal goods, fuel imports are also estimated using specialized information. In the long term, imports of consumption goods are assumed to be a constant share of the total purchase of durable goods. The equation describing short-term behavior is:

$$\begin{aligned} \Delta \log QM_C &= \phi_{QM_{C_0}} - 0.07 \left(\log QM_{C_{-1}} - \log PC_{D_{-1}} - \phi_{QM_{C_1}} \right) \\ &\quad + 0.51 \Delta \log PC_D + 0.11 \Delta \log PC_{D_1} - 0.35 D901, \end{aligned} \quad (32)$$

where the numbers in parentheses are Newey-West corrected t statistics, the adjusted R squared is 0.65, and the average quadratic error is 5.4 percent. The LM serial correlation test resulted in $F = 0.520$ (with a p value of 0.597); the Jarque-Bera normality test resulted in $\chi^2 = 2.695$ (with a p value of 0.260); and the White heteroskedasticity test resulted in $N \cdot R^2 = 5.966$ (with a p value of

0.743). The estimation period is 1986:3 to 2001:1.

The long-term adjustment is rather slow, with a half-life of error totaling almost four quarters. Changes in durable goods purchases affect consumption imports in the short term: a 1 percent increase in purchases of durable goods is associated with a 0.5 percent rise in consumption goods with a one-quarter lag and 0.1 percent rise with a two-quarter lag.

To estimate the behavior of capital goods imports we assume that in the long term, they tend to a constant percentage of total investment in machinery. The equation describing short-term changes in these imports is expressed as:

$$\begin{aligned} \Delta \log QM_K = & \phi_{QM_{K_0}} - 0.07 \left(\log QM_{K_{-1}} - \log GFK_{MACH_{-1}} - \phi_{QM_{K_1}} \right) \\ & + 1.02 \Delta \log GFK_{MACH} + 0.12 \Delta \log QM_{K_{-1}} - 0.13 D984, \end{aligned} \quad (33)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.88, and the average quadratic error is 3.1 percent. The LM serial correlation test resulted in *F* = 0.316 (with a *p* value of 0.730); the Jarque-Bera normality test resulted in *c*² = 1.131 (with a *p* value of 0.568); and the White heteroskedasticity test resulted in *N·R*² = 17.046 (with a *p* value of 0.048). The estimation period is 1986:3 to 2001:1.

As in the case of consumption goods imports, this equation shows a relatively slow long-term adjustment, with a half-life of deviations of somewhat less than one year. Changes in capital imports seem to follow changes in investment in machinery rather closely, with a coefficient of 1.0 for this last variable. Long-term deviations thus tend to be infrequent, but persistent.

Finally, intermediate, imports of nonfuel goods are estimated assuming that these maintain a constant ratio to GDP in the long term, depending on the real exchange rate. The equation for demand for these imports is expressed as

$$\begin{aligned} \Delta \log QM_{NFL} = & \phi_{QM_{NFL_0}} \\ & - 0.50 \left(\log QM_{NFL_{-1}} - \log Y_{-1} + 1.09 \log RER_{-1} + \phi_{QM_{NFL_1}} \right) \\ & + 1.79 \Delta \log Y + 1.06 \Delta \log Y_{-1} - 0.55 \Delta \log RER_{-1} \\ & + 0.28 \Delta \log QM_{NFL_{-3}} - 0.08 D962 - 0.08 D912, \end{aligned} \quad (34)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.61, and the average quadratic error is 3.7 percent. The LM serial correlation test resulted in *F* = 0.358 (with a *p* value of 0.041); the Jarque-Bera normality test resulted in *c*² = 2.016 (with a *p* value of 0.365); and the White heteroskedasticity test resulted in *N·R*² = 12.521 (with a *p* value of 0.819). The estimation period is 1988:2 to 2001:1.

In the long term, a 1 percent increase in the real exchange rate translates into an estimated 1.1 percent increase in the imports analyzed here. Long-term deviations have a half-life of about one quarter. In the short term, these imports increase faster than GDP. A 1 percent increase in GDP leads to a short-term rise of 1.8 points in intermediate, nonfuel goods imports with a one-quarter lag and an increase of 1.0 points with a two-quarter lag. The real exchange rate also negatively affects these imports in the short term. An increase in the moving average (a contemporary variable and a lag) for the real exchange rate leads to a 0.6 percent decline in these imports.

It is also necessary to estimate imports and exports of nonfinancial services, financial services, and net transfers. We assume that imports of nonfinancial services represent a constant percentage of goods imports in the long term. The short-term dynamic is expressed as

$$\begin{aligned} \Delta \log MS &= \phi_{MS_0} - 0.07 \left(\log MS_{-1} - \log MG_{TOT_1} - \phi_{MS_1} \right) \\ &\quad + 0.46 \Delta \log MG_{TOT_2} - 0.26 \Delta \log MS_{-1} \\ &\quad - 0.20 \Delta \log MS_{-2} + 0.29 D881, \end{aligned} \tag{35}$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.50, and the average quadratic error is 5.4 percent. The LM serial correlation test resulted in *F* = 0.325 (with a *p* value of 0.571); the Jarque-Bera normality test resulted in *c*² = 2.082 (with a *p* value of 0.353); and the White heteroskedasticity test resulted in *N·R*² = 10.773 (with a *p* value of 0.630). The estimation period is 1986:4 to 2001:1.

As with nonfinancial services imports, we assume that nonfinancial services exports represent a constant ratio to total exports of goods in the long term. For these exports, the short-term dynamic is expressed as

$$\begin{aligned} \Delta \log XS = & \phi_{XS_0} - 0.40 \left(\log XS_{-1} - \log XG_{TOT_1} - \phi_{XS_1} \right) \\ & + 0.39 \Delta \log XG_{TOT_2} + 0.90 \Delta \log YS_{-2} \\ & - 0.34 \Delta \log XS_{-1} - 0.56 \Delta \log Y_3 + 0.07 D984, \end{aligned} \quad (36)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.48, and the average quadratic error is 3.0 percent. The LM serial correlation test resulted in *F* = 0.371 (with a *p* value of 0.693); the Jarque-Bera normality test resulted in *c*² = 2.550 (with a *p* value of 0.279); and the White heteroskedasticity test resulted in *N·R*² = 31.848 (with a *p* value of 0.007). The estimation period is 1990:1 to 2000:4.

The current account

The current account of the balance of payments measured in current dollars (*CAF*) is obtained through the following sum:

$$CAF = XGF - MGF + XSF - MSF + BFSF + NTF, \quad (37)$$

where *XSF* denotes exports of nonfinancial services in foreign currency (current dollars), *MSF* denotes imports of nonfinancial services in foreign currency, *BFSF* denotes the balance of financial services in foreign currency, and *NTF* the net transfers from abroad in foreign currency. The volume of exports and imports of goods are estimated as explained above. The volume, expressed in 1986 dollars, is transformed into current dollars using the unit value index (*Índice de Valor Unitario*) for the corresponding exports and imports (*UVIX* and *UVIM*):

$$XGF = QX_{PRINC} \cdot UVIX_{PRINC} + QX_{OTHER} \cdot UVIX_{OTHER} \text{ and} \quad (38)$$

$$\begin{aligned} MGF = & QM_C \cdot UVIM_C + QM_K \cdot UVIM_K \\ & + QX_{INTERM} \cdot UVIX_{INTERM} + QX_{NFL} \cdot UVIX_{NFL}. \end{aligned} \quad (39)$$

Forecast figures for imports of nonfinancial services, in constant 1986 pesos, are translated into current dollars using the deflator for

services imports and the nominal exchange rate. The conversion applied is

$$MSF = MS \left(\frac{PMS}{NER} \right), \quad (40)$$

where PMS denotes the deflator for nonfinancial services imports.

Exports of nonfinancial services are converted to current dollars using a similar formula to that used for nonfinancial services imports, multiplying the constant peso value by the deflator for nonfinancial services exports and dividing it by the nominal exchange rate. The unit conversion rate is

$$XSF = XS \left(\frac{PXS}{NER} \right). \quad (41)$$

Financial services are forecast using the stock of net international assets (IAF).²¹ The net balance for these services is expressed as

$$BFSF = RIA \cdot IAF, \quad (40)$$

where RIA denotes an average interest rate on net international assets. Finally, net transfers from abroad are forecast without using econometric approximations.

2.4 Aggregate Supply, Prices, and Costs

The final transmission of cyclical fluctuations in the economy receives a stylized treatment in MEP1, with a simple Phillips curve for the gap between GDP and potential GDP with the acceleration or deceleration of underlying inflation. Movements in the exchange rate also affect this gap. The effect of noncore components of inflation, such as perishable goods, fuel, and regulated fee inflation, is added in.

In MEP2, the transmission of shifts in aggregate demand to prices is described more explicitly through the explicit treatment of the labor market and margins. In the short term it is assumed that activity performs similarly to expenditure, so employment stems from derived demand, which in turn depends on the relative cost of labor and capital

21. This stock is updated using data on the surplus (deficit) in the current account: $IAF = IAF_{-1} + CAF$.

accumulation. The short-term equilibrium between supply and demand in the labor market determines the unemployment rate, affecting wage pressures. The effect of unit labor costs comes from the combination of wage pressures and trends in average labor productivity, while the cyclical conditions in the economy affect the foreseeable performance of sales margins. The sum of these elements, along with pressures from imported costs, determine the level and behavior of underlying prices. The prices of regulated services and fuels receive explicit treatment, as in MEP1.

In the model, aggregate supply in the economy reflects the cost structure in the long term. The technology is Cobb-Douglas, so the distribution of costs among factors is constant in the long term. This imposes restrictions on employment's performance, which is assumed to adjust to balance situations involving higher or lower real wages compared with average productivity. Similarly, wages are determined by institutional factors to a large degree. Indexation to past inflation has a significant impact on the short-term performance of wages, while public sector adjustments strongly affect the service component.

The retail price structure is consistent with another Cobb-Douglas distribution technique, which combines unit labor costs associated with the domestic production of consumption goods, import costs associated with imported supply components or with imported finished goods, and services.

Productive capacity

This section works with a Cobb-Douglas production function that relates the aggregate value of three kinds of inputs: private employment (PN), capital stock in construction (K_{CONSTR}), and capital in machinery and equipment (K_{MACH}). The employment considered corresponds to the total population of those employed minus employees in special employment programs, without subtracting those affected by the hiring bonus. Capital stocks include both the public and private sectors. Two additional variables come into play in the production function: total factor productivity (TFP), which corresponds to the technology level, and capital utilization (UT), which is assumed to be equal for the two kinds of capital.

$$Y = TFP \cdot NP^{0.53} \cdot K_{\text{CONSTR}}^{0.29} \cdot K_{\text{MACH}}^{0.18} \cdot UT^{0.47}. \quad (43)$$

The parameters of the production function are calculated as an average of the income share of each input. The capital utilization rate is associated with the unemployment rate (U).²²

$$UT = 1 - U. \quad (44)$$

TFP is obtained by breaking down growth sources in line with the production function. Because PN is used, total factor productivity includes improvements in education quality and hours worked.

Potential output is constructed by imposing a normal use rate for resources (with a natural unemployment rate) and cleaning procyclical movement out of TFP.²³ For trend TFP, a Hodrick-Prescott (HP) filter is used in which the parameter λ is set to 10,000 owing to the sensitivity of the method to values at the extreme limits of the sample.

$$\bar{Y} = \overline{TFP} \cdot LF^{0.53} \cdot K_{\text{CONSTR}}^{0.29} \cdot K_{\text{MACH}}^{0.18} \cdot \overline{UT}^{0.47}. \quad (45)$$

Finally, the capacity gap corresponds to the difference between the log of output and the log of potential output:

$$GAP = \log Y - \log \bar{Y}. \quad (46)$$

Labor demand

Imbalances in the distribution of factorial income are gradually corrected through changes in labor demand. The log-linear specification for labor demand compares the logarithm of employment minus employment programs ($\log PN$) with the logarithm for real, seasonally adjusted GDP ($\log Y$) and a long-run correction term for the participation of the labor factor (α_N).²⁴ In addition, the regression includes terms that explain employment and a dummy variable.

22. Based on Contreras and García (2002).

23. Although some factors introduce movement into the cycle (hours worked, level of effort, labor force), the evidence reveals that the procyclical movement remains even when it is controlled for (Contreras and García, 2002). We nonetheless control for the rate of utilization.

24. Employment without employment programs ($PN = N - PEE$) does include hiring subsidies.

$$\begin{aligned}\Delta \log PN = & \phi_{PN} - 0.14 \left(\ln \alpha_N - \ln 0.53^* \right)_{-1} + 0.24 \Delta \log Y \\ & - 0.12 \Delta \log Y_{-1} + 0.20 \Delta \log Y_{-2} + 0.02 D933,\end{aligned}\tag{47}$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.47, and the average quadratic error is 0.77 percent. The LM serial correlation test (with 4 lags) resulted in *F* = 0.564 (with a *p* value of 0.690); the Jarque-Bera normality test resulted in $\chi^2 = 0.415$ (with a *p* value of 0.812); and the White heteroskedasticity test resulted in $N \cdot R^2 = 14.741$ (with a *p* value of 0.195). The estimation period is 1987:2 to 2001:3.

The constant for the correction vector is calibrated, so results are consistent with a constant distribution of income. To estimate this constant the wage bill is divided by nominal GDP (*YN*).

$$\alpha_N = \frac{CL \cdot NW + 0.6 W \cdot NSE}{YN}.\tag{48}$$

When calculating the wage bill it is necessary to weight two different types of workers, those who earn wages (*NW*) and those who are self-employed (*NSE*). The first contribute to social security, so their share of GDP is measured using labor costs (*CL*). The second, in contrast, do not have this benefit, and we thus consider their wage to be 60 percent of average nominal wages in the economy.

Private wages

The wage equation explains the behavior of nominal wages ($\log W$). The wages used in this equation are average nominal wages in the economy, so they include both public and private wages. Nominal wage performance is explained by changes in the difference between unemployment (*U*) and its natural level (assumed to be 8 percent), the logarithm of the public wage adjustment index ($\log GWAI$), and inflation during the previous semester ($\log CPI$), owing to indexing clauses.

Theory indicates that in the long term, real private wages must grow proportionately to average labor productivity (*LQ*), ensuring that the factorial distribution of income remains constant; this is in fact observed empirically during the period under analysis (see the stylized facts in section 1). Public wages are therefore adjusted according to the wage

adjustment index for government employees. To reach a balance, the increase in real wages must be composed of an increase in productivity and real growth in the government adjustment figure. Calibrating the regression constant, which corresponds to long-term productivity growth and private wages' share of wage growth, imposed this condition.

Because real wages cannot depend on inflation in the long term, the inflation term and wage adjustment coefficients must add up to one. The coefficient tests for both variables do not allow the rejection of the null hypothesis—that is, that these add up to one, so real wages do not depend on inflation in the long term.

The results of the equation, estimated using OLS, are as follows:

$$\begin{aligned}\Delta \log W = & \left(1 - 0.17\right) \Delta Q - 0.08(U - 0.08) \\ & + 0.91 \frac{\Delta \log CPI_{-1} + \Delta \log CPI_{-2}}{2} \\ & + 0.17 \Delta \log GWAI + 0.01 D881 - 0.02 D912,\end{aligned}\quad (49)$$

where the numbers in parentheses are Newey-West corrected *t* statistics, the adjusted *R* squared is 0.83, and the average quadratic error is 0.60 percent. The LM serial correlation test (with 4 lags) resulted in *F* = 0.682 (with a *p* value of 0.607); the Jarque-Bera normality test resulted in χ^2 = 3.617 (with a *p* value of 0.164); and the White heteroskedasticity test resulted in $N \cdot R^2$ = 38.619 (with a *p* value of 0.003). The estimation period is 1986:3 to 2001:3.

Finally, to describe the sectoral behavior of wages, we use the following calibration for private and public wages, respectively:

$$\Delta \log PW = \frac{\Delta \log W - 0.17 \Delta \log GWAI}{0.83} \text{ and} \quad (50)$$

$$\Delta \log GW = \Delta \log GWAI. \quad (51)$$

Underlying inflation

The long-term price equation describes the behavior of inflation within a price index that excludes regulated services, perishables,

meat, and fish (INFCPI_{X1}). A cointegration equation ensures that the steady-state price level is equal to a margin over production costs. These correspond to the private unit labor cost (CLU), the cost of public services through a proxy that is public wages ($\log GW$), and the imported component of costs ($\log CIMP$). Margins evolve over time according to the behavior of costs and the inflation dynamic.

The (log of the) unit labor cost corresponds to the private wage (PW) divided by average labor productivity (Y/N) plus VAT .

$$\log CLU = \log \left(\frac{PW}{Y/N} \right) + \log VAT. \quad (52)$$

To construct the imported component of costs we add together the logarithm of the external price index ($\log EXPI$), the log of the nominal exchange rate ($\log NER$), the logarithm of one plus the VAT ($\log VAT$), and the logarithm of one plus the tariff ($\log TAR$).

$$\log CIMP = \log EXPI + \log NER + \log VAT + \log TAR. \quad (53)$$

The change in inflation depends on lags of the output gap (GAP) and terms describing the dynamics. We also considered the role of expectations, including those regarding inflation for the following period, $E(\text{INFCPIX1})$. This was estimated using a limited-information method. The instruments used to estimate expected inflation were lags in the variable itself, the output gap, inflation targeting, unemployment, productivity, public and private wages, the exchange rate, and oil price growth. A term for lagged inflation was also included.

$$\begin{aligned} \Delta \text{INFCPI}_{X1} = & 0.52_{(2.68)} + 0.58_{(4.51)} E(\Delta \text{INFCPI}_{X1})_{+1} + 0.09_{(2.03)} GAP \\ & - 0.18_{(-4.93)} \log CPI_{X1-1} + 0.13_{(3.85)} \log CLU_{-1} \\ & + 0.04_{(3.16)} \log GW_{-1} + 0.02_{(1.83)} \log CIMP_{-1} \\ & - 0.33_{(-2.26)} \text{INFCPI}_{X1-1} + 0.13_{(3.61)} \log CLU \\ & + 0.04_{(2.02)} \log CIMP + 0.01_{(3.97)} D2 - 0.002_{(-1.03)} D3, \end{aligned} \quad (54)$$

where the numbers in parentheses are Newey-West corrected t statistics, the adjusted R squared is 0.78, and the average quadratic error is 0.45 percent. The LM serial correlation test (with 4 lags) resulted in $F = 1.311$ (with a p value of 0.281); the Jarque-Bera normality test resulted in $\chi^2 = 0.104$ (with a p value of 0.950); and the White heteroskedasticity test resulted in $N \cdot R^2 = 45.973$ (with a p value of 0.102). The estimation period is 1987:1 to 2001:3.

2.5 Deflators and Relative Prices

This section introduces deflators for the user cost of capital and durable goods and for aggregate demand and GDP. In the latter case, the deflators draw on the *Indices de Valor Unitario de las Importaciones y Exportaciones* (import unit value index, $UVIM$; export value index, $UVIX$) that are calculated and published by the Balance of Payments Department of the Central Bank of Chile. The import index is calculated for each component: imports of consumption goods ($UVIM_C$), capital goods ($UVIM_K$), and intermediate fuel ($UVIM_{FL}$) and nonfuel ($UVIM_{NFL}$) goods. For exports, the calculation is performed for the exports of principal goods ($UVIX_{PRINC}$) and other exports ($UVIX_{OTHER}$).

The price indices mentioned above are Paasche indices, while volume indices are Laspeyres indices. Price indices are such that when multiplied by the quantity index, the result is the export value (or an index of the same).²⁵ Unit value indices are consistent with price assumptions for the main export and import goods and inflation assumptions for the most important foreign economies and their exchange rates. This forecast is exogenous to the other model forecasts.

The financial servicing of foreign accounts consists mainly of net interest payments on short-, medium-, and long-term public and private debt, interest received on foreign exchange reserves, and profits on investment from abroad and located abroad. Overall, we can calculate an implicit interest rate for net international assets (RIA). To make assumptions about the future accrual of profits and interest payments, the Central Bank's Balance of Payments Department develops a forecast using this implicit interest rate.

25. For more detail, see Meza and Pizarro (1982).

The user cost of capital and durable goods

The user cost of capital is calculated separately for machinery (CK_{MACH}) and construction (CK_{CONSTR}).²⁶ For machinery the user cost of capital is

$$CK_{MACH} = TAF_{MACH} (MORT + DEP_{MACH}) \frac{PGFK_{MACH}}{P}, \quad (55)$$

where TAF_{MACH} is a tax adjustment factor, $MORT$ is the interest rate on mortgages, DEP_{MACH} is the depreciation rate for capital in machinery, $PGFK_{MACH}$ is the deflator of capital in machinery, and P is the deflator of gross domestic product. The tax adjustment factor is expressed as

$$TAF_{MACH} = (1 - 0.6 TUT + DEP_{MACH}) \frac{1 + TAR}{(1 - VAT)(1 - TUT)}, \quad (56)$$

where TUT is the tax rate on company profits, TAR is the customs tariff, and VAT is the value added tax. Likewise, for the case of construction, the user cost of capital is expressed as

$$CK_{CONSTR} = TAF_{CONSTR} (MORT + DEP_{CONSTR}) \frac{PGFK_{CONSTR}}{P}, \quad (57)$$

where the tax adjustment factor is expressed as

$$TAF_{CONSTR} = (1 - 0.6 IT + DEP_{CONSTR}) \frac{1 + TAR}{(1 - VAT)(1 - IT)}. \quad (58)$$

For the user cost of durable goods (CK_D), the following equation is used:²⁷

$$CK_D = \left(\frac{CPI_D}{CPI_H} \right) \left(\frac{PRC8 - DEP_D}{1 + PRC8} \right). \quad (59)$$

This calculation indicates that the cost is a rising function of the

26. The capital cost calculation is based on work by Bustos, Engel, and Galetovic (2000).

27. For details on how to obtain and motivate this cost, see Obstfeld and Rogoff (1996).

interest rate ($PRC8$), the price of durable goods over nondurable consumption goods (CPI_D/CPI_H), and an inverse function of the depreciation rate for these goods. The durable and nondurable goods CPI is calculated by selecting the corresponding products from the CPI basket of the National Statistical Institute (INE).²⁸

Deflators for aggregate demand and GDP

In the case of expenditure on consumption goods, it is assumed that the relevant deflator (PPC) moves according to changes in the CPI:

$$\Delta \log PPC = \Delta \log CPI . \quad (60)$$

With regard to investment, we distinguish between the deflator for gross formation in machinery ($PGFK_{MACH}$), the deflator for gross formation in construction ($PGFK_{CONSTR}$), and the deflator for investment in inventory ($PIINV$). The first moves according to the price of capital goods imports, because about half of this kind of investment is in goods from abroad. Moreover, we assume that because of the law of one price, the even price of these goods of domestic origin should not deviate much from the price of imported goods. The equation is therefore expressed as

$$\Delta \log PGFK_{MACH} = \Delta \log UVIM_K + \Delta \log NER . \quad (61)$$

For construction, costs are primarily of domestic origin. Changes in the deflator thus correspond to a weighted average of changes in labor costs and the CPI_{X1} :

$$\Delta \log PGFK_{CONSTR} = \phi_{PGFK_{CONSTR}} \Delta \log CL + (1 - \phi_{PGFK_{CONSTR}}) \Delta \log CPI_{X1} . \quad (62)$$

The deflator of inventory investment is associated with import prices. As mentioned above, an important part of these inventories is imported. Changes in this deflator are therefore expressed as

$$\Delta \log PIINV = \Delta \log UVIM + \Delta \log NER . \quad (63)$$

For the deflator of government expenditure on consumption, we assume that

28. For more detail, see Gallego and Soto (2000).

$$\Delta \log PGC = \phi_{PGC} \Delta \log GW + (1 - \phi_{PGC}) \Delta \log CPI_{X1} . \quad (64)$$

The deflator of imports of goods (*PMG*) is expressed as the conversion of the unit value index, expressed in constant 1986 dollars:

$$\log PMG = \log UVIM + \log NER - \log NER86 + \phi_{PMG} , \quad (65)$$

where *NER86* denotes the average nominal exchange rate in 1986 and a constant is included to adjust the base year. The deflator for imports of services, which is necessary to convert constant pesos to current dollars, is assumed to depend on the nominal exchange rate and external prices, and it includes a constant to adjust the base year:

$$\log PMS = \log EXPI_{MS} + \log NER - \log NER86 + \phi_{PMS} . \quad (66)$$

The deflator of exports has a similar treatment. Thus, the deflator of the export of goods (*PXG*) is expressed as

$$\log PXG = \log UVIX + \log NER - \log NER86 + \phi_{PXG} . \quad (67)$$

Likewise, the deflator of the exports of nonfinancial services is expressed as

$$\log PXS = \log EXPI_{XS} + \log NER - \log NER86 + \phi_{PXS} . \quad (68)$$

The GDP deflator is the one used to compare nominal figures in current pesos to real figures in constant pesos. Therefore, the GDP deflator is simply the result of dividing nominal GDP by real GDP, expressed as follows:

$$P = \frac{PPC \cdot PC + PI \cdot I + PGC \cdot GC + PX \cdot X + PM \cdot M}{PC + I + GC + X + M} , \quad (69)$$

where

$$PI \cdot I = PGFK_{MACH} \cdot GFK_{MACH} + PGFK_{CONSTR} \cdot GFK_{CONSTR} , \\ + PIINV \cdot IINV \quad (70)$$

$$PX \cdot X = PXG \cdot XG + PXS \cdot XS , \text{ and} \quad (71)$$

$$PM \cdot M = PMG \cdot MG + PMS \cdot MS , \quad (72)$$

3. IMPULSE RESPONSES (MEP2)

In this section we look at the response of a number of key macroeconomic variables to temporary and permanent shocks to the monetary policy interest rate. We contrast the results from the MEP2 with the response to the same shock under the MEP1 and a VAR model of the economy.²⁹

3.1 Temporary Shock and Robustness of the Model

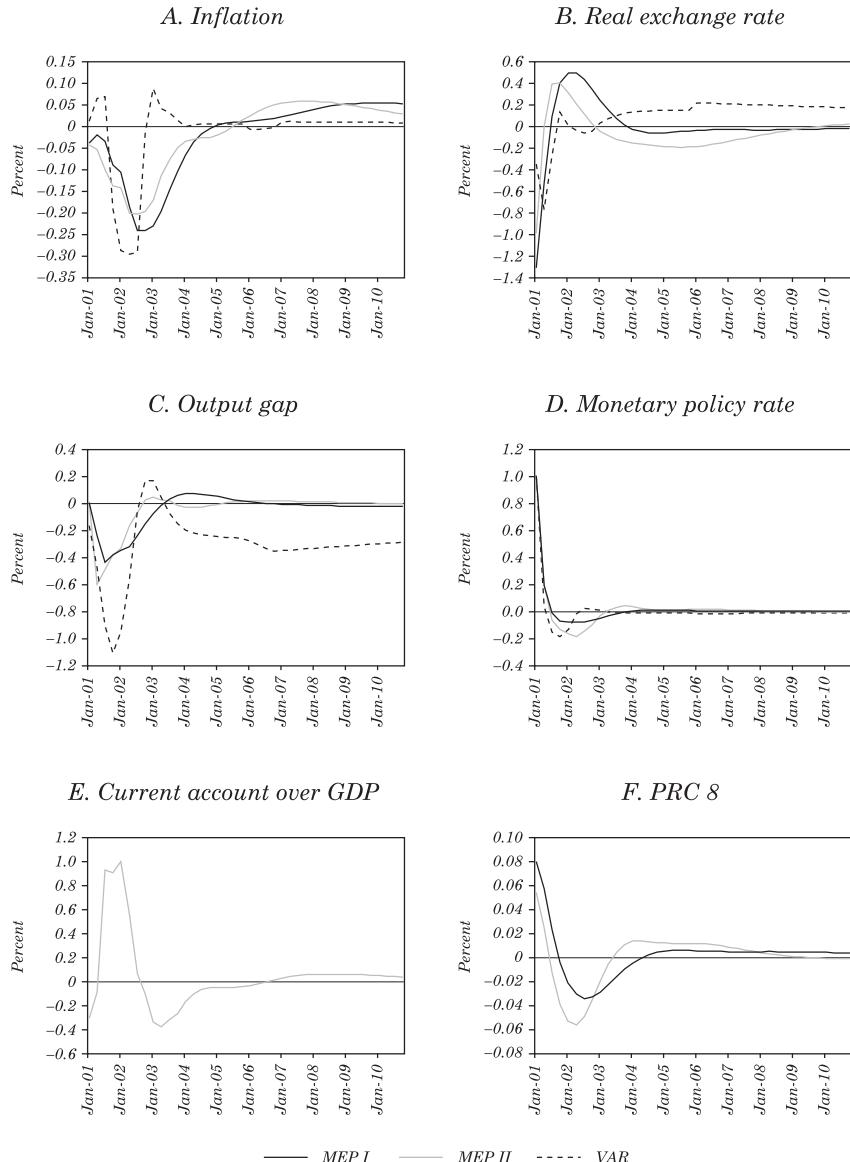
This section examines the response of key macroeconomic variables to a temporary shock (one quarter) to the monetary policy interest rate under the three different models described above. In particular, we look at the response of inflation, GDP, and the real exchange rate. We also compare the evolution of the monetary policy rate after the shock. Even though the shock is temporary, the trajectory of the monetary policy rate after the first period depends on the response of the monetary authority to the conditions in the economy. All responses are depicted in figure 11.

The six graphs in the figure show that the main variables of the different models behave in a fairly similar fashion. The monetary policy rate rises in all cases by 100 basis points and drops back to stay around the initial level after two to three quarters. The first panel shows that in response to the change in the monetary policy rate, the minimum value for the inflation rate is about 0.20 percentage points below the initial level, according to the MEP2. This value is about 0.05 percentage points larger for the MEP2 than for the MEP1 and about 0.10 percentage points larger than for the VAR. The minimum inflation (maximum deflation) occurs after seven quarters according to the MEP2, after eight quarters according to the MEP1, and after six quarters according to the VAR,. The VAR shows an initial inflationary period that is, however, not significantly different from zero (confidence bands are not shown to keep the picture clear). According to both the MEP1 and the MEP2, inflation drops initially by 0.05 percentage points and smoothly converges to the minimum point. Convergence to the long-run equilibrium is smoother according to the MEP1 and the MEP2 than to the VAR.

With respect to GDP, all three models show a contractionary effect in the very first quarters after the change in the monetary

29. The VAR model is described in Bravo and García (2002).

Figure 11. Response to a Temporary Shock to the Monetary Policy Rate^a



Source: Authors' calculations.

a. The shock is modeled as a 1-percentage-point increase.

policy rate. The minimum GDP gap occurs earlier under the MEP2 (in the first quarter after the shock) than under either the MEP1 or the VAR. The GDP gap reaches a minimum of about -0.6 percent based on the MEP2, which is slightly less than the -0.4 percent implied by the MEP1 and considerably larger than the -1.1 percent implied by the VAR. All three models show a relatively smooth recovery of the growth output gap, and the gap closes for all three model around the same date.

The real exchange rate dynamics are also reasonably similar for the three models, although the VAR model shows some differences. All three models show an initial real appreciation that ranges from 0.4 percent for the VAR (with a subsequent appreciation reaching a real appreciation of 0.8 percent in the second quarter) to 1.3 percent for the MEP1, with the MEP2 showing an intermediate result of a 1.0 percent real appreciation. Both the MEP1 and the MEP2 exhibit a subsequent depreciation and then a convergence to the initial level. The VAR shows a very mild appreciation relative to the initial level (not significantly different from zero).

An advantage of the MEP2 over both the MEP1 and the VAR presented above is that it allows us to calculate the current account of the balance of payments. The fifth panel in figure 11 shows the response of the current account as a percentage of GDP to the 100 basis point temporary shock to the monetary policy rate. Initially, the current account deteriorates, reaching a mild deficit of -0.3 percent in response to the initial appreciation of the real exchange rate. The current account is already on the surplus side by the third quarter. The surplus is due to both the depreciation of the real exchange rate and the fall in GDP. The maximum surplus of almost 1 percent of GDP is achieved after five quarters. The current account drops back to the initial level after seven quarters. The rise of the monetary policy rate induces a current account surplus that takes off after three quarters, reaches its maximum (of 1 percent of GDP) after five quarters, and lasts for about seven quarters.

3.2 Permanent Shock

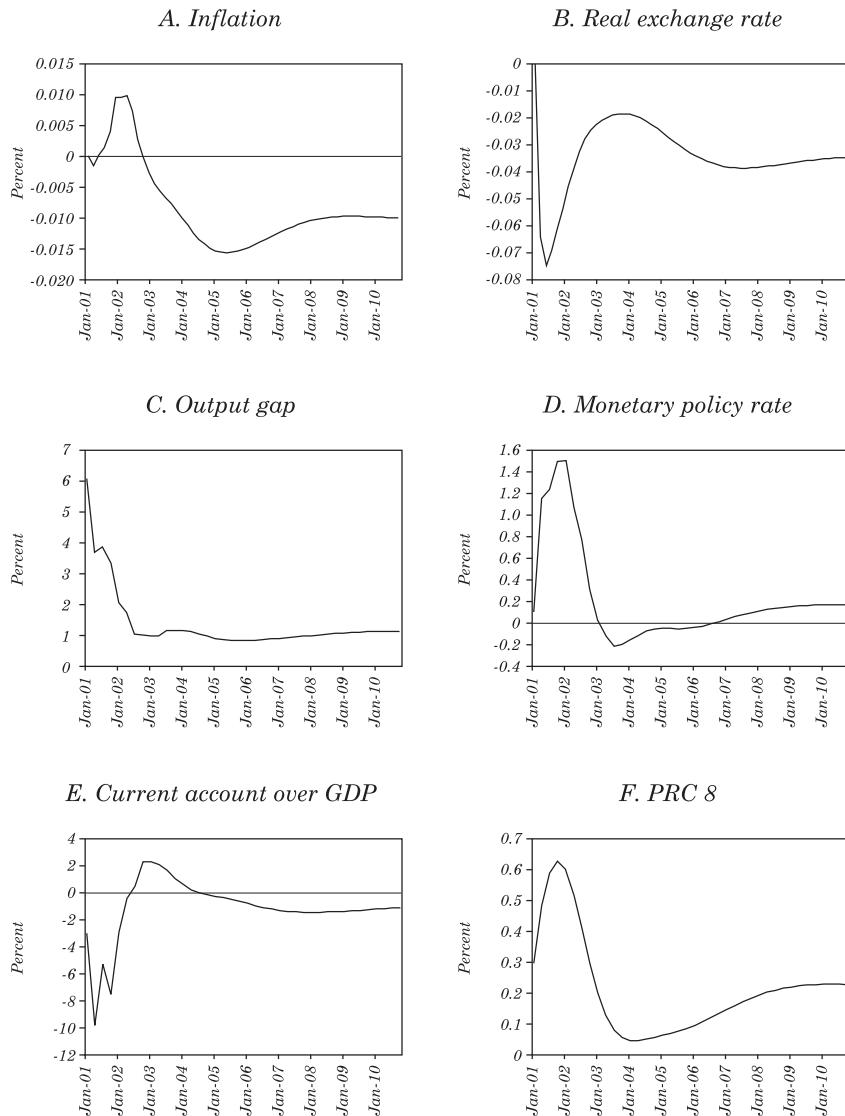
An important advantage of the MEP2 over a simple gap model, such as the MEP1, is that the steady state is well defined. This allows us to investigate the effects of permanent shocks both in the short- to middle-run dynamics and in the long-run impact. Figure 12 shows the response of a number of key variables to a permanent

increase of 5 percentage points in the ratio of government spending to GDP. This shock to aggregate demand translates into an increase in GDP of 6 percent. GDP increases by more than government spending because of an effect on investment and consumption. Both these variables are procyclical in the short run. The real exchange rate, in anticipation of the rise in domestic interest rates, tends to appreciate by about 6.5 percent. The appreciation and the increase in GDP together induce a current account deficit that rises from 3 percent of GDP in the quarter of the shock to almost 10 percent of GDP a quarter later. Inflation builds up slowly in response to the increased output gap and reaches a maximum of about 1 percent five quarters after the shock.

The monetary policy rate increases considerably only a quarter after the shock, in response to the increased output, the rise in inflation and future inflation, and the increase in the foreign spread, all of which affect expected inflation. A drop in GDP, a drop in inflation, and a recovery of the real exchange rate and the current account follow the increase in the monetary policy rate. In particular, GDP drops back toward its initial level, and it is less than 1 percent above the initial level within about seven quarters. Inflation enters into a mild but persistent deflationary period after the eighth quarter. The current account deficit tends to close, following a short surplus period. The real exchange rate remains appreciated by 3 percent relative to the initial level, and the monetary policy rate remains above the initial steady-state level by 20 basis points.

The price of copper is a critical variable, given the commodity's importance in Chilean production and exports. Figure 13 presents the response of key variables to a permanent drop of 20 percent in the price of this commodity. The current account deteriorates with the drop in the price of copper, reaching a deficit of about 4.5 percent of GDP. This deficit reflects the importance of copper in total Chilean exports. The deterioration of the trade balance also translates into a fall of GDP of 1.1 percent. An initial increase in the real exchange rate (7.5 percent), inflation (0.5 percent), and the foreign spread induce an increase in the monetary policy rate of 20 basis points, despite the initial negative output gap. The increase in interest rates and the depreciation of the real exchange rate imply higher costs of investment, particularly investment in machinery that has an important imported component. This cost increase reduces both investment and potential output in the long run. This, in turn, will lower GDP in the long run. Inflation tends to drop back to the target

Figure 12. Response to a Permanent Shock to Government Spending^a



Source: Authors' calculations.

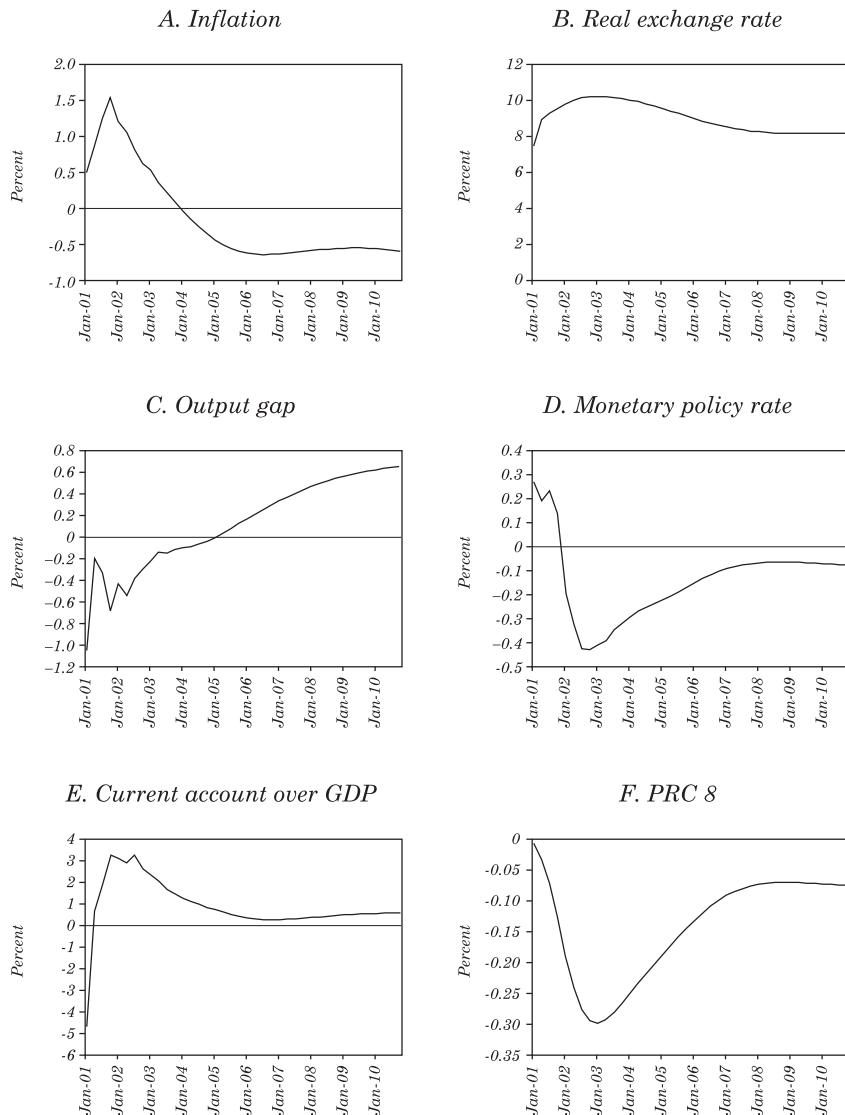
a. The shock is modeled as a 5-percentage-point increase the ratio of government spending to GDP.

level, and the monetary policy rate falls with inflation to become expansionary rather than contractionary after five quarters. The real exchange rate remains appreciated by about 8 percent in the long run with respect to the initial level.

The price of oil is also important for the Chilean economy, as oil is an important component of Chilean imports. A permanent increase of 20 percent in this price has effects that are very similar, at least qualitatively, to the impact of an increase in the price of copper. Fluctuations in all variables are smaller for the case of the shock to the price of oil (see figure 14).

A final exercise we present here is a permanent increase of 100 basis point in the relevant foreign interest rate. Results are presented in figure 15. This increase has two immediate effects: namely, to raise the monetary policy rate and the real exchange rate. Both these effects operate to reduce GDP. Inflation tends to increase first and drops later owing to the negative GDP growth and the rise in the monetary policy rate. Output tends to return to its initial level in the long run, but it remains slightly below that level. Inflation converges slowly to the target level. The current account remains in surplus, inducing a drop in the foreign spread that partially compensates for the higher foreign interest rates, while the real exchange rate remains appreciated by about 1 percent relative to the initial steady-state level.

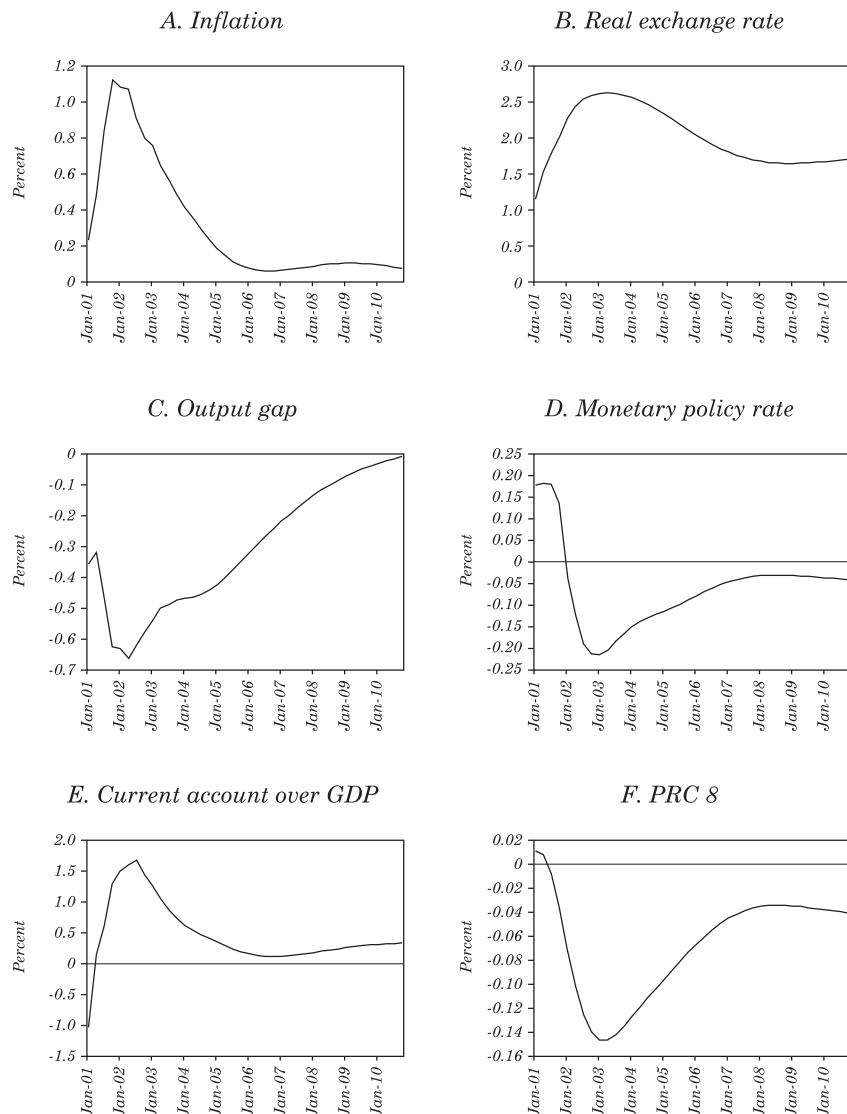
Figure 13. Response to a Permanent Shock to the Price of Copper^a



Source: Authors' calculations.

a. The shock is modeled as a 20-percent decrease in the price of copper.

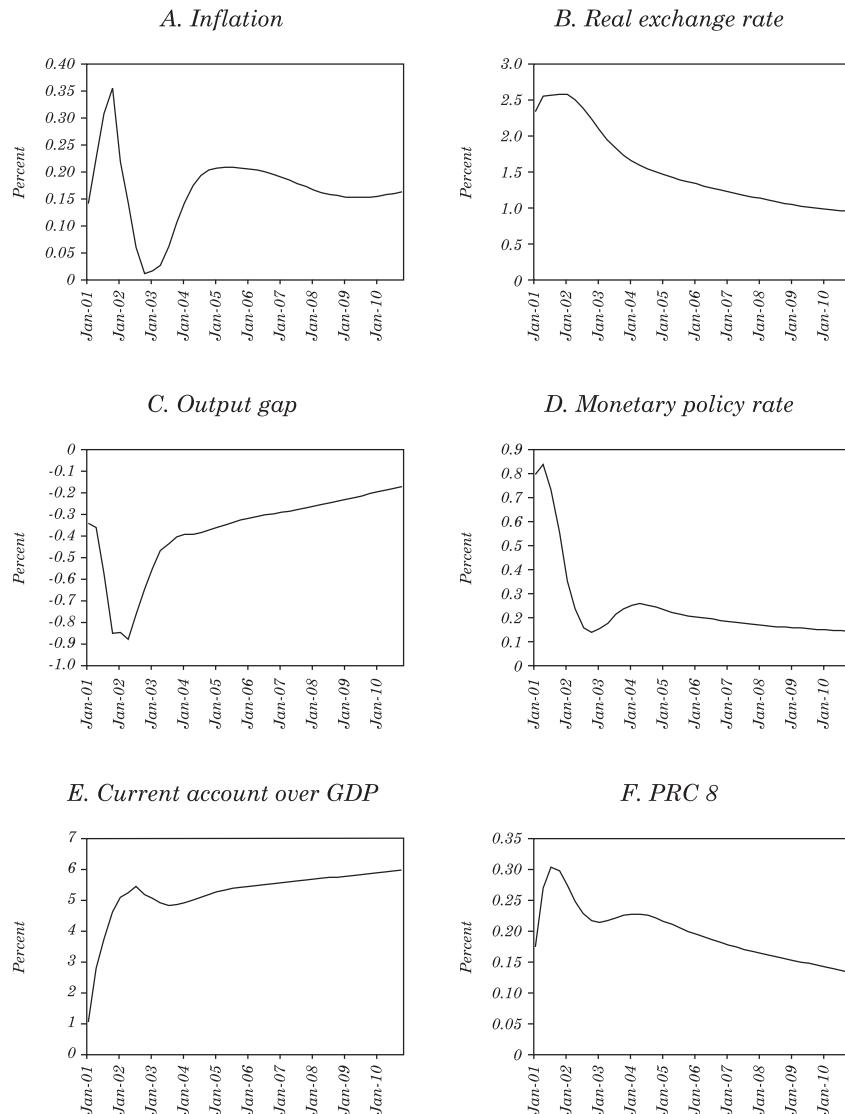
Figure 14. Response to a Permanent Shock to the Price of Oil^a



Source: Authors' calculations.

a. The shock is modeled as a 20-percent increase in the price of oil.

Figure 15. Response to a Permanent Shock to the International Interest Rate^a



Source: Authors' calculations.

a. The shock is modeled as a 100-point increase in the rate.

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GENERAL EQUILIBRIUM DYNAMICS OF EXTERNAL SHOCKS AND POLICY CHANGES IN CHILE

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This paper explores Chile's macroeconomic dynamics with the help of a general equilibrium model parameterized for the Chilean economy. The model is based on microanalytic foundations, and its basic relations are derived from intertemporal optimization by a group of forward-looking agents endowed with rational expectations. The economy's short-term equilibrium thus depends on the current and anticipated future paths of policy and external variables. The model also introduces critical real-world features—such as short-run wage rigidities and a group of myopic agents—that generate deviations from the frictionless full-employment equilibrium of the unconstrained neoclassical paradigm.

Using a parameterization derived from econometric estimates on Chilean data, we apply the model to simulate impact, transition, and steady-state effects of shifts in policy and external variables. We focus on the 1997–99 period of domestic policy changes and adverse foreign shocks—that is, the events associated with the Asian crisis—that led to Chile's 1998–99 recession. We simulate the individual and combined effects of the latter shocks to account for the observed downturn.

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This paper is essentially an extension of earlier work on macroeconomic dynamics for representative open economies and for Chile (Schmidt-Hebbel and Servén, 1994a, 1994b, 1995a, 1995b, 1996, 2002). It adds to a scarce literature analyzing developing countries with the help of nonlinear dynamic macroeconomic models based on optimizing behavior under rational expectations, with well-defined short-term and stationary equilibrium properties.

Section 1 offers a brief summary of the model structure, its steady state, dynamics, stability, and solution procedure. Full details are available in the companion paper by Schmidt-Hebbel and Servén (2002). The dynamics of the model are characterized by the combination of backward-looking dynamic equations describing the time paths of predetermined variables, such as asset stocks, and forward-looking equations describing the trajectory of asset prices. The model displays hysteresis, such that its steady state is path-dependent: it is affected by initial conditions and the entire adjustment path followed by the economy in response to a shock.

Section 2 describes the model's parameterization for the Chilean economy. The model's main structural equations are estimated econometrically, using quarterly data spanning the 1986–97 period. This is complemented with calibration of all relevant variables to the model's base quarter (1997:2).

Section 3 reports the dynamic response of the Chilean economy to the adverse external shocks, the expansionary fiscal policy, and the contractionary monetary policy that were observed in Chile in 1997–99. Our simulations can account for part of the behavior of Chile's key macroeconomic variables during the 1998–99 recession. Brief conclusions close the paper.

1. THE MODEL

The economy produces a single final good, which can be used for consumption and investment at home or for sale abroad. This good is an imperfect substitute for the foreign final good, and its production requires the use of an imported intermediate input. Consumers hold four assets: money and domestic-currency debt issued by the consolidated public sector (namely, the government plus the central bank), foreign-currency bonds, and equity claims on the domestic capital stock. Foreigners hold domestic equity but not domestic public debt. The public sector also holds (net) foreign assets. To bring money into the model and thus allow for the inflationary finance of public

deficits, we assume that its services yield utility to consumers. Capital mobility is not restricted. In the absence of risk and uncertainty, all nonmonetary assets are perfect substitutes, so their anticipated rates of return satisfy the corresponding uncovered parity conditions. In addition, the economy faces given world interest rates (that is, the small-country assumption for financial markets). Both goods and asset markets clear continuously, but the labor market may not clear instantaneously as a result of real or nominal wage rigidity. Staggered wage setting along the lines of Calvo (1983) generates nominal inertia; average wages are indexed to a distributed lag of current and lagged consumer price inflation and react slowly to deviations from full employment.

In a simultaneous-equations model such as ours, no specific equation determines any particular variable, but equality between the demand for the domestic good and its supply can be viewed as determining the real exchange rate. Consequently, money market equilibrium with an exogenously set money supply then determines the nominal exchange rate, given a fully flexible nominal exchange rate regime.

The dynamics of the model arise from two basic sources: the accumulation of assets and liabilities dictated by stock-flow consistency and the forward-looking behavior of private agents. Expectations are formed rationally, which, absent uncertainty, amounts to perfect foresight. Anticipated and realized values of the variables can only differ as the result of unexpected shocks or the arrival of new information about the future paths of exogenous variables.

Behavioral rules explicitly combine two benchmark specifications: neoclassical, intertemporally optimizing firms and consumers; and myopic firms and households, with wage inflexibility.¹ Without myopic agents and wage rigidity, the model would reduce to a standard open-economy neoclassical model of intertemporally optimizing agents, such as that of Servén (1995).²

Following the standard theory of investment under convex adjustment costs (Lucas, 1967; Treadway, 1969), neoclassical firms maximize their market value and link their investment decisions to Tobin's q (Tobin, 1969), or the present value of the additional profits

1. Export demand and wage setting are the only behavioral equations in the model that do not follow (explicitly or implicitly) from first principles.

2. Adjustment to disturbances would then involve trivial dynamics, with monotonic convergence to the steady state; see Servén (1995). The role of myopic agents in amplifying fluctuations is examined in Schmidt-Hebbel and Servén (1994a, 1994b).

associated with the marginal unit of capital relative to its replacement cost (Hayashi, 1982). Classical consumers gear their augmented consumption (consisting of goods and money services) to their permanent income, as derived from Ramsey-style intertemporal utility maximization (Ramsey, 1928). In contrast, myopic consumers gear their consumption expenditure to their disposable income, while shortsighted firms adjust their investment to a myopic version of Tobin's q (namely, the current marginal productivity of capital relative to its replacement cost). Consequently, in the steady state —when disposable income equals permanent income and the marginal product of capital is constant—both kinds of myopic agents behave the same as neoclassical agents.

Technology and preferences are kept as simple as possible—mostly by assuming unit elasticities of substitution, although this specification can be easily generalized. Two-stage budgeting in consumption and investment allows separation between the determination of the intertemporal path of expenditure and its allocation to domestic and foreign goods (thus avoiding the use of ad hoc import functions). Harrod-neutral technical progress ensures the existence of steady-state growth, at a level given by the sum of the rates of technical progress and population growth.

The model's detailed structure is presented in Schmidt-Hebbel and Servén (2002). Behavioral equations for firms, consumers, the public sector, and the external sector, along with the corresponding market-clearing conditions, are presented in appendix A.

1.1 Steady State

The long-run equilibrium of the model is characterized by constant output in real per capita terms (so that long-run growth equals the growth rate of the effective labor force), constant per capita real asset stocks, constant relative prices, and constant real wages with full employment. The government's budget must therefore be balanced.³ The current account deficit must equal the exogenously given flow of foreign investment, which, in turn, is just sufficient to keep foreign equity holdings unchanged (in real per capita terms).

3. Since asset stocks have to remain constant relative to the effective labor force, the real value of net government liabilities must increase at the rate of growth of the effective labor force, g .

Since the per capita real money stock is constant, long-run inflation equals the rate of expansion of per capita nominal balances. A constant real exchange rate implies that domestic and foreign real interest rates are equalized by uncovered interest parity and nominal exchange depreciation is determined by the difference between domestic and (exogenously given) foreign inflation. Hence, across steady states, changes in the money growth rate are fully reflected in the inflation rate (and thus in the nominal interest rate) and in the nominal depreciation rate.

By combining the model's equations, we could eventually reduce the steady-state equilibrium to two independent relations in the real exchange rate and real wealth: a goods market equilibrium condition and a zero private wealth accumulation condition (in real per capita terms). Together they imply a constant stock of per capita net foreign assets. Goods market equilibrium defines an inverse long-run relation between real wealth and the real exchange rate: higher wealth raises private consumption demand and requires a real exchange rate appreciation for the domestic goods market to clear. Further, the fact that production requires the use of imported inputs (namely, intermediates and capital goods) implies that across steady states, real output (and hence also the capital stock and the real wage) is inversely related to the real exchange rate: a real depreciation raises the real cost of imported inputs and therefore reduces the profitability of production.

Real wealth accumulation can cease only when augmented per capita consumption equals the per capita return on wealth. This poses the well-known requirement that for a steady state to exist, the rate of time preference must equal the exogenously given world interest rate—but then the zero wealth accumulation condition provides no information whatsoever on the steady-state level of wealth. Any wealth stock is self-replicating since the return on wealth is entirely consumed. This means that the steady-state wealth stock must be found from the economy's initial conditions and from its history of wealth accumulation or decumulation along the adjustment path. Hence, the steady-state values of wealth and the real exchange rate, as well as all other variables related to them, depend not only on the long-run values of the exogenous variables, but also on the particular trajectory followed by the economy. The model thus exhibits hysteresis. This reflects the general result that forward-looking consumption behavior by infinitely lived households that exhibit a constant rate of time preference and face perfect capital markets yields path dependence of the steady state (Giavazzi and Wyplosz, 1984).

An important implication of the model's hysteresis is that transitory disturbances generally have long-run effects. Turnovsky and Sen (1991) highlight this process for the case of fiscal policy.⁴ The quantitative importance of these effects, however, turns out to be quite modest empirically.

1.2 Dynamics, Stability, and Model Solution

The model's dynamics combine predetermined variables (that is, asset stocks), which are subject to initial conditions, and jumping variables (mostly asset prices). For the dynamic system not to explode, the variables that are not predetermined have to satisfy certain terminal (transversality) conditions. Solving the model basically amounts to finding initial values for the nonpredetermined variables such that after a shock, the model will converge to a new stationary equilibrium. Necessary and sufficient conditions for the existence and uniqueness of such initial values are well known for the case of linear models, but not for nonlinear systems such as the one at hand.⁵ While we cannot provide a formal proof of stability, we found numerically that the model always converged to the new long-run equilibrium under reasonable parameter values.

The requirement that the predetermined variables satisfy initial conditions, while the jumping variables must satisfy terminal conditions, poses a two-point boundary-value problem, for which several numerical solution techniques exist.⁶ Our solution method combines several approaches. As with multiple shooting (Lipton and

4. Turnovsky and Sen (1991) use a nonmonetary model with intertemporally optimizing consumers in which transitory fiscal disturbances have long-run effects. This conclusion depends critically on the endogeneity of the labor supply, which makes long-run employment endogenous. In our case, the dependence of the long-run capital stock on the real exchange rate ensures that transitory fiscal shocks have permanent effects despite constant employment across steady states; see Servén (1995).

5. See Blanchard and Kahn (1980) and Buiter (1984) on linear models. In principle, we could linearize our system around a steady state to analytically determine the conditions under which the transition matrix possesses the saddle-point property. This would be a difficult task, however, given the large dimensionality of our system.

6. See, for example, Judd (1998); Marimon and Scott (1999). In our case, path dependence of the steady state rules out a number of solution methods—such as reverse shooting (Judd, 1998) or backward integration (Brunner and Strulik, 2002)—that are based on a time reversal of the dynamic problem, such that it is solved backwards from the final steady state.

others, 1982), we shoot the model forward starting from an arbitrary guess about the initial values of the nonpredetermined variables and ending at an arbitrary solution horizon (that is, a finite approximation of the infinite horizon problem). Once we have found a solution for the selected solution horizon, we then extend the horizon and recompute the solution path. This prevents the solution from being distorted by the choice of too short a time horizon (which would force the model to reach the steady state too early).⁷ We keep extending the horizon in this fashion until the resulting changes in the solution path of the endogenous variables fall below a certain tolerance, at which time the process stops.⁸

2. MODEL PARAMETERIZATION FOR CHILE AND INITIAL STEADY-STATE SOLUTION

Parameterization involves choosing values for the model's behavioral parameters and calibrating the equations and budget identities to a given base period. We estimated the model's parameters using Chilean quarterly data spanning 1986–97, a period of high growth and probable parameter stability. We calibrated the model equations and budget constraints to the second quarter of 1997 (1997:2), a base period of full employment that preceded the 1997–98 Asian and Russian crises and 1998–99 domestic recession. We imposed steady-state equilibrium conditions on the data for 1997:2, that is, we assume that per capita state variables and relative prices are constant for the purpose of our simulations.⁹ Hence, the first period of our counter-factual

7. This endogenous determination of the solution horizon was first adopted in the extended path algorithm of Fair and Taylor (1983), and it is also a feature of other solution methods; see Judd (1998).

8. For the actual simulations, the model was made discrete, and we used a very strict convergence criterion in which we required that the maximum relative change between solutions in any variable at any period not exceed one-thousandth of one percent. Depending on the experiment under consideration, this required a horizon between 40 and 290 periods (quarters) for convergence. In practice, the length of the simulation horizon required for convergence is strongly affected by two parameters governing the speed of adjustment of the system: the elasticity of real wages to employment (that is, the slope of the augmented Phillips curve) and the magnitude of investment adjustment costs.

9. This is a common assumption for simulations based on rational expectations models. It allows us to focus on the impact, transition, and steady-state effects of policy shifts, uncontaminated by the nonstationary initial equilibrium of the economy. The slack variables chosen for the two independent budget constraints were total taxes and foreign transfers to the government.

simulations could be interpreted as 1997:3, if 1997:2 had been a stationary equilibrium period. Next we summarize the five steps followed in our model parameterization.

2.1 Quarterly Database

The main database was assembled from various sources, mostly from the Central Bank of Chile and the Chilean Budget Office.¹⁰ For several variables, we interpolated annual data to obtain quarterly time series. We used standard interpolation techniques to generate quarterly data for physical and human capital stocks (full sample period) and for investment prices, consumption prices, and disposable private income (subsample before 1990).¹¹ In the case of nonhuman capital, we built quarterly values using quarterly investment flows and a quarterly depreciation rate of 1.1 percent. In the case of human capital, we used quarterly values for wages and the labor force to construct quarterly observations. In the case of consumption prices, investment prices, and private disposable income, we used a modified Chow-Lin procedure.¹²

All variables are expressed as ratios to the labor force in efficiency units (the actual labor force augmented by the rate of Harrod-neutral technical progress) to conform to the model.

2.2 Calibration of Nonestimated Model Parameters

Three parameters were computed directly from the database: the domestic content of consumption and of investment (from the National Accounts and Trade Statistics published by the Central Bank of Chile) and the Harrod-neutral technical progress growth rate. In all cases we used the simple quarterly average for 1986–97. The import content of investment (29 percent) is six times as large as the import content of consumption (5 percent); this coincides with cross-country data reported in Servén (1999). The Harrod-neutral technical progress growth rate is 2.4 percent a year and corresponds

10. In particular, Central Bank of Chile (1998); *Boletín Mensual* (Central Bank of Chile, various issues); *Estadísticas de las Finanzas Públicas*, (Budget Office, various issues); and other data published by the Central Bank of Chile.

11. We used the values calculated in Braun and Braun (1999) as a benchmark for physical and human capital stocks in 1995:4.

12. The modification makes use of quarterly data available since 1991 and applies the seasonal pattern of the 1991–97 series to complement the traditional Chow-Lin method in constructing 1986–90 data.

to the average for 1986–97. We borrowed other parameter values from previous studies. For the subjective discount rate, we chose the value of the international interest parity level estimated for Chile in 1997 by Loayza and Gallego (1999). For the intertemporal elasticity of substitution in consumption, we used a value of 1.0, which is consistent with previous econometric estimations for Chile (Schmidt-Hebbel, 1987; Arrau, 1989) and with the log utility formulation in the model.

To improve our characterization of the steady state, we fixed the following parameter values: the labor force growth rate is an 1.6 percent a year (and thus stationary annual output growth is 4.0 percent, or the sum of the labor force growth rate and a 2.4 percent rate of Harrod-neutral technical progress); the annual money growth rate is 7.0 percent (which is consistent with an annual steady-state inflation at the inflation target of 3.0 percent and stationary output growth at 4.0 percent); and the flow of foreign investment relative to output is 2.0 percent.

2.3 Econometric Estimations

For our estimations using quarterly data, we set exogenously the rates of capital depreciation, steady-state growth, and the subjective discount rate.¹³ The estimation results are reported in appendix B. In a number of cases, one-time events and unexplained outliers would call for further specification analysis; here we content ourselves with making occasional use of dummy variables.

The speed of convergence to a new steady state and the transition path of endogenous variables depend critically on the values of the following key parameters. The elasticity of nominal wages with respect to employment is 0.32 (it would be infinity under instantaneous labor market clearing). Nominal wages are indexed to current consumer price index (CPI) inflation and one- and two-period lagged CPI inflation, with weights of 14 percent, 57 percent, and 29 percent, respectively. The quadratic adjustment cost coefficient for investment is 15, implying a slow investment response to shocks. The shares of neoclassical consumers and firms in aggregate private consumption and private investment are 66 percent and 53 percent, respectively, which is substantially below the unconstrained

13. Estimations are based on quarterly data, so all present and estimated rates are defined on a quarterly basis.

neoclassical benchmark of a 100 percent share.¹⁴ Calibrated and estimated model parameters are reported in appendix C.

2.4 Calibrated Base-period Values of Predetermined Variables

We fitted the base-period values (1997:2) of predetermined variables in two stages, in which we first added regression residuals to the estimated intercepts to replicate observed values and then forced budget constraints to hold with equality in 1997:2 at constant asset stocks (such that real stocks grow at the exogenous steady-state growth rate). The calibrated sector budget constraints are reported in appendix C. We chose total foreign assets held by the private sector and total taxes as the slack variables for the two independent budget constraints. The values are -199.0 percent of gross domestic product (GDP) for the stock of foreign assets held by the private sector (the actual value was -185.0 percent in 1997:2) and 13.2 percent of GDP for total taxes (the actual value was 16.3 percent in 1997:2). The base-period values of predetermined variables are also reported in appendix C.

2.5 Calibrated Base-period Values of Endogenous Variables

Appendix C also summarizes the initial steady-state values of the model's endogenous variables, obtained from the model's solution for the base period. They replicate actual 1997:2 values, except for taxes and foreign assets held by the private sector, as discussed above.

3. SIMULATION RESULTS

The model discussed above is useful for assessing the dynamic adjustment to foreign shocks and domestic policy shifts in Chile

14. Several studies estimate, using various techniques, the share of myopic or credit-constrained consumers ($1-\lambda_C$) in Chile and in other developed and developing countries. For Chile, Corbo and Schmidt-Hebbel (1991) estimate $1-\lambda_C$ at 0.60 for the 1968–88 sample period; Schmidt-Hebbel and Servén (1996) report a value of 0.45 for 1963–91; Villagómez (1997) finds 0.46 for 1970–89; Bandiera and others (1999) report 0.55 for 1970–95; and Bergoeing and Soto (in this volume) estimate 0.75 for 1986–98. Finally, López, Schmidt-Hebbel, and Servén (2000) use a panel of developed and developing countries; they estimate the share of constrained consumers to be 0.40 for the world sample, 0.40 for member countries of the Organization for Economic Cooperation and Development (OECD), and 0.61 for developing countries.

because it is based on an explicit forward-looking, optimizing framework that accounts for monetary and fiscal policies and relevant external variables. Here we use the model presented above to trace down the dynamic response of Chile's macroeconomy to the combination of expansionary fiscal policy, adverse foreign shocks, and contractionary monetary policy observed in 1997–98, which led to the 1998–99 recession. We also compare our simulation results to the actual response of Chile's macroeconomy in 1998–99.

The simulated policy changes comprise an expansionary fiscal policy (which raises public consumption by 1.54 percentage points, from 10.50 percent to 12.04 percent of GDP) and a contractionary monetary policy (which reduces annual money growth from 7.00 percent to 4.00 percent). We also consider a composite adverse external shock, which combines a rise in the relevant foreign interest rate (by 1.20 percent), a decline in export prices (by 12.00 percent), and a reduction in foreign output growth (by 2.24 percent).¹⁵ All shocks are temporary and assumed to last for eight quarters. They are unanticipated at period zero (that is, 1997:3), but at that time their future time path becomes known with certainty.

Next we describe the external shocks and policy changes that were actually observed in 1997–99 in Chile. We then report and discuss our simulation results.

3.1 The 1997–99 Period

After twelve years of high average growth, Chile was hit in 1997–98 by adverse external shocks that, combined with an expansionary fiscal policy and a contractionary monetary policy, led to a mild recession in 1998–99. Annual GDP growth fell to 3.3 percent in 1998 and –1.1 percent

15. Previous papers explore the dynamic macroeconomic effects of external shocks and policy shifts in representative economies and in Chile, using a model based on annual data frequency. Schmidt-Hebbel and Servén (1994b) analyze fiscal policy under alternative means of financing, while Schmidt-Hebbel and Servén (1994a, 1995a) assess the impact of external shocks in a representative open economy. Schmidt-Hebbel and Servén (1994c) examine the macroeconomic dynamic response to structural shocks in Chile (including a decline in the foreign real interest rate, an increase in the subjective discount rate, and an increase in the rate of technical progress); Schmidt-Hebbel and Servén (1995b) look at the effects of contractionary monetary policies in Chile; and Schmidt-Hebbel and Servén (1995b) assess the effects of fiscal policy in Chile. Finally, Servén (1995) explores analytically the impact of fiscal disturbances and foreign transfers in a nonmonetary model closely related to ours.

in 1999.¹⁶ The economy partly recovered after 2000, at a pace of positive but relatively modest growth. Inflation fell quickly during the recession, from 6.5 percent in 1997 to 4.4 percent in 1998 and 2.5 percent in 1999. As a result, convergence to low stationary inflation consistent with the long-term inflation target range was accomplished in the 1998–99 period. After appreciating continuously from the early 1990s through 1998, the real exchange rate depreciated by 5 percent in 1999, 4.8 percent in 2000, and 12.7 percent in 2001. The ratio of the current account deficit to GDP peaked at 6.0 percent in 1998 and then fell to 0.2 percent in 1999.

To our knowledge, only two papers assess the causes of Chile's recent downturn. First, Corbo and Tessada (2002) find that the 1998–99 recession was the result of external shocks (namely, lower terms of trade and reduced capital inflows) and monetary policy adjustment. The monetary contraction reflected the Central Bank's concern that inflation would rise in response to the nominal exchange rate depreciation and a very expansionary fiscal policy. In the second paper, Bergoeing and Morandé (2002) focus on the effects of labor market reforms. Using a calibrated model, they estimate that the expected increase in labor taxes explains much of the output decline. The existing explanations for the 1998–99 recession can thus be divided into policy-related factors (fiscal expansion, monetary adjustment, and labor tax increase) and adverse foreign shocks (lower terms of trade, higher foreign interest rates, and lower capital inflows).

We use our model to simulate the response of the Chilean economy to these shocks in a stylized way. We do not attempt to match the dynamics of Chile's key macroeconomic variables quarter by quarter for four reasons. First, ours is a small structural model comprising a parsimonious specification based on deep behavioral parameters that are largely derived from optimizing behavior, thereby excluding ad hoc, but possibly empirically relevant, right-hand-side determinants. The model's strength, which stems from its simple structure and transparent dynamics and steady-state properties, comes at a cost: it is not the ideal tool for tracking the short-run dynamics of any given endogenous variable. Second, we start from an initial simulation period (calibrated to 1997:2) at which we assume, for expositional and simulation convenience, that the economy is at a stationary position; this is an obvious departure from reality. Third,

16. GDP data are measured at 1986 relative prices.

we assume that all shocks are temporary and, most importantly, that this is known with certainty at the time of their occurrence. Fourth, all shocks take place for the same time length (eight quarters), and when we simulate their combined effects, we assume that they occur simultaneously. This was only approximately the case in Chile, as our subsequent data discussion illustrates.

Table 1 summarizes the actual behavior of key foreign and policy variables observed over periods roughly equal to eight quarters, in 1997–99 in Chile. The table reports the corresponding shocks, calculated as deviations from trends (estimated with the Hodrick-Prescott filter). The external environment for Chile deteriorated significantly during and after the Asian crisis, as reflected by a higher cost of borrowing, lower export prices, lower GDP growth of trading partners, and lower foreign capital inflows (not considered in the table). Shortly before the start of the Asian crisis, fiscal policy was relaxed, as reflected in an increase in the ratio of government consumption to GDP by 1.5 percent of GDP between 1997:2 and 1999:1. The Central Bank reacted to the Asian crisis and the fiscal relaxation by adopting a restrictive monetary stance, which is evident in the 3.0 percent lower annual growth in M1. The final column reports the eight-quarter shocks—which are set quantitatively close to the actual shocks—that are used in the simulations below.

Table 1. Actual and Simulated Shocks

<i>Type of shock and variable</i>	<i>Actual external and policy shocks observed in Chile</i>			<i>Eight-quarter simulated shocks (percent change)</i>
	<i>Initial period</i>	<i>Final period</i>	<i>Average change (percent)</i>	
External Shocks				
Change in relevant external interest rate ^a	1997:2	1999:1	1.20	1.20
Change in export prices	1998:1	1999:4	-12.00	-12.00
Change in world GDP growth ^b	1997:4	1999:4	-2.24	-2.24
Domestic Policy Shocks				
Change in government consumption	1997:2	1999:1	1.54	1.54
Monetary contraction	1998:1	1999:3	-3.00	-3.00

Source: Authors' calculations, based on data from the Central Bank of Chile and the Budget Office.

a. The relevant external interest rate is the sum of the foreign real interest rate and the country risk premium.

b. Change from Hodrick-Prescott (HP) trend growth.

Next we discuss the simulation results, first separately for the fiscal expansion, the monetary contraction, and the composite external shock (sections 3.2 through 3.4), and then by simulating the combination of all three shocks (section 3.5). Figure 1 depicts the dynamic response of all relevant endogenous variables to each of the four shocks, including the composite external shock. Figure 2 provides more detail on the dynamic response of four key macroeconomic variables in reaction to the three individual external shocks that comprise the aggregate foreign shock.

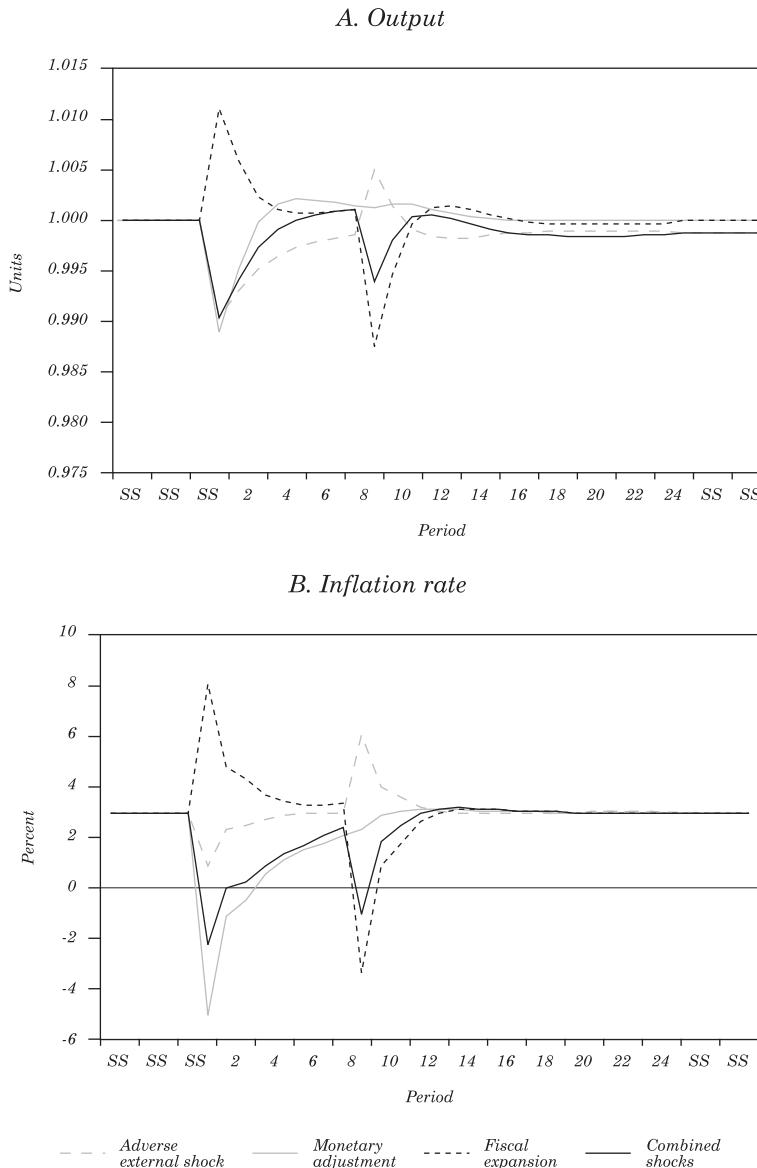
3.2 Fiscal Expansion

We simulate the effects of a temporary, debt-financed fiscal expansion that raises public consumption by 1.54 percentage points, from 10.5 percent to 12.04 percent of GDP. This policy shift causes the public debt stock to rise monotonically from 131 percent of GDP in the first quarter to 141 percent in the eighth quarter, with a further jump to 145 percent in the ninth quarter (owing to the high interest rate in the eighth quarter, discussed in detail below). The public debt stock then stays at that level thereafter. The increased public debt triggers a small steady-state increase of tax revenues of 0.03 percent of GDP (to meet the extra debt service) and a larger transitory increase in periods nine through twelve.

If all consumers were forward-looking, a temporary expansion in government consumption would lead to a transitory decrease in private consumption, by an amount consistent with the wealth loss from the temporary fiscal expansion and the transitory substitution of goods consumption for money services (caused by the increase in nominal interest rates; see below). To this, however, we must add the reaction of the almost 35 percent of consumers who are myopic and thus respond to temporary changes in variables that affect their current disposable income. As the real wage declines on impact and the real appreciation reduces the real value of foreign transfers received by the private sector, current disposable income falls. Aggregate private consumption is thus lowered for eight periods by less than would be the case under a permanent policy change, but by more than would be observed in the absence of myopic consumers.

Since public consumption falls only on domestic goods, the fiscal shock raises aggregate demand for national goods. This causes on impact (that is, in the first period) a real exchange rate appreciation and an increase in investment, output, and employment. The real

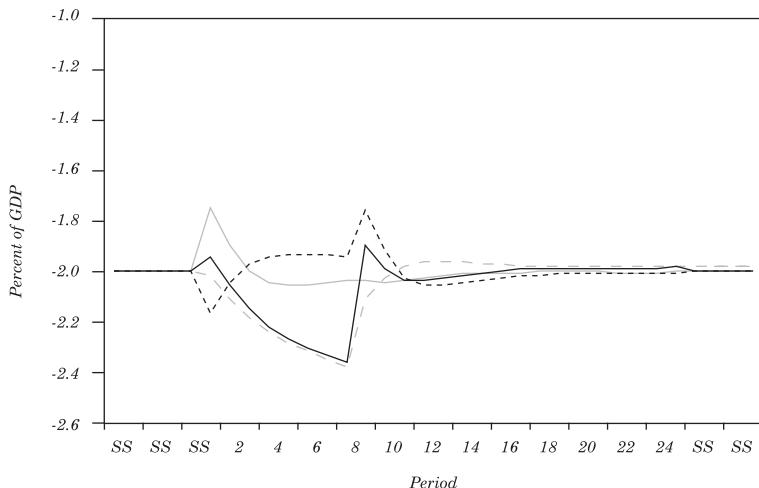
Figure 1. Dynamic Response of All Variables to All Shocks



Source: Authors' calculations.

Figure 1. (continued)

C. Current account



D. Real exchange rate

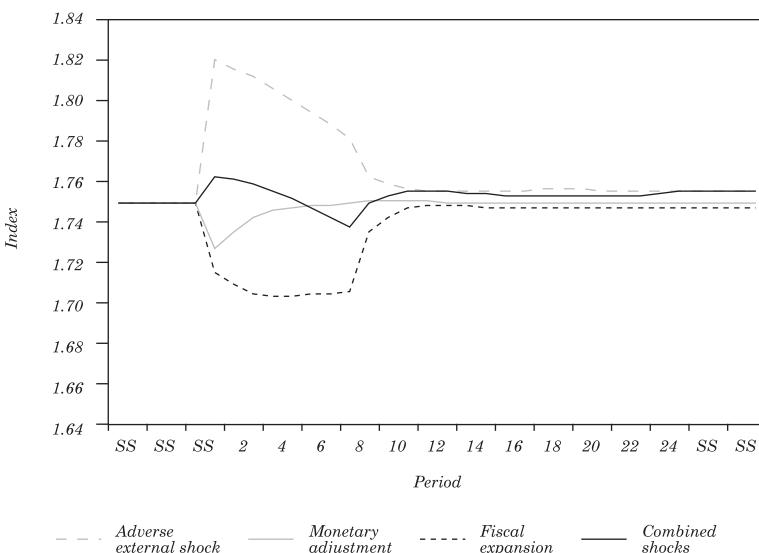
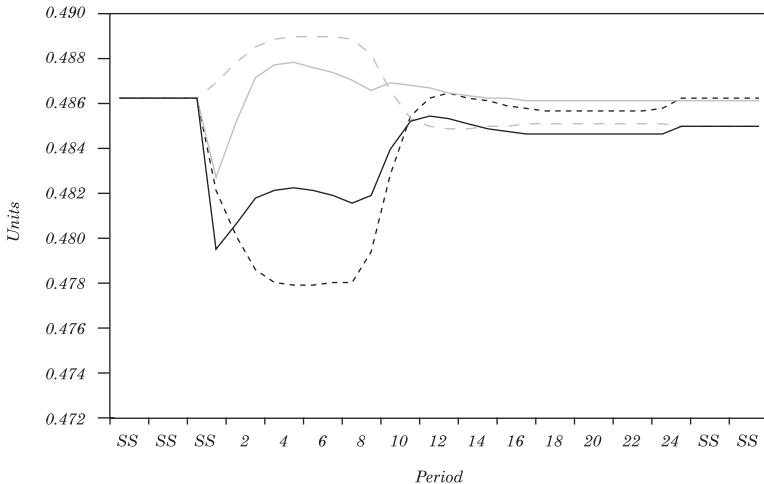


Figure 1. (continued)

E. Private consumption



F. Private investment

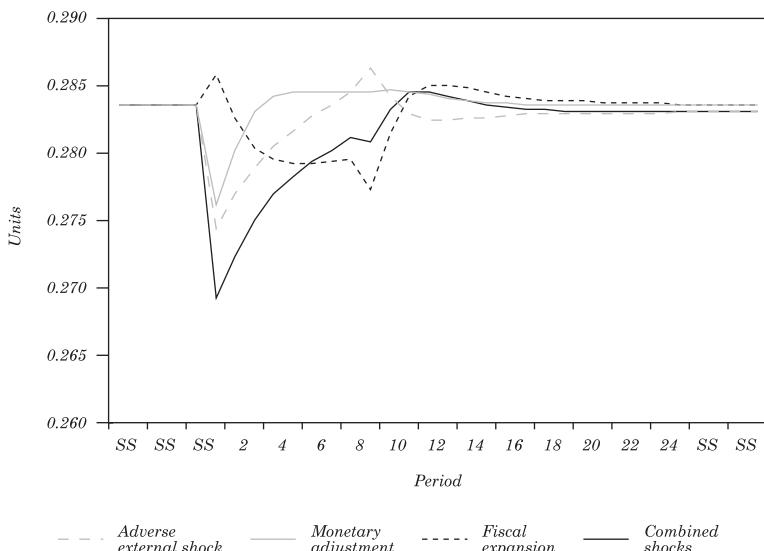
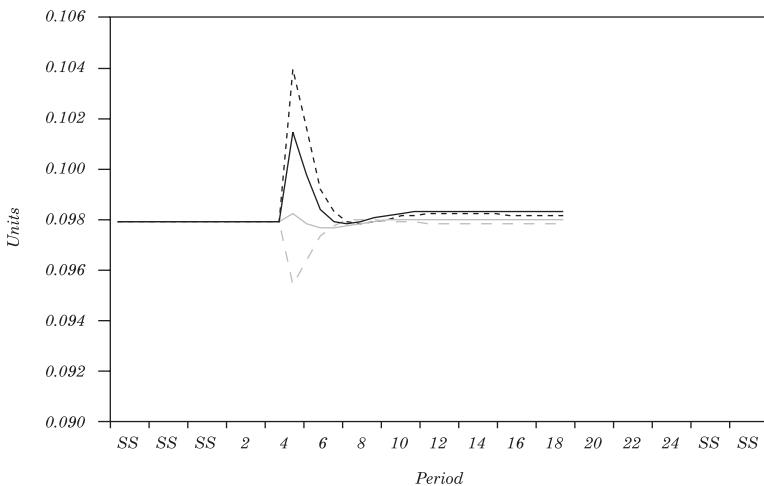


Figure 1. (continued)

G. Tax revenues



H. Public debt stock

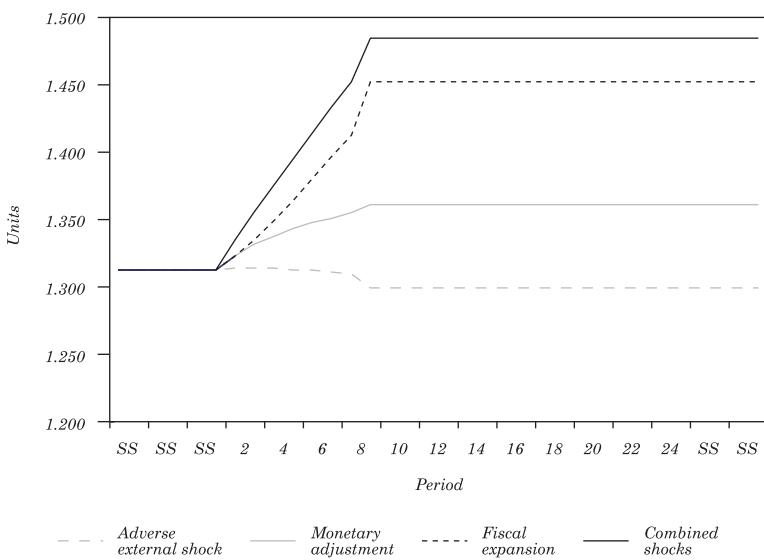
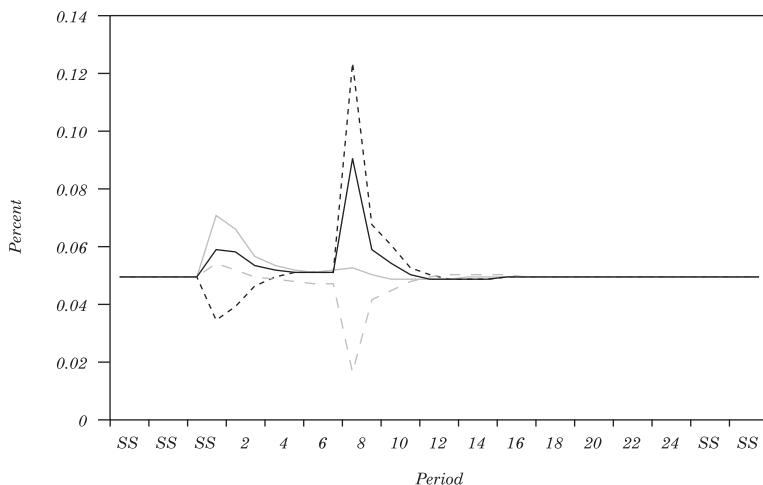


Figure 1. (continued)

I. Real interest rate



J. Tobin's q

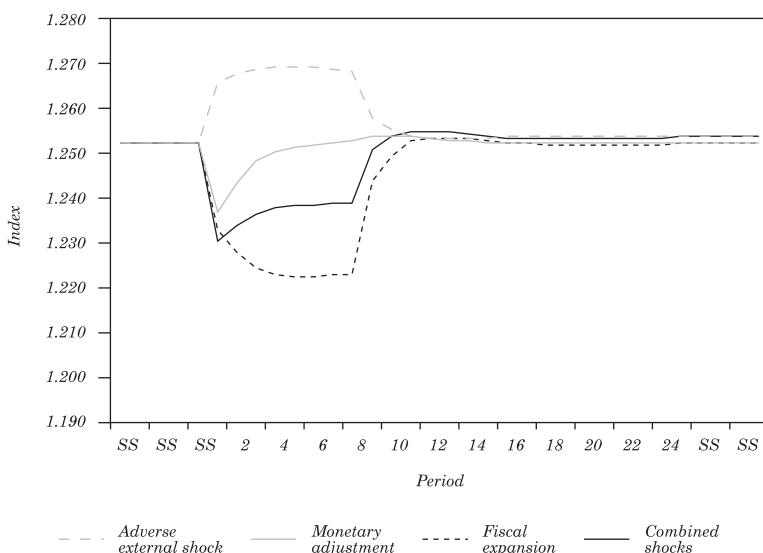
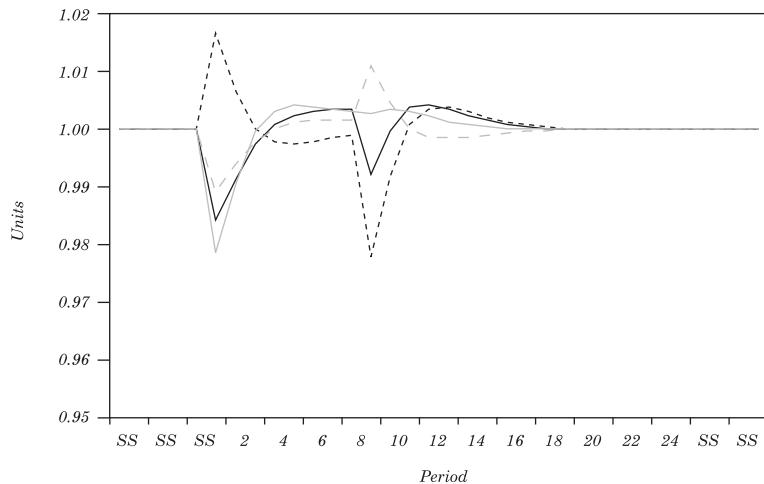
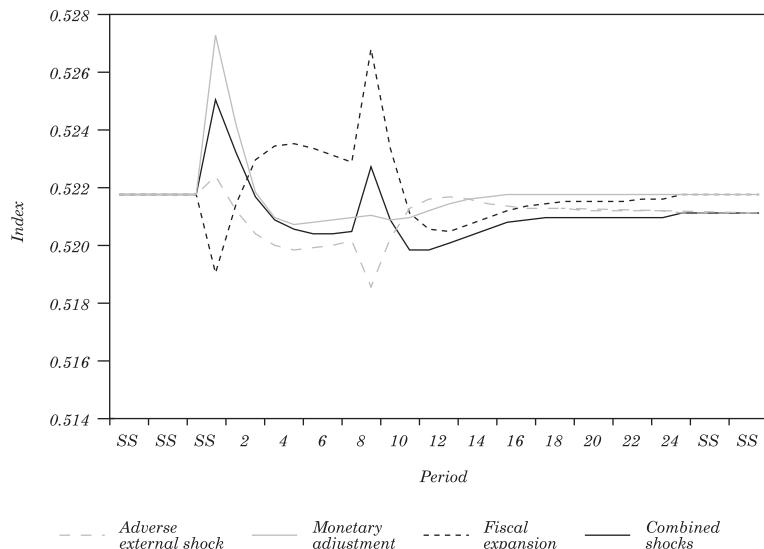


Figure 1. (continued)

K. Employment



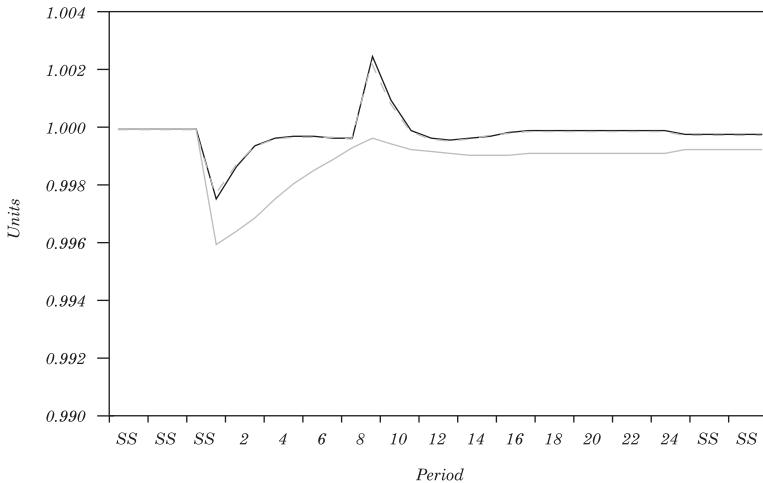
L. Real wage



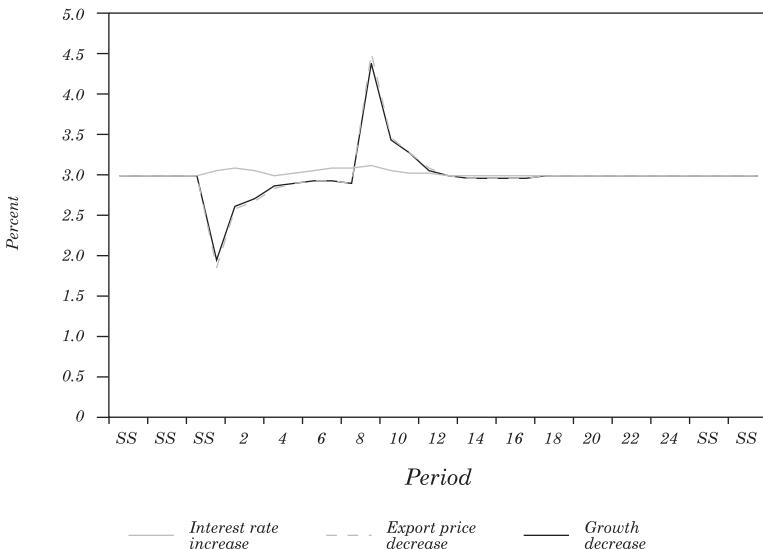
— Adverse external shock — Monetary adjustment - - - Fiscal expansion — Combined shocks

Figure 2. Dynamic Response of Main Variables to External Shocks

A. Output



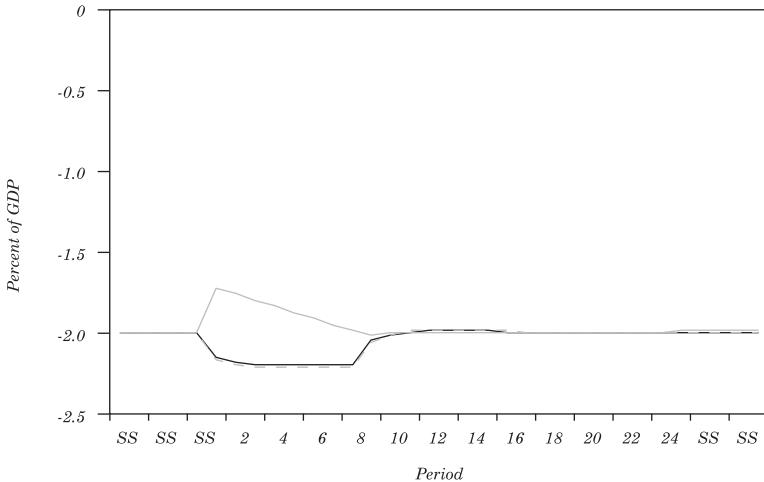
B. Inflation rate



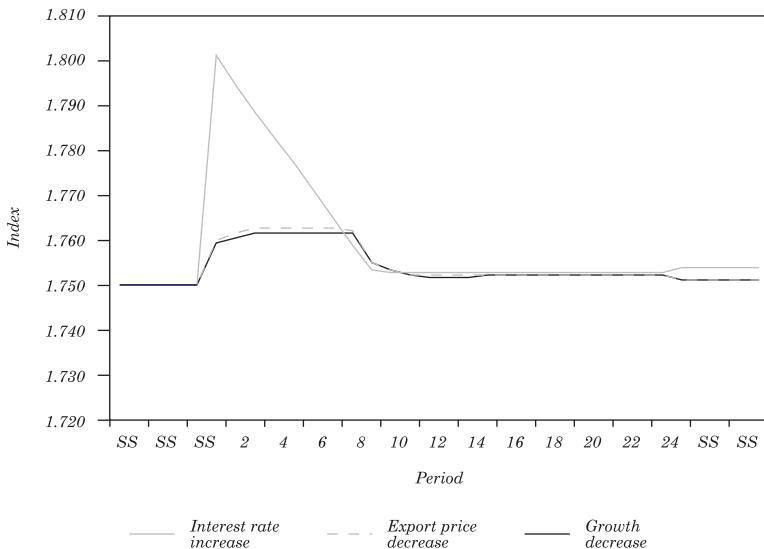
Source: Authors' calculations.

Figure 2. (continued)

C. Current Account



D. Real exchange rate



exchange rate gradually appreciates further in periods two through seven, which reflects the delayed wage reaction and the output contraction after the first period. The real exchange rate appreciation during the initial periods is mirrored in the drop in the ex ante domestic real interest rate in periods one through four, as dictated by uncovered real interest rate parity.

With regard to investment, myopic investors (the 50 percent of investors who adjust their investment to contemporaneous marginal productivity of capital) cause capital accumulation to react strongly to current output. This is observed in periods one through three and again from period nine until the new steady state is reached. Neoclassical investors react to the temporary output boom differently: they correctly anticipate further real appreciation, which creates an incentive to postpone investment. As a result, Tobin's q declines, and capital accumulation by neoclassical investors falls in periods one through eight. When we aggregate the two kinds of investors, the private investment rate exhibits a slight increase in the first period and a subsequent decline.

Inflation, given an unchanged flow supply of money, is determined by the response of money demand to the changes in the nominal interest rate and private consumption. The consumption decline in period one lowers money demand, causing inflation to rise from 3 to 8 percent on impact.

During the transition, wages are affected by contemporaneous and backward indexation to inflation. Sluggish wage adjustment implies that the increase in labor demand on impact and in subsequent periods is not matched by a real wage rise consistent with maintaining full employment. Slow wage adjustment in period one and subsequent periods leads to overemployment, causing a rise in employment by 1.6 percent on impact.

The ratio of the current account to output shows a strong cycle, mirroring the dynamics of consumption and investment, output, and the real exchange rate. The current account deficit increases marginally in the first period and then improves as output expands and aggregate consumption and investment decline after period one.

To understand the dynamic path of most variables under a temporary change, it is crucial to focus on the time around which the temporary shock is reverted, that is, before and after quarters eight and nine. When the temporary fiscal expansion reverts in period nine, private consumption rises back to a level close to its initial steady-state value. An expenditure switch back to imported

goods takes place at that time, consistent with the shift from public to private consumption; this causes a 1.7 percent real exchange rate depreciation (at a quarterly rate). The exchange rate depreciation is fully anticipated and hence fully reflected by the domestic real interest rate, which increases to 12.4 percent (at an annual rate).

Inflation reaches its trough in period nine, when the temporary fiscal expansion is reversed. Thereafter inflation returns toward its unchanged long-run level of 3 percent. Lower inflation in periods ten through twelve raises real wages beyond levels consistent with full employment. Employment therefore falls by 2.1 percent in quarter nine, deepening the recession induced by the decline in aggregate demand for national goods that takes place in the ninth quarter. The cyclical downturn of employment and output in quarters nine through eleven is offset by overemployment and high output in quarters twelve through sixteen—a reflection of the lagged effect of inflation on real wages.

The steady-state effects are almost negligible since the shock is temporary, and final steady-state values are very close to initial steady-state levels for all variables. The second-order differences are explained by the economy's transition path, which also affects steady-state values as a result of the model's hysteresis.

3.3 Monetary Contraction

This section describes the effects of a temporary monetary contraction that reduces money growth from 7 to 4 percent. Debt financing replaces seigniorage collection (specifically, its inflation tax component), as public debt increases to a new steady-state level of 136 percent of GDP. The process is as follows. First, lower money growth leads to a drop in inflation over the first ten periods, starting with a large initial decrease to -5 percent. This raises the stock demand for base money relative to annual output in the first ten quarters. Despite the rise in real money demand, the decline in nominal money growth leads to a decline in seigniorage from 0.9 percent of annual GDP to an average level of 0.5 percent of GDP on impact. The abovementioned increase in public debt matches the drop in seigniorage.

The private consumption of both optimizing and myopic consumers is reduced on impact. Classical consumers reduce their consumption levels in the first period in response to the interest rate spike in that period (prompted by the real exchange rate depreciation between

quarters one and two), while the myopic consumers do so as a result of the reduction in disposable income that results from the recession caused by the monetary crunch. The interest rate spike in the first quarter also depresses private investment. First-period deflation in consumer prices raises real wages, thereby reducing employment and output supply.

The impact effect on the exchange rate is, in principle, ambiguous because both aggregate demand and aggregate supply decline in the first quarter, reducing output. Given our model's parameter configuration, however, the supply contraction dominates the demand reduction, such that the relative price of national goods rises, as seen in a real exchange rate appreciation on impact.

All variables start to reverse their previous patterns in the second period. A lower real interest rate prompts an aggregate demand response, and high inflation reduces real wages, causing an increase in employment. Subsequently, all variables begin to converge toward their steady-state levels, some of them monotonically and others with disruption around quarter eight, when the temporary monetary contraction is reversed. As expected, most variables attain new stationary levels that are very close to their initial steady-state values.

Forward-looking consumers anticipate the future gradual real exchange rate depreciation resulting from the upcoming monetary expansion. This leads to a temporary increase in interest rates, a rise in consumption and investment, and even overemployment between periods four and fourteen. We can exemplify the role of forward-looking behavior in determining the model's dynamics by looking at inflation. The government's reversion from public debt to monetary financing in the ninth quarter is anticipated early on, which leads to a gradual rise in inflation to 3.0 percent in the third quarter and thereafter, without any jumps occurring at the time of shock reversal.

3.4 External Shocks

Our third simulation is a composite external shock comprising a 1.2 percent rise in the relevant foreign interest rate, a 12 percent decrease in export prices, and a 2.24 percent decline in trend foreign output growth. We start by analyzing each shock individually. Figure 2 depicts their respective dynamic impacts on four key variables: output, inflation, the real exchange rate, and the current account. Figure 1 presents the combined effect of the three external shocks.

First, the high foreign interest rate involves a wealth loss for the domestic economy because of its net debtor position vis-à-vis the rest of the world. Classical consumers reduce their consumption level accordingly, which permanently lowers aggregate demand and output levels and further depreciates the real exchange rate. A second effect of the foreign interest rate hike is derived from its temporary character. As forward-looking consumers and firms anticipate a reversion of interest rates in quarter nine and thereafter, their intertemporal spending pattern responds accordingly. With interest rates above their long-run level (which is equal to consumers' subjective discount rate), consumption drops on impact and then follows a rising pattern. The same pattern is observed in the case of Tobin's q and private investment.

Inflation responds to the initial output slump by rising to 3.2 percent on impact. It then starts to oscillate at levels close to 3 percent and finally converges close to 3 percent in the twelfth quarter and thereafter. The inflationary shock lowers real wages. Employment falls, however, in response to the aggregate demand contraction, which also explains the drop in output (0.45 percent on impact and 0.1 percent in the steady state). The opposite cycle of slight overemployment and overproduction is observed in quarters eight through ten. Increased inflation in the first quarter raises government revenue from seigniorage, so that public debt decreases on impact. The current account improves on impact; this reflects a very sharp contraction of demand, which outweighs the increased service on foreign debt.

Now consider the second external shock. A reduced export price has two first-round effects: a decline in income proportional to the loss in the terms of trade (which lowers private consumption) and a transitory reduction in the supply of exports (which causes a transitory supply contraction and unemployment). Because the change in export prices is temporary, the wealth effects for neoclassical consumers are relatively small, and their consumption declines only slightly in quarters one through eight.

The real exchange rate depreciates on impact by 0.6 percent. This causes a small decline in investment (because it raises the price of imported capital goods), which triggers the output contraction discussed above. Output—which contracted by 0.3 percent in the first period—partially recovers to attain a new stationary level only 0.02 percent below its initial steady state. The gradual recovery in aggregate supply in periods two through five leads to a slight real exchange rate depreciation; this is largely reversed in period nine,

when export prices return to their initial level.

The export price shock and its derived output contraction cause a one-time inflation drop to 1.9 percent in the first period. Wage sluggishness precludes real wages from declining on impact to the level consistent with full employment. Employment therefore declines by 0.4 percent on impact, which contributes marginally to deepening the output contraction. The labor market normalizes after three periods, when the effects of the temporary inflation shock fade away.

The export price shock reversion in the ninth quarter leads to a subsequent recovery of most variables to levels close to their initial values. The real exchange rate appreciates in period nine, while the ex ante real interest rate consistently drops to 3.3 percent in the eighth quarter. The interest rate effect raises Tobin's q , which, in conjunction with a less depreciated exchange rate, now leads to an increase in private investment. The increase in aggregate demand is accompanied by a temporary output expansion and an increase in inflation to 4.5 percent in period nine, which leads to overemployment and reinforces the output increase.

The current account deficit mimics the pattern of income and aggregate demand, especially consumption. It registers an increased deficit in periods one through nine and subsequently converges to its stationary level.

The third external shock—namely, a reduction in foreign output growth—has effects that are qualitatively very similar to those of the export price decline, because both work through their impact on the demand for exports. Coincidentally, their quantitative effects are also very similar (the effects in figure 2 are almost undistinguishable). We therefore do not discuss this shock separately.

The composite effect of the three external shocks (figure 1) roughly reflects the relative intensity of each foreign shock separately.¹⁷ Output drops by 1 percent on impact; inflation declines to 0.9 percent in the first quarter (reflecting the positive effect of the foreign interest rate shock and the negative effects of the two shocks on exports); the real exchange rate depreciates by 4 percent on impact (mainly as a result of the huge impact of the interest rate shock); and the current account deficit increases to 2.2 percent of output, on average, in quarters one through eight.

17. Second-order interaction and feedback effects cause the combined effects to differ from the simple sum of the effects of the three separate shocks.

3.5 A Comparative Evaluation of the Three Shocks

When the economy is affected by the composite external shock and the two policy shocks at the same time, their combined effects are almost equivalent to the sum of the consequences of the three separate shocks. The negative output effects of the monetary and external shocks are almost similar on impact, but the cumulative effect of the external shock is larger because it results in a more gradual adjustment of the economy's key variables. In fact, the cumulative output loss caused by the external shock is 4.4 percent in the first twenty-four quarters, versus 0.06 percent in the case of the monetary contraction. The fiscal shock, in turn, has a positive cumulative effect on output of 0.7 percent in the first twenty-four quarters.

Inflation falls well below 3 percent for twelve quarters as a result of the large effect of the monetary contraction, the relatively small effect of the external shock, and the reversion of the fiscal contraction in periods nine through eleven. The monetary contraction has a persistent effect on inflation, which is a consequence of the forward-looking nature of the model. The main effects of the other shocks occur around the first and the ninth quarters—that is, at the start and end of the temporary shocks.

The real exchange rate depreciates relative to its initial level in the first eight periods, mostly driven by the influence of the composite adverse external shock. Figure 2 suggests that the steady-state exchange rate depreciation is a consequence of the interest rate shock, as a result of the model's hysteresis. Finally, the current account deficit also increases in periods one through eight, mainly in response to the external shocks.

These results highlight the fact that different shocks have different relative consequences for different variables. The composite foreign shock—which represents the adverse consequence of the Asian and Russian crises on the Chilean economy—clearly had the largest effect on the three key real variables: output, the current account, and the real exchange rate. Not surprisingly, the monetary contraction had the largest effect on inflation. The timing of the different shocks also matters. For example, the composite external shock and monetary contraction are equally important in explaining the large initial output drop in the first period.

The final question that we address is how well our simulations fit Chile's actual macroeconomic dynamics in 1997–99. For this

purpose, we report the mean deviations from trend of the four key macroeconomic variables in four consecutive eight-quarter windows, starting in 1997:3, 1997:4, 1998:1, and 1998:2, respectively (see table 2). We chose the latter windows because the computed deviation is sensitive to the selected window, which is probably a result of the large quarterly volatility of each variable. We then report the simulation results for the same four variables in response to the simultaneous adverse external shock, fiscal expansion, and monetary contraction (shown in figure 1).

Table 2 shows that the simulation results in terms of eight-quarter averages for the real exchange rate and the current account are reasonably close to the actual macroeconomic behavior observed in Chile (averaged across the four selected windows). However the simulation results for output and inflation do not closely match the actual responses of these variables in 1997:3 to 2000:1.

Table 3 provides a different perspective on the comparison of actual and simulated responses of the key variables, based on maximum deviations and trough-to-peak and peak-to-trough cyclical changes. On the whole, two facts emerge: actual and simulated changes go in the same direction; and their magnitudes generally differ, with the exception of the inflation rate (the model tends to generate too little variation in real variables). We attribute the differences between our out-of-sample simulations and the actual

Table 2. Actual and Simulated Quarterly Deviations of Key Macroeconomic Variables in Chile

<i>Percent</i>				
<i>Period</i>	<i>Output</i>	<i>Inflation</i>	<i>Real exchange rate</i>	<i>Current account</i>
Actual data				
1997:3–1999:2	1.32	0.03	1.25	-1.44
1997:4–1999:3	0.51	-0.27	0.74	-0.97
1998:1–1999:4	-0.34	-0.78	0.60	0.05
1998:2–2000:1	-0.96	-0.52	-0.02	0.66
1997:3–2000:1 (average)	0.47	-0.15	0.54	-0.43
Model simulation				
Eight quarters	-0.21	-2.19	0.15	-0.42

Source: Central Bank of Chile and authors' calculations.

behavior of Chile's key macroeconomic variables to three factors. First, we do not simulate all the shocks that hit the Chilean economy between 1997 and 2000. Second, our model is a parsimonious specification for Chile that is largely based on dynamic optimizing behavior and consistent stock-flow relations; it does not attempt to match the quarterly dynamics of Chile's key macroeconomic variables in the 1986–97 period. Finally, Chile's economy probably faced structural changes and restrictions in 1998–99 (including severe domestic credit constraints and strong wage resistance to unemployment) that were not present in the preceding period and thus are not captured by our model.

Table 3. Actual and Simulated Maximum Deviations and Changes over the Cycle, 1997:3 to 2001:1

<i>Percent</i>				
<i>Indicator</i>	<i>Output</i>	<i>Inflation</i>	<i>Real exchange rate</i>	<i>Current account</i>
Actual maximum deviation from equilibrium	-3.80	-2.90	4.15	-3.10
Period of actual deviation	1999:2	1999:1	1998:1	1998:1
Simulated maximum deviation from equilibrium	-0.96	-5.20	1.26	-0.40
Actual change from trough to peak	3.39	5.38	5.49	8.08
Length of actual trough to peak	6 quarters	7 quarters	4 quarters	8 quarters
Simulated change from trough to peak	1.08	5.36	1.04	0.47
Length of simulated trough to peak	6 quarters	13 quarters	4 quarters	1 quarter
Actual change from peak to trough	-8.63	-6.47	-6.78	-5.20
Length of actual peak to trough	6 quarters	5 quarters	6 quarters	3 quarters
Simulated change from peak to trough	-0.96	-5.20	-1.41	-0.43
Length of simulated peak to trough	1 quarter	1 quarter	8 quarters	7 quarters

Source: Central Bank of Chile and authors' calculations.

4. CONCLUSION

We have developed and applied a macroeconomic general equilibrium model that is fully parameterized for the Chilean economy. The model's basic relations are characterized by intertemporal optimization by rational forward-looking agents and real-world features—such as short-run wage rigidities and myopic agents—that generate deviations from the frictionless full-employment equilibrium of the unconstrained neoclassical paradigm. We numerically calibrated the model to the second quarter of 1997 and then applied it to simulate the dynamics of Chile's economy in response to the actual out-of-sample foreign shocks and policy shifts that led to the 1998–99 recession. Our comparison of simulated and actual dynamics yields mixed results, illustrating the power and the limitations of a parsimonious optimizing dynamic model in yielding out-of-sample simulations for an economy subject to regime shifts and structural change.

APPENDIX A

Model Variables and Equations

This appendix first lists our notation and definition of the variables and then presents the model equations.

All stock and flow variables other than interest rates are defined in real terms. Current-price domestic (foreign) income and transfer flows and prices are deflated by the price of the domestic good (foreign price deflator). All stock and flow variables other than prices and interest rates are defined in terms of units of effective labor force. Domestic (foreign) relative prices are measured in real domestic (foreign) currency units.

Population, labor, and employment

n	Population growth rate
v	Harrod-neutral technical progress rate
$g = v + n$	Growth rate of effective labor force
I	Employment (relative to effective labor force)

Domestic income, transfers, and capital flows

d	Dividends
d^*	Profit remittances abroad
T	Taxes

Foreign income, transfers, and capital flows

f_G^*	Foreign transfers to the public sector
f_P^*	Foreign transfers to the private sector
Y^*	Foreign income
FDI	Foreign direct investment

Domestic stocks

a	Total wealth of the private sector
b	Domestic debt of the public sector
v	Market value of domestic firms

m	Domestic base money
h	Human wealth of the private sector
K_1	Physical capital of intertemporally optimizing firms
K_2	Physical capital of myopic firms

Foreign stocks

b_G^*	Foreign assets held by the public sector
b_P^*	Foreign assets held by the private sector

Goods flows

Y	Gross output of final goods
Z	Augmented private consumption (inclusive of money services)
C	Private consumption of goods
C^*	Private consumption of imported goods
C^N	Private consumption of domestic goods
G	Public consumption of domestic goods
J	Gross domestic investment (inclusive of adjustment costs)
I_1	Gross installation of new capital by intertemporal optimizing firms
I_2	Gross installation of new capital by myopic firms
J^N	Investment in domestic goods
J^*	Investment in foreign goods
I_G	Public investment subsidy
X	Exports
M	Intermediate imports

Rates and shares

i	Nominal interest rate on domestic public debt
r	Real interest rate on domestic public debt
r^*	Real interest rate on foreign assets/liabilities
μ	Growth rate of the nominal money stock
ρ	Consumers' subjective discount rate

δ	Depreciation rate of physical capital
x	Fraction of equity owned by domestic agents
λ_C	Share of intertemporally optimizing consumers
λ_I	Share of intertemporally optimizing firms

Domestic goods prices

All domestic goods prices are relative to the price of the domestic final good.

p_Z	Deflator of augmented private consumption
p_C	Deflator of private consumption goods
p_C^N	Deflator of private domestic consumption goods
p_K	Investment deflator

Foreign goods prices

All foreign goods prices are relative to the price of the foreign final good.

p_C^*	Deflator of consumption imports
p_K^*	Deflator of investment imports
p_M^*	Deflator of intermediate imports
p_X^*	Deflator of export-competing goods

Other domestic prices

q_1	Tobin's marginal q for intertemporally optimizing firms
q_2	Tobin's marginal q for myopic firms
w	Real wage per effective labor unit
W	Nominal wage per labor unit
Ω	Weighted average of current and lagged consumer prices
P^C	Nominal private consumption deflator

Real exchange rate

$$e = (E P^*)/P \text{ Real exchange rate}$$

E	Nominal exchange rate
P	Nominal price of the domestic good (domestic price level)
P^*	Nominal external deflator (foreign price level)

The model equations

In the equations that follow, all stock and flow variables other than prices and interest rates are scaled to the labor force in efficiency units. Time is denoted by t . One dot over a variable denotes its right-hand time derivative; two dots denote the second time derivative. The exponential function is denoted as \exp and the natural logarithm as \ln .

Consumers' utility function:

$$U = \int_0^\infty \exp[(g - \rho)t] \ln\{Z[C(C^N, C^*), m]\} dt \quad (1)$$

Augmented consumption deflator:

$$p_Z = [\beta p_C^{1-\sigma} + (1-\beta) i^{1-\sigma}]^{1/(1-\sigma)} \quad (2)$$

Goods consumption deflator:

$$p_C = (e p_C^*)^{1-\eta} \quad (3)$$

Consumers' budget constraint:

$$\begin{aligned} (wl + e f_p^* - T) + xd - & \left(g + \frac{\dot{P}}{P} \right) m + (r - g)b + (r^* - g)e b_p^* \\ & = (e p_C^* C^* + p_C^N C^N) + \dot{m} + \dot{b} + e \dot{b}_p^* + v \dot{x} \end{aligned} \quad (4)$$

Human wealth:

$$h = \int_0^\infty \exp[(g - r)t] (wl + e f_p^* - T) dt \quad (5)$$

Total wealth:

$$a = m + b + eb_p^* + xv + h \quad (6)$$

Nominal interest rate:

$$i = r + \frac{\dot{P}}{P} \quad (7)$$

Uncovered interest rate parity:

$$r^* = r + \frac{\dot{e}}{e} \quad (8)$$

Private aggregate consumption demand:

$$C = (\rho - g) \frac{a}{p_c} + (1 - \lambda_c) \left[\frac{wI - T + ef_p^* - (\rho - g) h}{p_c} \right] - \frac{im}{p_c} \quad (9)$$

Base money market equilibrium:

$$m = C \frac{(1-\beta)}{\beta} \left(\frac{p_c}{i} \right)^\sigma \quad (10)$$

Private domestic goods consumption demand:

$$C^N = \eta p_c C \quad (11)$$

Private imported goods consumption demand:

$$C^* = (1 - \eta) \frac{p_c C}{ep_c^*} \quad (12)$$

Production function:

$$Y = \alpha_0 I^{\alpha_1} K^{\alpha_2} M^{(1-\alpha_1-\alpha_2)} \quad (13)$$

Total investment:

$$J = I + \frac{\phi}{2} \left\{ \frac{[I - (g + \delta)K]^2}{K} \right\} \quad (14)$$

Capital stock accumulation:

$$\dot{K} = I - (g + \delta)K \quad (15)$$

Dividends:

$$d = Y - wI - ep_M^* M - p_K J + p_K I_G \quad (16)$$

Labor demand:

$$l = \alpha_1 \frac{Y}{w} \quad (17)$$

Imported materials demand:

$$M = (1 - \alpha_1 - \alpha_2) \frac{Y}{ep_M^*} \quad (18)$$

Domestic goods aggregate investment demand:

$$J^N = \gamma p_K J \quad (19)$$

Imported goods aggregate investment demand:

$$J^* = (1 - \gamma) \frac{p_K J}{ep_K^*} \quad (20)$$

Intertemporal Tobin's q :

$$q_t = \int_0^\infty \exp[-(r + \delta)t] \left\{ \alpha_2 \frac{Y}{K} - p_K \frac{\phi}{2} \left[\left(\frac{I_1}{K_1} \right)^2 - (g + \delta)^2 \right] \right\} dt \quad (21)$$

Myopic Tobin's q :

$$q_2 = \frac{\left\{ \alpha_2 \frac{Y}{K} - p_K \frac{\phi}{2} \left[\left(\frac{I_2}{K_2} \right)^2 - (g + \delta)^2 \right] \right\}}{(r + \delta)} \quad (22)$$

Aggregate investment demand:

$$I = \frac{K}{\phi} \left[\frac{\lambda_I q_1 + (1 - \lambda_I) q_2}{p_K} - 1 \right] + (g + \delta) K \quad (23)$$

Public sector budget constraint:

$$(T + e f_G^* - G - p_K I_G) - (r - g) b + (r^* - g) e b_G^* = e \dot{b}_G^* - \dot{b}_G - \mu m \quad (24)$$

Export demand for national imports:

$$X = (e p_X^*)^{\varepsilon_1} y^* \exp^{\varepsilon_0} \quad (25)$$

Accumulation of foreign investors' per capita holdings of equity:

$$-\dot{x} v = e FDI - g(1 - x)v \quad (26)$$

Dividends earned by foreign investors (profit remittances abroad):

$$d^* = (1 - x)d \quad (27)$$

Balance of payments identity in real foreign-currency units:

$$\begin{aligned} & \left(\frac{X}{e} - p_C^* C^* - p_K^* J^* - p_M^* M + f_P^* + f_G^* \right) + (r^* - g)(b_P^* + b_G^*) \\ & - \frac{d^*}{e} = \left(\dot{b}_P^* + \dot{b}_G^* \right) - FDI \end{aligned} \quad (28)$$

Goods market equilibrium:

$$Y = C^N + J^N + G + X \quad (29)$$

Nominal wage setting rule:

$$\frac{\dot{W}}{W} = g + \omega(l-1) + \chi \left(\frac{\dot{\Omega}}{\Omega} \right) \quad (30)$$

Time path of the weighted average of current and lagged consumer prices:

$$\frac{\ddot{\Omega}}{\Omega} = \frac{\theta}{1-\theta} \left(\frac{\dot{P}_c}{P_c} - \frac{\dot{\Omega}}{\Omega} \right) \quad (31)$$

Real wage per effective labor unit:

$$\frac{\dot{w}}{w} = \omega(l-1) + \chi \frac{1-\theta}{\theta} \left(\frac{\ddot{\Omega}}{\Omega} + \frac{\dot{p}_c}{p_c} \right) + (\chi-1) \frac{\dot{P}}{P} \quad (32)$$

APPENDIX B

Econometric Estimations

We estimate five sets of equations: the system estimation of money demand and aggregate consumption; real wages; production function; aggregate private investment; and export demand. Coefficient *t*-statistics are reported in parentheses. Following each equation, we report the adjusted R^2 (R^2A), the standard error of the regression (*SE*), and (except the system equation) the *p* values of Breusch-Godfrey *LM* serial correlation tests at four and eight lags. We generally removed any seasonality of the variables using X-11 ARIMA. In all cases, instrumental variables correspond to four lags of the endogenous variable. The sample period is 1986:1 to 1997:1.

Money Demand and Aggregate Private Consumption

Estimated using weighted two-stage least squares (2SLS). We include dummy variables for 1992:3, 1995, and 1996:4. Hence,

$$\ln \left(\frac{m}{C} \right) = \ln \left(\frac{1 - 0.7251}{0.7251} \right) - 0.0780 \underset{(6.48)}{\ln} \left(\frac{i}{p_C} \right), \underset{(3.20)}{}$$

$$R^2A = 0.25 \quad SE = 0.047$$

$$C = (0.012 - 0.010) \left(\frac{a}{p_C} \right) + \left(1 - 0.656 \right) \left[\frac{wl - T + ef_P^* - (0.012 - 0.010)h}{p_C} \right] - \frac{i m}{p_C},$$

$$\underset{(3.45)}{}$$

$$R^2A = 0.19 \quad SE = 0.035$$

Real Wage

Estimated using 2SLS, with dummy variables for 1991–92:

$$\begin{aligned} d\ln(w) = & 0.034 + 0.3192 \ln(I) + 0.1365 d\ln(p_C) \\ & + 0.5699 d\ln(p_{C,-1}) + (1 - 0.1365 - 0.5699) d\ln(p_{C,-2}), \end{aligned}$$

$$R^2 A = 0.66 \quad SE = 0.011 \quad LM(4) = 0.38 \quad LM(8) = 0.45$$

Production Function

Estimated using ordinary least squares (OLS) in first differences, with dummy variables for 1990:1, 1992:3, and 1993:1:

$$\begin{aligned} d\ln\left(\frac{Y}{K}\right) = & \left(0.3969 - 1\right) d\ln(K) + 0.5218 d\ln\left(\frac{I}{K}\right) \\ & + \left(1 - 0.3969 - 0.5218\right) d\ln\left(\frac{M}{K}\right), \end{aligned}$$

$$R^2 A = 0.56 \quad SE = 0.014 \quad LM(4) = 0.62 \quad LM(8) = 0.87$$

Aggregate Private Investment

Estimated using 2SLS. The estimation generates implausible values when adjustment costs are left unrestricted; to resolve this, we restricted the adjustment cost coefficient after performing a grid search for the value that maximizes $R^2 A$. The estimation includes dummy variables for 1994:4 and 1995:1.

$$\begin{aligned} I = & 0.136 \frac{K}{15} \left\{ \left[0.5299 q_1 + (1 - 0.5299) \frac{0.397(Y/K)}{(0.0099 + 0.0108)} \right] - 1 \right\} \\ & + 0.136 (0.0099 + 0.0108) K + (1 - 0.136) I_{-1}, \end{aligned}$$

$$R^2 A = 0.94 \quad SE = 0.001 \quad LM(4) = 0.49 \quad LM(8) = 0.25$$

Export Demand

Estimated using 2SLS in first differences:

$$\begin{aligned} d\ln(X) = & 0.0206 + 0.1320 \text{ } d\ln(ep_X^*) \\ & + 0.6830 \text{ } d\ln(Y^*) + 0.03 \text{ } d\ln(X_{-1}) \end{aligned}$$

$$R^2A = 0.46 \quad SE = 0.036 \quad LM(4) = 0.18 \quad LM(8) = 0.11$$

APPENDIX C**Parameterization and Calibration of the Model**

This appendix lists of the calibrated and estimated model parameters, the calibrated sector budget constraints, the base-period values of the predetermined variables, and the initial steady-state values of the model's endogenous variables, obtained from the model's solution for the base period.

Structural coefficients

Money demand

- Goods content of augmented consumption (β): 0.6337
- Interest rate elasticity (σ): 0.078

Wage equation

- Employment elasticity (ω): 0.3192
- Indexation to current inflation (γ): 0.1365
- Indexation to one-period lagged inflation (θ): 0.5699

Production function

- Constant (α_0): 0.4676
- Labor share (α_1): 0.5218
- Capital share (α_2): 0.3969

Private investment demand

- Share of unconstrained firms (λ_1): 0.5299
- Adjustment costs to investment (ϕ): 15
- Rate of depreciation of physical capital (δ): 0.0108
- Share of domestic goods in investment (γ): 0.7141

Private consumption demand

- Share of unconstrained consumers (λ_C): 0.6556
- Share of domestic goods in consumption (η): 0.9523

Export demand

- Constant (ε_0): 0.0206
- Real exchange rate elasticity (ε_1): 0.1320
- Foreign income elasticity (ε_2): 0.6830

Calibration of the sector budget constraints

The public sector budget constraint is defined as follows:

$$(T + e f_G^* - G - p_K I_G) + \left(g + \frac{\dot{P}}{P} \right) m - (r - g)b + (r^* - g) eb_G^* = e \dot{b}_G^* - \dot{b},$$

calibrated to the initial steady state:

$$\begin{aligned} & [0.1018 + 1.75 * 0.0001 - 0.1045 - 1.1 * 0] \\ & + (0.0099 + 0.0074) * 0.3154 - (0.0123 - 0.0099) * 1.3138 \\ & + (0.0123 - 0.0099) * 1.75 * 0.0640 = 0 - 0 \end{aligned}$$

The external sector budget constraint takes the following form:

$$\left(\frac{X}{e} - p_C^* C^* - p_K^* J^* - p_M^* M + f_P^* + f_G^* \right) + (r^* - g)(b_P^* + b_G^*) - \frac{d^*}{e} = \left(\dot{b}_P^* + \dot{b}_G^* \right) - FDI,$$

calibrated to the steady state:

$$\begin{aligned} & \left(\frac{0.2160}{1.75} - 0.9002 * 0.0242 - 0.9002 * 0.0822 - 1 * 0.0465 + 0.0043 + 0.0001 \right) \\ & + (0.0123 - 0.0099) * (-1.9938 + 0.0640) - \frac{0.0436}{1.75} = 0 + 0 - 0.0200. \end{aligned}$$

The private sector budget constraint is defined as follows:

$$\begin{aligned} & [Y - p_K J - e p_M^* + e f_P^* - T - p_C C] - d^* - \left(g + \frac{\dot{P}}{P} \right) m + (r - g)b \\ & + (r^* - g) eb_P^* = \dot{m} + \dot{b} - e FDI + e \dot{b}_P^* \end{aligned}$$

calibrated to the initial steady state:

$$(1 - 1.1 * 0.2836 - 1.75 * 1 * 0.0465 + 1.75 * 0.0043 - 0.1018 - 0.9 * 0.4862) \\ - 0.0436 - (0.0099 + 0.0074) * 0.3154 + (0.0123 - 0.0099) * 1.3138 \\ + (0.0123 - 0.0099) * 1.75 * (-1.9938) = 0 + 0 + 1.75 * -0.0200 + 0.$$

Base-period values of predetermined variables

Income, transfers, and capital flows

Foreign transfers to the public sector (f_G^*): 0.0001

Foreign transfers to the private sector (f_P^*): 0.0043

Foreign income (Y^*): 1.0000

Foreign direct investment (FDI): 0.0200

Stocks

Domestic debt of the public sector (b_G^*): 1.3138

Foreign assets held by the public sector (b_G^*): 0.0640

Goods flows

Public consumption of national goods (G): 0.1045

Rates¹⁸

Real interest rate on foreign assets/liabilities (r^*): 0.05

Growth rate of the nominal money stock (μ): 0.07

Harrod neutral technical progress (v): 0.024

Population growth (n): 0.016

Foreign prices

Intermediate imports (p_M^*): 1.0000

Consumption imports (p_C^*): 0.9002

Investment imports (p_K^*): 0.9002

Export-competing goods (p_X^*): 1.0000

Initial steady-state values of endogenous variables

Income, transfers, and capital flows

Dividends (d): 0.1330

Taxes (T): 0.1018

18. For clarity, we give the rates here in annual terms. The simulation model uses the equivalent quarterly values, which are also used to calculate the sector budget constraints and the initial steady-state values of endogenous variables. Figures 1 and 2, with simulation results, depict rates in annual terms.

Private disposable income (Y^D): 0.4274

Profit remittances abroad (d^*): 0.0436

Stocks

Private sector total wealth ($a + h$): 187.4863

Nonhuman wealth of the private sector (a): 10.7757

Stock of domestic equity held by foreigners (f_e): 1.1368

Domestic base money (m): 0.3154

Human wealth of the private sector (h): 176.7107

Physical capital (K): 13.7164

Foreign assets held by the private sector (b_p^*): -1.9938

Goods flows

Private aggregate consumption (C): 0.4862

Private consumption of imported goods (C^*): 0.0243

Private consumption of national goods (C^N): 0.4619

Gross domestic investment (J): 0.2836

Private investment in national goods (J^N): 0.2014

Private investment in imported goods (J^*): 0.0822

Exports (X): 0.2160

Intermediate imports (M): 0.0465

Total imports: 0.1530

Trade balance: 0.0630

Current account surplus: -0.0200

Output (Y): 1.0

Employment

Employment (I): 1.0

Rates

Nominal interest rate on public debt (i): 0.08

Real interest rate on public debt (r): 0.05

Inflation rate: 0.03

Relative goods prices

Private aggregate consumption deflator (p_C): 0.9

Aggregate investment deflator (p_K): 1.1

Other prices

Real exchange rate (e): 1.75

Real equity price (Tobin's q) in units of domestic output: 1.2526

Real wage per effective labor unit (w): 0.5218

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ON THE DETERMINANTS OF CHILEAN ECONOMIC GROWTH

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If looked at since the mid-1980s, Chile's economic performance has been fairly impressive compared not only with the rest of Latin America, but also with most of the countries in the world. From a long-run perspective, however, Chile did not display such an outstanding performance in the 1960s and 1970s. In fact, the growth of Chile's per capita gross domestic product (GDP) was way below the average of East Asia, member countries of the Organization for Economic Cooperation and Development (OECD), and the world economy during those two decades. When compared with the other Latin American countries, the Chilean economy was about average in the 1960s and below average in the 1970s, and it outperformed the rest of Latin American economies in the 1980s and 1990s. This difference is even larger if we consider the period 1984–1998.¹

Depending on the period under consideration, Chile presents statistically significant differences with respect to other Latin American countries, not only in average per capita GDP growth, but also in its volatility. Informal evidence shows that Chile is influential in the sense that valuable information with respect to the economic performance of the region would be left out without Chile. This is so because Chile

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1. This analysis is based on the latest Penn World Tables; see Summers and Heston (1991) for details.

displays four characteristics that are not present (at least to the same extent) in other countries. First, Chile's economic performance (in terms of both growth rate and volatility) was similar to the average of the Latin American countries considered until the oil crisis. Between the oil crisis and the debt crisis, Chile displayed atypical vulnerability given the low growth and high volatility exhibited during those crises. Third, the speed of recovery after these crises is unsurpassed by the other countries. Finally, after the debt crises, Chile exhibited not only the highest growth rates of the region, but also a level of volatility that is not statistically different from the average of the region.

A usual candidate for explaining the economic performance of an economy is its investment rate. However, the correlation between per capita GDP growth and the investment rate is at most 0.35. Furthermore, while the investment rate declined steadily from 1960 to 1973, it rose from 1984 to 1998. It could be argued that in the first period, the contribution of capital to growth was very important, while in the second, the recovery from the deep recession of the early 1980s made the growth rate lead the economy to higher investment rates. Anecdotal (statistical) evidence is readily available, given that Granger causality tests suggest that both the level and first difference of per capita GDP preceded the investment rate in the 1984–2000 period, while there is no discernible direction of statistical causation in the 1960–1973 period.

It would be instructive to have formal measures for evaluating the determinants of such a heterogeneous performance during these periods. The issue of particular interest involves identifying which characteristics made it so average until the oil crisis and so sensitive to the two major international crises in the early 1970s and 1980s—and which contributed to the accelerated growth rates and decreased volatility that came after these episodes. Studying Chile's economic performance is interesting not only because of its remarkable differences in terms of growth rates and volatility relative to other countries in the region, but also because it has experienced major swings in terms of its institutional arrangements and economic policies.

This paper provides a qualitative and quantitative evaluation of the main factors behind the Chilean growth process. The rest of the paper is organized as follows: section 1 provides the historical background for the period under analysis. Section 2 conducts a growth accounting exercise that aims to recover total factor productivity (TFP). Section 3 takes the results from section 2 and conducts a multivariate time series analysis that includes several measures of distortions of the Chilean economy and evaluates which of them are

important determinants (or consequences) of its economic performance. Section 4 presents a model that incorporates the features found to be relevant in the previous section and quantifies the growth effects of several shocks. Finally, section 5 summarizes the main conclusions and draws policy implications from the Chilean experience.

1. HISTORICAL BACKGROUND

One of the purposes of this paper is to better understand the role of economic policy in the Chilean growth process. This section presents a brief overview of Chile's past economic policies. Lüders (1998) provides a long-term analysis (1820–1995) of the performance of the Chilean economy and compares it with other developing and developed countries. Here, we focus on the last forty years, for which more reliable information is available.

Chile achieved its political independence from Spain in 1810. According to Lüders (1998), the first period of Chilean economic history can be characterized as liberal, with two distinct subperiods 1820–1878 and 1880–1929 (before and after the Pacific War). In the first subperiod, Chile grew above the Latin American average (1.39 percent versus 0.1 percent for the region), while in the second subperiod the growth rate was about average with respect to the same group of countries. The Pacific War had a positive wealth effect for the Chilean economy, but the annexation of nitrate and silver mines may have induced two negative effects: a rapid increase in government expenditures (more rent-seeking activities) and a Dutch disease phenomenon that cut off some traditional activities. From the political standpoint, the second phase of liberal economy was unstable, with a civil war in 1891 and military takeovers in 1924 and 1927–1932.

After the Great Depression, Chile initiated a strategy of import substitution, mainly owing to the negative experience with the price of nitrate. The sudden drop in the price and sales of most of the products that Chile exported induced a significantly negative wealth effect. According to Lüders (1998), Chile was one of the economies that suffered the most during the Great Depression: per capita GDP fell by 47 percent and exports by 79 percent.

The economic ideas that were prevalent at the time also led the economy toward inward-oriented economic policies. An active role was assigned to the government, which implemented industrial policies and created state-owned enterprises. The manufacturing industry was protected with high tariffs, nontariff barriers, and multiple exchange

rates. All these movements were implemented between 1940 and 1970, with a weak and unsuccessful attempt to reverse this trend between 1959 and 1961.

In 1970, the newly elected socialist government exacerbated the combination of inward-oriented economic policies and government intervention. From that year until 1973, Chile could accurately be described as a virtually closed economy. Economic policy between 1971 and 1973 was characterized by strong government interventions; price, interest rate and exchange rate controls; high tariff and nontariff barriers to trade and to international capital flows; and a very high inflation rate. The government also expropriated a significant number of private companies in this period.

The military coup of 1973 initiated a movement from high government intervention toward a market-oriented economy. Among the most important changes, the economic policy focused on price liberalizations, an aggressive opening of the economy to trade and international capital flows, a reduction in the size of government, and privatizations. Chile also introduced pioneering reforms to the social security regime, financial markets, and the health care system. One of the most profound reforms was the trade liberalization that eliminated all the nontariff barriers and reduced tariffs to 10 percent across the board (except for automobiles).

All these changes coincided with major international crises (namely, the oil crisis and the debt crisis). The first occurred when the economy was starting the reforms, and the sum of the external shock and the reform affected the performance of GDP. The second crisis stemmed from a mix of a negative external shock (an increase in the international interest rate and a deterioration of the terms of trade) and internal policy mistakes. A fixed exchange rate policy, combined with a very low convergence of domestic to international inflation, induced a large real appreciation of the peso relative to the dollar, creating a large current account deficit. Given the external situation, the foreign sector was not willing to finance the current account deficit; at the same time, the financial system was not consolidated in terms of regulation, supervision, and expertise.² The Chilean economy thus experienced a twin crisis (external and financial).

The real exchange rate appreciation of that period constituted a second shock for the tradables sector (the trade reform being the first), which induced several bankruptcies and the need for increased productivity in that sector. The manufacturing sector experienced

2. See Fuentes and Maquieira (2000) and the references therein.

important reallocations of resources coupled with productivity increases.³ The peso was devaluated in 1982, and tariffs were increased until 1985 (reaching a peak of 35 percent across the board) and then lowered until 1991.

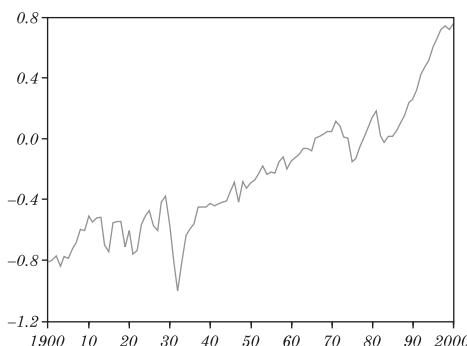
The major economic reforms formulated in the 1980s were left virtually unchanged after the return to democracy in 1990. The newly appointed government reduced tariffs even further, from 15 percent to 11 percent (in 1991), and negotiated free trade agreements with Canada, Colombia, the European Union, Korea, Mercosur, Mexico, and the United States, and Venezuela. These agreements reduced the average tariff paid on imported products. Recently, the tariff structure has been reduced even further (from 11 percent to 8 percent) for countries that are not members of free trade agreements.

This brief overview can be summarized by the evolution of per capita GDP in figure 1. It uses data from Braun and others (2000) and Díaz, Lüders, and Wagner (1999) for the period up to 1995 and official growth rates from the Central Bank of Chile for 1996–2000.

2. TOTAL FACTOR PRODUCTIVITY ANALYSIS

This section derives several estimates of total factor productivity (TFP) that are later used to uncover factors behind the growth process.

Figure 1. Log of per Capita GDP, 1900–2000



Source: Brown and others (2000), Diaz, Lüders, and Wagner (1999) and Central Bank of Chile.

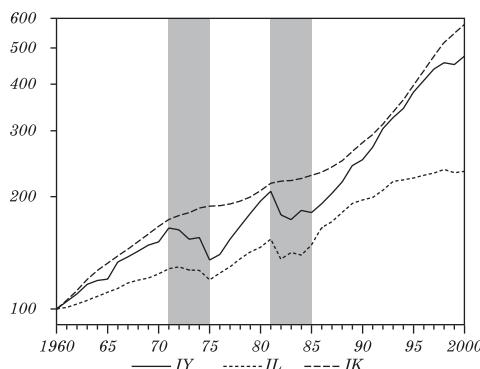
3. See Fuentes (1995); Álvarez and Fuentes (2003). Fuentes (1995) shows that the trade and market reform period (1975–1982) featured substantial increases in the productivity of different manufacturing sectors. A pattern across sectors could not be found, so this feature is consistent with the idea of a mushroom process.

2.1 Data

Given the data availability and its degree of reliability, we conducted this analysis for the period 1960–2000 using National Accounts records. The capital stock was estimated using the perpetual inventory system from 1940.⁴ The data on labor corresponds to the number of people occupied each year and is obtained from the National Institute of Statistics (INE).

Figure 2 shows the evolution of GDP, capital stock, and labor for 1960–2000 (expressed as indices). As can be seen, the capital stock grew faster than labor and GDP over the whole sample. Five periods are clearly distinguishable: three periods of rapid growth and two severe recessions.⁵ In the first growth period, GDP growth was accompanied by a faster increase in the capital stock and a smooth upward trend in labor. After the recession in the mid-1970s, the economy grew very fast with a relatively slow increase in capital and labor until the beginning of the debt crisis. This profound recession caused with a high increase in the unemployment rate. The economy bounced back starting in the mid-1980s, with a quick recovery in terms of employment and a later rise in the growth rate of capital.

Figure 2. Evolution of GDP, Labor, and Capital, 1960–2000
Index 1960 = 100, with log scaling



Source: Chumacero and Fuentes (2002).

4. Herman Bennett kindly provided this series.
5. The economy experienced a short recession beginning in the last quarter of 1998, with a recovery in 2000. In some parts of our analysis, we assume that the third period of expansion ends in 1998.

2.2 Methodology Used to Estimate TFP Growth

The data discussed in the previous section can be used to estimate TFP growth. One of the key elements for understanding the contribution of productivity is the measurement of production factors and any changes in their quality over time. Here we provide two estimates of TFP growth: one based on the raw data of capital and labor and one that corrects labor with a quality index.

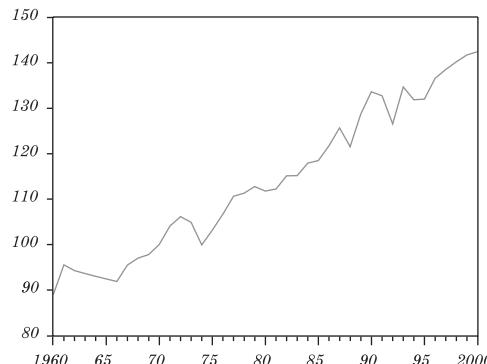
Input quality

An important part of the contribution to the growth process in Latin America has been the increase in the quality of factors (Elias, 1992). One of the usual ways to adjust the raw data is by using a correction that augments labor and capital. For labor, we use the estimate made by Roldos (1997), which considers that there are different types of labor, L_j with wages w_j such that the quality correction becomes

$$\sum_{j=1}^n \frac{w_j L_j}{wL}. \quad (1)$$

Figure 3 shows the evolution of this index over time. We compare it with an estimation of human capital stock found in Braun and others (2000), where the authors express the level of education of the labor force in tertiary education equivalence using the relationship with market wages. The correlation between the two variables is 0.98.

Figure 3. Labor Quality Index



Source: Roldos (1997).

Roldós (1997) also provides a quality index for the capital stock. The construction of the index hinges on relative rental rates of different types of capital. As this information is not available, the author estimates this rate using the market price of investment goods. Figure 4 shows the evolution of this index, which presents two disturbing features. The quality of capital declined throughout the 1960s, and the quality of capital goods in 1995 was at about the same level as in 1960. The former trend, in particular, is difficult to explain. We therefore chose not to use this variable in the study.

Greenwood and Jovanovic (2000) provide another view of improvement in the quality of the capital stock. They associate quality with the evolution of the relative price of investment in terms of consumption; when this relative price decreases, the quality of capital goods rises. There are at least two problems with this interpretation. First, at the aggregate level, there are no permanent decreases in the relative price of equipment (even though we separated equipment from structure). In the case of computers, for example, we can expect a continuous decreases in their relative prices, but this may not be the case for other types of equipment. When a higher quality of equipment appears on the market, its price might be higher than that of earlier models, since the firm may exploit monopoly rents to pay for research and development (R&D) costs (quality ladder models, as in Grossman and Helpman, 1991); the price of equipment may thus actually rise. The second reason is that in linear technology models of endogenous growth, a decrease in the price of an investment good will increase capital accumulation and, ultimately, the growth rate. This would be the case when an economy opens to trade and starts importing capital goods at a lower price (Jones and Manuelli, 1990).

Figure 5 shows the evolution of the prices of equipment goods and investment goods relative to consumption goods. Although they seem to follow the evolution of the real exchange rate (rather than being good estimates of the quality of capital), we assess the impact of these relative prices on TFP in the next section.

TFP growth measures and capital share estimates

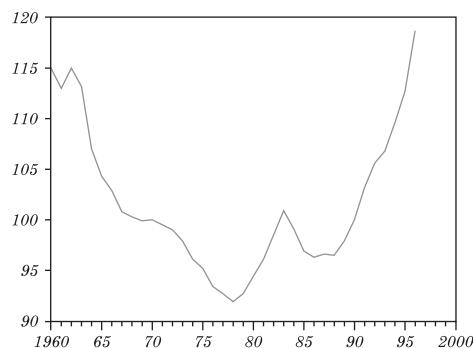
Given the considerations discussed above, we analyze two different formulations for TFP. The first does not consider any correction for changes in factor quality, while the second includes a correction for human capital (TFPH). Thus the equations for TFP growth are

$$\hat{\text{TFP}} = \hat{Y} - \alpha \hat{K} - (1 - \alpha) \hat{L} \text{ and} \quad (2)$$

$$\hat{\text{TFPH}} = \hat{Y} - \alpha \hat{K} - (1 - \alpha) \hat{L} - (1 - \alpha) \hat{H}, \quad (3)$$

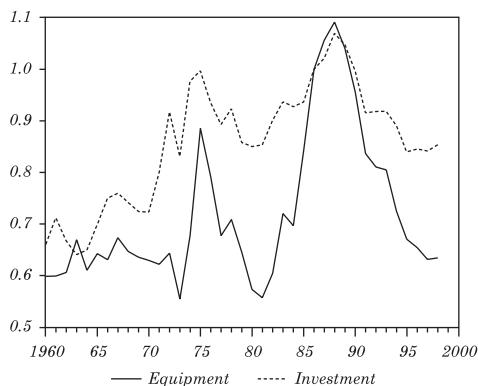
where H represents the index of labor quality and \hat{w} denotes the growth rate of variable w . With either measurement, TFP growth includes both improvements in the quality of capital over time and the technological shock.

Figure 4. Capital Stock Quality Index



Source: Roldós (1997).

Figure 5. Price of Equipment and Investment Goods Relative to Consumption Goods



Source: Chumacero and Fuentes (2002).

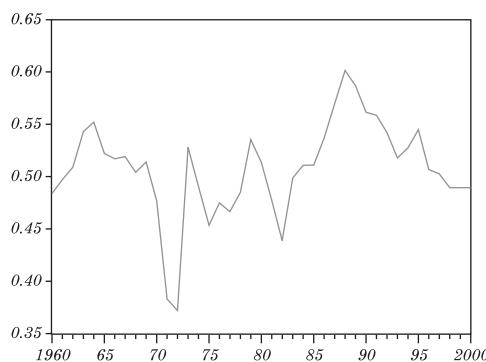
The key parameters necessary for estimating TFP are the factor-output elasticities. From the viewpoint of pure growth accounting, the estimates of the elasticities are given by the capital and labor shares from the National Accounts. These shares vary from year to year, so we made the calculations using the average capital and labor shares for two years and the average shares for the entire period ($\alpha = 0.50733$). There is not much difference between these two choices. An alternative estimation used in this exercise is the capital share conventionally used in the growth literature (0.333). The correlations of the growth rates of estimates of TFP under different assumptions for α is never smaller than 0.98.

Despite the similarities of the TFP measures using a variable or a constant α , there is always a reasonable doubt as to which model best describes the data. For instance, a CES function may do a better job than a Cobb-Douglas production function. Figure 6 provides informal evidence suggesting that a constant capital-output elasticity is not a bad approximation. In particular, the value in 2000 is about the same as in 1960 and close to the average. A regression on a constant, however, shows that the mean is not stable over time. This fact could be reconciled with changes in the input-output matrix from the National Accounts (1977 and 1986).

2.3 Estimation of TFP Growth

Table 1 shows the TFP growth rate for the entire period (1960–2000) and for two subperiods. The first subperiod corresponds to the inward-oriented phase, while the second starts with the trade reform.

Figure 6. Capital Share



Source: Chumacero and Fuentes (2002).

Table 1. Growth Accounting for Periods of Economic Orientation and Rapid Growth^a

<i>Period</i>	<i>GDP growth</i>	<i>TFP</i> ($\alpha =$ 0.507)	<i>TFP</i> ($\alpha =$ 0.333)	<i>TFPH</i> ($\alpha =$ 0.507)	<i>TFPH</i> ($\alpha =$ 0.333)
1960–2000	3.97	0.67	1.07	0.06	0.24
1960–1974	3.19	0.06	0.55	-0.37	-0.04
1975–2000	4.40	1.00	1.36	0.29	0.39
<i>Rapid growth</i>					
1960–1971	4.65	0.91	1.41	0.18	0.42
1975–1981	7.32	3.97	3.65	3.27	2.69
1985–1998	7.36	2.23	2.72	1.54	1.77

a. TFPH denotes the inclusion of human capital in total factor productivity.

Source: Authors' calculations.

The table indicates a difference of more than one percentage point between periods, mostly accounted for by differences in TFP growth. This feature signals that the elimination of distortions may have significantly increased the economy's efficiency.

The lower panel of the table presents the TFP growth rate for the shorter periods of rapid growth in the Chilean economy. Two of these correspond to the trade liberalization of the 1970s and the tariff reduction of the late 1980s and early 1990s (after the debt crisis). The performance of TFP growth is rather poor over the whole sample (growing at most at 1 percent), while GDP grew at 4 percent per year, on average.

As figure 2 made clear, we distinguish three episodes of growth. It is instructive to evaluate the differences in growth rates of TFP among these periods. The GDP growth rate in the 1975–1981 and 1985–1998 episodes might be influenced by the recovery from the two deep recessions of the 1970s and 1980s, but both cases feature significant increases in TFP that are not apparent in the 1960s. Average TFP growth reached its highest value in the trade reform period (the late 1970s), which is characterized by important factor reallocations, firm bankruptcies, and the creation of new firms. In the longest period of continuous growth (1985–1998), TFP growth was somewhere between 1.5 and 2.7 percent—a more modest rate than in the 1975–1981 episode.

How important was TFP in accounting for GDP growth? This is important because both TFP growth rates and GDP growth rates were higher in the 1975–1981 and 1985–1998 episodes. Table 2 shows the contribution of factor accumulation (including human capital) and TFP to growth. As expected, the contribution of TFP for the entire period was very small after including human capital. The most important

Table 2. Growth Accounting for Periods of Rapid Growth^a

<i>Parameter value and period</i>	<i>Labor</i>	<i>Human capital</i>	<i>Capital</i>	<i>TFPH</i>
$\alpha = 0.5073$				
1960–2000	0.27	0.15	0.57	0.01
1960–1971	0.25	0.15	0.56	0.04
1975–1981	0.29	0.09	0.17	0.45
1985–1998	0.25	0.09	0.45	0.21
$\alpha = 0.3333$				
1960–2000	0.36	0.2	0.38	0.06
1960–1971	0.33	0.21	0.37	0.09
1975–1981	0.39	0.13	0.11	0.37
1985–1998	0.33	0.12	0.3	0.25

a. TFPH denotes the inclusion of human capital in total factor productivity.
Source: Authors' calculations.

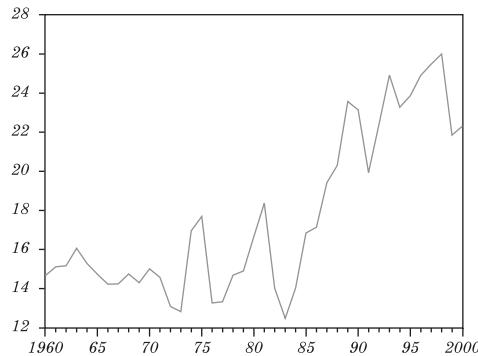
contribution to growth was physical capital, which accounts for 57 percent of total GDP growth.

The growth rate of GDP over the 1960s is characterized by capital accumulation, human capital accumulation, and the lack of total factor productivity growth. As expected, the TFP growth rate played a key role in accounting for growth after 1975, but capital accumulation results in an important difference between the 1975–1981 and 1985–1998 periods. Furthermore, while capital accumulation accounts for the successful period after the debt crisis, it was not as fast as in the 1960s. As the growth literature predicts, trade liberalization and the movement of the Chilean economy toward a free market economy that began in the mid-1970s brought important total factor productivity growth.

Our TFP growth estimates are also capturing improvements in the quality of the capital stock and other factors (such as changes in relative prices, resources allocations, and so forth), as mentioned above. From this viewpoint, and following Greenwood and Jovanovic (2000), the reduction in trade restrictions should have increased the average quality of the capital stock and thus led to a higher TFP growth. This feature is even more important if we take into consideration that the contribution of capital accumulation was very high in the first period of growth (1960–1971), while the other two periods featured a lower rate of capital accumulation accompanied by higher growth rates in the Chilean economy. This is in line with economic theory that suggests that opening the economy to trade and the elimination of distortions increase the average quality of capital and improve the allocation of capital toward sectors with higher marginal productivity. The evolution of the investment rate presented in

Figure 7. Investment Rate, 1960–2000

Percent of GDP



Source: Chumacero and Fuentes (2002).

figure 7 (using current prices) highlights the efforts from increasing the investment rate in the last period.

Trade reform and the reduction of government intervention in the economy are key features to consider when evaluating the performance of the economy in the 1980s and 1990s. As mentioned in section 1, however, several other reforms could also account for the increased marginal productivity of capital and increased growth, including the banking and capital market reforms combined with the new bankruptcy law.⁶ In a recent paper, Bergoeing and others (2002) highlight these reforms as key for explaining the fast recovery of the Chilean economy after the debt crisis.

Another important difference between the rapid growth of the 1960s and that of the other two episodes lies in the contribution of human capital. Two caveats can be made with respect to this observation. First, educational attainment has increased continuously over time, such that “enough” human capital may already have been accumulated by the 1970s, making the marginal contribution of human capital modest. Second, the human capital series was measured using relative wages, but the changes in these wages may be due to factors other than human capital accumulation. At any rate, studies show that even when measured differently, the contribution of human capital is not that different from what we find here (Schmidt-Hebbel, 1998).

6. Fuentes and Maqueira (2000) provide an explanation of how these laws affected the recovery of the banking system after the deep banking crisis in the early 1980s.

3. MULTIVARIATE ANALYSIS

The above section constructed variables for better understanding the growth experience of the Chilean economy, in particular outlining the evolution of total factor productivity and identifying its importance at different stages of the recent Chilean growth history. This series can be used to evaluate the main determinants of the variables and thus the determinants of growth. Here, we conduct several econometric exercises that provide quantitative and qualitative guidelines with respect to the type of theoretical model that can be used to understand the growth dynamics of the Chilean economy.

3.1 Factors behind TFP

In section 2 we obtained several estimates for TFP. We now consider a set of variables that may be associated with them, including time series for terms of trade, variables that capture the evolution of distortionary policies (such as tariffs and fiscal expenditure over GDP), and the prices of equipment and investment goods relative to consumption goods.⁷

Our econometric formulations begin with over-parameterized models. Careful reductions and reparameterizations then generate models for TFP series (in logs) that can be expressed as

$$f_t = a_0 + a_1 t + a_2 f_{t-1} + a_3 f_{t-2} + a_4 p_t + a_5 p_{t-2} + a_6 T_t + a_7 T_{t-1} + a_8 g_{t-1} + e_t , \quad (4)$$

where a_i are coefficients to be determined, f is the log of each TFP series, p is the log of the price of equipment goods relative to consumption goods, T is the log of the terms of trade, and g is the ratio of fiscal expenditures to GDP.

Table 3 shows the results of the estimations (for statistically significant variables only). Given the close association between the TFP measures, the characteristics and even the coefficients associated with

7. The last variables take into account the derivations of Greenwood and Jovanovic (2000). In the spirit of that paper, movements of relative prices would be related to the quality of the capital stock and not directly to TFP per se. Consequently, if either of these relative prices appears as significant, we could subtract their participation from the TFP series. Nevertheless, a case could be made for associating the evolution of these relative prices to modifications in distortionary policies, thereby making these prices a combination of the effects of increases in the quality of capital and reduced distortions.

each variable are remarkably similar: in all cases, reductions in the price of equipment goods relative to consumption goods, improvements in the terms of trade, and reductions in the participation of government expenditures to GDP are positively associated with our measures of TFP. We also find that TFP can be characterized as trend stationary (consistent with our results from section 2). Thus, every transitory shock on the variables included in the regressions would have only transitory effects on the levels of our TFP estimates.

This does not mean that policies are not important, but rather that transitory policy shocks do not have permanent effects, although they have effects on the level of the series. As expected, a_4 and a_5 , when significant, are negative; if these variables measure the quality of capital, a reduction in the price of equipment relative to consumption goods signals an improvement in the quality of capital stock.

Table 3. Results of TFP Regressions^a

Parameter	TFP ($\alpha = 0.507$)	TFP ($\alpha = 0.333$)	TFPH ($\alpha = 0.507$)	TFPH ($\alpha = 0.333$)
a_1	0.008 (0.001)	0.010 (0.004)	0.005 (0.001)	0.006 (0.001)
a_2	0.349 (0.135)			
a_3	-0.269 (0.116)	-0.405 (0.182)	-0.501 (0.155)	-0.377 (0.156)
a_4	-0.220 (0.038)	-0.303 (0.033)	-0.259 (0.032)	-0.283 (0.035)
a_5		-0.141 (0.068)	-0.197 (0.061)	-0.210 (0.065)
a_6	0.083 (0.026)	0.082 (0.038)	0.164 (0.033)	0.116 (0.039)
a_7		0.083 (0.030)		0.072 (0.033)
a_8	-0.571 (0.119)	-0.410 (0.139)	-0.852 (0.113)	-0.576 (0.114)
<i>Summary statistic^b</i>				
Adjusted R^2	0.940	0.963	0.913	0.915
Durbin-Watson statistic	2.199	1.895	2.015	1.858
Q	0.115	0.199	0.241	0.793
Q^2	0.741	0.109	0.159	0.467
Jarque-Bera normality test (p value)	0.629	0.572	0.852	0.365
Ramsey test (p value)	0.174	0.286	0.081	0.167

a. Standard errors are in parenthesis.

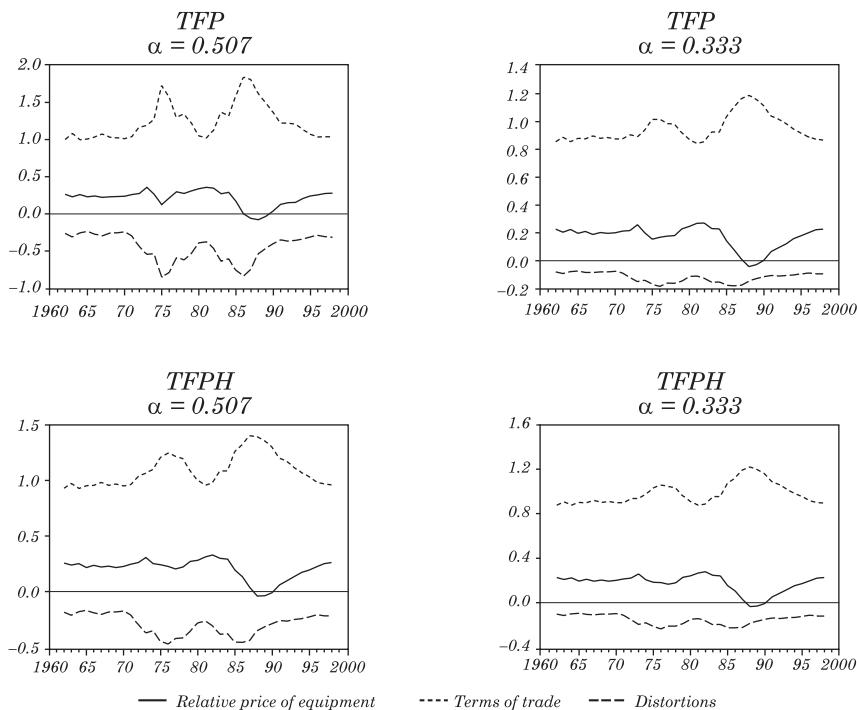
b. Q equals the minimum p value of the Ljung-Box test for white noise on the residuals; Q^2 is the minimum p value of the Ljung-Box test for white noise on the squared residuals.

Source: Authors' calculations.

In this regard, this variable captures the exclusion of the adjustment for the quality of the capital stock in our growth accounting exercise, as well as possible reductions in distortions. Also of interest is the positive effect of the terms of trade on TFP and the negative and statistically significant effect of the size of the government as a fraction of GDP. It may be argued that this last variable can not be considered exogenous given that it may have been used to conduct countercyclical policies. We find evidence that g is weakly exogenous to the parameter of interest (in the sense of Hendry, 1995), thus conditioning our estimates of TFP on g is a valid econometric practice.

Figure 8 presents the contribution of each variable to TFP after we have removed the trend and persistence component. We find that the evolution of the terms of trade accounts for almost all of the variation in TFP (excluding the trend component) and that the negative effect of our measure of distortions more than offsets the improvements in the quality of the capital stock.

Figure 8. Effect on TFP



Source: Authors' calculations.

Given that all of our TFP estimates are robustly associated with these three variables, we estimate a simple model for the level of (log) GDP that associates it with them. Next, we use the impulse response functions of the innovations of these variables on GDP as a metric with which to compare the theoretical model developed in the next section. This simple econometric formulation provides well-behaved residuals and successfully passes all of our specification tests. It is given by

$$y_t = b_0 + b_1 t + b_2 y_{t-1} + b_3 p_t + b_4 T_t + b_5 g_t + e_t, \quad (5)$$

where b_i are coefficients to be determined, y is the log of GDP, and all the other variables are as defined in equation (4).

We find that the price of equipment relative to consumption goods and our proxy for distortions are negatively associated with GDP, while improvements in the terms of trade have positive effects on GDP (see table 4). Consistent with our previous findings, we model y as a trend stationary series; all the regressors included thus have only transitory effects over the scale variable. Furthermore, weak exogeneity conditions are satisfied by p , T , and g .

Next, we estimate laws of motion for p , T , and g as univariate time series models. These simple specifications provide good statistical approximations for the processes of each variable and are able to account for most of their dynamic characteristics.⁸

Table 4. Results of GDP Regressions

Parameter	<i>y</i>	Standard error
b_1	0.017	0.005
b_2	0.615	0.106
b_3	-0.163	0.064
b_4	0.107	0.051
b_5	-0.634	0.174
<i>Summary statistic^a</i>		
Adjusted R^2	0.99	
Durbin-Watson statistic	1.817	
Q	0.262	
Q^2	0.15	
Jarque-Bera normality test (<i>p</i> value)	0.099	
Ramsey test (<i>p</i> value)	0.257	

a. Q equals the minimum *p* value of the Ljung-Box test for white noise on the residuals; Q^2 is the minimum *p* value of the Ljung-Box test for white noise on the squared residuals.

8. VAR models were also considered for obtaining the multivariate representation of these variables. Our results do not change significantly if a VAR(1) representation is considered instead of simple univariate representations.

4. BACK TO FUNDAMENTALS

Chumacero and Fuentes (2002) calibrate a dynamic stochastic general equilibrium model that explicitly introduces the theoretical counterparts of p , T , and g . This section summarizes the model and presents the results of that earlier paper.

The economy is inhabited by a representative agent who maximizes the expected value of lifetime utility as given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) , \text{ with} \\ u(c_t, l_t) = \theta \ln c_t + (1 - \theta) \ln(1 - l_t) , \quad (6)$$

where $0 < \theta < 1$ and where c_t and l_t represent consumption of an importable good and labor in period t . Two goods are produced in this economy; good 1 is not consumed domestically, while good 2 (the importable good) is produced domestically and can also be imported. We assume that the output of the exportable good (y_1) is constant and can be sold abroad at a price (expressed in terms of the importable good) of T_t . Thus, T_t represents the terms of trade in our economy. The production technology for the importable good is described by

$$y_{2,t} = e^{z_t} K_t^\alpha L_t^{1-\alpha} , \quad (7)$$

where α is the compensation for capital as a share of output of sector 2. As before, production in this sector is also affected by a stationary productivity shock, z_t , that follows an AR(1) process (that is, autoregressive of order one).

The resource constraint of the economy is given by

$$c_t + i_t + g_t = T_t y_1 + y_{2,t} , \quad (8)$$

where investment (i) and government expenditures (g) are expressed in units of consumption of importables.

The capital accumulation equation is

$$k_{t+1} = (1 - \delta) k_t + i_t q_t , \quad (9)$$

where q denotes the current state of technology for producing investment goods and represents investment specific technological change (following Greenwood, Hercowitz, and Krusell, 2000). Given that i is expressed in consumption units, q determines the amount of

investment in efficiency units that can be purchased for one unit of consumption. Thus, a higher realization of q directly affects the stock of new capital that will be active in production in the next period. We assume that $\ln(q)$ follows an AR(1) process.

As discussed in Greenwood, Hercowitz, and Krusell (2000), the relative price for an efficiency unit of newly produced capital is the inverse of q , using consumption of the importable good as numéraire. This $1/q$ is our theoretical counterpart to p of section 3.

Finally, the government of this economy levies taxes on labor and capital income at the rates τ_l and τ_k . Part of the revenue raised by the government in each period is rebated back to agents in the form of lump-sum transfer payments (F), and part of it is lost in government expenditures that do not provide services to the representative agent. The government's budget constraint is then

$$F_t + g_t = \tau_k r_t k_t + \tau_l w_t l_t , \quad (10)$$

where r and w represent the market returns for the services provided by capital and labor. Finally, we also assume that $\ln(g)$ follows an AR(1) process.

The base configuration of the parameters is presented in table 5. Note that θ is set to reproduce a steady-state participation rate of l equal to 0.35 and the depreciation rate is calibrated to match the average investment rate in the steady state. The persistence and volatility of p , T , and g are made consistent with AR(1) estimates obtained with observed data on the price of equipment relative to investment, the terms of trade, and government expenditures (in this case we include a time trend that is absent in the model). Finally, the persistence and volatility of the technology shocks are estimated by simulation to match as closely as possible the results of table 5.

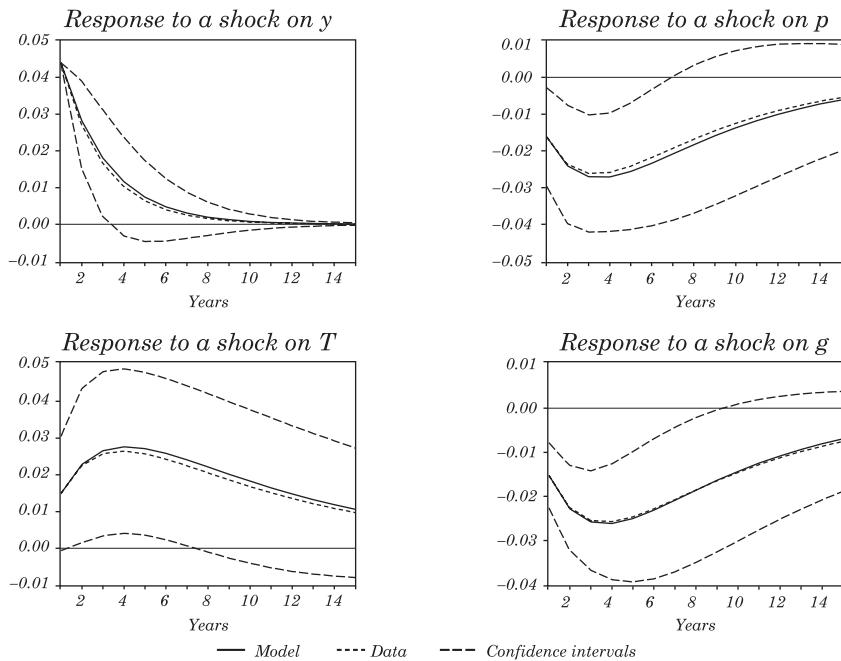
Table 5. Parameters

Block	Parameters	
Preferences	$\beta = 0.980$	$\theta = 0.430$
Technology	$\alpha = 0.333$	$\delta = 0.060$
Taxes	$\tau_k = 0.25$	$\tau_l = 0.25$
Shocks	$\rho_z = 0.730$ $\rho_p = 0.844$ $\rho_T = 0.892$ $\rho_g = 0.895$	$\sigma_z = 0.040$ $\sigma_p = 0.100$ $\sigma_T = 0.140$ $\sigma_g = 0.024$

Once we have set the values of the parameters, we solve the model, simulate artificial realizations from it, and compare the impulse response functions of several shocks. According to our specification, the policy functions of the control variables cannot be obtained analytically, and we have to resort to numerical methods. We use a second-order approximation to the policy function using perturbation methods. This method has the advantage of explicitly incorporating the volatility of shocks in the decision rule, and it is superior to traditional linear-quadratic approximations (see Schmitt-Grohé and Uribe, 2004).

Figure 9 presents the results of comparing the impulse response functions of shocks on the innovations of the equation that describes y in equation (5) and innovations on p , T , and g from their univariate representations. Along with the impulse response functions and the 95 percent confidence intervals obtained from the data, the figure shows the impulse response function obtained from a long simulation of the model. Our results indicate an almost perfect match between the impulse response functions of the model and the data.

Figure 9. Impulse Response Functions: Model and Reality



Source: Authors' calculations.

The results of the impulse response functions point to a positive shock of 10 percent on the price of equipment relative to investment has a negative (but transitory) effect on GDP of almost 3 percent after three years. On the other hand, a positive shock of 14 percent to the terms of trade has a positive effect on GDP that, on average, reaches its peak of almost 3 percent after three years. Finally, a transitory increase of 2.4 percent in the share of government expenditures over GDP has an exactly offsetting effect on GDP (decline of 2.4 percent) after three years.

Thus, our theoretical model not only captures the first moments of key variables of the Chilean economy, but matches almost perfectly the impulse response functions of the dynamic characterization of GDP. This shows that a model incorporating the price of equipment relative to consumption goods, the terms of trade, and distortions (measured as the share of government expenditures in GDP) predicts the same qualitative and quantitative responses of GDP to transitory shocks.

5. CONCLUDING REMARKS

The objective of this study was to better understand the factors behind the growth dynamics in Chile. Chile has experienced deeper recessions than most Latin American countries when faced with an external shock (the Great Depression, the oil shock and external debt), but at the same time it has experienced an impressive and stable growth in the past sixteen years.

Looking at the evolution of GDP over the last four decades, we distinguish three periods of continuous growth: 1960–1971, 1975–1981, and 1985–1998. The first period corresponds to a moderately inward-oriented economy; the second is the period of major trade liberalization and market reforms; and the third represents the period in which many of the reforms from the previous decade were consolidated. Two other characteristics worth highlighting are that the periods of growth had different lengths and different growth rates. While the economy grew at less than 5 percent in the 1960s, the growth rate was above 7 percent in the other two periods.

The question of why the recent growth period is so different from that of the 1960s can be addressed by analyzing the behavior of TFP growth. No reliable measures of the quality of capital stock are available, however, so we used series for human capital along with different

capital shares to estimate TFP.⁹ Our results suggest that physical capital and human capital accumulation were the most important factors behind growth in the 1960s, while TFP played a major role in the other two periods, especially in 1975–1981. In the 1985–1998 period, both capital accumulation and TFP growth account for growth.

Following the literature on growth and distortions, we examined whether distortions have anything to do with the evolution of the level of TFP after controlling for good luck (positive external shocks measured by the terms of trade), exogenous technological progress, and the quality of capital (proxied by the price of equipment relative to consumption, following Greenwood and Jovanovic, 2000). We found that exogenous technological shocks, the terms of trade, the price of equipment relative to consumption, and distortions account for a good deal of the evolution of TFP. Of these, the terms of trade and distortions have the largest impact on the level of TFP.

The main policy implication that can be drawn from the Chilean experience—for other countries as well as for Chile itself—is that good policies matter. The most robust measure of distortions that we found in this document is captured by the share of fiscal expenditures on GDP. This variable not only offsets the positive effects of improvements in the quality of capital goods, but also has detrimental effects on the level and volatility of the Solow residuals. External shocks are important, of course, but among the variables that can be controlled by the authority, distortionary policy contributes most to explaining several of the episodes of mediocre growth in Chile.

These findings provide guidelines with respect to the features that a theoretical model should have in order to account for the dynamics of our TFP estimates and the dynamics of GDP itself. Building on these observations, we calibrate, solve, and simulate a small open economy model that incorporates terms-of-trade shocks, the price of investment relative to consumption goods, and distortionary taxes that help finance government expenditure. This model is able to replicate (almost exactly) the impulse response functions of several shocks on the trajectory of GDP. We find that a 1 percent transitory increase in the share of government expenditures in GDP has a detrimental effect on GDP of the same order of magnitude (a decrease of 1 percent in GDP) by the third year. Transitory increases of 1 percent in the terms of trade or decreases in the relative price of investment

9. We used two values extensively: 0.507 (from pure growth accounting) and 0.333 (from the growth literature).

goods have positive and temporary effects on GDP, which are not as important as the quantitative effects of increased distortions.

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HOW WELL DOES A MONETARY DYNAMIC EQUILIBRIUM MODEL ACCOUNT FOR CHILEAN DATA?

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Since Kydland and Prescott published their influential work in 1982, the literature on monetary real business cycle models has proved its ability to account for regularities in the data for developed countries.¹ Few works, however, attempt to do so for emerging Latin American economies.²

The aim of this paper is to determine how well a money-in-the-utility-function model with a Taylor rule can match some particular monetary stylized facts from the Chilean data between 1986 and 2000. In particular, it focuses on a theoretical explanation for what the empirical literature calls the price puzzle, namely, the comovement between the interest rate and the inflation rate. This is considered a puzzle because the traditional Mundell-Fleming model predicts that a positive change in the interest rate—that is, a restrictive monetary policy—should cause a decrease in private spending and thus a fall in the inflation rate.

The price puzzle is a relationship found in many VAR-type estimates for Chile and other economies. Morandé and Schmidt-Hebbel (1997) are the first authors to find a statistically significant price puzzle for the Chilean economy. Later papers find a similar link between

* The author was working at the Central Bank of Chile at the time this article was written.

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1. See, for instance, Christiano and Eichenbaum (1992), Cooley and Hansen (1995), Christiano, Eichenbaum, and Evans (1997), and McCallum and Nelson (1997) for the United States; Dhar and Millard (2000) for the United Kingdom; Folkertsma (1999) for Netherlands.

2. Perhaps Chile is the exception; see Acuña and Oyarzún (2001) and Bergoeing and Soto (2002). RBC models for the Chilean economy without monetary variables were formulated and calibrated by Quiroz (1991), Quiroz and others (1991), and Chumacero and Fuentes (2002).

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prices (in levels or growth) and interest rates in certain VAR specifications, with either statistically significant or nonsignificant results.

In this paper I formulate, solve, and calibrate a dynamic stochastic general equilibrium model to evaluate its ability to replicate the main features of the Chilean economy, including the price puzzle, for the 1986–2000 period. I find that a positive transitory policy interest rate shock causes a temporary (nonsignificant) decline in output, a transitory decrease in real money balances, and a temporary increase in the inflation rate. These findings are relatively consistent with impulse response functions obtained from a five-variable vector autoregression (VAR) estimated for Chile. The theoretical model proposed is thus able to explain and reproduce the comovement between the interest rate and inflation. This comovement is caused by a Fisher effect: an increase in the nominal interest rate generates an increase in inflation, leaving the real interest rate virtually unchanged. The effect is strengthened by a monetary policy expressed by a Taylor rule that depends positively on inflation deviation. An analogous explanation is given in some recent theoretical studies (see Monnet and Weber, 2001; Alvarez, Lucas, and Weber, 2001).

The study is organized as follows. Section 1 provides an overview of the studies related to real business cycle (RBC) models calibrated for the Chilean economy, highlighting the main characteristics of the models, methods of solution, objectives, and results. Section 2 presents a brief description of the Chilean regularities during the 1986–2001 period on the basis of the most important results of estimating a vector autoregression model. The idea is to obtain impulse response functions that will be used as a metric for comparing them with those simulated by the theoretical model. Thus, a dynamic stochastic general equilibrium model is formulated, solved, and calibrated in section 3, considering the presence of distortionary taxes in an open economy. The solution of the model is adequately achieved using a perturbation method (second-order approximation) proposed by Schmitt-Grohé and Uribe (2001). Section 4 describes the results of calibrating the model and examines whether it is capable of replicating the VAR impulse response functions. Concluding remarks are provided in the last section.

1. PREVIOUS STUDIES ON RBC MODELS FOR THE CHILEAN ECONOMY

The calibration of RBC models in Chile started in the early 1990s with the work of Quiroz and others (1991) (see table 1). The authors

use the Kydland and Prescott (1982) framework to replicate several second moments of Chilean output and investment rate series from 1977 to 1990.³ They find that this model can replicate sample volatilities but has problems with autocorrelations. In a separate study, Quiróz (1991) formulates a two-good small open economy model with labor adjustment costs to replicate some regularities exhibited by the real exchange rate during the 1977–1990 period. He concludes that the model is able to match the real exchange rate volatility and its negative correlation with wages, the price of copper, and capital inflows, but its high autocorrelation remains unexplained.

Acuña and Oyarzún (2001) present one of the first papers to include monetary variables in an RBC framework and then to analyze the role of monetary shocks with Chilean data. They use Cooley and Hansen's (1989) cash-in-advance model. The results of their calibration show similarities with actual data in the comovement of the simulated variables (except capital and money stocks), but they have difficulty replicating several volatilities (namely, GDP, employment, prices, and productivity) and phase shifts (see table 1). They conclude that introducing an erratic monetary rule improves the model's ability to reproduce consumption behavior.

Bergoeing and others (2001) wonder whether tax policy changes can explain the different recoveries in Chile and Mexico during the past two decades. Based on a basic RBC model with income taxes, they conclude that while tax policy is important, it can only explain a small fraction of the differences in the two countries' recoveries.

Chumacero and Fuentes (2002) formulate a small open economy model that includes the relative price of investment and income taxes. Their objective was to assess the determinants of growth of the Chilean economy between 1960 and 2000. They found a close fit among VAR impulse response functions of GDP and those of simulated output when there is a shock on terms of trade, fiscal distortions (fiscal expenditures as a percentage of GDP), and the relative price of equipment.

Finally, Bergoeing and Soto (2002) use the work of Cooley and Hansen (1989) and McGrattan (1994) as the basis for five specifications of RBC models (with cash-in-advance, labor, and wage rigidities) with which they replicate several empirical regularities and assess the role of monetary and fiscal variables in Chilean business cycles. One of their specifications achieves close fit in prices and output volatility, consumption volatility, and its correlation with output,

3. Defined as investment as a percentage of output.

Table 1. Characteristics of RBC Models Calibrated for the Chilean Economy

Author (year)	Theoretical framework ^a	Features of the calibration	Data frequency and span	Objective and results
Quiroz and others (1991)	DSGE model. Infinitely lived agent in a one-good closed economy. Based on Kydland and Prescott (1982) with time-to-build restrictions.	Filter: Not reported. Method of solution: Linear quadratic. Metric: Standard deviations; contemporaneous cross-correlations; first- to third-order auto-correlations. ^b	Quarterly data, 1977:1 to 1990:4	Objective: To replicate regularities (several sample moments). Results: Good fit for volatility of output and investment and for first autocorrelation of investment. Difficulties replicating cross correlations and autocorrelations of output. Contrary signs obtained for third-order autocorrelations of output and investment.
Quiroz (1991)	DSGE factor model. Infinitely-lived agent. 2-good, small open economy. Four sectors and cost of adjustment of labor. Based on Corbo (1985).	Filter: Not reported. Method of solution: Linear quadratic. Metric: Standard deviations; contemporaneous cross-correlations; first- to fourth-order auto-correlations. ^b	Quarterly data, 1977:1 to 1990:4	Objective: To replicate empirical regularities of the real exchange rate (volatility, contemporaneous cross-correlations, and auto-correlations). Results: Good fit for volatility of output and investment and for contemporaneous cross-correlation with wages, price of copper, and foreign capital inflows. Difficulties replicating real exchange rate autocorrelations.
Acuña and Oyarzún (2001)	DSGE model. Infinitely lived agent in a one-good closed economy. Based on Cooley and Hansen's (1989) cash-in-advance model.	Filter: Hodrick and Prescott (1997). Method of solution: Linear quadratic with distortions. Metric: Standard deviations; contemporaneous and first- to fifth-order cross-correlations. ^b	Quarterly data, 1986:1 to 2000:1	Objective: To replicate regularities (several sample moments) and assess the role of money in Chilean business cycles. Results: Good fit for direction of variables except capital stock and money. Difficulties replicating GDP, employment, prices, inflation, and productivity volatility; phase shift of all variables except consumption, prices, and productivity; output-money correlation.

Table 1. (continued)

Author (year)	Theoretical framework ^a	Features of the calibration	Data frequency and span	Objective and results
Bergoeng and others (2001)	DGE model. Infinitely lived agent in a one-good closed economy. Basic growth model with income tax.	Filter: Not used. Method of solution: Not reported. Metric: Decomposition of average annual changes in real output per worker. ^b	Annual data, 1981 to 2000	Objective: To explain the Chilean and Mexican recoveries (1985 to 2000). Results: Tax policy is important, but it cannot explain more than a small fraction of the differences in both countries' recoveries. Good fit for average annual changes in real output per working-age person. Difficulties replicating work and capital effort in the early 1980s.
Chumacero and Fuentes (2002)	DSGE model. Infinitely lived agent in a two-good, small open economy. Includes relative price of investment and income taxes. Based on Greenwood, Hercowitz, and Krusell (2000).	Filter: Not used. Method of solution: Perturbation method (second-order approximation). Metric: VAR coefficients; impulse-response functions of real GDP.	Annual data, 1960 to 2000	Objective: To replicate regularities (several impulse-response functions) and assess the determinants of growth in Chilean economy. Results: Good fit for response of output to a shock on terms of trade, fiscal expenditures as a percentage of GDP (fiscal distortions), and price of equipment relative to consumption.
Bergoeng and Soto (2002)	DSGE models (five specifications). Infinitely lived agent in a two-good, closed, cash-in-advance economy, with labor and wage rigidities. Based on Cooley and Hansen (1989) and McGrattan (1994).	Filter: Hodrick and Prescott (1997). Method of solution: Linear quadratic. Metric: Standard deviations; cross/autocorrelations. ^b	Quarterly data, 1986:1 to 2000:1	Objective: To replicate regularities (several sample moments) and assess the role of monetary and fiscal variables in Chilean business cycles. Results: Good fit for prices and output volatility, consumption volatility, and its correlation with output. Difficulties replicating correlations of output and price level (and inflation) and of hours worked and average productivity. Correlations of money and other variables not reported.

Source: Author's compilation.

a. DSGE denotes dynamic stochastic general equilibrium. DGE denotes dynamic general equilibrium.

b. Confidence intervals of the metric are not reported.

but it has some difficulties replicating the correlations between output and the price level, output and inflation, and hours worked and average productivity. They also find that the inclusion of wage rigidities does not contribute significantly to matching the data.

In summary, most previous works do not consider monetary variables or the relation between these and real variables, and when they do, they have some trouble replicating sample moments. Money is considered an exogenous variable, and the economy is supposed to be closed to international trade, both of which might be seen as unrealistic assumptions for the past two decades in Chile. Finally, most of these models use linear quadratic methods that might be inadequate in certain cases.⁴

2. STYLIZED FACTS: VAR-BASED IMPULSE RESPONSES

In this section I estimate a vector autoregression (VAR) model to characterize the Chilean economy during the period of study and obtain impulse response functions and confidence intervals. I then use these functions and intervals as a metric of comparison with those from the model presented in the next section.

As mentioned, the data consist of monthly series from January 1986 to December 2000, so the recent period of nominalization of monetary policy by the Central Bank of Chile is not taken into consideration. The purpose is to compare the data and the simulated series from the theoretical model during the period when the Central Bank had a unique monetary policy (in this case, a UF-indexed monetary policy).⁵

The VAR estimated herein is a five-variable model that also considers a trend and seasonal dummy variables. The variables used are the log of the terms of trade, the log of (gross) UF-indexed policy interest rate,⁶ the log of the (gross) inflation rate, the log of M1 in real terms, and the log of the monthly economic activity index (IMACEC) of Chile. Appendix A shows the sources of the data. These

4. I return to this point in section 4.1.

5. The *Unidad de Fomento* (UF) is a unit of account used for commercial and financial transactions in Chile.

6. The interest rate paid on ninety-day bonds issued by the Central Bank (*tasa de pagarés reajustables del Banco Central*) from 1986 to 1995, and the policy interest rate (*tasa de política monetaria*) from 1995 to 2000. Both rates are UF indexed.

variables were chosen as the empirical counterpart of the main variables explained by the theoretical model presented in the next section.

The steps taken to estimate the VAR are the following. First, I computed information criteria, such as the Schwartz or Hannan-Quinn criteria, to determine the optimal number of lags of the VAR. Second, I tested the stationarity of the representation, checking whether the eigenvalues are inside the unit circle. Third, I verified whether residuals present a normal multivariate distribution; departures from normality imply that the confidence intervals should be constructed through a bootstrapping technique as long as the residuals are a white noise process.⁷ Finally, I computed the VAR impulse response functions and, accordingly, their confidence intervals. The results are presented in appendix B; the impulse response functions are shown in figures C1 and C2 in appendix C.

I conclude that the optimal lag length should be two, following Hannan-Quinn information criterion.⁸ Although the Schwartz criteria preferred a lag length of one, the confidence intervals and the impulse response functions in this case do not differ significantly from those when the Hannan-Quinn criterion is used. Since all the eigenvalues are inside the unit circle, the chosen system presents covariance stationarity. The residuals are a white noise process, but they show important departures from normality. The 95 percent confidence intervals of impulse response functions are therefore calculated using bootstrapping.

The ordering followed in the estimation of the VAR model is the one presented above. The confidence intervals of the impulse response functions are almost invariant to alternative orderings. Moreover, following Pesaran and Shin (1998), a generalized decomposition of the variance-covariance matrix—in which impulse-response analysis is invariant to the ordering of the variables—was performed and the results were very similar (see appendix C).

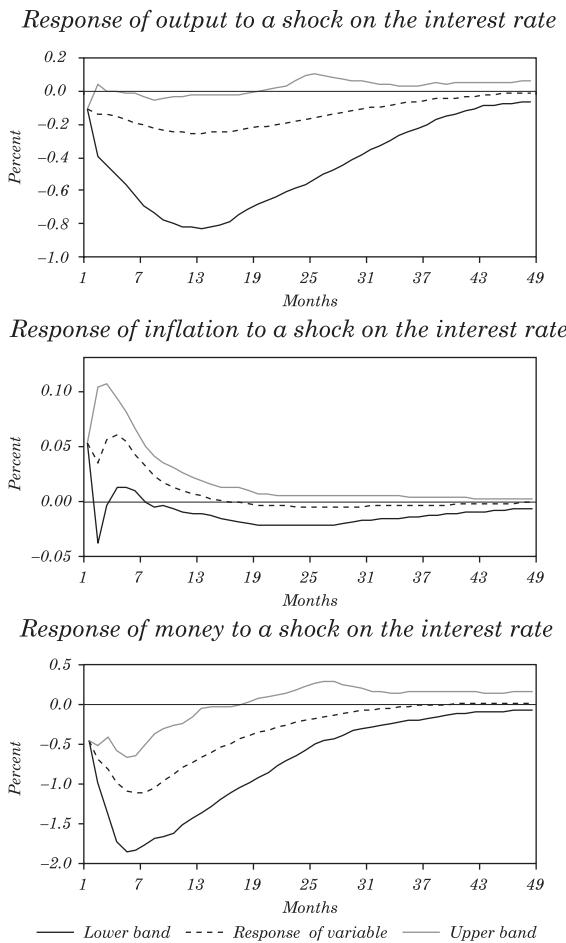
Figure 1 shows the main impulse-response function derived from the VAR model using Cholesky decomposition. Based on the outcomes obtained from the estimation, I arrive at three key conclusions. First,

7. A likelihood ratio test (LRT) was performed to confirm white noise residuals.

8. The Hannan-Quinn criterion was chosen for two reasons. First, the Akaike criterion is known to be inconsistent, and it tends to overfit. In this case, Akaike prefers an optimal lag of twenty-four, which would imply an overparameterized model. Second, the shapes of the impulse response functions do not vary significantly if choosing the Schwartz criterion with only one lag. Using an AR(1) technological shock in the theoretical model implies that output follows an AR(2) process, and this is consistent with a VAR(2) empirical model.

the output level tends to decline in the face of a temporary shock to the (UF-indexed) policy interest rate. This effect is statistically significant between the fifth and the eighteenth month. However, a VAR with one lag, following the Schwartz criterion, shows a nonsignificant decrease in output when there is a shock to the interest rate. This result can thus be summarized as a slightly significant or non-significant decline in the output level.

Figure 1. Impulse Response Functions from the VAR Model
(VAR(2) and Cholesky Decomposition)



Source: Author's calculations.

Second, the inflation rate rises in response to a transitory interest rate shock. The increase is statistically significant between the third and sixth month. This result is robust to the use of any ordering or number of optimal lags. This phenomenon is called the price puzzle in the economic literature: that is, if an increase in the interest rate is seen as a restrictive monetary policy, then the inflation rate should decrease (instead of increasing as empirical evidence shows) as predicted in a standard Mundell-Fleming model with a Keynesian aggregate supply.

This stylized fact also appears in other studies for Chile. For example, Morandé and Schmidt-Hebbel (1997), Calvo and Mendoza (1998), and Cabrera and Lagos (1999) all find a statistically significant price puzzle. Works that find a nonsignificant price puzzle include Valdés (1998), Chumacero (2003), and Parrado (2001).⁹ García (2001) attempts to solve this puzzle, but he imposes a strong assumption of the endogeneity of the inflation target. Similarly, most of the econometric specifications in Parrado (2001) only find it for the 1991–2001 period.

Third, a policy rate shock implies a negative effect on real money balances. Thus there is no evidence of liquidity puzzle. This effect is statistically significant for more than a year and is also invariant to the use of any ordering or number of optimal lags.

The confidence intervals of the impulse response functions are used below as a metric of comparison for testing the capability of the theoretical model—presented in the next section—to match Chilean data. Basically, I am interested in finding a theoretical framework capable of explaining and replicating the facts shown above: the comovement of the inflation and interest rates and the effects of an interest rate shock on output and money.

3. THE MODEL

This section describes the main characteristics of the proposed model. The general features to be considered are the household's utility function, which depends on consumption, real money holdings, and leisure; a Taylor rule followed by the monetary authority; demand for nominal and UF-indexed bonds; the presence of technological and fiscal expenditure shocks; constant distortionary taxes; and an open economy.

9. The price puzzle is present in certain VAR specifications and sometimes when using prices in levels or growth.

3.1 Households

Consider an economy characterized by an infinitely lived agent that optimizes a utility function that depends on real private consumption (c_t), real money balances (m_t), and leisure (l_t):

$$E_t \left[\sum_{t=0}^{\infty} \beta^t u(c_t, m_t, l_t) \right], \quad (1)$$

where $0 < \beta < 1$ is the subjective discount factor and $E\{\cdot\}$ the expectations operator.

The representative household's constraint is as follows:

$$\begin{aligned} c_t + i_t + b_t + b_t^U + m_t &\leq (1 - \tau_L) w_t L_t + (1 - \tau_K) r_t K_t + q_t y_2 + T_t + \frac{m_{t-1}}{1 + \pi_t} \\ &+ \frac{(1 + R_t) b_{t-1}}{1 + \pi_t} + (1 + R_t^U) \left(\frac{U_t}{U_{t-1}} \right) \left(\frac{b_{t-1}^U}{1 + \pi_t} \right) + D_t, \end{aligned} \quad (2)$$

where i_t denotes real investment in period t ; b_t is the real stock of bonds; b_t^U is the UF-indexed real stock of bonds; τ_L and τ_K are (constant) taxes on labor and capital income, respectively; w_t denotes the real wage; L_t represents the level of employment;¹⁰ r_t is the real cost of capital; K_t is the stock of physical capital; q_t is the relative price of exportable goods to importable goods, or the terms of trade; T_t denotes real lump-sum transfers; π_t is the inflation rate; R_t represents the nominal (net) interest rate; R_t^U is the UF-indexed (net) interest rate; D_t are firm profits; and U_t denotes the value of one UF in period t , which evolves according to the following equation:

$$\frac{U_{t+1}}{U_t} = (1 + \pi_t)^{1-v} (1 + \pi_{t-1})^v, \quad (3)$$

where v is equal to $9/30$. This value represents the number of days in a month that the UF growth depends on inflation in period $t-1$, whereas for the rest of the month ($21/30$) it depends on inflation in

10. The household is endowed each period with one unit of time, which it divides between leisure ($1 - L_t$) and work (L_t).

period t . In other words, UF growth in $t + 1$ is a weighted geometric mean of the inflation rate in t and the inflation rate in $t - 1$.

I assume that two goods are produced in this economy; the first good (y_1 , or the importable good) is produced domestically and can be imported, while the second one (y_2 , or the exportable good) is not consumed domestically and is supposed to be constant.

Next, I assume the following specification for the utility function:

$$u(c_t, m_t, l_t) = \log c_t + \phi \log m_t + \eta \log (1 - L_t) . \quad (4)$$

Capital accumulation has the following law of motion:

$$K_{t+1} = (1 - \delta) K_t + i_t , \quad (5)$$

where δ is the rate of capital depreciation.

The law of motion of the exogenous terms of trade is

$$q_t = (1 - \rho_q) q_0 + \rho_q q_{t-1} + \varepsilon_{qt} , \quad (6)$$

where $\varepsilon_{qt} \sim \text{i.i.d.}(0, \sigma_q^2)$; $q_0 > 0$; and $0 < \rho_q < 1$.

Finally, in the description of the economy, I suppose a Taylor rule that depends positively on the output and inflation deviations from steady-state values plus an autoregressive term:

$$R_{t+1} = (1 - \theta_3) R_0 + \theta_1 \log\left(\frac{y_{1t}}{y_1^*}\right) + \theta_2 \log\left(\frac{1 + \pi_t}{1 + \pi^*}\right) + \theta_3 R_t + \varepsilon_{R,t+1} , \quad (7)$$

where $R_0, \theta_1, \theta_2 > 0$ and $0 < \theta_3 < 1$ and where y_1^* is the steady-state output level of (importable) goods, π^* represents the steady-state inflation rate, and $\varepsilon_{R,t+1}$ is a zero-mean shock with variance σ_R^2 . R_0 corresponds to the long-run (or steady-state) interest rate.

In a decentralized equilibrium, the agent maximizes equation (1) subject to equations (2) through (7). Accordingly, the first-order conditions are as follows:

$$\frac{1}{c_t} - \lambda_t = 0 , \quad (8)$$

$$\frac{\phi}{m_t} - \lambda_t + \beta E_t \left(\frac{\lambda_{t+1}}{1 + \pi_{t+1}} \right) = 0 , \quad (9)$$

$$-\frac{\eta}{(1-L_t)} + \lambda_t(1-\tau_L)w_t = 0 , \quad (10)$$

$$-\lambda_t + \beta(1+R_{t+1})E_t\left(\frac{\lambda_{t+1}}{1+\pi_{t+1}}\right) = 0 , \quad (11)$$

$$-\lambda_t + \beta(1+R_{t+1}^U)\frac{U_t}{U_{t-1}}E_t\left(\frac{\lambda_{t+1}}{1+\pi_{t+1}}\right) = 0 , \quad (12)$$

$$-\lambda_t + \beta E_t\lambda_{t+1}\left[(1-\tau_K)r_{t+1} + (1-\delta)\right] = 0 . \quad (13)$$

Since the nominal and UF-indexed bonds are risk-free assets, R_{t+1} and R_{t+1}^U are known in period t , they are placed out of the expectation operator. Moreover, equations (11) and (12) imply the arbitrage condition between the assets:

$$(1+R_{t+1}^U)\frac{U_t}{U_{t-1}} = (1+R_{t+1}) . \quad (14)$$

This is a statement of interest rate parity, which says that the representative agent is indifferent between investing in an asset that yields a nominal return and investing in an asset that yields a UF-indexed return. Given that the law of motion of the UF's is known in period $t+1$, equation (14) implies that any shock to the nominal interest rate is totally transferred to the UF-indexed interest rate and vice versa. Therefore, using the nominal or the UF-indexed interest rate as monetary policy is indifferent in this context.

3.2 Firms

The representative firm maximizes its profit given by equation (15),

$$D_t = y_t - w_t L_t - r_t K_t , \quad (15)$$

subject to a returns-to-scale technology:

$$Y_{1t} = F(K_t, L_t, Z_t) = A_0 K_t^\alpha L_t^{1-\alpha} e^{zt} , \quad (16)$$

where $A_0 > 0$ and $0 < \alpha < 1$. Also, z_t is a technological shock that follows an autoregressive process:¹¹

$$z_t = \rho_z z_{t-1} + \varepsilon_{zt}, \quad (17)$$

where $0 < \rho_z < 1$ and where $\varepsilon_{zt} \sim \text{i.i.d. } (0, \sigma_z^2)$.

Thus, the firm maximizes equation (15) subject to equations (16) and (17), obtaining the following first-order conditions:

$$\alpha A_0 \left(\frac{L_t}{K_t} \right)^{1-\alpha} e^{zt} - r_t = 0 \text{ and} \quad (18)$$

$$(1-\alpha) A_0 \left(\frac{K_t}{L_t} \right)^\alpha e^{zt} - w_t = 0. \quad (19)$$

3.3 Public Sector

The government budget constraint is

$$\begin{aligned} g_t + T_t &= \tau_L w_t L_t + \tau_K r_t K_t + m_t - \frac{m_{t-1}}{1+\pi_t} + b_t - \frac{(1+R_t)b_{t-1}}{1+\pi_t} \\ &+ b_t^U - (1+R_t^U) \frac{U_t}{U_{t-1}} \frac{b_{t-1}^U}{1+\pi_t}, \end{aligned} \quad (20)$$

where g_t is the exogenous government expenditure. The model also considers a stationary law of motion for the fiscal policy:

$$g_t = (1 - \rho_g) g_0 + \rho_g g_{t-1} + \varepsilon_{gt}, \quad (21)$$

where $g_0 > 0$ and $0 < \rho_g < 1$ and where $\varepsilon_{gt} \sim \text{i.i.d. } (0, \sigma_g^2)$.

11. Assuming a first-order autoregressive process is quite standard in RBC literature, even for Chile. In this model, this is supposed to generate a first- or second-order autoregressive process for the simulated variables and be consistent with the empirical model estimated in the last section, which is a VAR(2). Chumacero and Fuentes (2002) show that if the productive shocks follow an AR(1) process in a general equilibrium model, then output follows an AR(2) process.

3.4 The Economy

Equations (2) and (20) imply that aggregate demand equals production in both sectors:

$$c_t + i_t + g_t = y_{1t} + q_t y_2 . \quad (22)$$

Summing up, the parameters of the basic structure are $\alpha, \beta, \delta, \eta, \tau_K, \tau_L, \phi, A_0$, and y_2 ; those related to the exogenous autoregressive processes are $\rho_g, \rho_{q'}, \rho_{z'}, \sigma_g, \sigma_{q'}, \sigma_z, g_0$, and q_0 ; and those related to the Taylor rule are $\theta_1, \theta_2, \theta_3, \sigma_R$, and R_0 . The state variables are $b_{t+1}, b_{t+1}^U, g_t, K_{t+1}, q_t$ and z_t . The controllable state variables are π_r, R_r and R_t^U , and the control variables are c_r, L_r and m_r . The steady-state solution of the model is presented in appendix D.

4. CALIBRATION AND RESULTS

This section describes the parameterization of the model and then presents the main results. As outlined above, twenty-two parameters appear in the equations that characterize behavior around the steady state. Previous studies based on Chilean data have assigned values to some of these parameters. Table 2 summarizes some of the most frequent values used for common parameters for the Chilean economy and, as a reference, some values for the U.S. economy. For example, the capital-share parameter values used in these studies for Chilean data are between 0.33 and 0.60, even though most of the studies use a value in the 0.33–0.40 range. Parameters such as the subjective discount factor, the autoregressive coefficient of the technological shock, the capital depreciation rate have similar values throughout the literature when they are compared in the same frequency.¹²

I therefore assume three criteria for assigning values to each parameter of the model. First, I use some of the standard parameter values given in previous literature for Chile (according to table 2). Second, I find the parameter value necessary to match some steady-state values for the Chilean economy (such as the steady-state consumption as a percentage of GDP and the steady-state inflation rate).

12. Remember that the calibration must be done in terms of monthly data. For instance, a monthly subjective discount factor of 0.996 corresponds to an annual value of 0.953.

Table 2. Parameters Used in Previous Studies

Study	Country and period		Preference and technology				σ_g	δ
		β	ϕ	α	ρ_z			
McGrattan (1994)	U.S., 1947-1987	0.985	NP	0.397	NC	0.0980	0.0226	
Cooley and Hansen (1995)	U.S., 1954-1991	0.989	NP	0.400	0.950	0.0070	0.0190	
Quiroz and others (1991)	Chile, 1977-1990	NR	NP	NR	0.999	0.0200	0.0000	
Acuña and Oyarzún (2001)	Chile, 1986-2000	0.986	NP	0.400	0.990	0.0178	0.0250	
Bergoeing and others (2001)	Chile, 1981-2000	0.980	NP	0.600	NR	NR	0.0800	
Chumacero and Fuentes (2002)	Chile, 1960-2000	0.980	NP	0.333	0.730	0.0400	0.0600	
Bergoeing and Soto (2002)	Chile, 1986-2000	0.979	NP	0.37-0.4	0.981	0.0990	0.0200	
Walsh (1998)	U.S., (NR)	0.989	0.05	0.400	0.950	0.0089	0.0190	
Exportables sector and fiscal policy								
	ρ_q	σ_q	τ_l	τ_k	g_0	ρ_g	σ_g	
McGrattan (1994)	U.S., 1947-1987	NP	NP	NP	70.990	NC	0.078	
Bergoeing and others (2001)	Chile, 1981-2000	NP	NP	0.51-0.12	NP	NP	NP	
Chumacero and Fuentes (2002)	Chile, 1960-2000	0.892	0.14	0.25	0.25	NR	0.895	0.024
Bergoeing and Soto (2002)	Chile, 1986-2000	NP	NP	NP	0.089	0.760	0.097	

Source: Author's compilation.

NR: Not reported.

NP: Not a parameter in the study.

NC: Not comparable, since the study did not use an AR(1) process.

Finally, I adjust the parameter values to allow the model to match the metric of comparison (the confidence intervals of the impulse response functions). Table 3 reports the parameter values assumed for the calibration and the corresponding criterion used in each case.

4.1 Main Results

The model is solved using a perturbation method developed by Schmitt-Grohé and Uribe (2001). This method consists of a second-order approximation to the policy functions of the dynamic equilibrium model. As the authors state, first-order approximation methods are not well suited to handling issues such as welfare comparisons across alternative stochastic or policy environments. Furthermore, the linearized decision rules for evaluating second-order approximations to the objective function ignore some second-order terms of the objective function. Such problems do not arise with the use of second- or higher-order approximations.

Figure 2 presents the responses of a transitory shock to the log of the (gross) interest rate. The shock given is positive to represent a restrictive monetary policy. The increase is 0.5 percent (50 basis points) of the annual policy rate (or 0.04 percent in monthly terms). The following results are found. First, the positive shock to the interest rate has a transitory negative, but not significant effect on the output level. The increase in interest rate implies an increase in the cost of capital (by the arbitrage condition between the physical capital and financial capital markets). This generates a reduction in the demand for capital—which is only partially offset by an increase in labor stemming from a substitution effect—and a fall in output. The insignificant fall in output probably results from the absence of price rigidities in the goods or labor markets.

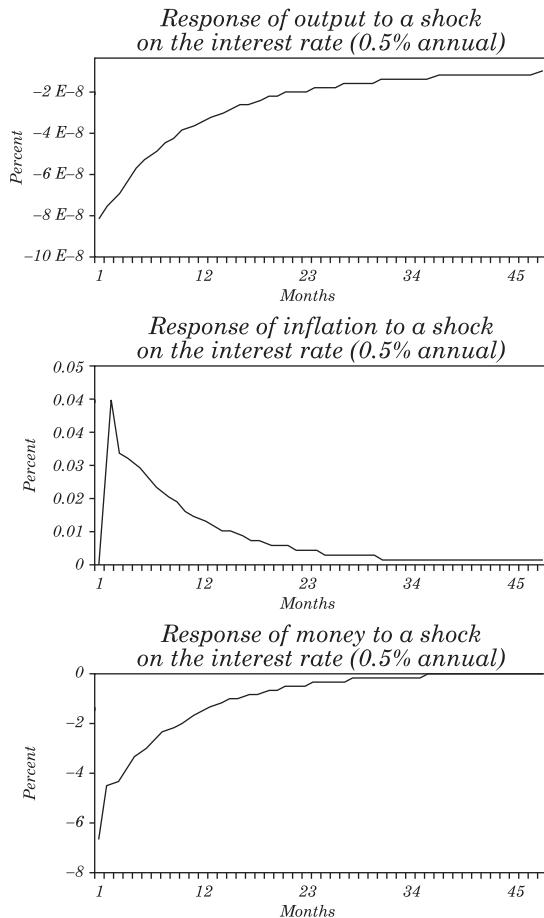
Second, the policy shock causes a transitory increase in the inflation rate. As mentioned in section 2, this is called the price puzzle in the empirical literature. This effect has a straightforward explanation based on the theoretical model proposed here: an increase in the interest rate produces a similar effect on inflation, leaving real interest virtually unchanged owing to a Fisher effect. That is, the Fisher equation implies that higher interest rates are associated with higher inflation rates, which is exactly the relationship shown in figures 1 and 2. This explanation of the comovement of the interest rate and inflation is given in previous studies, but without a specific application for a particular economy. Monnet and Weber (2001) present a

Table 3. Parameterization of the Model^a

Parameter	Symbol	Value	Criterion of choice
Basic structure			
Capital share	α	0.35	Previous literature (between 0.33–0.4)
Subjective discount factor	β	0.996	Previous literature. The value implies a steady-state real interest rate of 5%
Depreciation rate	δ	0.09/12	Previous literature and calibration of investment as a percentage of GDP (22% +/- 3.3%)
Utility sensitivity to leisure	η	1.2	Calibration of steady-state labor between 0.3 and 0.4
Capital taxes	τ_k	0.25	Source: Chumacero and Fuentes (2002)
Labor taxes	τ_L	0.25	Source: Chumacero and Fuentes (2002)
Utility sensitivity to money	ϕ	0.005	Calibration of impulse response functions and previous literature
Technological constant	A_0	0.9	Calibration of consumption as a percentage of GDP (63% +/- 2.3%)
Exportable output	y_2	1.5	Calibration of exportable output as a percentage of GDP (35% +/- 5%)
Exogenous autoregressive processes			
Government AR(1) coefficient	ρ_g	0.76	Source: Bergoeing and Soto (2002)
Terms-of-trade AR(1) coefficient	ρ_q	0.961	AR(1) estimates (data: 1986.01–2000.12)
Technological AR(1) coefficient	ρ_x	0.9	Calibration of impulse response functions and previous literature
Government expend. volatility	σ_g	0.008	Source: Bergoeing and Soto (2002)
Volatility	σ_q	0.0127	AR(1) estimates (data: 1986.01–2000.12)
Technological volatility	σ_x	0.0001	Calibration of impulse response functions and GDP volatility
Steady-state government expenditure	\bar{g}_0	1.22	Calibration of government expenditures as a percentage of GDP (13.3% +/- 5%) AR(1)
Steady-state terms of trade	q_0	1.072	estimates (data: 1986.01–2000.12)
Taylor rule			
Taylor rule AR(1) coefficient	θ_1	0.67	Calibration of impulse response functions
Output deviation coefficient	θ_2	0.1	Calibration of impulse response functions
Inflation deviation coefficient	θ_3	0.2	Calibration of impulse response functions
Taylor rule volatility	σ_R	0.68e-4	Calibration of impulse response functions
Taylor rule constant	R_0	0.0061	Calibration of steady-state inflation around 2.64%

Source: Author's compilation.
 a. AR(1) denotes a first-order autoregressive process.

Figure 2. Impulse Response Functions from the Theoretical Model



Source: Author's calculations.

discussion that reconciles the positive relation between the interest rate and inflation (the Fisher view) and the negative relationship between those variables (the liquidity view). Alvarez, Lucas, and Weber (2001) develop an analogous explanation with the inclusion of segmented markets. In the model presented above, the reason for the comovement is that the nominal interest rate affects inflation only and not the real interest rate. This effect is strengthened in the model owing to the assumption of a Taylor rule that depends positively on inflation deviation from the steady state.

This result does not imply that a central bank should increase the policy interest rate to fight an inflation process. According to equation (7), a reduction in the long-run inflation rate target should increase the interest rate, and the central bank would then follow a monetary policy consistent with economic agents' expectations. Both inflation and interest rate should thus decrease, converging to the new steady-state equilibrium.

Third, the positive policy shock produces a temporary decrease in real money holdings through the function of the demand for money. That is, the agents respond to a positive interest shock by increasing their demand for nominal bonds (and, consequently, lowering their money holdings). Values for the inflation and output deviation coefficients higher than those assumed in table 3 ($\theta_2 = 0.1$ and $\theta_3 = 0.2$) generate explosive equilibrium or indeterminacy, results that are consistent with those found by Christiano and Gust (1999). This topic represents an interesting avenue for future research on the Chilean economy.

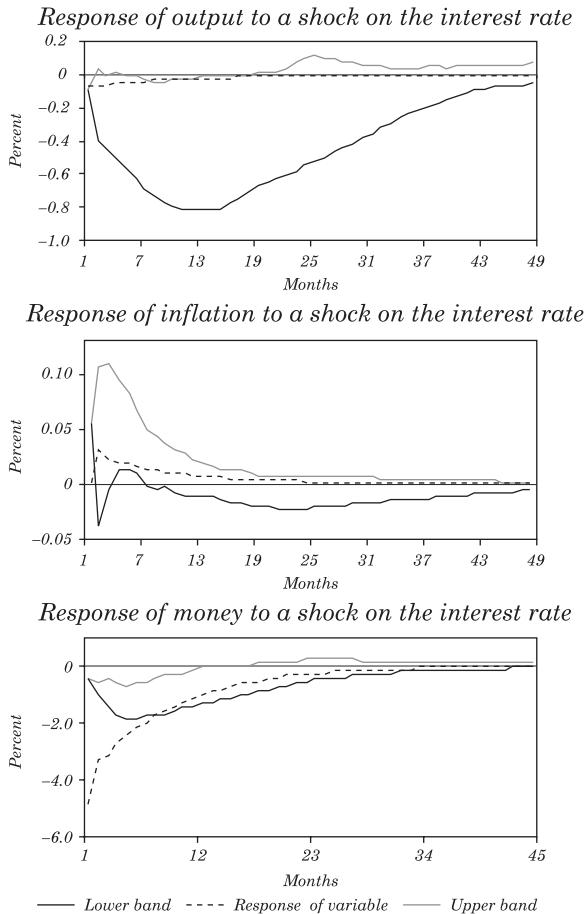
4.2 How Well Does the Model Match the VAR?

To determine whether the theoretical and empirical models correspond, I compare the responses of the variables from the VAR (the empirical model) and the theoretical model when they face an equivalent positive temporary policy rate shock. As before, the analysis focuses on the responses of output, inflation, and money.

Figure 3 reports the confidence intervals of the impulse response functions (the upper and lower bands) and the response of each variable from the theoretical model. The shock consists of an increase of 0.03 percent in the interest rate (0.36 percent in annual terms). As shown in the figure, the theoretical model matches the VAR relatively well, albeit with some observations. The response of output given by the theoretical model is not as significant as the real response in the data. The response of the inflation rate is inside the confidence intervals from the second period. Finally, the response of real money balances is negative in both the model and the VAR, but in the model, its trajectory falls out of the bands from the first to the ninth period.¹³

13. An analogous exercise with generalized decomposition was performed, with similar results (see figure C3 in appendix C).

**Figure 3. VAR Confidence Intervals and Impulse Response Functions from the Theoretical Model
(VAR(2) and Cholesky Decomposition)**



Source: Author's calculations.

5. CONCLUSIONS

Most previous RBC-type works for the Chilean economy do not consider monetary variables or the relations among these and real variables—and when they do, they have some trouble replicating sample moments. Such studies usually consider money an exogenous variable, and the economy is closed to international trade, both of which

are unrealistic assumptions for the past two decades in Chile. Finally, they generally use linear quadratic methods that might be inadequate in certain cases, as discussed in section 4.

The goal of this paper was to find out how well a money-in-the-utility-function model with a Taylor rule can account for some monetary stylized facts from the Chilean data for the 1986–2000 period. Basically, I focused on the replication and theoretical explanation of what has been called the price puzzle (that is, the comovement between the interest rate and the inflation rate), which is found in many VAR-type estimates for Chile and other economies. The previous works that consider real business cycle models with monetary variables essentially ignore monetary relationships altogether or explain only a few of their features, generally some second moments.

This paper has formulated, solved, and calibrated a dynamic stochastic general equilibrium model for the Chilean economy between 1986 and 2000. The solution of the model was adequately achieved using a perturbation method proposed by Schmitt-Grohé and Uribe (2001). The metric consists of confidence intervals of impulse response functions from a five-variable VAR. These variables were chosen as the empirical counterpart of the main variables explained by the theoretical model presented in section 3.

I find that a positive transitory policy interest rate shock causes a temporary (but not significant) fall in output. From a theoretical viewpoint, the increase in the interest rate implies an increase in the cost of capital and, consequently, a reduction in the demand for capital and output. The decline is consistent with the sign of the impulse response function from the VAR estimated in section 2. While this effect is statistically significant in that case, a VAR with one lag, following the Schwartz criterion, shows a nonsignificant decrease in output following a shock to the interest rate.

The policy shock also causes a transitory increase in the inflation rate—the price puzzle. The theoretical model proposed here provides a straightforward explanation to this puzzle: an increase in the interest rate produces a similar effect on inflation, leaving real interest virtually unchanged, owing to a Fisher effect, which is strengthened by a Taylor rule that depends positively on inflation deviation. A similar explanation is given in some recent studies (Monnet and Weber, 2001; Alvarez, Lucas, and Weber, 2001), but it has never been proved for a particular economy.

Finally, a transitory increase in interest rates decreases real money balances. This effect is relatively consistent with the impulse response functions obtained from the VAR from the ninth period of analysis.

APPENDIX A

Data and Sources

The terms of trade variable is the log of terms of trade, taken from Bennett and Valdés (2001). The interest rate is the log of the (gross) UF-indexed interest rate paid on ninety-day bonds issued by the Central Bank of Chile (the PRBC) from 1986 to 1995; and UF-indexed policy interest rate from 1995 to 2000. The inflation rate is the log of (gross) inflation rate (or growth of the consumer price index). Money is the log of M1 deflated by the consumer price index. Output is the log of Chile's monthly economic activity index (Imacec). Data on the interest rate, inflation rate, money, and output are all from the Central Bank of Chile.

APPENDIX B

Supplemental Tables

This appendix reports the results of the preliminary steps taken in estimating the VAR, including the information criteria and lags, the roots of the characteristic polynomial, and tests for white noise residuals. With regard to Gaussian residuals, a test for normality was applied to the VAR residuals. The test statistic value was 236.17 and the p value was 0. Based on Doornik and Hansen (1994), this statistic is χ^2 distributed with ten degrees of freedom (18.3 at 5 percent; 16.0 at 10 percent). The null hypothesis, which is the normality of the residuals, is rejected.

Table B1. Model Selection Criteria by Lag

Number of lags	Akaike	Schwartz	Hannan-Quinn
0	-39.75	-38.59	-39.28
1	-48.26	-46.66	-47.61
2	-48.70	-46.65	-47.87
3	-48.86	-46.35	-47.84
4	-48.84	-45.87	-47.63
5	-48.75	-45.31	-47.35
6	-48.61	-44.71	-47.03
7	-48.45	-44.07	-46.67
8	-48.39	-43.54	-46.42
9	-48.40	-43.07	-46.24
10	-48.28	-42.47	-45.92
11	-48.15	-41.85	-45.59
12	-48.36	-41.57	-45.60
13	-48.47	-41.19	-45.52
14	-48.43	-40.65	-45.27
15	-48.42	-40.14	-45.06
16	-48.35	-39.56	-44.78
17	-48.37	-39.07	-44.59
18	-48.68	-38.86	-44.69
19	-48.64	-38.30	-44.44
20	-48.82	-37.96	-44.41
21	-49.11	-37.72	-44.48
22	-49.68	-37.76	-44.84
23	-50.07	-37.61	-45.01
24	-51.34	-38.34	-46.06

Source: Author's calculations.

Table B2. Roots of Characteristic Polynomial^a

<i>Root</i>	<i>Modulus</i>
0.93 + 0.06i	0.94
0.93 - 0.06i	0.94
0.91	0.91
0.45 - 0.25i	0.51
0.45 + 0.25i	0.51
0.48	0.48
-0.36	0.36
0.29	0.29
-0.14	0.14
0.14	0.14

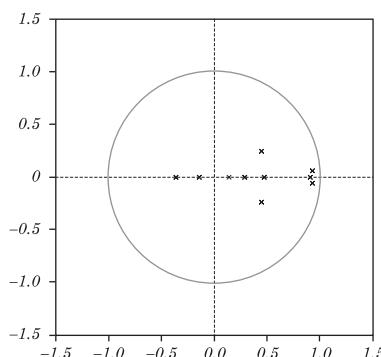
Source: Author's calculations.

a. No root lies outside the unit circle. The VAR specification satisfies the stability condition.

Table B3. Tests for White Noise Residuals^a

<i>Number of lags</i>	<i>Akaike</i>	<i>Schwartz</i>	<i>Hannan-Quinn</i>	<i>P value</i>
0	-49.94	-49.85	-49.90	0.00
1	-49.71	-49.17	-49.49	1.00
2	-49.73	-48.74	-49.33	0.29
3	-49.63	-48.19	-49.05	0.26
4	-49.58	-47.67	-48.81	0.15
5	-49.47	-47.10	-48.50	0.23
6	-49.33	-46.50	-48.18	0.41
7	-49.18	-45.87	-47.83	0.66
8	-49.13	-45.35	-47.60	0.61
9	-48.98	-44.72	-47.25	0.83
10	-48.81	-44.07	-46.88	0.96
11	-48.87	-43.64	-46.74	0.91
12	-48.94	-43.22	-46.62	0.85

Source: Author's calculations.

a. The *p* value of the LRT test refers to the null hypothesis that the residuals are white noise at different numbers of lags. All the information criteria prefer 0 as an optimal lag for the VAR estimate of the residuals. In this case, the null cannot be rejected.**Figure B1. Inverse Roots of AR Characteristic Polynomial**

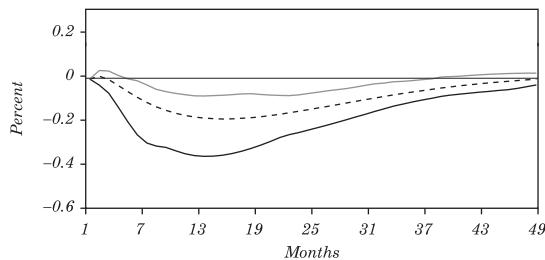
Source: Author's calculations.

APPENDIX C

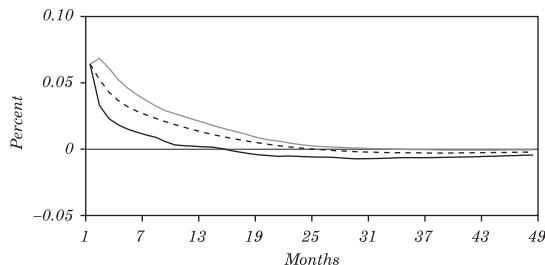
Impulse Response Functions

**Figure C1. Impulse Response Functions from the VAR Model:
VAR(1) and Cholesky Decomposition**

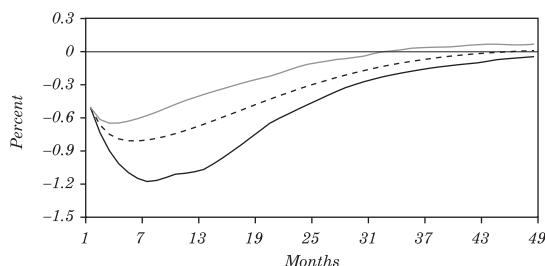
Response of output to a shock on the interest rate



Response of inflation to a shock on the interest rate



Response of money to a shock on the interest rate

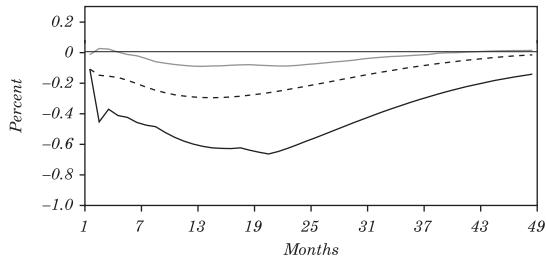


— Lower band - - - Response of variable — Upper band

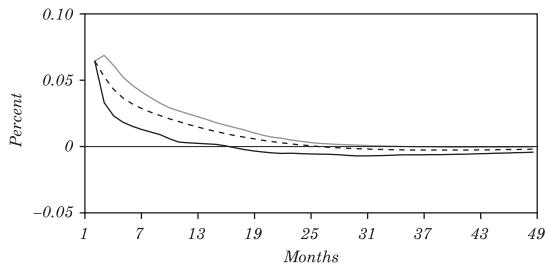
Source: Author's calculations.

Figure C2. Impulse Response Functions from the VAR Model: VAR(2) and Generalized Decomposition

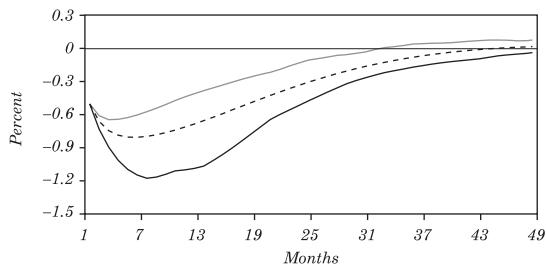
Response of output to a shock on the interest rate



Response of inflation to a shock on the interest rate



Response of money to a shock on the interest rate

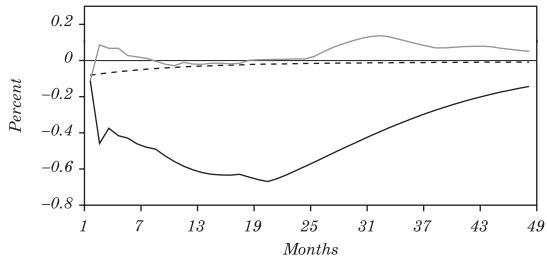


— Lower band - - - Response of variable — Upper band

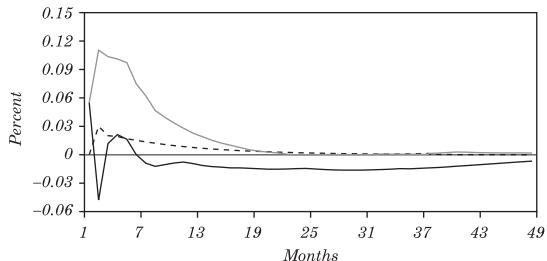
Source: Author's calculations.

Figure C3. VAR Confidence Intervals and Impulse Response Functions from the Theoretical Model: VAR(2) and Generalized Decomposition

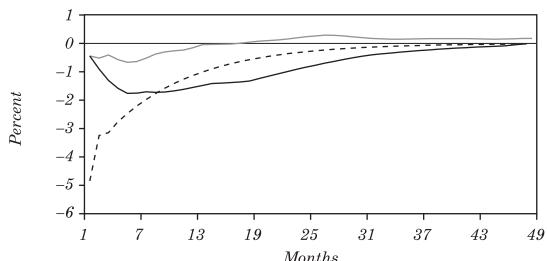
Response of output to a shock on the interest rate



Response of inflation to a shock on the interest rate



Response of money to a shock on the interest rate



— Lower band - - - Response of variable — Upper band

Source: Author's calculations.

APPENDIX D

Steady-state Equilibrium of the Model

In steady state, equation (7) implies the steady-state net interest rate:

$$R^* = R_0 . \quad (23)$$

Substitution of equation (23) in equation (11) generates the steady-state inflation rate:

$$1 + \pi^* = \beta (1 + R^*), \quad (24)$$

where the asterisk denotes steady-state values.

Rearranging equation (13) and using equation (18) yield the following:

$$K^* = L^* \left[\frac{\alpha A_0 \beta (1 - \tau_K)}{1 - \beta (1 - \delta)} \right]^{\alpha/(1-\alpha)} = \omega_0^{\alpha/(1-\alpha)} L^* , \quad (25)$$

$$\text{where } \omega_0 = \left[\frac{\alpha A_0 \beta (1 - \tau_K)}{1 - \beta (1 - \delta)} \right] > 0 .$$

Using equations (8), (10), (19) and (25) and rearranging, one obtains an expression for steady-state consumption that depends on steady-state employment:

$$\begin{aligned} c^* &= \left[\frac{(1 - \alpha)(1 - \tau_L) A_0}{\eta} \right] \left[\frac{\alpha A_0 \beta (1 - \tau_K)}{1 - \beta (1 - \delta)} \right]^{\alpha/(1-\alpha)} (1 - L^*) \\ &= \omega_1 \omega_0^{\alpha/(1-\alpha)} (1 - L^*) , \end{aligned} \quad (26)$$

$$\text{where } \omega_1 = \left[\frac{(1 - \alpha)(1 - \tau_L) A_0}{\eta} \right] > 0 .$$

Taken together, equations (22), (25), (26), the steady-state level of investment from equation (5), and the steady-state government expenditure from equation (21) allow one to find the steady-state level of employment:

$$L^* = \frac{\omega_0^{\alpha/(1-\alpha)} \omega_1 + g_0 - q_0 y_2}{\omega_0^{\alpha/(1-\varepsilon)} (A_0 + \omega_1 - \delta \omega_0)} . \quad (27)$$

With equation (27), one can calculate the steady-state capital stock, investment, consumption, and production. Finally, equations (8), (9), (23), (24), (26), and (27) generate the steady-state money balances:

$$m^* = \phi c^* \left(\frac{1+R^*}{R^*} \right).$$

Note that the demand for money depends positively on consumption and negatively on the nominal interest rate.

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TESTING REAL BUSINESS CYCLE MODELS IN AN EMERGING ECONOMY

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One of the most dynamic areas of macroeconomic research in recent decades is that of real business cycle (RBC) models. Since the seminal work by Kydland and Prescott (1982), a number of papers have tested the ability of neoclassical general equilibrium models to account for economic fluctuations. The original framework of Kydland and Prescott has been extended to include labor market rigidities (Hansen, 1985), taxes and government expenditures (McGrattan, 1994b), money and inflation (Cooley and Hansen, 1995), open economies (Backus, Kehoe, and Kydland, 1995), and increasing returns to scale in production (Weber, 2000). Each of these extensions successfully solves the limitations of calibrated models in replicating particularities of the data, and they provide rich explanations of business cycles, albeit at the cost of increasing complexity.

Although RBC models have been successfully applied to developed economies, their ability to replicate the data of emerging countries remains largely unexplored. In the case of Chile, there are only a few noteworthy exceptions.¹ This paper provides the first systematic exploration of RBC models with Chilean data, starting with the original Kydland and Prescott framework and introducing increasing degrees

This research benefitted from the generous support of the Central Bank of Chile. We are grateful for comments and suggestions made by S. Claro, C. Johnson, and C. Sims. Facundo Piguillem provided superb assistance.

1. Quiroz (1991); Quiroz and others (1991).

of complexity in the analysis. The purpose of this exercise is to test the capacity of RBC models both to replicate the salient characteristics of the observed aggregate fluctuations of the economy in the 1986–2000 period and to provide insights regarding the contribution of fiscal and monetary policies to the cycle.

The challenge to RBC models posed by the Chilean experience is formidable. First, the economy experienced rapid but unstable growth in the 1986–2000 period. Although gross domestic product (GDP) grew at an average annual rate of 6.7 percent, it also experienced significant year-to-year fluctuations, from a high 10.1 percent growth in 1989 to only –0.8 percent in 1999. In the same period, GDP growth in the United States was 2.6 percent and fluctuated within a narrower range of –1 percent to 4 percent. Second, in this period Chile experienced a remarkable reduction in inflation, from a high annual rate of 27 percent in 1989 to less than 3 percent in 1999, which suggests that the contribution of both nominal and real fluctuations might have played an important role during the period. Third, the economic structure of a developing country such as Chile differs markedly from that of industrial economies precisely in those underlying parameters that govern the mechanics of RBC models. Particularly different are the stock of capital and the capital-output ratio, the size and composition of government expenditures, the composition of consumption and investment, and the size of technological shocks.

The structure of the paper is as follows. Section 1 provides a snapshot of the most salient features of economic cycles in Chile.² We use simple statistics to discuss the relative importance of the shocks to GDP and its components and to assess their temporal structure. Section 2 provides a brief description of the different general equilibrium models we use, stressing the role of technology shocks, the effect of real and monetary frictions (such as labor rigidities and cash-in-advance constraints), the impact of fiscal and monetary policy shocks, and the derived decision rules of optimizing agents. Section 3 of the paper describes the data—some of which was collected especially for this study—and presents the parameterization of the different calibrated models. We also discuss the main difference between Chile's key (deep) parameters and those of industrial economies, in particular the United States. Section 4 presents the main empirical results, including the simulation of the models and the analysis of impulse-response functions. In section 5,

2. For a complete description, see Bergoeing and Suárez (2001).

we follow Canova, Finn, and Pagan (1994) in viewing our artificial economies as restricted versions of more general vector autoregression (VAR) models. We thus use econometric techniques to test the restrictions imposed by the structure of the model and the linearization process. Finally, section 6 highlights our main conclusions and suggests future extensions of this work.

1. CHARACTERIZING THE ECONOMIC FLUCTUATIONS OF THE CHILEAN ECONOMY

The stylized facts that characterize business cycles in Chile were obtained from the longest available database with consistent information on a quarterly basis, which covers from 1986 to 2000. As expected, economic fluctuations in Chile present important similarities when compared to the features of business cycles in industrialized countries (see, for example, Backus, Kehoe, and Kydland, 1995), but they also present interesting peculiarities.

We follow Lucas (1977) in defining business cycles as deviations from their long-run trend. The definition and computation of this trend are controversial, however. The literature contains a rich debate on the abilities of different statistical methods to decompose time series into long- and short-term fluctuations (see Baxter and King, 1995; Guay and St-Amant, 1996). The relative advantages of competing techniques such as those of Beveridge and Nelson (1981), Watson (1986), Hodrick and Prescott (1997), and Baxter and King (1995) are not yet established. Harvey and Jaeger (1993) criticize mechanical filters, showing that the Hodrick-Prescott (HP) filter can induce spurious cyclicalities when applied to integrated data. Guay and St-Amant (1996) find that the HP and Baxter-King (BK) filters perform poorly in identifying the cyclical component of time series that have a spectrum with the shape characteristic of most macroeconomic time series. Baxter and King (1995) note that two-sided filters such as the HP and BK filters become ill-defined at the beginning and end of samples.

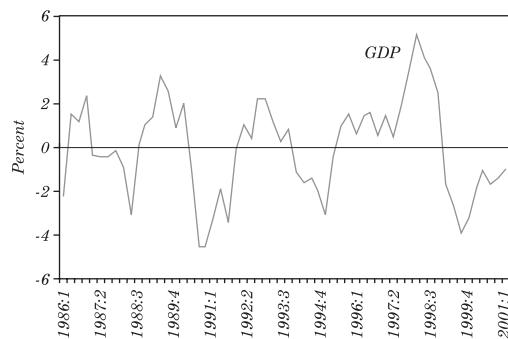
Notwithstanding this debate, we follow the standard practice of the business cycle literature and report all stylized facts using the deviations of the variables from their long-run trend obtained with the Hodrick-Prescott filter. Since the purpose of our paper is to assess the capacity of this type of model to describe the regularities of Chile's economic cycles, this choice allows us to compare our results to the evidence gathered for other countries. Canova (1998) similarly supports

the use of the HP filter because economists ought to be “looking through the same window” when comparing results among models.

We report several statistics for the HP-filtered data.³ In particular, we consider four variables: the amplitude of fluctuations (volatility), represented by the standard deviation of the cyclical component of each series; the ratio of the standard deviations of the series to that of output (relative volatility); the contemporaneous correlation of the cyclical components of a variable and that of output; and the phase shift, represented by the correlation coefficients between leads and lags of each variable and output.⁴ A variable leads output by i quarters if their cross correlation peaks i quarters before output. Since all variables are in logarithms, the change in the trend component represents the growth rate.

Figure 1 shows the evolution of the cyclical GDP in the period under analysis. The sample contains three clear cycles (measured from peak to peak), though they differ in magnitude and length. The size and volatility of GDP cycles are rather large: considering that the quarterly trend is 1.8 percent in the sample, the peak of the cycle would be equivalent to observing an annualized growth rate of 20 percent, while at the trough it would amount to growth rate of -15 percent.

Figure 1. Quarterly GDP Deviations from Trend



Source: Authors' calculations.

3. All series are seasonally adjusted using the X-12-ARIMA procedure and expressed in natural logarithms before being filtered, with the exception of the percent variables, such as inflation and interest rates, which are in levels.

4. As is customary, if the contemporaneous correlation is close to one, we label the variable as procyclical; if it is close to minus one, we call it countercyclical; and if it is close to zero, we use acyclical.

Additional information is presented in table 1, which reports numerical indicators of the amplitude and phase of the fluctuations of GDP and other key macroeconomic variables. This information points to several general similarities in the Chilean business cycle vis-à-vis that of industrialized countries, but it also highlights interesting differences. For example, the volatility of GDP in Chile—which reaches 2.20—is much higher than in most industrialized economies.⁵ This higher volatility is partly a reflection of structural characteristics of the Chilean economy (such as the relative absence of automatic stabilizers, shallow financial markets, and a less diversified production structure), but it is also consistent with the high growth rate sustained by Chile in the sample period.

Table 1. Main Indicators of the Business Cycle in Chile, 1986–2000

Variable	Volatility ^a	Volatility relative to that of output	Correlation with output	
			Contemporaneous	Peak quarter ^b
Output	2.20	1.00	1.00	0
Consumption, total	2.43	1.11	0.83	0
Consumption, nondurables	1.88	0.86	0.60	-1
Consumption, durables	15.94	7.25	0.80	0
Investment	7.47	3.23	0.83	0
Capital	1.32	0.60	0.41	-3
Avg. hours worked	1.07	0.74	0.21	-2
Total hours worked	1.92	0.87	0.44	-2
Employment	1.23	0.56	0.48	+2
Real wages	1.37	0.62	0.38	-1
Government consumption	1.55	4.04	-0.08	+2
Money	5.47	2.49	0.64	+1
Price level	2.12	0.96	-0.26	0
Inflation	0.93	0.42	-0.06	+3

Source: Authors' calculations.

a. Volatility is measured as the standard deviation times one hundred.

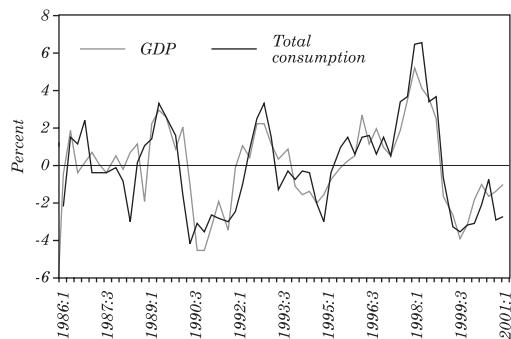
b. A plus sign indicates a lead; a minus sign indicates a lag.

Private consumption is procyclical in Chile, as it is in most countries: it moves in synchronicity with GDP, with a high correlation coefficient of 0.82 (see figure 2). Consumption is highly volatile. This

5. Volatility in Europe from 1970 to the mid-1990s was only 1.01, on average (Backus, Kehoe, and Kydland, 1995). The United States exhibits higher volatility (1.72) in the 1954–1991 period (Cooley and Hansen, 1995).

feature is one of the challenges that business cycle models have to face. Since RBC models are essentially neoclassical, consumption is usually modeled under the permanent income hypothesis. In this setting, consumption volatility should be smaller than that of output, since agents that optimize intertemporally tend to smooth out consumption. The apparent excess volatility of consumption is, in part, the result of using total consumption data. When consumption is separated into purchases of durable and nondurable goods, their volatility is markedly different (see figure 3). The volatility of durable goods is 8.5 times higher than that of nondurable goods.⁶ In what follows, we restrict consumption to nondurable goods and include purchases of durable consumption goods as a component of investment. Although the volatility of the purchases of nondurable consumption goods is smaller than that of total consumption or GDP, it remains rather high (1.88). This may stem, in part, from the existence of liquidity constraints (namely, credit restrictions), a characteristic that our business cycle models should also address.⁷

Figure 2. Quarterly GDP and Total Consumption Deviations from Trend

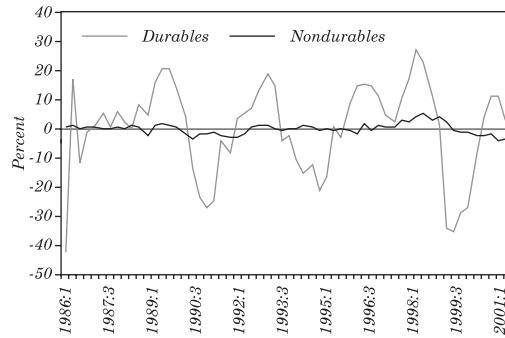


Source: Authors' calculations.

6. The higher volatility of the consumption of durable goods does not arise primarily from the changes in relative prices, as the price deflator of durable goods exhibits the same volatility as its counterpart for nondurable goods.

7. An alternative hypothesis to account for the high relative volatility of nondurable consumption is that income risk is not completely diversifiable (see Carroll, 2001). A number of industrialized countries exhibit very high volatility in consumption nondurable goods (for example, France, Germany, and Japan). In Canada, Switzerland, and the United States, volatility relative to GDP is lower than in Chile.

Figure 3. Quarterly Durable and Nondurable Consumption Deviations from Trend



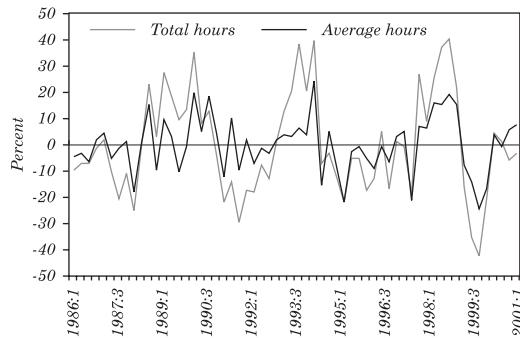
Source: Authors' calculations.

A second challenge that the Chilean data poses for business cycle models involves the nature of shocks in labor markets. Unemployment displays wide fluctuations, falling from a high 15.4 percent in 1986 to a low of 5.6 percent in 1998 and then rebounding to 9.2 percent in 2000. Total hours worked are more volatile than real wages (see table 1). In a neoclassical labor market, total hours worked should display very low volatility because most of the adjustment should fall on wages. In Chile, on the contrary, the volatility of hours worked is quite high (1.92) and much higher than that of real wages (1.37), suggesting the existence of substantial rigidities or adjustment costs in the labor market. We find additional evidence of such rigidities when we split total hours worked into average hours worked per worker and the number of workers employed (employment). As shown in figure 4, average hours worked fluctuate less than total hours, suggesting that most of the adjustment corresponds to the entry and exit of workers from the labor market rather than marginal adjustment in working schedules.⁸

An additional puzzle posed by agents' behavior in labor markets involves fluctuations in real wages and their correlation with hours worked. In the Chilean case, the volatility of labor productivity is almost as high as that of GDP, but it shows virtually no correlation with hours worked (estimated at 0.12). This is a worrisome feature for our business

8. As expected, the relative volatility of employment in Chile is higher than that in Australia (0.34) or Japan (0.34) and, surprisingly, similar to that in Europe (0.85), a continent characterized by sustained unemployment. Part of this heterogeneity in labor market performance reflects differences in institutional arrangements.

Figure 4. Quarterly Total and Average Hours Worked Deviations from Trend



Source: Authors' calculations.

cycle models because one of the weaknesses of the original Kydland and Prescott specification is its inability to replicate the low correlation between hours worked and productivity levels or wages.

A third interesting feature of the business cycle in Chile is the presence of large fluctuations in investment. As a fraction of GDP, gross fixed capital formation increased from a low of 15 percent in the mid-1980s to over 28 percent in the late 1990s. This expansion of investment was characterized by very high volatility, which reached 7.47 in the sample period, more than three times the volatility of GDP. When the purchase of durable goods is added to investment, volatility increases to 8.21.

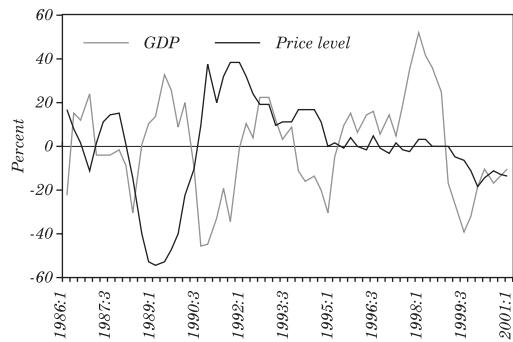
As in most emerging economies, government expenditure in Chile displays some characteristics that are very different from developed economies. The size of the government measured by public consumption (as percent of GDP) is quite small in Chile, reaching less than 10 percent in the 1986–2000 period. The government spends around 5 percent of GDP on capital formation (mostly infrastructure), which we include in total investment. Government consumption is quite unstable, with a volatility of 8.8, and it is largely uncorrelated with fluctuations in GDP.⁹ This high volatility suggests that government expenditures might play an important role in causing economic fluctuations. Finally, public expenditures represent substantial transfers of goods and services (such as health and

9. Government consumption in the United States and Europe is around 18 percent of GDP (Backus, Kehoe, and Kydland, 1995). It is typically uncorrelated with GDP and displays lower volatility.

education) for many groups of the society. These groups also pay taxes, however, so that the net effect of changes in fiscal policies on economic activity and welfare may be ambiguous. The business cycle models developed below explicitly address this issue.

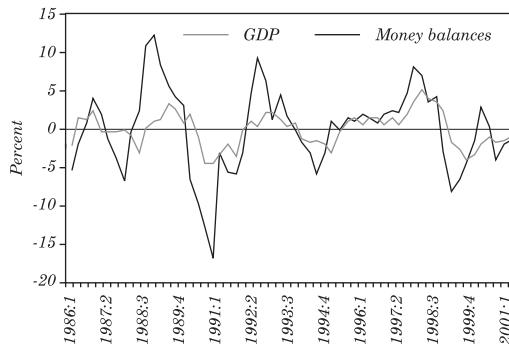
Chile also differs from developed economies with regard to monetary shocks. As mentioned, inflation in Chile declined slowly from 27 percent in 1989 to around 3 percent in 2000, largely as a result of the gradualist monetary policy approach employed by the Central Bank (Morandé, 2002). The volatility of money, as measured by per capita real M1, is quite high (5.84), and money shocks are strongly correlated with GDP fluctuations (0.70). As a matter of fact, money cycles display a striking synchronicity with GDP fluctuations, as depicted in figure 5, and lead the cycle by one quarter. This certainly reflects the effects on the real side of the economy of the Central Bank's choice to base its policy instruments on the real interest rate—as opposed to targeting monetary aggregates—during the last ten years. Anti-inflationary policies have, unsurprisingly, induced marked volatility in the price level (2.12). Inflation has also been quite persistent, which is a direct result of the anti-inflationary policies implemented in the period compounded by the high degree of price indexation of the Chilean economy.

Figure 5. Quarterly GDP and Prices Deviations from Trend



Source: Authors' calculations.

Prices, on the other hand, display a negative correlation with GDP (see figure 6). This, together with the fact that real wages are procyclical, suggests that supply shocks are an important source of fluctuations in aggregate activity.

Figure 6. Cyclical Components of GDP and Money Balances

Source: Authors' calculations.

2. BUSINESS CYCLE MODELS

The original model by Kydland and Prescott has been extended to include, among other issues, household production (Benhabib, Rogerson, and Wright, 1991); labor hoarding (Burnside, Eichenbaum, and Rebelo, 1993); a limited version of open economies (Backus, Kehoe, and Kydland, 1995); money and inflation (Cooley and Hansen, 1995); incomplete markets and heterogeneous agents (Rios-Rull, 1992); and increasing returns to scale (Devereux, Head, and Lapham, 1996). In this section, we present a stylized business cycle model for the Chilean economy and discuss the rationale for the main extensions we later test. Based on the description of the salient characteristics of economic cycles in Chile presented in section 1 and with the purpose of evaluating the relative contribution of macroeconomic policies, we develop a model that focuses on government expenditures and monetary shocks and includes real-side shocks as captured by technological shocks. The main characteristic of our model is that it encompasses within the framework of a general equilibrium setup a number of important features of the economy, including productivity growth, fiscal expenditures, monetary policy, and labor market rigidities. The main drawback is that it neglects some the real and financial aspects of international business cycles and their effect on the private sector.

This section also presents the algorithms to obtain analytical and numerical solutions to the general equilibrium optimization problem. Here, our discussion only sketches the main issues, and we refer the reader to Cooley (1995) for detailed discussions on the different techniques.

2.1 A Model with Monetary and Fiscal Policy and Labor Rigidities

We analyze the importance of technological, fiscal, and monetary shocks as the sources of aggregate fluctuations in Chile. The analysis emphasizes the role of real and monetary frictions, such as quantitative labor rigidities, a cash-in-advance constraint, and wage contracts.

We develop a general model economy characterized by a government that engages in fiscal and monetary policy, a large number of identical firms, and a large number of identical consumers, all of whom are infinitely lived. Later, we simplify this general model on several dimensions to emphasize specific features of the model economy. In all models calibrated below, the production function is taken to be the same, while the different specifications we test are obtained through changes in the utility function and the nature of government policies.

In our general model, money is held because it is required to purchase consumption goods or some subset of consumption goods. We introduce this cash-in-advance motive for holding money into the basic indivisible labor RBC model. Money is created by the government according to an exogenous law of motion. In addition, government taxes consumption and collects the revenues of taxation to finance government consumption and lump sum transfers. Initially, there is no money illusion; nonneutralities arise only because anticipated inflation acts as a distortionary tax on activities involving the use of cash. The economy will be neutral with respect to unanticipated changes in the money supply. Later, we incorporate wage contracts into the model, in order to analyze the properties of an economy in which monetary policy is not neutral.

Each household's objective is to choose sequences of cash and credit consumption of goods, represented by $\{c_{1t}\}_{t=0}^{\infty}$ and $\{c_{2t}\}_{t=0}^{\infty}$, respectively; hours of leisure $\{h_{1t}\}_{t=0}^{\infty}$; investment $\{i_{1t}\}_{t=0}^{\infty}$; and money to be carried into the next period $\{m_{1t}\}_{t=0}^{\infty}$. The households maximize the expected discounted utility,

$$\max E \sum_{t=0}^{\infty} \beta^t \left[\alpha \log c_{1t} + (1 - \alpha) \log (c_{2t} + \pi g_t) - \gamma h_t \right], \quad (1)$$

subject to several constraints. The first is their budget constraint,

$$(1 + \tau_t) P_t c_{2t} + p_t i_t + m_{t+1} = P_t (w_t h_t + r_t k_t) + m_t, \quad (2)$$

which states that expenditures in period t on cash goods, c_{1t} , on credit goods, c_{2t} , on investment goods, i_t , and on money to be carried into the next period, m_{t+1} , cannot exceed their income. They have various sources of income, including income from renting capital to firms, $r_t k_t$ and from allocating part of their one unit of time to work, $w_t h_t$. Another source is currency carried from the previous period, m_t , plus a nominal transfer (or tax) paid at the beginning of period t , T_t , as shown next in the cash-in-advance restriction:

$$(1 + \tau_t) P_t c_{1t} = T_t + m_t. \quad (3)$$

The government taxes both types of private consumption at the tax rate τ_t . P_t is the price level in period t . Capital next period is assumed to be equal to new investment plus what remains after depreciation:

$$k_{t+1} = (1 - \delta) k_t + i_{t+1}. \quad (4)$$

The utility function specification follows Hansen (1985) in assuming that households can work a fixed number of hours, h_t , or none at all. At the aggregate level, the model predicts that a certain fraction of workers is employed h_t hours per period and a certain fraction is unemployed. This assumption, which is represented by the linearity of leisure in the utility function, allows greater substitution between leisure at different dates.¹⁰ Finally, government consumption in period t , g_t , is assumed to be weighted in utility by π . This weight depends on the relative price of private consumption of the cash good and public consumption. If $\pi = 1$, then public consumption and private cash-consumption goods are perfect substitutes. If $\pi = 0$, however, public consumption does not affect the utility of the households.

The per capita money supply is assumed to grow at the rate $e^{\mu_t} - 1$ every period, that is,

$$M_{t+1} = e^{\mu_t} M_t, \quad (5)$$

10. The standard specification, called divisible labor, introduces leisure as $\gamma \log h$ into the utility function. For a detailed description of the indivisible labor setting, see Rogerson and Wright (1992).

where μ is revealed at the beginning of period t . In this context, the government budget constraint is given by,

$$P_t g_t + T_t = \tau_t P_t (c_{1t} + c_{2t}) + M_{t+1} - M_t. \quad (6)$$

The representative firm seeks to maximize profit, which is equal to $Y_t - w_t H_t - r_t K_t$. Aggregate output, Y_t , is produced according to the following constant-return-to-scale technology,

$$Y_t = e^{z_t} K_t^\theta H_t^{1-\theta}, \quad (7)$$

where K_t and H_t are the aggregate capital stock and labor input, respectively.

The technology shock, z_t , is assumed to be revealed at the beginning of period t . The first-order conditions for the firm's problem yield the following functions for the wage rate and the rental rate of capital:

$$w_t = (1 - \theta) e^{z_t} \left(\frac{K_t}{H_t} \right)^\theta \text{ and} \quad (8)$$

$$r_t = \theta e^{z_t} \left(\frac{H_t}{K_t} \right)^{1-\theta}. \quad (9)$$

Finally, the following market-clearing constraint is assumed to be satisfied:

$$c_{1t} + c_{2t} + i_t + g_t = e^{z_t} K_t^\theta H_t^{1-\theta}.$$

The stochastic shocks evolve according to the following laws of motion:

$$\begin{aligned} z_{t+1} &= (1 - \rho_z) \bar{z} + \rho_z z_t + \varepsilon_{t+1}^z, \\ \mu_{t+1} &= (1 - \rho_\mu) \bar{\mu} + \rho_\mu \mu_t + \varepsilon_{t+1}^\mu, \\ g_{t+1} &= (1 - \rho_g) \bar{g} + \rho_g g_t + \varepsilon_{t+1}^g, \text{ and} \\ \tau_{t+1} &= (1 - \rho_\tau) \bar{\tau} + \rho_\tau \tau_t + \varepsilon_{t+1}^\tau. \end{aligned} \quad (10)$$

To guarantee a stationary solution in the limit, we transform variables so that all variables in the deterministic version of the household's problem converge to a steady state. In particular, we define

$$\hat{m}_t = \frac{m_t}{P_t}; \hat{P}_t = \frac{P_t}{M_{t+1}},$$

and we use this to eliminate m_t and P_t from the problem.

The Bellman equation for the household's problem can now be written as follows:

$$v(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t) = \max \left[\alpha \log c_{1t} + (1 - \alpha) \log (c_{2t} + \pi g_t) - \gamma h_t + \beta E_t(z_{t+1}, \mu_{t+1}, \tau_{t+1}, g_{t+1}, K_{t+1}, k_{t+1}, \hat{m}_{t+1}) \right]$$

subject to

$$\begin{aligned} c_{1t} &= \frac{1}{1 + \tau_t} \left[T_t + \frac{m_t}{P_t} \right], \\ c_{2t} &= (1 - \theta) e^{z_t} \left(\frac{K_t}{H_t} \right)^\theta h_t + \theta e^{z_t} \left(\frac{H_t}{K_t} \right)^{1-\theta} k_t - i_t - \frac{m_{t+1}}{P_t}, \\ T_t &= \frac{e^{\mu_t} - 1}{P} - g_t y_t, \end{aligned} \tag{11}$$

$$I_t = K_{t+1} - (1 - \delta) K_t, \text{ and}$$

$$i_t = k_{t+1} - (1 - \delta) k_t,$$

and to the decision rules

$$\begin{aligned} K_{t+1} &= k(z_t, \mu_t, \tau_t, g_t, K_t), \\ H_{t+1} &= h(z_t, \mu_t, \tau_t, g_t, K_t), \text{ and} \\ P_{t+1} &= p(z_t, \mu_t, \tau_t, g_t, K_t). \end{aligned} \tag{12}$$

The last line gives the perceived functional relation between the aggregate state, $(z_t, \mu_t, \tau_t, g_t, K_t)$, and per capita investment, per capita hours, and the price level. In equilibrium, these functions must satisfy the requirements of the following definition: A recursive competitive equilibrium consists of a set of decision rules for the household,

$$c_{1t}(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t), c_{2t}(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t),$$

$$k_{t+1}(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t), h_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t), \text{ and}$$

$$m_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t);$$

a set of per capita decision rules, $K_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t)$ and

$$H_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t);$$

pricing functions, $P_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t)$,

$$w_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t), \text{ and } r_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t);$$

a government transfer function, $T_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t)$; and

a value function, $v_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t)$,

such that households optimize, solving the functional equation $v_t(z_t, \mu_t, \tau_t, g_t, K_t, k_t, \hat{m}_t)$ from the previous Bellman problem, given the pricing functions and the per capita decision rules and the associated decision rules of c_1 , c_2 , k , h , and \hat{m} ; the firm optimizes, solving the functions w and r given by equation (8); the government satisfies its budget constraint, given by equation (6); and individual decisions are consistent with aggregate outcomes:

$$K(z, \mu, \tau, g, K) = K'(z, \mu, \tau, g, K),$$

$$h(z, \mu, \tau, g, K) = H'(z, \mu, \tau, g, K), \text{ and} \quad (13)$$

$$\hat{m}'(z, \mu, \tau, g, K) = 1.$$

We solve for the linear per capita decision rules to yield a linear-quadratic approximation of this economy. The methods employed are described in detail in Hansen and Prescott (1995).

Finally, if we introduce several simplifications, we can transform the previous general model into a standard real business cycle model (as in Prescott, 1986) or a real business cycle model with fiscal policy as the only policy source of aggregate shocks (as in McGrattan, 1994a). For example, if we eliminate the cash-in-advance constraint and set $m_t = g_t = \tau_t = 0$, for all t , and $\alpha = 1$, the model converges to a standard real business cycle economy, where technology shocks are the sole source of fluctuations.

2.2 Introducing Nominal Wage Rigidities

The empirical evidence, presented in section 1, shows that both prices and wages are highly persistent in Chile. Furthermore, a significant portion of the labor force (especially manufacturing) participates in long-term contracts, and labor markets show evidence of rigidities in that aggregate hours fluctuate more than wages do. A relevant question, within this context, is how relevant nominal contracts are, in practice, as a propagation mechanism of nominal shocks in Chile.

Several papers have studied the implications of nominal wage contracts in the United States, within the equilibrium business cycle literature (see, for example, Cooley and Hansen, 1995). Here, we incorporate nominal wage contracts to evaluate the relevance of nominal rigidities for the main features of the Chilean business cycles.

We modify the cash-in-advance model studied in the previous section, following Cooley and Hansen (1995). Specifically, we impose the constraint that the nominal wage rate for period t be agreed one period in advance. In other words, at the end of period $t - 1$, the nominal wage rate for period t is competitively determined on the basis of expectations about the technology, fiscal, and monetary shocks. Households then choose consumption and investment in period t , after the shocks are revealed. In addition, firms unilaterally choose employment to equate the marginal product of labor to the realized real wage.

From the first-order condition for the firm's problem, we know that

$$w_t = (1 - \theta) e^z \left(\frac{K_t}{H_t} \right)^\theta. \quad (14)$$

In this setting, this implies that

$$\log W_t^c = \log(1 - \theta) + \theta(\log K_t - \log \hat{H}_t) + E[\log P_t | \Omega], \quad (15)$$

where W_t^c is the nominal wage rate, which is a function of z_{t-1} , μ_{t-1} , g_{t-1} , and τ_{t-1} . Individual's consumption and investment choices are functions of the full state vector, $(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_t, k_t, m_t)$ while per capita consumption, investment, and employment are functions of the aggregate full state vector $(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_t)$. Furthermore, Ω is the aggregate information set, consisting of $(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_t)$. Finally, \hat{H}_t is the expected labor input given Ω , for which W_t^c is the market-clearing wage. Taking W_t^c as given, households choose their desired labor supply, \hat{H}_t , as a function of $(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_t, k_t, m_t)$. The firm, also taking W_t^c as given, chooses its demand for the expected labor input by maximizing expected profits given the information set, Ω . The resulting equilibrium contract wage will equate the conditional expected value of the marginal product of labor multiplied by the price level, given Ω .

Once the full state vector $(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_t)$ is revealed, the firm chooses the actual hours worked, H , such that the marginal product of labor is equal to the realized real wage. Together with equation (14), we have that

$$H(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_t) = \left[\frac{(1 - \theta)e^{z_t} P_t}{W_t^c(\Omega)} \right]^{\frac{1}{\theta}} K_t. \quad (16)$$

Using equation (16) to eliminate W_t^c , we obtain

$$\log H_t = \log \hat{H}_t + \frac{1}{\theta} [\log P_t - E(\log P_t | \Omega)] + \frac{1}{\theta} \varepsilon^z. \quad (17)$$

Equation (17) implies that $\log H_t - \log \hat{H}_t$ is an independent and identically distributed (i.i.d.) random variable with zero mean. Finally,

$$\log h_t = \log \hat{h}_t + \frac{1}{\theta} [\log P_t - E(\log P_t | \Omega)] + \frac{1}{\theta} \varepsilon^z, \quad (18)$$

and, therefore, households understand that their choice for $\hat{h}_t(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_r, k_r, m_p)$ will differ from their actual hours worked, $h(z_{t-1}, \mu_{t-1}, \tau_{t-1}, g_{t-1}, K_r, k_r, m_p)$, by the realization of this random variable.

As before, in order to solve the representative household dynamic programming problem, we transform the price level and monetary stock so that all variables are stationary in the limit.

3. PARAMETERIZATION OF THE CHILEAN ECONOMY

The models were parameterized using quarterly data for the 1986–2000 period. The data are expressed in real 1986 pesos and were deseasonalized using the X-12-ARIMA procedure (sources and detailed definitions of the data are described in the appendix). Most macroeconomic variables such as GDP, consumption, and investment were obtained from national accounts compiled by the Central Bank. The data were adjusted to match the variables in the model. We used Gallego and Soto's (2001) breakdown of private consumption into durable and nondurable goods. These series does not cover housing, so output series were adjusted to exclude the imputed housing services and include the services provided by the stock of durable goods. Total consumption includes private consumption in nondurable goods and government consumption. Gross investment figures were also adjusted to exclude residential construction (that is, housing) and include purchases of durable goods and public investment.

The capital stock series were obtained recursively using the perpetual inventory method, based on an estimate of the end-of-period capital stock in machinery and nonresidential buildings for 1985 by Hofman (2000). We included also the stock of durable goods calculated by Gallego and Soto (2001). We assumed a quarterly depreciation rate (δ) of 2.0 percent. The depreciation rate computed by regressing the depreciation series on the capital stock yields a similar estimate of 1.9 percent. For the 1986–2000 period the capital-to-quarterly output ratio is 9.2.

The breakdown of time between work and leisure was obtained as follows. Total available hours per week were computed by multiplying the labor force by 100 hours per week. Total hours worked per week were computed using average hours worked and employment. We obtained an estimated share of leisure of 57 percent, which is substantially below the standard 70 percent in benchmark models for developed economies. Casual evidence suggests our estimate is likely

to be accurate since part-time work is very uncommon in the formal labor market in Chile and occasional surveys tend to support the notion that work schedules are markedly longer than in developed economies. The complete set of parameters is displayed in table 2.

Table 2. Parameterization

Model	Parameter						
	β	δ	γ	θ	π	μ	α
Frictionless labor, no government	0.9787	0.02	1.0302	0.4	—	—	—
Labor rigidities, no government	0.9787	0.02	1.8654	0.4	—	—	—
Labor rigidities, government	0.9787	0.02	1.7829	0.37	0.45	—	—
Labor rigidities, government and money	0.9787	0.02	1.7829	0.37	0.45	0.04	0.753

Source: Authors' calculations.

Some of the parameters were obtained from the Euler conditions of the general equilibrium models described before. For example, the discount factor was obtained from the Euler condition for consumption, $\beta = (1 + r)^{-1}$. We used the 1986–2000 annualized average of the real interest rate (9.1 percent) to obtain an estimate of β of 0.978. The share of capital in output, θ , was also obtained from the first-order conditions of the optimization problem,

$$\theta = \frac{1 - \beta(1 - \delta)}{\beta(y/k)} .$$

The calibrated parameter is 0.40 in models that exclude the government and 0.36 in models that include the government. These values are much lower than the factor share of capital in GDP reported by the Chilean national accounts (0.59). We do not use this estimate for two reasons. First, measured labor compensation in countries like Chile fails to account for the income of most self-employed and family workers, who make up a large fraction of the labor force. Gollin (2002) shows that for countries with sufficient data to adjust for this mismeasurement, the resulting capital shares tend to be close to 0.30. In fact, the estimate for the Chilean economy is 0.367. Second, a high capital share implies implausibly high rates of return on capital in our numerical experiments. A capital share of 59 percent would imply an annual real interest rate of over 22 percent.

The parameter of leisure in the utility function (γ) also depends on the specification of the labor market and the presence of the government. For models that assume a frictionless labor market and no government, parameter γ was calibrated as

$$\gamma = \frac{(1-\theta)h}{n[1-\delta(k/y)]}, \quad (19)$$

while in models that consider both institutional rigidities in the labor market and the presence of the government, this parameter was calibrated as

$$\gamma = \frac{(1-\theta)h}{(1+\tau)n[1-\delta(k/y)-g(1-\pi)]}. \quad (20)$$

The calibrated γ parameters are in the range [1.05, 1.76], suggesting that there is little curvature in the labor supply function.

In the absence of microeconomic studies of the Chilean case, the proportion of government expenditures that is valued by consumers, π , was estimated using the following Euler equation:

$$\frac{U'(c_t)}{\beta U'(c_{t+1})} = 1 + r_t - \delta = \frac{c_{t+1} + \pi g_{t+1}}{\beta(c_t + \pi g_t)}. \quad (21)$$

From this first-order condition, we ran the following nonlinear regression:

$$c_t = \frac{1}{\beta(1+r_t-\delta)} c_{t-1} + \pi \left[g_t - \frac{g_{t-1}}{\beta(1+r_t-\delta)} \right] + \varepsilon_t. \quad (22)$$

The estimated parameter is $\pi = 0.45$ (with a standard deviation of 0.26), implying that less than half of government expenditures is valued by consumers as a substitute for private consumption.

To obtain an estimate of the proportion of the transactions made by consumers using cash, we used the Euler equations for consumption, which implies

$$\frac{C_t}{C_t^R} = \frac{1}{\alpha} + \frac{1-\alpha}{\alpha} R_t, \quad (23)$$

where C_t/C_t^R is the inverse proportion of cash goods in total consumption. Since cash-in-advance restrictions hold, $C_t/C_t^R = C_t/M_t$. Following Cooley and Hansen (1995), we regressed the ratio of nondurable consumption money (M1) on the nominal interest rate. We estimated the model using nonlinear least squares and obtained a point estimate of 0.753 (with a standard deviation of 0.005). This estimation is not necessarily an accurate measure of cash goods, since M1 includes money held by firms, but the latter is a very small proportion of money balances in the Chilean case.

The dynamic stochastic general equilibrium models consider four forcing variables (namely, technology shocks, government consumption, taxes, and money growth). Technology shocks were obtained directly from the data using the calibrated factor shares as $\lambda_t = y_t/(k_t^\theta h_t^{1-\theta})$. As mentioned in section 1, the processes of the four shocks are parameterized estimating the following canonical regressions:

$$\Delta \log x_t = \bar{x}_t (1 - \rho_x) + \rho_x \log x_{t-1} + \varepsilon_t^x. \quad (24)$$

The values of \bar{x} correspond to the average sample values of each variable. The average technology shock, $\bar{\lambda}$, was set at 1.0 since it is only a scale parameter. The average growth in the per capita money supply is 4.0 percent, while government consumption amounts to 8.9 percent of GDP and taxes 14.8 percent. The AR(1) processes fitted to the detrended variables yield the coefficients in table 3 and show no sign of residual correlation. We also computed the variance of the innovations of these shocks ($\sigma_{\rho_x}^2$), as shown in table 3.

Table 3. Stochastic Processes of Innovations

Forcing variable	\bar{x}	ρ_x	$\sigma_{\rho_x}^2$
Technology shock	1.000	0.981	0.0099
Money growth	0.040	0.506	0.0084
Government consumption	0.089	0.760	0.0094
Taxes	0.165	0.846	0.0124

Source: Authors' calculations.

4. TESTING REAL BUSINESS CYCLE MODELS IN AN EMERGING ECONOMY

Before we present the simulation results, we evaluate how the parameters of the Chilean economy compare with those used in studies of developed economies. Table 4 presents a summary of the key parameters. The Chilean economy, like other emerging economies, differs from developed economies in fundamentals aspects. First and foremost, capital is more scarce in emerging economies than in developed economies. As presented in the table, the ratio of capital to annual output in Chile is markedly lower than in the United States. Real interest rates are therefore substantially higher, reaching 9.1 percent in the 1986–2000 period; this is almost twice as high as the rates considered in benchmark models for developed economies (McGrattan, 1994a; Cooley and Hansen, 1995; Backus, Kehoe, and Kydland, 1995). This, in turn, implies that intertemporal effects are less important in Chile because the future is more heavily discounted.

Table 4. Comparison of Key Parameters^a

Parameter	Chile (1986–2000)	United States (1947–1987)	United States (1954–1991)
Capital-output ratio	9.25	10.70	13.30
Discount rate	0.98	0.99	0.99
Leisure time	0.58	0.73	0.69
Labor curvature			
Frictionless market	0.99	2.33	2.53
Market rigidities	1.70	3.22	—
Share of gov. expend. in utility function	0.47	0.00	—
Volatility of GDP	2.20	1.81	1.72
Variance of innovations			
Technology	0.0099	0.0096	0.0070
Money	0.0251	—	0.0089
Government expenditures	0.0094	0.0061	—

Source: Authors' calculations.

a. The values for Chile are the authors' calculations for this paper; the values for the United States (1947–1987) are from McGrattan (1994a); and the values for the United States (1954–1991) are from Cooley and Hansen (1995).

A second important difference is the working of labor markets. The most striking feature is the curvature of labor in the utility function. Substitution—a feature that does not depend on labor market rigidities—is in the range of 2.33–3.22 in the United States; it is less than half that in Chile. This reflects the smaller amount of leisure

time allocated by Chilean workers, as well as the larger share of capital in factor incomes. Moreover, Hansen (1985) substantially improves the ability of real business cycle models to replicate the U.S. data on output and labor markets when he increases this parameter from 2.33 to 3.22.

The third important difference between emerging and developed economies involves the volatility of shocks and their effect on output and its components. The volatility of output in Chile—measured as the variance of the detrended log of GDP—is 30 percent higher than in the United States and as much as 20 percent higher than in the European economies (European data are taken from Backus, Kehoe, and Kydland, 1995). The volatility of technological shocks seems to be very similar in Chile, the United States, and Europe. Money shocks, however, are three times larger in Chile than in the developed countries, and inflation and prices are therefore also twice as volatile in Chile than in the United States. Government expenditures in Chile are 50 percent more volatile than in the United States and most European economies, reflecting the dependence of the Chilean fiscal account on a narrower tax base.

The last notable difference is in consumers' valuation of the goods provided by the government. McGrattan (1994a) estimates an extreme case for the U.S. economy: zero valuation. In the Chilean case, the estimated value is substantially larger, indicating that consumers benefit from government expenditures but also need to smooth out this additional source of stochasticity.

4.1 Simulation Results

Table 5 reproduces the main indicators of the Chilean business cycle we would like to replicate using our RBC models. Our simplest model (labeled model 1 in the table) corresponds to the case in which we exclude the government, allow for divisible labor, and introduce only one source of stochasticity in the form of technological shocks (this is the simplest Kydland-Prescott type of model). The results show that the model is successful in replicating a number of the features of the data: it reproduces 75 percent of the volatility of output and investment, but falls short of matching that of consumption, labor supply, and capital stock.¹¹ It also produces a positive and significant correlation between hours worked

11. The estimated volatility of the stock of capital (1.32) is distorted by the 1999–2000 recession and the limitations of the HP filter. When we computed it for the 1986–1998 period, we obtained a value of 0.90, which is higher than values for the United States and Europe (0.5).

and productivity; this is at odds with the data, which shows a negative correlation. This simple model also replicates some of the correlation between the variables and output, but in general terms it is unsatisfactory. For some variables it generates excessive contemporaneous correlation (for example, consumption, investment, and labor productivity), while for others it fails to capture the true relationship, in particular in the case of capital and total hours worked. By construction the model does not replicate any nominal variable.

Table 5. Simulated Business Cycle Models for the Chilean Economy

<i>Model feature, indicator, and variable</i>	<i>Actual data 1986–2000</i>	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>
Model feature						
Labor rigidities	Excluded	Included	Included	Included	Included	Included
Gov. consumption	Excluded	Excluded	Included	Included	Included	Included
Money	Excluded	Excluded	Excluded	Included	Included	Included
Wage indexation	Excluded	Excluded	Excluded	Excluded	Included	Included
Volatility						
Output	2.20	1.65	2.12	2.14	2.22	2.51
Consumption	1.88	0.69	0.82	1.64	2.22	2.01
Investment	8.21	6.08	8.27	9.04	9.70	12.32
Capital	1.32	0.42	0.56	0.59	0.65	0.65
Hours Worked	1.92	0.59	1.38	1.54	1.52	2.54
Labor Product.	1.92	1.08	0.83	1.02	0.84	1.11
Prices	2.12	—	—	—	2.17	1.84
Inflation	0.93	—	—	—	1.29	0.96
Contemporaneous correlation with output						
Output	1.00	1.00	1.00	1.00	1.00	1.00
Consumption	0.60	0.94	0.92	0.64	0.36	0.47
Investment	0.83	0.98	0.98	0.81	0.93	0.94
Capital	0.41	0.08	0.09	0.12	0.10	0.04
Hours worked	0.49	0.98	0.98	0.90	0.97	0.90
Labor product	0.72	0.99	0.93	0.74	0.90	0.19
Prices	-0.26	—	—	—	-0.54	-0.34
Inflation	-0.06	—	—	—	-0.32	0.13
Correlation of hours and wages	-0.38	0.94	0.83	0.37	0.76	-0.24

Source: Authors' calculations.

The second model in the table extends the previous model to include labor market rigidities. This model better represents the data on this dimension, as it now replicates 80 percent of the volatility of hours worked. Likewise, output and investment fluctuations are now almost identical to the data, but consumption and labor productivity remain poorly represented. The model does not correctly replicate the dynamics of the economy, as it attaches too much contemporaneous correlation between most variables and output, and it fails to replicate the correlation between hours worked and labor productivity.

The third model extends the second to include the fiscal side of government activities. As displayed in the table, the introduction of government expenditures significantly improves the ability of the business cycle model to replicate the volatility of consumption. The model's reproduction of the functioning of the labor market is still disappointing, as is apparent in the insufficient volatility of labor productivity and the positive—yet much smaller—correlation between hours worked and productivity. Its estimates of the correlation of output to most variables (namely, consumption, investment, labor productivity) come close to the actual data, although it falls short of replicating the correlation of output to capital.¹²

The results of these first three models suggest, first, that business cycle models are able to replicate a substantial fraction of the observed fluctuations of the real side of the economy; second, that introducing government expenditures is a more promising way to model economic fluctuations than introducing labor market rigidities; and, third, that some dimensions of the working of the labor market are not correctly replicated by these models.

For policy purposes, one would like business cycle models to replicate not only real-side fluctuations, but also nominal variables such as inflation and prices. Moreover, one should expect a gain on the real side if the inability of these three initial models to replicate the volatility of consumption is linked to the existence of liquidity constraints. Our fourth model introduces cash-in-advance constraints to the third model. The model successfully replicates the volatility of the price level and slightly overestimates that of inflation. It would thus seem that the model is able to replicate the volatility of

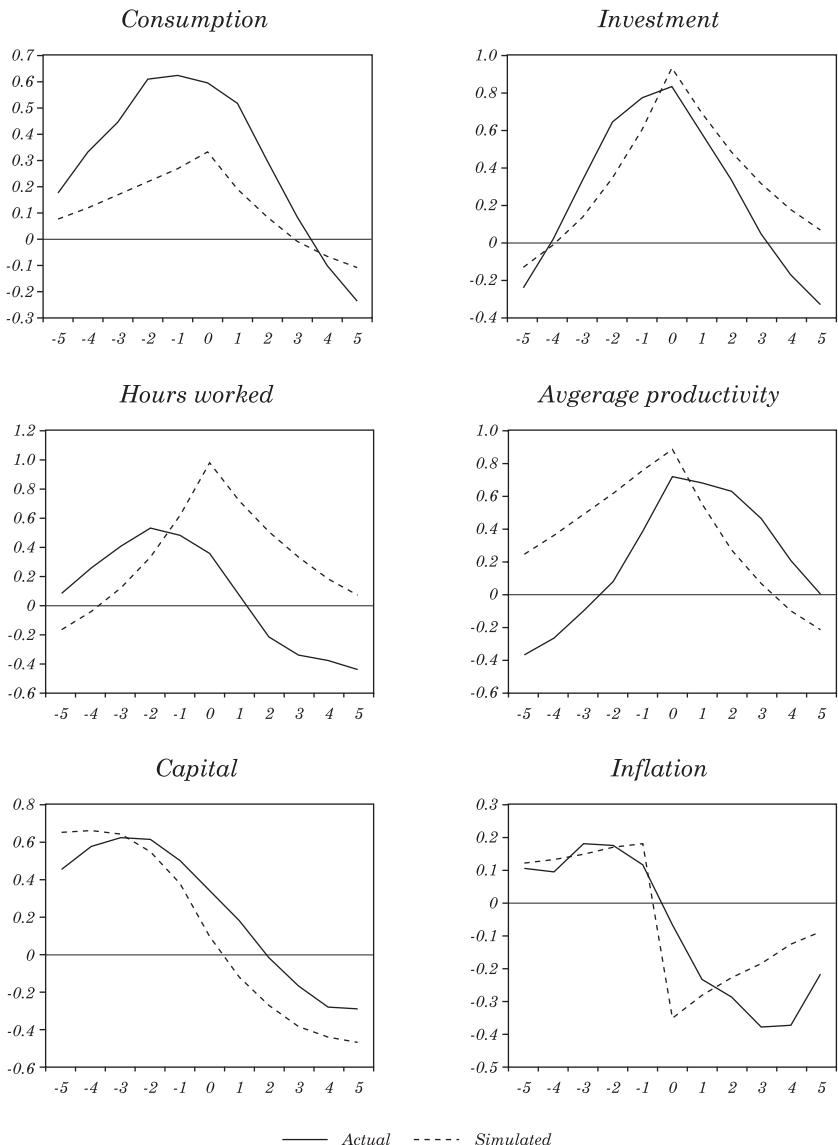
12. Again, when we exclude the 1999–2000 recession, the correlation of output and capital stock is only 0.14.

consumption and its correlation with output and that liquidity constraints are irrelevant. The results are very different, however, when we split consumption into cash goods (that is, liquidity constrained) and credit goods (unconstrained). The volatility of unrestricted consumption is 1.70 and its correlation with output cycles is 0.70; both values are very close to the data. In the case of restricted goods, the volatility of consumption is 2.30, while its correlation with output cycles is 0.34. The model thus matches the data reasonably well along this dimension, as well. Nevertheless, the model continues to produce a labor market equilibrium solution that does not match the data and is unable to find a significant correlation between output and the price level or inflation. As in all previous models that exclude government expenditures, the correlation between hours worked and average productivity levels is disappointingly high.

Finally, our fifth model attempts to overcome the inability of the RBC model to address the correlation between hours worked and productivity levels by introducing wage indexation. The logic of using wage rigidities is that the RBC model is allocating too much variation to labor supply and not enough to changes in labor demand (that is, it allows nominal wages to match changes in relative prices). Once indexation is enabled, the negative correlation between hours worked and productivity is reproduced in general terms. Most features of the nominal side of the data are also adequately reproduced, including the volatilities of inflation and prices. This comes at the cost of inducing excess volatility in almost all real variables, including output, investment, and hours worked. In addition, the working of the labor market is not well captured, since simulated labor productivity is not as volatile as in the data and exhibits little contemporaneous correlation with output.

Our artificial economies should also be able to replicate the dynamics of the different variables in the cycle. We used model 4 to compute the correlations of the main endogenous variables and output arising from the simulated economies and compared them with the same correlations observed in the data. As shown in figure 7, the model tracks the dynamics of investment, the capital stock, and inflation quite closely, but it performs less impressively with regard to consumption, hours worked, and average productivity.

Figure 7. Actual and Simulated Cross Correlations^{a,b}

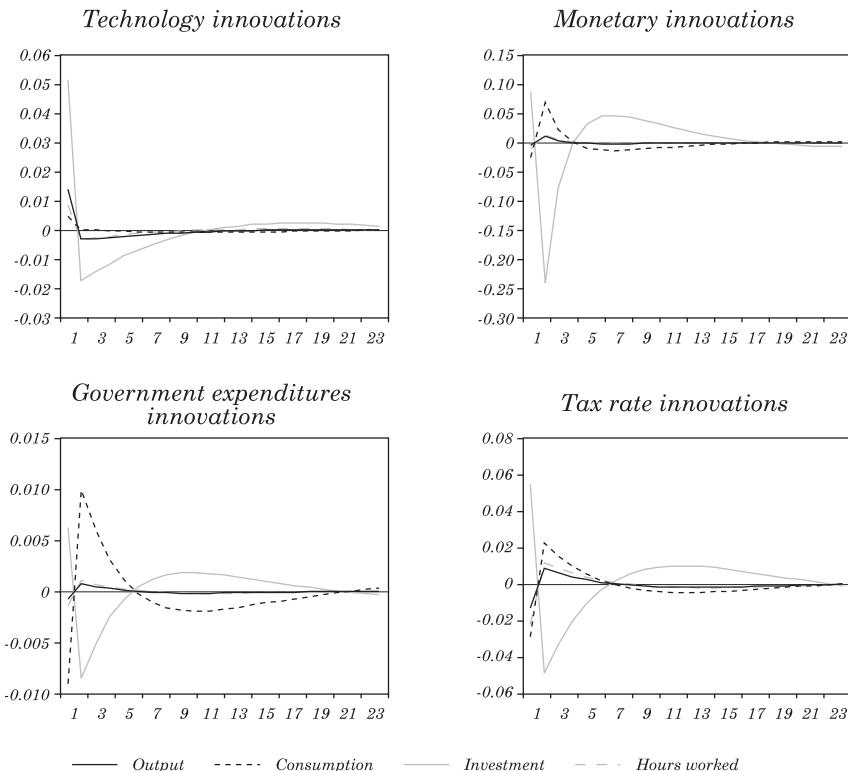


Source: Authors' calculations.

- a. Correlations of the respective variable's logs and leads with GDP.
 b. Quarterly series.

A second way to assess RBC models is to study their dynamic response to innovations in forcing variables. We again selected model 4 to study impulse-response functions because it is our best representation of the data and because it allows us to discuss fiscal and monetary shocks. Figure 8 plots the responses of output, consumption, investment, and hours worked to a one-standard-deviation shock to the technological process, money growth process, government expenditure process, and tax process. The responses to temporary shocks, although quite short-lived, cause agents in the model to modify their consumption, investment, and leisure decisions. The effect on prices causes firms to modify their capital and labor hiring decisions.

Figure 8. Impulse Response Functions^a



Source: Authors' calculations.
a. Quarterly series.

Specifically, a temporary technology shock increases total factor productivity. Since the return to work is temporarily high, individuals are encouraged to substitute intratemporally from leisure to consumption, as well as intertemporally from current leisure to future leisure. Given the transitory nature of the shock, the positive wealth effect is likely to be relatively weak, and the effect on leisure should be small, such that employment is likely to respond positively to the transitory increase in productivity. The increased employment and productivity cause current period output to rise (the current period capital stock remains fixed). The consumption-smoothing motive suggests that a part of this increased output will take the form of additional new capital goods, so that current period investment spending will rise together with current period consumption.

A temporary money growth shock has almost no effect on output and hours, but it has a very large impact on consumption and investment. The transitory increase in the growth rate of money leads to an increase in investment, whereas consumption decreases since output does not change. As the cash-in-advance restriction becomes less relevant, consumption increases and investment decreases.

A temporary government expenditure shock—when the budget is balanced every period—reduces consumption, since government expenditure partially substitutes it in utility. The impact on output and hours worked is initially negative, but very low. Investment then increases and behaves in opposition to consumption through the recovery path toward the steady state.

Finally, the real response of the model to a transitory consumption tax shock is very similar to the response to a transitory government expenditure shock, since the condition of a balanced budget every period implies that increases in government expenditures are accompanied by reductions in the lump-sum transfer to consumers. The main difference resides in the distortionary effect of the consumption tax, as opposed to the lump-sum transfer. Consequently, all variables respond much more strongly than in the previous case.

4.2 How Robust Are RBC Models?

The above parameterization imposes a number of restrictions on the structure of the economy so that the calibrated business cycle model reflects a particular vision of the Chilean economy. A simple test of these restrictions is to change the structure of the parameters and the dynamic nature of forcing variables and then check whether the results depend on these key parameters. We performed this sensitivity analysis on our most ambitious specification (model 4), focusing on the two crucial policy parameters (namely, the proportion of government expenditures valued by consumers, π , and the proportion of cash goods, α) and the imputed share of capital in output, θ . The results, presented in table 6, suggest three main conclusions. First, changing the share of capital and labor in output does not induce important changes in the computed volatilities and correlations with output. Since the capital stock is a very parsimonious series, the model exhibits small volatility in general (except for consumption). Second, when the parameter for the valuation of public goods in the utility function is decreased from 0.45 to 0, the matching of variances and correlations is not evidently affected for output, investment, employment, and the nominal variables. Consumption, on the other hand, reacts in the expected way, becoming less volatile as we eliminate one source of instability for the consumer. Finally, when liquidity constraints are made more stringent (that is, when parameter α increases from 0.75 to 0.85), the general matching of variances and correlations for real variables is only marginally affected. Those for nominal variables improve slightly, suggesting that the value we used may underestimate the true value.

In summary, changing the main parameters of this real business cycle model does not produce important changes in the qualitative conclusions reached above, although in some cases it modifies the numerical outcomes of the model and their distance from the actual data. Although this is not a formal test, the results suggest that the parameterization does, in fact, reflect the underlying structure of the Chilean economy and that the selection of crucial parameters is not too arbitrary.

Table 6. Sensitivity Analysis of the Business Cycle Model of the Chilean Economy

<i>Indicator and variable</i>	<i>Actual data 1986–2000</i>	<i>Model 4 (1)</i>	<i>Increase θ from 0.37 to 0.45 (2)</i>	<i>Increase α from 0.75 to 0.85 (3)</i>	<i>Reduce π from 0.45 to 0 (4)</i>
Volatility					
Output	2.20	2.22	2.08	2.26	2.16
Consumption	1.88	2.22	2.31	2.22	1.65
Investment	8.21	9.70	7.80	9.92	9.15
Capital	1.32	0.65	0.54	0.66	0.10
Hours worked	1.92	1.52	1.48	1.57	1.41
Labor productivity	1.92	0.84	0.72	0.82	0.85
Prices	2.12	2.17	1.99	1.91	2.21
Inflation	0.93	1.29	1.13	1.03	1.33
Contemporaneous correlation with output					
Output	1.00	1.00	1.00	1.00	1.00
Consumption	0.60	0.36	0.28	0.36	0.39
Investment	0.83	0.93	0.94	0.93	0.97
Capital	0.41	0.10	0.08	0.10	0.10
Hours worked	0.49	0.97	0.97	0.97	0.97
Labor productivity	0.72	0.90	0.89	0.89	0.93
Prices	-0.26	-0.54	-0.44	-0.40	-0.57
Inflation	-0.06	-0.32	-0.27	-0.26	-0.33
Correlation of hours and wages	-0.38	0.76	0.76	0.76	0.82

Source: Authors' calculations.

4.3 Do RBC Structures Fit the Data?

Business cycle models can be viewed as restricted versions of more general VAR models. These restrictions, imposed by the structure of the model and the linearization process, can be tested using relatively simple statistical procedures (see Canova, Finn, and Pagan, 1994). The debate among econometricians about the empirical evaluation of these models remains controversial, however (Kydland and Prescott, 1996; Hansen and Heckman, 1996).

Following Canova, Finn, and Pagan (1994), we consider the following representation of model 4 described above (which includes government expenditures, taxes, labor rigidities, and cash-in-advance restrictions):

$$\mathbf{y}_t = \mathbf{A}\mathbf{z}_t \quad \text{and}$$

$$\mathbf{z}_t = \mathbf{F}\mathbf{z}_{t-1} + \mathbf{G}\boldsymbol{\varepsilon}_t, \quad (25)$$

where \mathbf{y} is the vector of variables of interest, \mathbf{z} represents the controlled and uncontrolled states (the latter are labeled x), $\boldsymbol{\varepsilon}$ represents the innovations, and \mathbf{A} , \mathbf{F} , and \mathbf{G} are matrices of coefficients. These matrices are, in general, combinations of the deep parameters presented in table 2; model 4 thus imposes on matrices \mathbf{A} and \mathbf{F} particular structures that can be tested directly against the sample data.

The first type of test arises from the long-run restrictions contained in matrix \mathbf{A} . When the forcing variables (or uncontrolled states, x) are integrated variables, matrix \mathbf{F} takes the following particular form:

$$\begin{vmatrix} \gamma & \delta \\ 0 & I_p \end{vmatrix},$$

where p of the eigenvalues of \mathbf{F} are unity, while the rest are the eigenvalues of γ . Since the latter are assumed to be less than one in business cycle models, there must be $(n - p)$ cointegrating vectors among the states. This is the first testable hypothesis that can be confronted with the data. In our particular case, the \mathbf{z} vector includes λ , g , μ , τ , and k .

The second testable implication of the RBC model as represented by equation (25) is that the residual of $\mathbf{y}_t - \mathbf{A}\mathbf{z}_t$ ought to be stationary and the cointegrating vector must be \mathbf{A} . Hence, a simple test of stationarity can be conducted to test this restriction.

Table 7 presents unit root tests for the deseasonalized data. The unit root tests do not reject the null hypothesis of nonstationarity in the state variables k and n or in the main variables of interest (output, consumption, and investment). The null is rejected, however, in all forcing variables except tax rates. The evidence is less robust for technology shocks. It is widely accepted that unit root tests can be very misleading as a result of low power, structural breaks, and the like (Hamilton, 1994).

Table 7. Unit Root Tests: Phillips-Perron Methodology^a

Variable	Level		
	Without trend	With trend	First difference
Money growth	-2.71	-4.00	-9.96*
Technology shock	-0.87	-1.76	-5.78*
Government expenditures	-2.04	-3.39	-6.04*
Taxes	-2.34	-2.84	-6.61*
Capital stock	-0.34	-2.34	-2.29
Output	-1.65	0.04	-4.54*
Consumption	-1.26	-0.58	-4.69*
Investment	-2.04	-1.08	-3.33*
Rejection value			
At 5 percent significance	-2.92	-3.50	-2.92
At 10 percent significance	-2.60	-3.18	-2.60

Source: Authors' calculations.

* Rejection of the null hypothesis at the 1 percent significance level.

a. The sample period is from 1986:1 to 2000:4. All data are seasonally adjusted, three-lag truncation.

Treating forcing variables as integrated processes implies that, according to the business cycle model, there should be three cointegrating vectors ($n = 5$, $p = 2$). Table 8 presents the result of estimating cointegrating vectors within the sample data using the Johansen procedure. The RBC restrictions are weakly supported by the data in the sense that we cannot reject the null hypothesis of three cointegrating vectors.

Table 8. Cointegration Tests: Johansen Methodology^a

Eigenvalue	Trace statistic	Critical value: 5 percent	Critical value: 1 percent	No. cointegrating equations
0.63	112.58	76.07	84.45	None **
0.35	58.65	53.12	60.16	At most 1 *
0.28	34.98	34.91	41.07	At most 2 *
0.20	17.39	19.96	24.60	At most 3
0.10	5.43	9.24	12.97	At most 4

Source: Authors' calculations.

* Rejection of the null hypothesis at the 5 percent significance level.

** Rejection of the null hypothesis at the 1 percent significance level.

a. The sample period is from 1986:1 to 2000:4. All data are seasonally adjusted, with four lags. The series used are capital, hours worked, technology shocks, money growth, and government expenditures.

Although the data suggest the existence of three cointegrating vectors, our RBC model does not necessarily produce exactly the same three vectors contained in the data. The second set of tests considers the implied reduced form of output, consumption, and investment, as described in equation (26), in terms of a combination of the deep parameters of the model. Since all endogenous variables are I(1), under cointegration η should be I(0).

$$\begin{aligned} y_t &= f_1(k_t, \tau_t, \lambda_t, g_t, \mu_t) + \eta_{y_t}, \\ c_t &= f_2(k_t, \tau_t, \lambda_t, g_t, \mu_t) + \eta_{c_t}, \quad \text{and} \\ i_t &= f_3(k_t, \tau_t, \lambda_t, g_t, \mu_t) + \eta_{i_t}. \end{aligned} \tag{26}$$

Augmented Dickey-Fuller tests of cointegration generated values of -3.85 for output, -5.43 for consumption, and -3.59 for investment. The three equations thus cointegrate, providing econometric support for the RBC model, its implied decision rules, and the dynamics of endogenous variables.

5. SUMMARY AND CONCLUSIONS

The goal of this paper was to test the ability of various RBC type of models to replicate the salient characteristics of the observed aggregate fluctuations of the Chilean economy in 1986–2000 and to provide insights into the contribution of fiscal and monetary policies as sources of business cycles. The Chilean economy provides an interesting case because it presents both similarities with developed economies and important idiosyncrasies that challenge RBC theory.

Our main findings can be summarized as follows. First, business cycle models are able to replicate much of the observed fluctuations of both the real and monetary sides of the economy. Second, of the five models considered in this paper, an economy with government expenditures and labor indivisibility emerges as the best representation to account for short-term fluctuations in Chile. Although monetary shocks and nominal contracts improve the predictions of that model in some dimensions, they either generate excessive volatility or fail even further to account for the observed labor market behavior. Finally, replicating the fluctuations in

consumption observed in the data may require placing additional constraints on the optimizing behavior of agents in our models.

This paper provides strong evidence of the relevance of supply-side shocks as sources of aggregate fluctuations in Chile. The main challenge for the future consists in better understanding the connection between international business cycles and local market dynamics, together with the behavior of labor markets.

APPENDIX

Data Sources and Definitions

The data are expressed in real domestic currency (1986 pesos) and were deseasonalized using the X-12-ARIMA procedure. The following series were obtained from *Indicadores económicos y sociales de Chile, 1960–2000* (Central Bank of Chile, 2001) and its companion CD and correspond to national accounts definitions: GDP, total consumption, gross investment, and housing services. We obtained money (M1A), interest rates, the consumer price index, population, and labor force from the same source. GDP series were adjusted to include the services provided by the stock of durable goods and exclude the imputed housing services. The breakdown of consumption into durable and nondurable goods, as well as the stock of durable goods and its imputed services, were obtained from Gallego and Soto (2001). Gross investment figures were adjusted to exclude housing (residential construction) and include purchases of durable goods. The capital stock series was obtained recursively using the end-of-period capital stock in machinery and nonresidential buildings estimated for 1985 by Hofman (2000), the gross investment series including durable goods, and a quarterly depreciation rate of 2 percent. Quarterly tax revenues by category were obtained using annual revenue data from the tax authority's webpage (www.sii.cl) and the standard related-series method. Labor force and average hours worked were obtained from the survey *Encuesta de ocupación y desocupación* released quarterly by the University of Chile Economics Department. Total available time was fixed at 100 hours a week.

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A TOOLKIT FOR ANALYZING ALTERNATIVE POLICIES IN THE CHILEAN ECONOMY

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As noted by Leeper (1995) “the business pages of leading newspapers give the impression that the effects of alternative monetary policies on the macroeconomy are well understood and predictable.” They tend “to write with great certainty that when the monetary authority raises interest rates it slows economic growth, and with it inflation, bidding down stocks and bonds. With equal certainty, press accounts report that the monetary policy responds to economic conditions.” Statements like “the recent strength of the economy will prompt the monetary authority to raise interest rates as a preemptive strike against inflation” are not uncommon. With the economy responding to policy and policy responding to the economy, it is hard to tell what causes what. Chile is no exception: similar statements are frequently found in local newspapers.

There is no consensus, however, regarding the interaction of economic conditions and policy. In fact, while several academic papers directly or indirectly try to identify the effects of alternative policies, most of the results found are, to say the least, inconclusive.¹

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1. Rosende and Herrera (1991), Rojas (1993), Eyzaguirre and Rojas (1996), Morandé and Schmidt-Hebbel (1997), Valdés (1998), Parrado (2001), and some specifications of Cabrera and Lagos (2002) find that output and inflation are affected by innovations in monetary policy. Mendoza and Fernández (1994), Morandé, García, and Johnson (1995), Calvo and Mendoza (1999), and some specifications of Cabrera and Lagos (2002) find complete ineffectiveness of the monetary policy to alter their trajectories.

The understanding and measurement of the quantitative effects of monetary policy are essential for evaluating the relative merits of alternative policy arrangements, yet few papers address the issue in an integrated and consistent way.² This paper does just that by combining sound statistical representations with theoretical models. In contrast, most of the empirical literature focuses on providing statistical descriptions of the data, with no correspondence between the statistical model used to develop the stylized facts that are being explained and a theoretical model that is consistent with them.

The effects that different policy arrangements may have on the economy are usually quantified statistically using vector autoregressions (VARs). While this technique may prove to be valuable for forecasting purposes, it is difficult to obtain a correspondence between the impulse response functions that are derived from it and the economic principles that arise from contesting theories (Hamilton, 1994). As discussed below, the VAR impulse response functions may not have any meaningful interpretation given the identifying restrictions imposed on them (they may come from linear combinations of different shocks), and they cannot provide reliable estimates of the effects of alternative policies. From a theoretical standpoint, in turn, few papers use models derived from first principles to address their empirical implications in an integrated fashion, such that they are subject to the Lucas critique from the get go.

This paper overcomes these shortcomings by integrating statistical models that are able to replicate the intertemporal dynamics of key economic variables with dynamic, stochastic, optimizing models. In the presence of a rival theoretical model, the statistical description of the data provides an objective metric with which to evaluate their merits.

The paper is organized as follows: Section 1 briefly describes the main problems that traditional statistical models have when they are used to quantify the effects of alternative policies. Section 2 presents a statistical model that can be used as a metric with which to compare the empirical implications of alternative theoretical models. Section 3 describes and estimates a simple optimizing model for replicating the stylized facts reported in section 2. Section 4 concludes.

2. Schmidt-Hebbel and Servén (2000) develop a deterministic general equilibrium model in which they impose liquidity constraints and wage rigidities. This model is calibrated and presents exercises regarding the effects of alternative policies.

1. IDENTIFIED VARs

VAR models have long been used to describe the dynamic interactions of key macroeconomic variables in an economy. Although these models have proved successful as forecasting tools, they rarely can be used to test competing theories and their results cannot be interpreted with sound economic principles. Some economists argue that this occurs because VARs are restricted versions of more structural models, since VARs usually ignore contemporaneous comovements, and they do not explicitly test any stance regarding the economic principles behind the dynamic interactions encountered. Furthermore, VAR models impose arbitrary decompositions on the variance-covariance matrix of the innovations (usually a Cholesky decomposition), making the impulse response functions sensitive to the ordering of the model. Several methodologies have been developed to overcome this shortcoming. However, these functions do not have any direct interpretation in terms of the dynamic consequences of shocks to any of the underlying innovations.³

Recently developed models try to overcome the shortcomings of traditional VARs. They are known as structural VARs (SVARs) or identified VARs (IVARs). The main characteristic of these models is that they nest traditional VARs and do not impose orthogonality restrictions among the contemporaneous interactions of the variables in the system. They also provide tools that can be used to conduct inference on the restrictions of competing statistical models and, in principle, provide estimates of the impulse response functions that are supposed to recover the underlying structure of the system.⁴ Nevertheless, the robustness of the conclusions drawn from IVAR exercises is questionable, as noted by Cochrane (1998) and more forcefully by Cooley and Dwyer (1998).⁵

3. Pesaran and Shin (1998) develop what they call generalized impulse response functions, which provide impulse response functions that are invariant to the ordering of the unconstrained VAR.

4. Appendix A provides a brief description of the IVAR methodology.

5. The term structural VAR is misleading in the sense that it may give the impression that these statistical objects can be understood as representations of behavioral relations grounded on first principles. This is usually not the case, however, as discussed below. In this paper I prefer to use the term IVAR to make explicit that these models provide tests that can help to decompose impulse response functions in a more formal way, but no structural (behavioral) implications are drawn from them.

1.1 The Usual Practices

As discussed above, several studies attempt to characterize the dynamic consequences of alternative policies in the Chilean economy, but most use traditional VARs and are thus subject to the critiques outlined.⁶ With rare exceptions (such as Calvo and Mendoza, 1999, and Valdés, 1998), the studies do not report confidence intervals for the impulse response functions. Furthermore, the studies that do report them rely on asymptotic approximations of the confidence intervals of the model, without performing formal tests for multivariate normality and vector white noise innovations or correcting for biases in the impulse response functions.⁷ Confidence intervals based on asymptotic approximations can be deceiving when departures from normality are important, given that normality imposes symmetry on them. Asymmetries may also be present when nonlinear structures are important, and positive and negative shocks may thus imply completely different trajectories. In such cases, confidence intervals for the impulse response functions may still be constructed relying on bootstrapping (Sims and Zha, 1995). However, this practice is, itself, subject to two problems. First, most of the variables included in the unrestricted VAR are usually statistically nonsignificant, but the

6. Valdés (1998) estimated what he termed a semi-structural VAR model, but the identifying assumption he imposes makes it no different from a specific ordering of an unrestricted VAR model, and it is not what I understand as an IVAR. His restrictions correspond to a Cholesky factorization in which the variable used to measure the monetary policy stance comes first, thus making it exactly identified. Obviously, no formal tests against alternative orderings or identifying assumptions can possibly be made in this context. In fact, the impulse response of that model can be directly computed without estimating the parameters with the methodology described in appendix A. Other examples of such a practice can be found in García (2001) and Cabrera and Lagos (2002). Parrado (2001) uses the IVAR methodology, but his results are subject to other problems.

7. When estimating VARs or IVARs, it is often forgotten that they need to be correctly specified prior to conducting impulse response exercises. As a minimum, vector white noise innovations are needed—that is, innovations that are orthogonal not only to their own past, but also to the past of the other innovations of the system. Furthermore, given that the construction of confidence intervals for the impulse response functions generally rely on asymptotic approximations, formal tests for multivariate normality of the residuals should be conducted. In the former case, Ljung and Box tests cannot be applied, as they rely on univariate specifications; Wilks, Portmanteau or LRT tests should be employed (see Lütkepohl, 1991, for details). This fact is independent of the information criteria chosen to select a model, given that it is used only to account for parsimony. In the latter case, Jarque-Bera univariate tests for normality are not appropriate, and multivariate specification should be used (Doornik and Hansen, 1994).

bootstrapped model takes their point estimates as given and thus unnecessarily inflates the confidence intervals. Second, and more importantly, the confidence intervals usually considered are constructed using Efron's suggestion, although these intervals do not have the correct coverage if the distribution under consideration is asymmetric, as is well documented. Given that bootstrapping is used precisely for these purposes, Hall's confidence intervals are better suited for dealing with departures from normality.

Another important consideration that has to be taken into account is the way in which some of the previous studies deal with nonstationarities. As Sims, Stock, and Watson (1990) demonstrate, VAR estimates with some integrated series are super consistent, but they have nonstandard asymptotic distributions. Impulse response functions from this type of series can be constructed from Monte Carlo or bootstrap approximations (methods that are now readily available and can be routinely performed). If the nonstationarity comes from deterministic trends, however, incorrectly differentiating the series may impose nontrivial dynamics on the model. In particular, this would incorporate a unit-root-type of vector moving average (MA) process in the series, such that the use of ordinary least squares (OLS) estimation would not be advisable.⁸ Care should thus be given to when and when not to differentiate a variable prior to estimating the VAR.

1.2 Unit Roots and Impulse Response Functions

With the exception of Parrado (2001), all of the studies discussed in the first section choose to differentiate the variable that captures the economy's level of activity (usually the monthly economic activity index, or Imacec). Typical examples of the unbelievable dynamics that result from impulse response functions using first differences on the scale variable can be found in Valdés (1998) and García (2001). Even if one assumes that their models were correctly specified in terms of lag selection and normality and that there were no biases associated with the estimated parameter, they find a significantly negative effect of what they refer to as the monetary policy innovation to the first difference of the scale variable. If the monetary policy innovation has

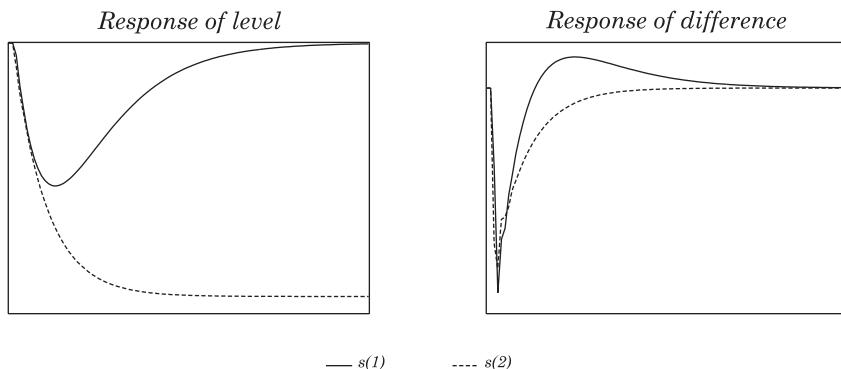
8. In this case, exact (unconditional) maximum likelihood estimation of the parameters should be conducted; this practice is rarely (if ever) followed, given that it is computationally demanding. Chumacero (2001a) describes a computationally efficient way of dealing with this problem.

a negative, though transitory, effect on the growth rate of the scale variable, what are the implications for the level of the series?

Figure 1 shows the implications for both levels and growth rates of a unit shock on the innovations estimated in that case.⁹ For the sake of comparison, I consider two types of shocks. The first, termed $s(1)$, corresponds to the effect (in both levels and differences) of a transitory shock when the scale variable is modeled in levels, thus making the shocks transitory and causing the level to revert to its deterministic trend. The second, $s(2)$, corresponds to the same exercise when the scale variable is modeled in differences. The $s(2)$ shocks on monetary policy have increasing and permanent effects on the level of the series even when the shock is not very persistent in terms of growth rates.

Which type of shock is correct? Chumacero and Quiroz (1996) and Chumacero (2000) find no evidence to support the practice of differentiating series such as Imacec.¹⁰ Even in that case, it is important to consider the implications of the shocks for the levels of scale variables once a unit root is introduced. As figure 1 makes clear, such a mighty power of the monetary policy is difficult to rationalize even in the most extreme of Keynesian models.

Figure 1. Implications of Different Impulse Response Functions



9. The parameters are not chosen to match exactly the impulse response of the studies in which significant effects are found, but are arbitrarily chosen to demonstrate the effects for the level of the series. The essence of the results would not change if the actual impulse response functions reported were used.

10. Chumacero (2001b) shows, at both the theoretical and empirical levels, that it is unlikely for a unit root to be present in scale variables such as Imacec.

1.3 Ordering, Causality, and Interpretation

An even more important problem with these results involves their interpretation. As mentioned, Valdés (1998) and Cabrera and Lagos (2002) use a specific ordering in the construction of the impulse response functions of their VARs, in which the monetary policy innovation is not caused by any other innovation. Although it is common practice to order VARs according to Granger causality results of the variables in levels, the decomposition of the variance-covariance matrix has little to do with that ordering. In fact, there is no theoretical basis for justifying a specific ordering of the impulse response functions generated from a Cholesky decomposition based on Granger causality, as they may have no relation with the order of precedence of the levels. More fundamentally, it is not difficult to imagine a theoretical economy in which none of the monetary variables has any effect whatsoever on the real sector but which presents the dynamics that supposedly justify the results of Valdés (1998) or Cabrera and Lagos (2002).

Consider for example, the case of a closed endowment economy with a representative agent that is interested in maximizing the following:

$$\varepsilon_0 \sum_{t=0}^{\infty} \beta^t u(c_t),$$

subject to

$$y_t + (1 + r_{t-1}) b_{t-1} \geq c_t + b_t,$$

where y is the level of the endowment, c is the level of consumption, b_t is the demand of a risk-free private bond that pays off a net return of r_t in the following period (this return is known at t), $u(\cdot)$ is strictly increasing and strictly concave, β is the subjective discount factor, and ε_t denotes the expectation operator conditional on the information available at time t .

Under the conditions stated above, the gross return on this asset is given by

$$(1 + r_t)^{-1} = \beta \varepsilon_t \left[\frac{u'(y_{t+1})}{u'(y_t)} \right], \quad (1)$$

which simply states that the gross return of the asset is a function of the intertemporal marginal rate of substitution (stochastic discount factor).

Consider now a special case of equation (1), in which I impose a constant relative risk aversion (CRRA) utility function with the Arrow-Pratt relative risk aversion coefficient denoted by γ (inverse of the intertemporal elasticity of substitution). Equation (1) can then be expressed as

$$(1 + r_t)^{-1} = \beta \varepsilon_t \left(\frac{y_{t+1}}{y_t} \right)^{-\gamma}. \quad (2)$$

The return on the asset is determined by solving equation (2), which requires explicitly introducing a law of motion for the endowment process. Consider two of such cases. The first assumes that the log of the endowment is difference stationary (DS) and the second that it is trend stationary (TS):

$$\text{Case 1 (DS): } \Delta \ln y_{t+1} = \alpha + \sum_{i=0}^k \delta_i \Delta \ln y_{t-i} + w_{t+1},$$

where, $w_t \sim N(0, \sigma_w^2)$, and

$$\text{Case 2 (TS): } \ln y_{t+1} = \eta + \alpha t + \sum_{i=0}^l \delta_i \ln y_{t-i} + v_{t+1},$$

where $v_t \sim N(0, \sigma_v^2)$.

In both equations, w and v are innovations, and k and l denote the number of lags necessary to produce them. Under these assumptions, the return on the asset can be computed as follows:

$$r_t \equiv \ln(1 + r_t) = \begin{cases} a_\varepsilon + \gamma \sum_{i=0}^k \delta_i \Delta \ln y_{t-i} & (\text{DS}) \\ a_v + \gamma \sum_{i=0}^l \delta_i \ln y_{t-i} - \gamma v_t & (\text{TS}) \end{cases}$$

where $a_i = \alpha\gamma - \ln\beta - 0.5\gamma^2\sigma_i^2$ for $i = w, v$.

This example shows that Granger causality and VAR results may be completely misleading when one attempts to identify impulse

response functions as effects of alternative policies. I therefore focus on rather simple dynamics that help build the case. Using a first-order autoregressive, or AR(1), process for DS, I compactly characterize the dynamics of the system by

$$\begin{bmatrix} \Delta \ln y_{t+1} \\ \ln(1+r_t) \end{bmatrix} = \begin{bmatrix} \alpha \\ a_w \end{bmatrix} + \begin{bmatrix} \delta & 0 \\ \delta\gamma & 0 \end{bmatrix} \begin{bmatrix} \Delta \ln y_t \\ \ln(1+r_{t-1}) \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} w_{t+1} \\ w_t \end{bmatrix}. \quad (3)$$

Since r_t is known at period t , VAR estimates and Granger causality tests would typically be made in a system that comprises $\Delta \ln y_t$ and $\ln(1+r_t)$. How would Granger causality results from a system like this look? Given that r_t is an exact function of the growth rate of the endowment in period t , there should be a strong contemporaneous correlation between variables whose sign will depend exclusively on the value of δ . (In fact, the contemporaneous correlation should be -1 or 1 , because the relationship among these variables is deterministic.) VAR models and Granger causality tests typically rely on regressions of lagged values of the variables, so Granger causality tests will display bidirectional Granger causality between the asset return and the growth rate.

If y is TS, $\Delta \ln y$ has a unit root in its MA component. With a pure trend stationary process, the system can be conveniently expressed as:

$$\begin{bmatrix} \Delta \ln y_{t+1} \\ \ln(1+r_t) \end{bmatrix} = \begin{bmatrix} \alpha \\ a_v \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta \ln y_t \\ \ln(1+r_{t-1}) \end{bmatrix} + \begin{bmatrix} 1 & -1 \\ 0 & -\gamma \end{bmatrix} \begin{bmatrix} v_{t+1} \\ v_t \end{bmatrix}. \quad (4)$$

Since both variables are functions of innovations, there is strong evidence in favor of unidirectional causality from the asset returns to the growth rate! The endowment presents a combination of two independent innovations, such that the contemporaneous correlation between growth and the asset return should be negative (on average), but possibly nonsignificant and rather small.

This exercise shows that not all that glitters is gold. In both cases, I find statistical evidence in favor of Granger causality from the asset return to the growth rate of the endowment, even though there is no real (economic) causation whatsoever in that direction in this simple setup. If anything, the endowment is the causal variable (in the real sense). Thus an econometrician who chooses to interpret Granger

causality tests and VAR results mechanically may completely misinterpret the actual structure of the economy.

It would not be difficult to replicate impulse response functions such as those described in figure 1 for economies such as those represented by equations (3) and (4) if the analyst takes the leap of faith that the policy instrument used by the monetary authority is the real interest rate (comparable to r). This cannot be the case, however, as demonstrated below. Even if it were, and the authority's instrument accurately reflected the real return of a risk-free bond, impulse response and Granger causality results cannot be interpreted as useful tools for identifying the effects of alternative policies. Economics—and not pure statistics—must be used to do so.

As the examples make clear, VARs or IVARs cannot be used to identify the effects of alternative policies. However, well-specified time series models can be used to provide a (statistically) objective metric for comparing alternative theoretical models (that are robust to the Lucas critique, at least in principle). I discuss this issue in the next section.

2. THE METRIC

This section presents the results of a nine-variable IVAR model for the Chilean economy. The model is intended to provide a good statistical description of the variables included, but I am careful not to provide a structural interpretation of it. Special attention is given to testing the proper order of the model and verifying whether the innovations are jointly Gaussian.

The variables taken into consideration correspond to monthly time series from January 1985 to July 2001 of the log of the industrial production index of the United States (y^*); the log of the first difference of the U.S. wholesale price index (WPI) (p^*); the log of real money holdings in the United States (m^*); the log of the federal funds rate (i^*); the log of the real exchange rate (e); the log of Chile's monthly activity index (y); the log of the first difference of the Chilean consumer price index (p); the log of domestic real money holdings (m); and the log of the monetary policy rate set by the Central Bank of Chile and denominated in UF (d).¹¹ In all cases, a quadratic trend was included to take into account possible smooth changes in trends over time.

11. The *Unidad de Fomento*, or UF, is a unit of account indexed to past and present inflation rates; it is widely used in Chile.

2.1 Parsimony

The first step in estimating the IVAR is to compute the unrestricted VAR. This computation is done following the usual OLS regressions for each variable on the system and choosing the optimal lags. Privilege must be given to a representation that is able to obtain innovations prior to reducing it to a parsimonious representation.

Model selection based on the Akaike information criterion (AIC) tends to choose models that are less parsimonious than the Bayesian (BIC), Hannan-Quinn (HQC), or final prediction error (FPE) criteria. In this case, AIC prefers a model with thirteen lags, while BIC and HQC choose only one lag. Finally, FPE prefers a VAR(2) model. Extensive likelihood ratio tests on the residuals show that even a VAR(1) is able to produce residuals that can be characterized as vector white noise processes but that present important departures from Gaussianity.

Table 1 shows the effect of a phenomenon that is often overlooked in practice. Since all models consider the dynamic interactions of nine variables, increasing the number of lags has nontrivial effects on the parsimony and accuracy of the estimation. In particular, more than 50 percent of the parameters are not statistically significant at standard levels even in the simple unconstrained VAR(1) models. Ignoring this fact may cause any unconstrained version of the model to induce spurious dynamics that are not present in the data. Furthermore, even small-order VAR models—such as a VAR(4)—have a huge saturation ratio (that is, the ratio between the number of parameters estimated in each equation and the sample size). In that particular example, more than 20 percent of the sample is compromised in estimating the parameters of each equation.

Table 1. Implications of the Choice of Different Lags

Order	Number of parameters	Saturation ratio	Percent of insignificant variables
1	108	0.061	0.509
2	189	0.107	0.614
3	270	0.154	0.704
4	351	0.201	0.729
5	432	0.249	0.771
6	513	0.300	0.791
7	594	0.346	0.806
8	675	0.395	0.824
9	756	0.444	0.783
10	837	0.495	0.808
11	918	0.545	0.849
12	999	0.597	0.822

Source: Author's calculations.

Not accounting for parsimony not only affects inference when obtaining bootstrapped confidence intervals, but it may also substantially modify the impulse response functions themselves. Figure 2 shows that this is indeed the case. Even when the traditional Cholesky decomposition is used to compute the impulse response functions, the apparent responses of the variables to the interest rate innovation are enhanced under the unconstrained VAR(2) model, which ignores the fact that more than 61 percent of the variables are redundant.¹²

2.2 Choice of the Impulse response Function

Once the VAR model is estimated, identification tests can be performed to assess the characteristics of the \mathbf{B}_0 matrix that best fits the data if IVAR models are to be considered. Recall that different specifications of this matrix will modify the impulse response functions nontrivially, so this point requires special attention. I used likelihood ratio tests, AIC, and BIC in the line of Leeper (1995) and Leeper, Sims, and Zha (1996) while testing these specifications.¹³

The preferred specification for \mathbf{B}_0 has a similar structure to the Cholesky decomposition. Contrary to the identifying assumption of Morandé and Schmidt-Hebbel (1997) and Valdés (1998), however, monetary instruments should be ordered precisely in the opposite direction, tending to react contemporaneously to innovations in the price equation and output equation. One important feature of using IVAR models is that inference on the contemporaneous associations of the innovations can be performed once the parameters of \mathbf{B}_0 are estimated by maximum likelihood. If this is done, most of the variables considered in \mathbf{B}_0 cannot be considered as statistically significant. Parrado (2001) imposes a different structure on his IVAR model, but most of the variables he considers are also insignificant.

Thus, IVAR models also impose arbitrary decompositions on the impulse response functions that result when statistically insignificant parameters are considered. I therefore report the impulse response functions that are obtained using Pesaran and Shin's (1998) methodology. In contrast with the Cholesky decomposition, generalized impulse response functions do not depend on the ordering of the equations; how-

12. As discussed above, the FPE criteria chooses the VAR(2) model, while BIC and HQ prefer the VAR(1) model. Nevertheless, the parsimonious VAR model in the case of the VAR(1) fails to produce vector white noise errors. I therefore conduct all the following exercises using a VAR(2) as the baseline model.

13. See appendix A for details.

ever, like the Cholesky decomposition, generalized impulse responses are exactly identified and tests for reductions cannot be performed.

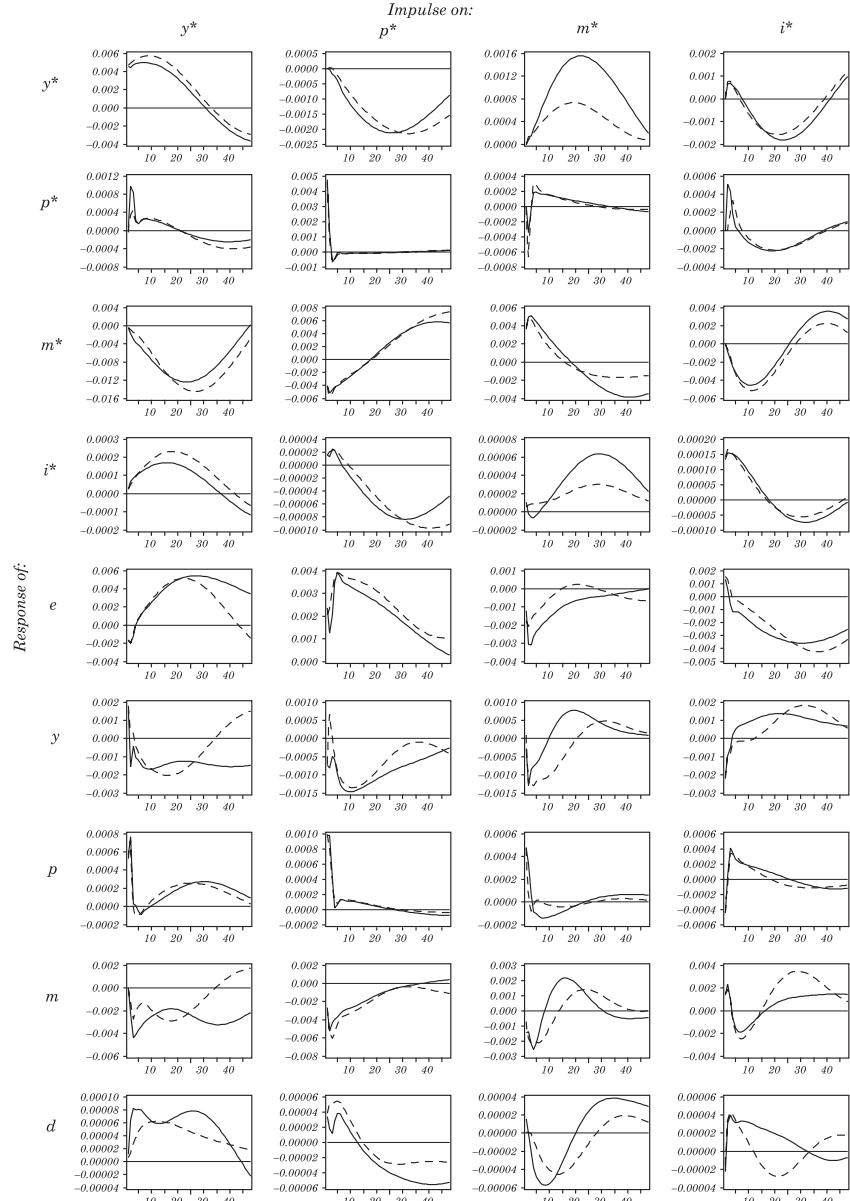
Figure 3 presents the generalized impulse response functions for four years (forty-eight months). Efron's 95 percent confidence intervals are also presented. As discussed above, Efron's bootstrapped confidence intervals may not have the correct coverage in the presence of asymmetries. Since this is precisely one of the sources of departures from normality, Efron's confidence intervals are not advisable.

The last two columns of figure 3 represent the effects of potential candidates for a measure of the monetary policy innovation. If innovations to m are considered monetary policy, surprise changes in the stock of money are persistent and predict subsequent movements in both inflation and output. The latter, however, is very short lived and dies out almost instantaneously. On the other hand, inflation increases only after a few periods (it is not statistically significant initially), and the response to m innovations in this system show what is sometimes called the liquidity puzzle: interest rates do not decline when m jumps upward. The liquidity effect, which hypothesizes that the policy-induced increased liquidity of a monetary expansion should lower interest rates, seems not to be present if innovations to m are considered measures of monetary policy stance.

The liquidity effect is not problematic if the innovations in the UF interest rates are considered monetary policy (last column). In this case, the initial shock can be interpreted as a monetary contraction. Here, the liquidity effect is strong until the fifteenth month and then eventually dies out. In terms of output, the d shock has a short-lived effect of contracting y . The problem with this shock arises when the effect on p is analyzed: monetary contractions tend to increase prices steadily. This results is very common in the literature (Leeper, Sims, and Zha, 1996) and has been labeled the price puzzle. Interpreting either column eight or column nine as a monetary contraction therefore requires accepting that monetary contractions produce inflation, which seems as unlikely as the notion that monetary expansions fail to lower interest rates.¹⁴ However, if d is considered the monetary policy instrument, the ninth column shows very plausible responses. That is, interest rates increase with positive shock on output and inflation.

14. The price puzzle is also present in the impulse response functions of Valdés (1998) when the inflation target is not considered. Several authors conclude that the price puzzle can be eliminated if terms of trade or the price of oil is included (Parrado, 2001). In the present case, however, including terms of trade did not change my results.

Figure 2. Effects of Not Considering Parsimony in Cholesky Impulse Response Functions^a



Source: Author's calculations.

a. Continuous line: parsimonious VAR; dashed line: unconstrained VAR.

Figure 2. (continued)

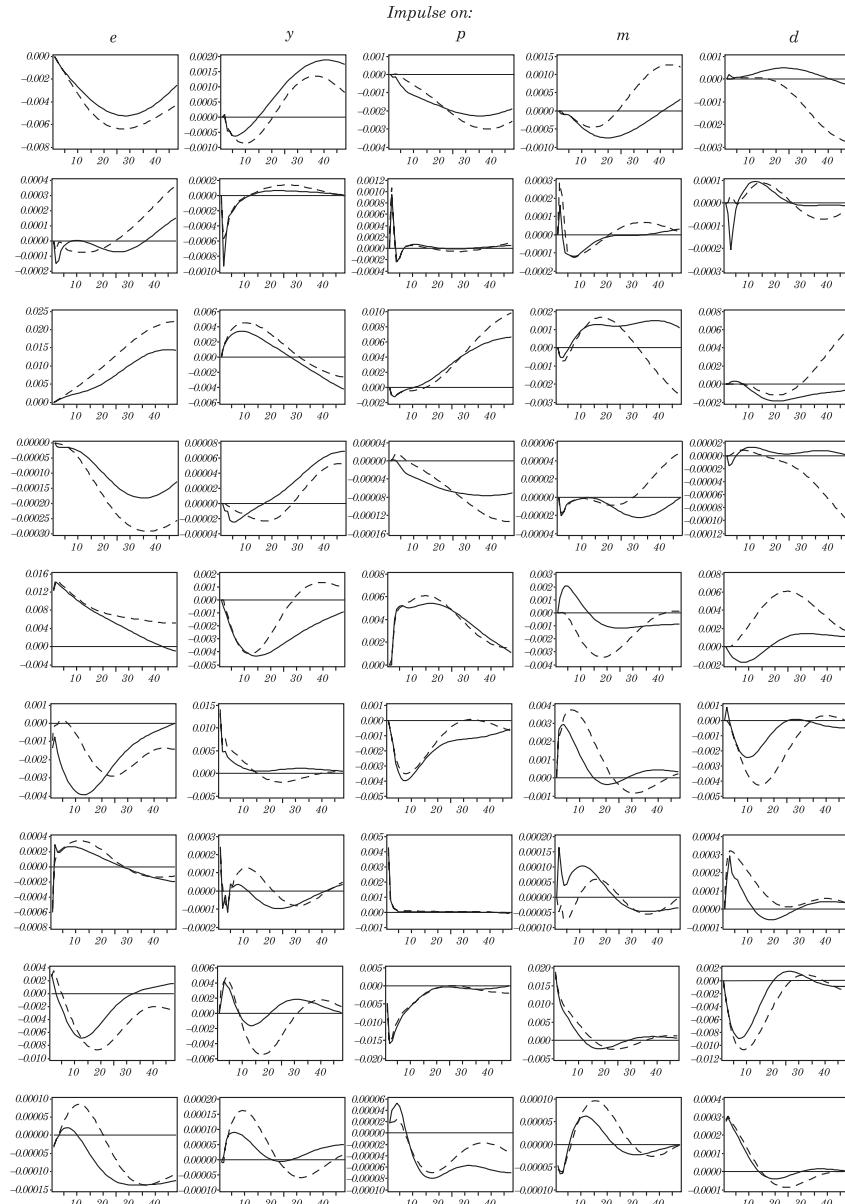
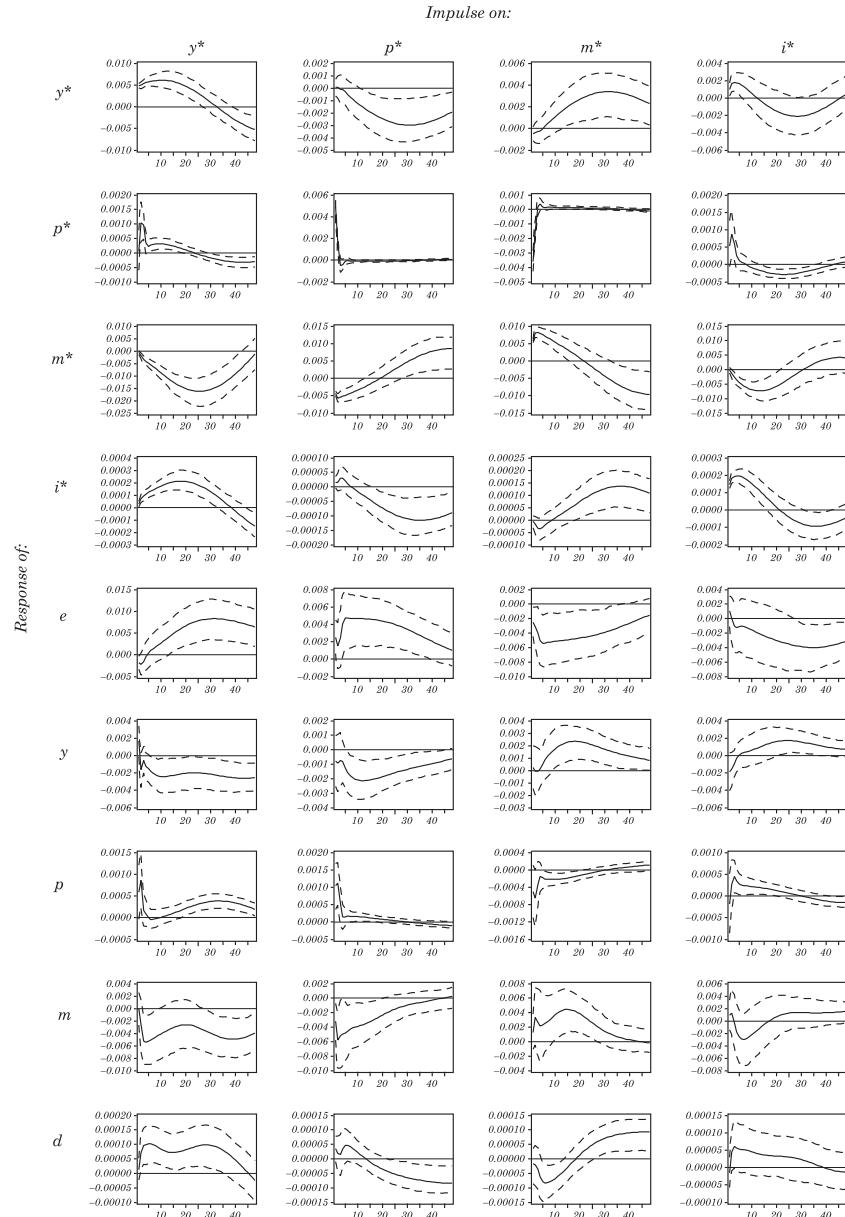


Figure 3. Generalized Impulse Response Functions^a

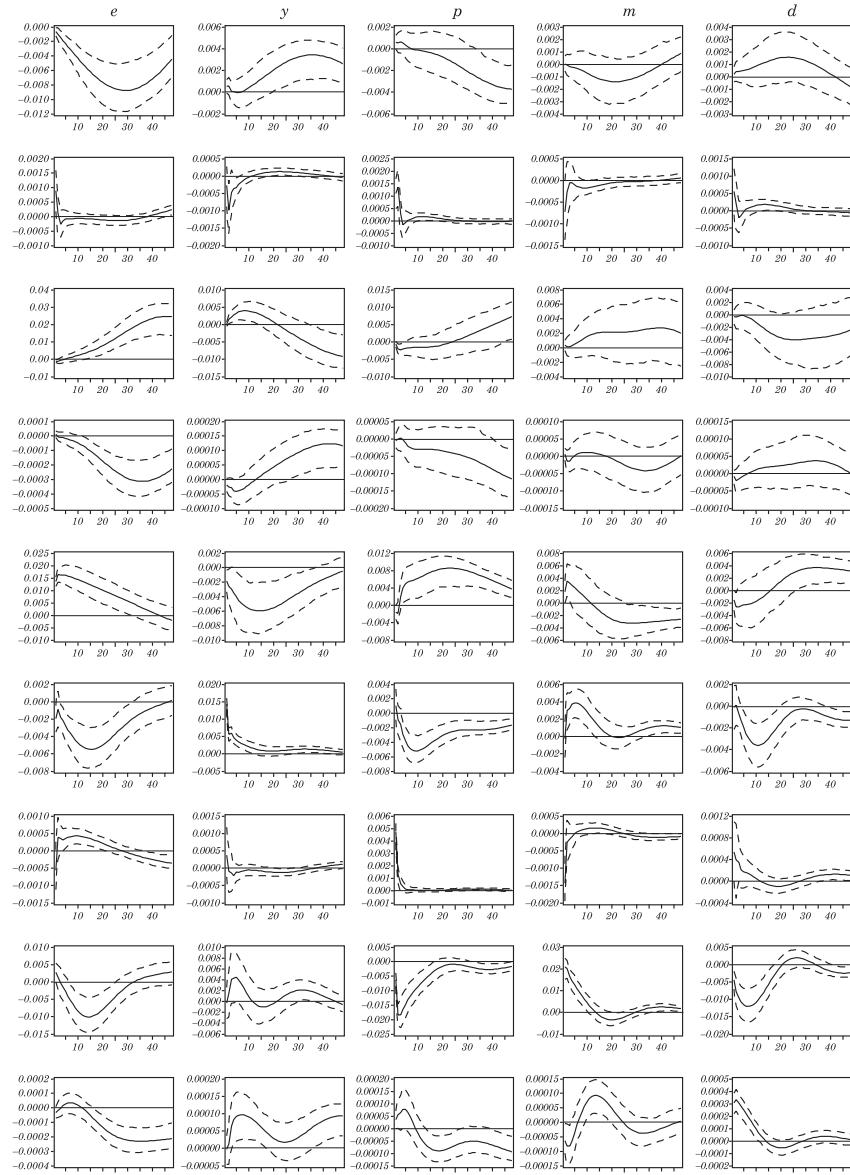


Source: Author's calculations.

a. Hall's bootstrapped confidence intervals in parenthesis.

Figure 3. (continued)

Impulse on:



The results from both IVAR and generalized impulse response functions show that care should be taken in interpreting these type of innovations as monetary policy. Of course, traditional VAR modeling renders even more implausible the dynamic responses of prices and output (as shown with the example of the s(2) shocks). The following section develops a theoretical model that helps explain why IVAR modeling is not sufficient for characterizing the effects of alternative policies and that this statistical exercise alone is not sufficient.

However, VAR estimates provide excellent statistical characterizations of the dynamic interactions of the variables considered. The difficulty of translating these statistical objects into structural economic models should not constitute a surprise. Thus, this model should only be considered a statistical representation, and no structural interpretation should be attempted. My results are simply a metric with which to obtain estimates of deep parameters of internally consistent dynamic models by using efficient method of moments (EMM).¹⁵ I then compare the responses of the variables in the theoretical model with those generated by the IVARs.

3. THE MODEL

This section develops a simple optimizing model, whose empirical implications will be compared with those of the econometric model described above. To make the model computationally manageable and to gain insights into the characteristics of the data that the model is and is not able to replicate, I introduce stringent assumptions in the stylized economy that is modeled. Needless to say, many of the assumptions come directly from the observed dynamic interactions of key variables in the IVAR estimated above.

I consider a simple economy in which agents try to maximize the expected discounted time-separable utility function:

$$\varepsilon_0 \sum_{t=0}^{\infty} \beta^t u\left(c_{ht}, c_{mt}, \frac{M_t}{P_{ht}}\right), \quad (5)$$

where c_{mt} is the consumption of tradable (importable) goods in period t , c_{ht} is the consumption of nontradable goods in period t , M_t denotes

15. See appendix D.

the nominal money stock that the individual acquires at the beginning of period t and then holds through the end of the period, P_{ht} is the price level of nontradable goods, β is the subjective discount factor, ε_t denotes the conditional expectation on information available on period t , and $u(\cdot)$ is a strictly increasing and strictly concave function in all its arguments.

A few observations are in order. I introduced money in the utility function to make money valuable in general equilibrium. Implicit in this assumption is that money may be valuable both as a store of wealth and a medium of exchange. Feenstra (1986) shows that this specification is equivalent to one derived from the literature of transaction costs. Of course, cash-in-advance constraints are merely special cases of the transaction costs technologies.¹⁶

Equation (5) is maximized subject to the budget constraint:

$$\begin{aligned}
 & q_{ht} + \frac{(1 + T_{mt}) P_{mt}^* E_t q_{mt}}{P_{ht}} + (1 + r_{t-1}) b_{t-1} + \frac{(1 + i_{t-1}) B_{t-1}}{P_{ht}} \\
 & + \frac{(1 + d_{t-1}) D_{t-1} U_t}{P_{ht}} + \frac{M_{t-1}}{P_{ht}} \\
 & \geq c_{ht} + \frac{(1 + T_{mt}) P_{mt}^* E_t c_{mt}}{P_{ht}} + b_t + \frac{B_t}{P_{ht}} + \frac{D_t U_t}{P_{ht}} + \frac{M_t}{P_{ht}} + \frac{Z_t}{P_{ht}},
 \end{aligned} \tag{6}$$

where E is the nominal exchange rate, T_m is the import tariff of a tradable good (q_m) that can be acquired in a competitive international market with price denoted by P_m , and q_h denotes the output of the nontradable good produced in the economy and sold at price P_h . Agents may also acquire indexed private bonds (in terms of nontradable goods, b) with sure return r that are in zero net supply, nominal government bonds (B) with (net) nominal return i , government bonds indexed to the UF (D) with net return d , and money balances that are carried to the next period. Finally, Z denotes lump sum taxes (or transfers) levied by the government. As a first approximation, the outputs of the different sectors of this economy will be characterized as stochastic endowments, thus making resource allocations irrelevant.

The problem of the representative consumer can then be summarized by the value function that satisfies

16. The neutrality found on the previous section may tempt one to work with specifications such as cash-in-advance. However, that type of specification imposes the assumption of constant velocity, which is not supported by the data.

$$v(s_t) = \max_{\{c_h, c_m, b, B, D, M\}} \left[u\left(c_h, c_m, \frac{M}{P_h}\right) + \epsilon \beta v(s_{t+1}) \right],$$

subject to equation (6) and the perceived laws of motion of the states s .¹⁷

The governments' budget constraint is given by

$$\begin{aligned} & \frac{T_{mt} P_{mt}^* E_t (c_{mt} - q_{mt})}{P_{ht}} + \frac{B_t}{P_{ht}} + \frac{D_t U_t}{P_{ht}} + \frac{M_t}{P_{ht}} + \frac{Z_t}{P_{ht}} + \frac{B_t^*}{P_{ht}} \\ &= \alpha_t q_t + \frac{(1 - \alpha_t) P_{mt}^* E_t}{P_{ht}} g_t + \frac{(1 + i_{t-1}) B_{t-1}}{P_{ht}} + \frac{(1 + d_{t-1}) D_{t-1} U_t}{P_{ht}} \\ &+ \frac{M_{t-1}}{P_{ht}} + \frac{(1 + i_{t-1})}{P_{ht}}, \end{aligned}$$

where g is the level of government expenditure (in terms of nontradables), α is the fraction of government expenditures destined to the consumption of nontradables, and B^* is the supply of government bonds to foreign investors.

Finally, I consider a representative foreign investor who solves a dynamic portfolio allocation problem, maximizing the following expected discounted utility:

$$\epsilon_0 \sum_{t=0}^{\infty} \beta^{*t} \omega \left(c_{mt}^*, \frac{M_t^*}{P_{mt}^*} \right)$$

subject to the constraint:

$$\begin{aligned} & q_{mt}^* + \frac{(1 + i_{t-1}) B_{t-1}^*}{E_t P_{mt}^*} + \frac{(1 + i_{t-1}^*) b_{t-1}^*}{P_{mt}^*} + \frac{M_{t-1}^*}{P_{ht}} \\ & \geq c_{mt}^* + \frac{B_t^*}{E_t P_{mt}^*} + \frac{b_t^*}{P_{mt}^*} + \frac{M_t^*}{P_{mt}^*} + \frac{Z_t^*}{P_{mt}^*}, \end{aligned} \tag{7}$$

where q_m^* is a stochastic endowment, c_m^* is the level of consumption of a composite good by the foreign representative agent, B^* is the demand of bonds supplied by the domestic government, and b^* is the demand for international bonds (issued by the foreign authority) that

17. I define $s_t = (q_{ht}, q_{mt}, r_{t-1}, i_{t-1}, d_{t-1}, b_{t-1}, B_{t-1}, D_{t-1}, M_{t-1}, P_{ht}, P_{mt}^*, E_t)$.

yield a return of i^* . The other variables are analogous to those in the domestic economy.

The foreign investor's value function satisfies

$$v^*(s_t^*) = \max_{\{c_m^*, b^*, B^*, M^*\}} \left[\omega \left(c_m^*, \frac{M^*}{P_m^*} \right) + \varepsilon \beta^* v^*(s_{t+1}^*) \right],$$

subject to equation (7) and the perceived laws of motion of the states s^* .¹⁸

The foreign government satisfies the following constraint:

$$\frac{b_t^*}{P_{mt}^*} + \frac{M_t^*}{P_{mt}^*} + \frac{Z_t^*}{P_{mt}^*} = g_t^* + \frac{(1 + i_{t-1}^*) b_{t-1}^*}{P_{mt}^*} + \frac{M_{t-1}^*}{P_{mt}^*}.$$

The market-clearing conditions for the tradable and nontradable markets are as follows:

$$q_{ht} = c_{ht} + \alpha_t g_t,$$

$$CA \equiv -(B_t^* - B_{t-1}^*) = P_{mt}^* E_t [q_{mt} - c_{mt} - (1 - \alpha_t) g_t] - i_{t-1} B_{t-1}^*, \text{ and}$$

$$CA_t^* \equiv (B_t^* - B_{t-1}^*) = P_{mt}^* E_t (q_{mt}^* - c_{mt}^* - g_t^*) + i_{t-1} B_{t-1}^* = -CA_t,$$

where the first equation describes the equilibrium in the domestic nontradable goods market; the second presents the equilibrium in the domestic tradable goods market, which shows that the current account balance must be compensated by the capital account balance; and the third equation shows the equilibrium condition of the foreign economy's goods market (expressed in terms of domestic currency), which displays a condition analogous the second. In general equilibrium, the current account balance of one economy is the negative of the other; thus the supply and demand of the tradable goods equate.

I define a recursive competitive equilibrium for these economies as a set of prices and policy functions such that markets clear. To find the policy functions compatible with the market-clearing conditions, one must solve the problems faced by each of the agents in these economies.

Appendix B demonstrates that the first-order conditions of both optimization problems can be used to obtain the value of the real

18. I define $s_t^* = (q_{mt}^*, i_{t-1}, i_{t-1}^*, b_{t-1}^*, B_{t-1}^*, M_{t-1}^*, P_{mt}^*, E_t)$.

exchange rate, e (defined as a relative price between tradables and nontradables), the equilibrium real interest rate for the risk-free indexed private bond, the nominal interest rate of the risk-free government bond, the demand for domestic real balances, the foreign nominal interest rate, the no-arbitrage condition, and the demand for foreign real money holdings.

3.1 An Example

The following example shows how prices and real variables are determined, thereby offering insight into the characteristics of the economy under consideration. I consider that the consumer has a Cobb-Douglas CRRA utility function of the form,

$$u\left(c_h, c_m, \frac{M}{P_h}\right) = \frac{\left[c_h^\varphi c_m^\delta (M/P_h)^{1-\varphi-\delta}\right]^{1-\gamma}}{1-\gamma},$$

where γ is the Arrow-Pratt CRRA coefficient. In the particular case that $\gamma \rightarrow 1$, the last equation can be conveniently expressed as

$$u\left(c_h, c_m, \frac{M}{P_h}\right) = \varphi \ln c_h + \delta \ln c_m + (1 - \varphi - \delta) \ln \frac{M}{P_h},$$

which is the functional form used for this example.

Suppose further that the domestic endowments follow first-order Markov processes that are independent of foreign and domestic nominal variables. Domestic government expenditures are a constant fraction of the production of nontradables and are partially financed by imposing a fixed import tariff on the tradable good. The monetary authority in the domestic economy sets a UF-indexed interest rate by supplying the amount of bonds that the foreign and domestic markets are willing to take at the referred rate. I introduce more structure to the domestic monetary policy as needed.

Using equations (B.11) through (B.16) from appendix B, the equilibrium conditions in this case are as follows:

$$e_t^* \equiv \frac{P_{mt}^* E_t}{P_{ht}} = \frac{\delta(q_{ht} - \alpha_t g_t)}{(1 + T_{mt})\varphi [q_{mt} - (1 - \alpha_t)g_t - N]} , \quad (8)$$

$$1 = \beta(1 + r_t) \varepsilon_t \left(\frac{q_{ht} - \alpha_t g_t}{q_{h,t+1} - \alpha_{t+1} g_{t+1}} \right), \quad (9)$$

$$1 = \beta(1 + d_t) \frac{U_{t+1}}{U_t} \varepsilon_t \left(\frac{q_{ht} - \alpha_t g_t}{q_{h,t+1} - \alpha_{t+1} g_{t+1}} \frac{P_{ht}}{P_{h,t+1}} \right), \quad (10)$$

$$1 = \beta(1 + i_t) \varepsilon_t \left(\frac{q_{ht} - \alpha_t g_t}{q_{h,t+1} - \alpha_{t+1} g_{t+1}} \frac{P_{ht}}{P_{h,t+1}} \right), \text{ and} \quad (11)$$

$$\frac{M_t}{P_{ht}} = \frac{1 - \varphi - \delta}{\varphi} (q_{ht} - \alpha_t g_t) \frac{1 + i_t}{i_t}, \quad (12)$$

where N is defined as the net amount of foreign private capital inflows in terms of the tradable good (current account deficit plus payments of interests).

While the results of the previous equations depend on the simple parameterization chosen, their qualitative implications will hold for a wide variety of functional forms for preferences. Equation (8) confirms several beliefs in popular culture. The real exchange rate appreciates with a decline in the productivity of nontradables, an increase in the productivity of tradables, increased net capital inflows, and trade protection. As Arrau, Quiroz, and Chumacero (1992) show, an increase in government expenditure has an ambiguous effect on the real exchange, depending not only on its propensity to consume nontradable goods, but also on the structure of private consumption.

Equation (9) presents the condition that determines the value of the real interest rate in this economy. Contrary to several claims, the monetary authority is not capable of affecting the real interest rate directly. In this economy, the real interest rate displays a positive relation with the growth rate of the nontradables sector in the long run. This means that an economy that is growing at a faster rate than another economy will have higher autarkic real interest rates. If there are limitations to the free flow of capital from one economy to the other, the economy that is growing faster will have a higher interest rate. This rate may have no relation with the real interest

rate set by the monetary authority, and thus the claim that the Central Bank sets the real interest rate is fundamentally incorrect.¹⁹ What, then, did the monetary authority set with instruments indexed to the UF?

Equations (10) and (11) have the answer. Both instruments must be arbitrated, given that the terms in the expectation operators coincide. It thus does not matter whether the authority sets a nominal or a UF-indexed rate. Nevertheless, the difference between the law of motion of the UF and the actual price level shows that the real interest rate will have fundamental differences with the UF-indexed rate. The difference between them is that the latter instrument and truly indexed bonds are contingent on the actual realization of inflation, whereas the former is (or at least should be) set considering the expected inflation rate. This difference between the two equations is precisely the same as that which prevents the Fischer equation from holding in the presence of uncertainty. The only case in which it would hold (on average) is when the inflation process is independent of the intertemporal marginal rate of substitution. This condition is not likely to hold because the reaction function of the monetary authority (particularly in Chile) is extremely dependent on its perception of the business cycle and the growth rate the economy. If the monetary authority sets an inflation target, equations (10) and (11) show that it must be consistent with the chosen interest rate. Thus, either of these equations will help one solve for the inflation rate, consistent with perceptions on the evolution of the economy (intertemporal marginal rate of substitution) and the monetary authority's policy rule.

Finally, equation (12) determines the demand for real money holdings. This equation is independent of parameters that may characterize the monetary authority's policy rule. If the policy rule changes, however, badly specified money demand equations may find evidence of instability even when there is none.

Several monetary policy arrangements can be examined even in this simple case. For example, if the authority sets the nominal exchange rate, no arbitrage conditions with the foreign investor will determine the nominal interest rate that is consistent with this policy.

19. Prior to the last quarter of 2001, the Central Bank of Chile set its policy rated with UF-indexed instruments. This fact led many specialists and nonspecialists to claim that the Central Bank sets the real interest rate, although this claim is fundamentally false.

Likewise, equation (12) will endogenously determine the money stock consistent with this policy.

3.2 Results

Section 2 examined how the problems of using VAR and IVAR impulse response functions to identify the effects of monetary policy are ill-conditioned practices. Regardless of the method used, it is difficult to rationalize several of the results that are supposed to capture the effects of monetary policy. Furthermore, as the theoretical model discussed above shows, several dynamic interactions between variables depend on the particular specification for the policy rule of the government.

My estimated model closes with a Taylor rule for the monetary authority:

$$\ln(1+i_{t+1}) = a_0 + a_1 \ln\left(\frac{Y_t}{Y_s}\right) + a_2 \varepsilon_t \ln\left(\frac{1+\pi_{t+1}}{1+\pi_s}\right) + a_3 \ln(1+i_t) + w_{t+1},$$

where y_s and π_s denote the steady state values for output and inflation.

The methodological steps are, first, to use the gradients of the VAR(2) discussed on section 2 as the matching conditions for the theoretical model. Second, I estimate the parameters of the theoretical model using EMM and the gradients of the VAR model as the metric. Third, once the estimates of the model are obtained, I undertake a long simulation of the theoretical model, estimate a VAR(2) with it, and derive the generalized impulse response function. Finally, I shock the theoretical model with a transitory innovation to the domestic interest rate and obtain the true impulse response function.²⁰

Figure 4 presents the results of comparing the impulse response functions that are obtained with the VAR(2) estimated with artificial data and the impulse response functions that come from the theoretical model. Several features are worth mentioning. First, the impulse response functions estimated with simulated data are broadly consistent with the data; that is, the model also produces a price puzzle, a small contraction of the level of activity, a slight appreciation, and strong liquidity effects. Second, the overidentifying restrictions test does not reject the null hypothesis that the model captures

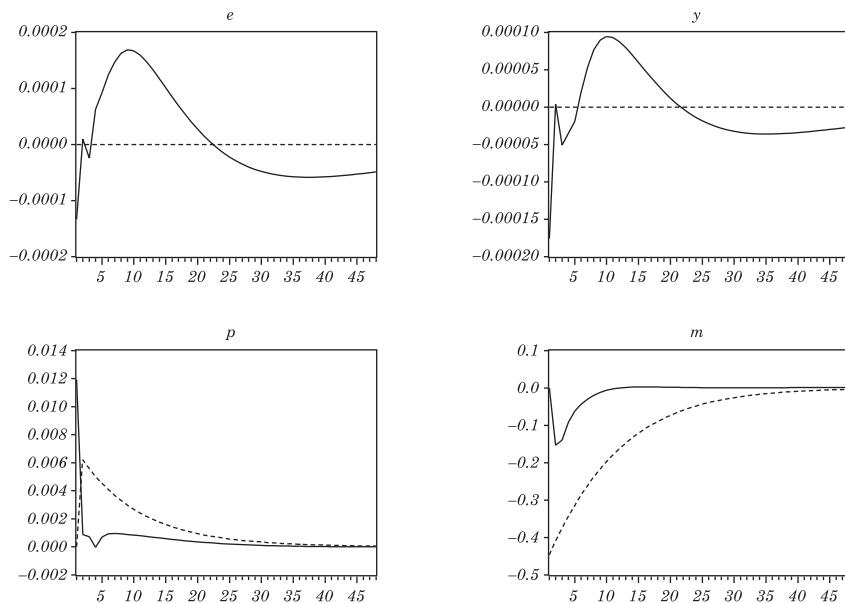
20. Here, true means the impulse response function that is consistent with the theoretical model and not the statistical object.

the dynamic interactions of the variables involved. Third, and most importantly, even though the model replicates the impulse response functions of the data, the true response of the variables with respect to a monetary innovation have little to do with the responses that come from the VAR.

By construction, the model presents a dichotomy between real and nominal variables. Monetary policy thus has no effect on the real exchange rate and output, even when the impulse response functions of the model show nonneutralities. This is so because interest rates carry information about the future evolution of the economy: a higher interest rate signals lower output today relative to the long run, since interest rates Granger cause output in this model (as it did in the example of section 1). It is not surprising, therefore, that the impulse response functions may show spurious responses of output to interest rate innovations.

A case for neutrality (or near neutrality) can be made precisely because of the presence of the price puzzle. Models that display important nonneutralities (with Phillips curves and such) would have a very difficult time trying to explain this puzzle. In the case at hand,

Figure 4. Response to Monetary Innovations^a



Source: Author's calculations.

a. Continuous line: generalized impulse response; dashed line: true impulse response.

however, the theoretical model predicts that inflation and interest rates should be positively correlated because of the inability of nominal variables to affect real variables. Thus, if the real interest rate remains basically constant, prices must move in the same direction as the nominal interest rate innovation. This follows simply from the interaction of the feedback of the Taylor rule and the dichotomy with real variables.

The model thus shows that only a few dimensions of the impulse response functions are truly consistent with the responses of fundamental models. The idea that VARs can help identify the effects of monetary policy is naïve.

4. CONCLUDING REMARKS

The objectives of this paper were twofold: first, to show that the traditional practice of quantifying the effects of monetary policy from the impulse response functions of VARs or IVARs is misleading, since it is impossible to recover structural shocks independently of the structure chosen; and second, to construct a simple metric with which to compare competing theoretical models. This second objective is important because the theoretical and empirical literature in the field of macroeconomics has not reached a consensus on which metric to use to judge a model's success in capturing key features of the data. This paper shows that such a metric can be constructed and that the statistical object that comes from it can help economists understand which features of different theoretical models are important and which are not.

The statistical model is a nine-variable VAR(2) whose impulse response functions cannot be directly considered structural. Furthermore, one has to concede that deflationary policies are inflationary and the money demand depends positively on interest rates.

The theoretical model that is estimated is broadly consistent with the VAR(2) model, but it has striking implications. First, by construction, it displays neutrality of the monetary policy. Second, because of this feature, it is not difficult to replicate impulse response functions that appear to be consistent with nonneutralities. Third, the price puzzle is only a puzzle for a model in which important nonneutralities are a major driving force. Finally, even when the model has built-in nonneutralities, they must not have first-order implications in order for the model to be consistent with the statistical object chosen.

APPENDIX A Estimation and Inference in an IVAR

This appendix presents a brief summary of the techniques used to estimate IVAR models, their differences with traditional VARs, and the methods developed to test their specification.

Consider a model of the type

$$\mathbf{B}_0 \mathbf{y}_t = \mathbf{k} + \mathbf{B}_1 \mathbf{y}_{t-1} + \dots + \mathbf{B}_p \mathbf{y}_{t-p} + \mathbf{u}_t , \quad (\text{A.1})$$

where \mathbf{y}_t is an n vector, \mathbf{k} is an n vector of constants, \mathbf{B}_i is an $n \times n$ matrix ($i = 0, \dots, p$), and \mathbf{u}_t is an n vector white noise process with (diagonal) variance-covariance matrix \mathbf{D} . Premultiplying equation (A.1) by the inverse of \mathbf{B}_0 , I obtain

$$\mathbf{y}_t = \mathbf{c} + \mathbf{C}_1 \mathbf{y}_{t-1} + \dots + \mathbf{C}_p \mathbf{y}_{t-p} + \mathbf{e}_t , \quad (\text{A.2})$$

where, given that \mathbf{u} is a vector white noise process and that $\mathbf{e} = \mathbf{B}_0^{-1} \mathbf{u}$, \mathbf{e} is also a vector white noise process with variance-covariance matrix $\boldsymbol{\Omega}$. Equation (A.2) is precisely the representation generally used in VAR models, thus making it interpretable as a reduced form of equation (A.1). The only case in which the VAR model would be equivalent to equation (A.1) is when \mathbf{B}_0 is an identity matrix. If some of the off-diagonal elements of this matrix are different from zero, the error terms on \mathbf{e} will be formed by linear combinations of the structural innovation, \mathbf{u} . Thus, the impulse response functions estimated with equation (A.2) cannot be interpreted as the dynamic response of the variables in the system to the underlying innovations.

To recover the structural parameters of equation (A.1), I use the parameters estimated from equation (A.2) to obtain an estimate of $\boldsymbol{\Omega}$; with it, I then solve the nonlinear system:

$$\boldsymbol{\Omega} = \mathbf{B}_0^{-1} \mathbf{D} \left(\mathbf{B}_0^{-1} \right)' , \quad (\text{A.3})$$

or the log-likelihood function that relates both variance-covariance matrices:²¹

$$\ell(\mathbf{B}_0, \mathbf{D}, \hat{\boldsymbol{\Omega}}) \propto \frac{T}{2} \ln \left(|\mathbf{B}_0|^2 - \ln |\mathbf{D}| - \text{tr} \left[\mathbf{B}_0' \mathbf{D}^{-1} \mathbf{B}_0 \hat{\boldsymbol{\Omega}} \right] \right) . \quad (\text{A.4})$$

21. See Hamilton (1994) for details.

One advantage of this approach is that the variance-covariance matrix of the parameters that solve equation (A.3) are readily available. Once the structural parameters are recovered, inference based on likelihood ratio (LRT) or Wald tests can be conducted as usual.

One important issue is that of identification. Since Ω is symmetric, there are $n(n + 1)/2$ distinct parameters in the variance-covariance matrix of the residuals of equation (A.2). Given that \mathbf{D} is diagonal, there are at most $n(n - 1)/2$ parameters that can be estimated in \mathbf{B}_0 if the order condition of identification is to be satisfied. Thus, some restrictions (which one hopes are testable) must be imposed. If z is used to denote the number of parameters estimated in \mathbf{B}_0 , the number of overidentifying restrictions is $r = [n(n - 1)/2] - z$. In that case, the LRT test for overidentifying restrictions is simply

$$\text{LRT} = 2 \left(-\frac{T}{2} \ln |\hat{\Omega}| - \frac{t}{2} n - \ell^* \right) \xrightarrow{D} X_r^2 , \quad (\text{A.5})$$

where ℓ^* is the value of the log-likelihood function that maximizes equation (A.4).

This methodology not only provides a robust way of estimating the effects of orthogonal innovations to the system, but it may also be a useful tool for discriminating among models. Recall that VARs impose a somewhat arbitrary ordering of the variables in the system, which will affect the resulting impulse response functions, while IVARs provide formal tests under which to contrast alternative orderings and contemporaneous relations among variables. This feature may constitute a valuable intermediate stage that provides insights with respect to the theoretical models that can and cannot be used to replicate the dynamic interactions among variables. Nevertheless, as IVARs heavily rely on the identifying assumptions imposed on them, they are useful only as intermediate devices between data and theory.

A healthy practice, whether using VARs or IVARs, is to compute standard errors (and thus confidence intervals) associated with the impulse response functions. Traditional econometric packages rely on the asymptotic distribution of the impulse response functions or on Monte Carlo experiments (based on the maintained hypothesis of Gaussian innovations) to construct them. These methods may, however, provide poor approximations of the confidence intervals in small samples, even with the assumption of normality (owing to the small sample bias of the OLS estimators). Another important problem with

this type of confidence intervals is that they are symmetric (owing to the assumption of normality). In finite samples, the innovations may have important departures from normality (typically leptokurtosis) and may not be symmetric (if there is skewness), such that the Monte Carlo approximation may not be advisable. In this case, bootstrap methods may be used to replicate the empirical distribution of the innovations. Sims and Zha (1995) also advise that constructing confidence intervals may help to correct the pervasive nature of the biases implicit in the VAR estimation. This can be done, again, with bootstrapping.²²

22. Christiano, Eichenbaum, and Evans (1996) provide a detailed description of the algorithm used to construct both the impulse response functions and confidence intervals with bootstrapping. Sims and Zha (1995) describe the algorithm used for bias reduction.

APPENDIX B Equilibrium Conditions for the Theoretical Model

This appendix derives the first-order conditions for the optimization problems of the domestic representative consumer and the representative foreign investor. These conditions are later used to describe the characteristics of the equilibrium conditions of the economies presented in the theoretical model.

The first-order conditions with respect to c_{ht} , c_{mt} , b_t , B_t , D_t and M_t for the representative domestic consumer are the following:

$$u'_{c_{ht}} - \lambda_t = 0 , \quad (\text{B.1})$$

$$u'_{c_{ht}} - \lambda_t (1 + T_{mt}) \frac{P_{mt}^* E_t}{P_{ht}} = 0 , \quad (\text{B.2})$$

$$\lambda_t - \beta \varepsilon_t v'_{b_t} = 0 , \quad (\text{B.3})$$

$$\lambda_t - \beta P_{ht} \varepsilon_t v'_{B_t} = 0 , \quad (\text{B.4})$$

$$\lambda_t - \beta \frac{P_{ht}}{U_t} \varepsilon_t v'_{D_t} = 0 , \text{ and} \quad (\text{B.5})$$

$$u'_{M_t} \frac{1}{P_{ht}} - \frac{\lambda_t}{P_{ht}} + \beta \varepsilon_t v'_{M_t} = 0 , \quad (\text{B.6})$$

where λ is the dynamic multiplier associated with the constraint described in equation (6) of the main text. The corresponding envelope conditions are

$$v'_{b_{t-1}} = \lambda_t (1 + r_{t-1}) , \quad (\text{B.7})$$

$$v'_{B_{t-1}} = \frac{\lambda_t}{P_{ht}} (1 + i_{t-1}) , \quad (\text{B.8})$$

$$v'_{D_{t-1}} = \frac{\lambda_t U_t}{P_{ht}} (1 + d_{t-1}) , \text{ and} \quad (\text{B.9})$$

$$v'_{M_{t-1}} = \frac{\lambda_t}{P_{ht}} . \quad (\text{B.10})$$

Combining equations (B.1) and (B.2) shows that the real exchange rate (e)—defined as the relative price between tradables and nontradables—is given by the ratio of marginal utilities between the consumption of both goods, corrected by the import tariff. That is,

$$e_t \equiv \frac{P_{mt}^* E_t}{P_{ht}} = \frac{u'_{c_{mt}}}{(1 + T_{mt}) u'_{c_{ht}}} . \quad (\text{B.11})$$

Combining equations (B.3) and (B.7) establishes the condition that determines the equilibrium real interest rate for the risk-free indexed private bond, while combining equations (B.4) and (B.8) yields the equilibrium condition that determines the nominal interest rate of the risk-free government bond. Finally, combining equations (B.5) and (B.9) gives the equilibrium interest rate for the UF indexed bond. That is,

$$1 = \beta(1 + r_t) \varepsilon_t \frac{u'_{c_{h,t+1}}}{u'_{c_{ht}}} , \quad (\text{B.12})$$

$$1 = \beta(1 + i_t) \varepsilon_t \left(\frac{u'_{c_{h,t+1}}}{u'_{c_{ht}}} \frac{P_{ht}}{P_{h,t+1}} \right) , \text{ and} \quad (\text{B.13})$$

$$1 = \beta(1 + d_t) \frac{U_{t+1}}{U_t} \varepsilon_t \left(\frac{u'_{c_{h,t+1}}}{u'_{c_{ht}}} \frac{P_{ht}}{P_{h,t+1}} \right) . \quad (\text{B.14})$$

In equation (B.14), U_{t+1}/U_t is known at period t , given that

$$\frac{U_{t+1}}{U_t} = \left[\frac{P_t}{P_{t-1}} \right]^a \left[\frac{P_{t-1}}{P_{t-2}} \right]^{1-a} , \quad (\text{B.15})$$

which can be approximated as 21/30.²³

23. The UF has a deterministic law of motion that depends on a weighted average of present and past inflation. With the assumption that a typical month has thirty days, the variation of the UF from the last day of month t to the last day of month $t+1$ is given by equation (B.15), where P is the consumption-based price level derived in appendix C.

Finally, combining equations (B.6) and (B.10), and using equation (B.13), I derive the condition that determines the demand for real balances:

$$\frac{u'_{M_t/P_{ht}}}{u'_{c_{ht}}} = \frac{i_t}{1+i_t} . \quad (\text{B.16})$$

These equations, combined with the market-clearing conditions and the policy rules followed by the public sector (as well as the functional form of preferences), determine the temporal trajectory of these variables.

The first-order conditions with respect to c_{mt}^* , B_t^* , b_t^* , and M_t^* for the representative foreign investor are the following:

$$\omega'_{c_{mt}^*} - \lambda_t = 0 , \quad (\text{B.17})$$

$$\lambda_t^* - \beta^* P_{mt}^* E_t \varepsilon_t v_{B_t^*}' = 0 , \quad (\text{B.18})$$

$$\lambda_t^* - \beta^* P_{mt}^* \varepsilon_t v_{b_t^*}' = 0 , \text{ and} \quad (\text{B.19})$$

$$\omega'_{M_t^*/P_{mt}^*} \frac{1}{P_{mt}^*} - \frac{\lambda_t^*}{P_{mt}^*} + \beta^* \varepsilon_t v_{M_t^*}' = 0 . \quad (\text{B.20})$$

where λ^* is the dynamic multiplier associated with equation (7) in the main text. The envelope conditions for this problem are given by

$$v_{B_{t-1}^*}' = \frac{\lambda_t^*}{P_{mt}^* E_t} (1 + i_{t-1}) , \quad (\text{B.21})$$

$$v_{b_{t-1}^*}' = \frac{\lambda_t^*}{P_{mt}^*} (1 + i_{t-1}^*) , \text{ and} \quad (\text{B.22})$$

$$v_{M_{t-1}^*}' = \frac{\lambda_t^*}{P_{mt}^*} . \quad (\text{B.23})$$

As in the previous problem, the equilibrium conditions for the foreign nominal interest rate, the no-arbitrage condition, and the demand for foreign real money balances can be found by combining the envelope and the first-order conditions, which yield

$$1 = \beta^* (1 + i_t^*) \varepsilon_t \left(\frac{\omega'_{c_{m,t+1}}}{\omega'_{c_{mt}}} \frac{P_{mt}^*}{P_{m,t+1}^*} \frac{E_t}{E_{t+1}} \right), \quad (\text{B.24})$$

$$1 = \beta (1 + i_t^*) \varepsilon_t \left(\frac{\omega'_{c_{m,t+1}}}{\omega'_{c_{mt}}} \frac{P_{mt}^*}{P_{m,t+1}^*} \right), \text{ and} \quad (\text{B.25})$$

$$\frac{\omega'_{M_t^*/P^*}}{\omega'_{c_{mt}}} = \frac{i_t^*}{1 + i_t^*}. \quad (\text{B.26})$$

The Euler equations of both problems were solved considering binding constraints (because of the assumption that both utility functions are strictly increasing). The values of these variables will be determined in general equilibrium by their interaction with the market-clearing conditions and the laws of motion of the states (including government policies).

With relatively mild conditions, existence and uniqueness for the value functions of both problems can be demonstrated using Blackwell's conditions for contraction and contraction mapping theorem arguments (see Altug and Labadie, 1995; Stokey, Lucas, and Prescott, 1989).

APPENDIX C

The Aggregate Consumption-based Price Index

This appendix derives the aggregate consumption-based price index for the constant elasticity of substitution (CES) utility function, extending the derivations of Obstfeld and Rogoff (1996) for an economy with a tradable good, a nontradable good, and money.

Let $c = f(c_h, c_m, n)$ be a composite consumption good that is a linear-homogeneous function of c_h , c_m , and n , where $n = M/P_h$. I am interested in finding a price index associated with c that will indicate how much of the good a consumer can obtain from a given level of expenditure Z (denominated in domestic currency).

I define the aggregate consumption-based price index, P , as the minimum expenditure $Z = P_h c_h + (1 + T_m) P_m^* E c_m + Wn$, such that $c = f(c_h, c_m, n) = 1$, given P_h , P_m^* , E , T_m and W . In this case W denotes the user cost of holding currency; the closed-form expression is derived below.

Consider the CES consumption index of the following form:

$$c = \left[\varphi^{1/\theta} c_h^{(\theta-1)/\theta} + \delta^{1/\theta} c_m^{(\theta-1)/\theta} + (1 - \varphi - \delta)^{1/\theta} n^{(\theta-1)/\theta} \right]^{\theta/(\theta-1)}; \quad (\text{C.1})$$

$\varphi, \delta \in (0, 1), \theta > 0.$

The highest value of the index, c , for a given value of Z (found by substituting the demands for each good in equation (C.1)) is given by

$$\left\langle \varphi^{1/\theta} \left[\frac{\varphi Z}{P_h D} \right]^{(\theta-1)/\theta} + \delta^{1/\theta} \left\{ \frac{\delta Z}{P_h \left[\frac{P_h}{P_m^* E (1 + T_m)} \right]^\theta D} \right\}^{(\theta-1)/\theta} + A \right\rangle^{\theta/(\theta-1)}, \quad (\text{C.2})$$

where

$$A = (1 - \varphi - \delta)^{1/\theta} \left[\frac{(1 - \varphi - \delta) Z}{P_h (P_h/W)^\theta D} \right]^{(\theta-1)/\theta},$$

$$D = \varphi + \delta \left(\frac{P_m^* E}{P_h} \right)^{1-\theta} + (1 - \varphi - \delta) \left(\frac{W}{P_h} \right)^{1-\theta}.$$

Defining P as the minimum expenditure needed to obtain $c = 1$, I solve for P by imposing $P = Z$ and equating equation (C.2) to 1. After trivial manipulations and using equation (B.11), I find that the price index is given by

$$P_t = P_{ht} \left\{ \varphi + \delta \left[e_t (1 + T_{mt}) \right]^{1-\theta} + (1 - \varphi - \delta) W^{1-\theta} \right\}^{1/(1-\theta)}.$$

W results from the ratio of the marginal utility of real money holdings and the marginal utility of consumption of nontradables. It is thus correct to infer that W_t is simply the right-hand side of equation (B.16). The consumption based price index adopts the form

$$P_t = P_{ht} \left\{ \varphi + \delta \left[e_t (1 + T_{mt}) \right]^{1-\theta} + (1 - \varphi - \delta) \left(\frac{i_t}{1+i_t} \right)^{1-\theta} \right\}^{1/(1-\theta)}. \quad (\text{C.3})$$

Expression (C.3) can be used to compute the evolution of the general price level, once the other prices are determined.

If equation (C.1) were Cobb-Douglas, (that is, if $\theta = 1$), then equation (C.4) would be

$$P_t = P_{ht} \left\{ 1 + \left[e_t (1 + T_{mt}) \right]^\delta + \left(\frac{i_t}{1+i_t} \right)^{1-\varphi-\theta} \right\}. \quad (\text{C.4})$$

A trivial extension of equation (C.3) for the case of the foreign economy is analyzed by Obstfeld and Rogoff (1996). In that case, the consumption-based price index is defined as

$$P_t^* = P_{mt}^* \left[\varphi^* + (1 - \varphi^*) \left(\frac{i_t^*}{1+i_t^*} \right)^{1-\theta^*} \right]^{1/(1-\theta^*)}, \quad (\text{C.5})$$

where the values of the parameters with superscripts correspond to those of the foreign consumers.

APPENDIX D

The Efficient Method of Moments

This appendix, which is based on Chumacero (1997), presents a brief introduction to the type of efficient method of moments (EMM) estimators that are used in the paper.²⁴

Consider a stationary stochastic process $p(y_t | x_t, \rho)$ that describes y_t in terms of exogenous variables, x_t , and structural parameters, ρ , which the researcher is interested in estimating. Consider an auxiliary model $f(y_t | x_t, \theta)$ that has an analytical expression whereas the $p(\cdot)$ density may not. Gallant and Tauchen (1996) propose using the scores

$$\frac{\partial \ln f(y_t | x_t, \theta)}{\partial \theta} \Bigg|_{\hat{\theta}_T},$$

where

$$\hat{\theta}_T = \arg \max_{\theta \in \Theta} \sum_{t=1}^T \ln f(y_t | x_t, \theta)$$

is the quasi-maximum likelihood estimator of $f(\cdot)$ for a sample of size T , to generate the generalized method of moments (GMM) conditions,

$$m_N(\rho) = \iint (\partial/\partial \theta) \ln f(y|x, \hat{\theta}_T) p(y|x, \rho) dy p(x|\rho) dx.$$

In cases in which analytical expressions for these integrals are not available, simulation may be required to compute them. In that case I define the moments as

$$m_N(\rho) = \sum_{n=1}^N (\partial/\partial \theta) \ln f(\tilde{y}_n | \tilde{x}_n, \hat{\theta}_T),$$

where N is the sample size of the Monte Carlo integral approximation drawn from one sample of y, x generated for a given value of ρ in the structural model.

24. The interested reader is referred to Gallant and Tauchen (1996) for a complete and formal treatment of this and other setups in which EMM can be applied. Chumacero (1997) presents Monte Carlo evidence showing that this technique is superior to GMM in several dimensions.

The GMM estimator of ρ with an efficient weighting matrix is given by

$$\hat{\rho}_N = \arg \min_{\rho \in \mathcal{R}} m'_N(\rho) \hat{W}_T^{-1} m_N(\rho), \quad (\text{D.1})$$

where, if the auxiliary model constitutes a good statistical description of the data-generating process of y , the outer product of the gradients (OPG) can be used in the weighting matrix; that is,

$$\hat{W} = \frac{1}{T} \sum_{t=1}^T \left[(\partial/\partial\theta) \ln f(y_t | x_t, \hat{\theta}_T) \right] \left[(\partial/\partial\theta) \ln f(y_t | x_t, \hat{\theta}_T) \right]' . \quad (\text{D.2})$$

Gallant and Tauchen (1996) demonstrate the strong convergence and asymptotic normality of the estimator presented in equation (D.1), as well as the asymptotic distribution of the objective function that $\hat{\rho}_N$ minimizes. That is, let k be the dimension of ρ and q the dimension of θ ; then

$$T J_T = T m'_N(\hat{\rho}) \hat{W}_T^{-1} m_N(\hat{\rho}) \xrightarrow{D} \chi^2_{q-k} ,$$

which corresponds to the familiar overidentifying restrictions test described by Hansen (1982). As in GMM, identification requires that $q > k$. Statistical inference may thus be carried out in identical fashion as in GMM. However, depending on the complexity of the auxiliary model, Wald-type tests based on the variance-covariance matrix obtained by differentiating the moments may be difficult to construct.

One major advantage of EMM is that the econometrician does not need to observe directly all the variables in the structural model to compute ρ . This feature is extremely attractive, because in many cases the poor small sample performance of GMM estimators is due to the limited amount of observations that the econometrician has for estimating the structural model.

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CHILE'S REGIONAL ARRANGEMENTS: THE IMPORTANCE OF MARKET ACCESS AND LOWERING THE TARIFF TO SIX PERCENT

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We define additive regionalism as the process of sequentially negotiating bilateral free trade agreements with all significant trading partners.¹ Chile is the country that has most clearly articulated a strategy of additive regionalism. The government of Chile has successfully concluded a free trade area with the Southern Common Market (Mercosur), Canada, and Mexico, and it is reportedly close to a free trade agreement with the United States.² Moreover, the government of Chile is

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1. Mexico, Singapore, and, to a lesser extent, Mercosur, may be following the same strategy.
2. Mercosur is a customs union between Argentina, Brazil, Paraguay, and Uruguay. Paraguay and Uruguay are too small to be included as separate countries in the dataset we employ, so our Mercosur region excludes them. In a free trade area, partner countries eliminate tariffs and export taxes or subsidies against each other, but retain separate tariffs against third countries. In a customs union, partner regions adopt a common external tariff. Chile has rejected a customs union with Mercosur.

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attempting to add the European Union, the rest of South America, and several other countries to its network of free trade arrangements.³ Proponents of the government's strategy point out that if a country were to negotiate free trade agreements with all of its trade partners, it would end up with zero effective tariffs on all imports—or free trade—despite the legal existence of positive most-favored-nation tariffs. In the process, it would also achieve preferential access to its partners' markets. Absent transition dynamics, this strategy may thus produce gains that are considerably larger than unilateral free trade.

Critics of Chile's additive regionalism strategy, such as Donoso and Hachette (1996), argue that agreements with southern countries are unlikely to be beneficial, so it is not worth delaying the benefits of unilateral and multilateral tariff liberalization to pursue these agreements. They argue that only agreements with the European Union, the United States, or Japan offer sufficient access to be worth pursuing. Advocates of the government's strategy, however, believe that agreements with smaller southern countries can also produce substantial gains. They further argue, as in Butelmann and Meller (1995), that additive regionalism will progressively reduce trade diversion costs, lower the effective average tariff in Chile, and provide considerably improved market access. They note that Chile can unilaterally lower its external tariff while simultaneously pursuing additive regionalism to further reduce trade diversion costs.

Does additive regionalism dominate free trade for Chile? If so, by how much? Most results regarding the welfare effects of regional arrangements are typically ambiguous at the theoretical level, and many questions are quantitative rather than qualitative. We therefore employ an eleven-region global computable general equilibrium (CGE) model to quantitatively examine the network of preferential arrangements that Chile is negotiating, as well as unilateral trade policy options in Chile. We also estimate the impact of global free trade as a reference point. Our model includes the Chilean economy, as well as the economies of Argentina, Brazil, Mexico, Central America, the rest of South America, Canada, the European Union, Japan, the United States, and an aggregate rest of the world. Consequently, we are able to estimate the impact on partner and excluded countries from each of the agreements we evaluate.

3. As of early 2001, Chile had reached preferential trade agreements with at least fifteen countries.

The analysis of regional trade arrangements is typically conducted in the framework of trade creation versus trade diversion, under which preferential tariff reduction is welfare inferior to nonpreferential tariff reduction. Wonnacott and Wonnacott (1981) show, however, that regional trade arrangements could produce more gains owing to improved market access to trading partners. That is, preferential tariff reduction results in a shift in demand toward partner countries. The exporters in partner countries receive a terms-of-trade improvement on their exports, which depends on the elasticity of supply of their exports.

This is what we mean by improved market access. Our model endogenously evaluates the impact of improved market access along with the traditional effects considered in theoretical analyses. We find that the results for the North American Free Trade Agreement (Nafta), Mercosur, and the additive regionalism policy point to the crucial importance of improved market access in preferential trading areas. Taken bilaterally, we find that trade diversion costs do indeed dominate the welfare effects of these agreements unless either sufficient market access is obtained in partner countries or third-country tariffs are lowered.

The results support the view that north-south agreements (for example, Chile with the United States or the European Union) are likely to provide sufficient market access to be beneficial, while the results for our south-south agreement (Chile and Mercosur) suggest the opposite under the 11 percent tariff regime that Chile employed prior to 1998. The agreements that include a northern partner increase the welfare of the members of the group in aggregate; only the Chile-Mercosur agreement results in net losses for the members as a group.

We show that Chile would reduce trade diversion costs, and increase the net gains from all of its regional arrangements, as a result of its policy of unilaterally lowering its tariff to 6 percent. Even the agreement with Mercosur would be beneficial with a 6 percent external tariff.⁴

We find that Chile's additive regionalism strategy of combining free trade agreements with four regions—Nafta, Mercosur,

4. Chile has enacted legislation that will lower its external tariff from 11 to 6 percent in stages, as suggested by our analysis. Our estimates could thus be viewed as an ex post assessment of the policy of lowering the external tariff. In fact, the vice president of the Chilean Central Bank used estimates from an earlier version of our study in his testimony before the Chilean Parliament in favor of lowering the external tariff.

the European Union, and rest of South America—produces welfare gains for Chile many times the value of unilateral free trade if it attains tariff-free access to all these markets. This supports the theoretical insight of Wonnacott and Wonnacott (1981). The gains are dramatically reduced, however, if the most highly protected sectors in the European Union and rest of South America are excluded from the agreements.⁵

We estimate that at least one of Chile's potential partners in its additive regionalism strategy loses in all of the options we evaluate. Adding the rest of South America to its network of agreements would substantially improve Chile's preferential access and welfare, but it would significantly reduce the real income of the rest of South America, which would suffer large trade diversion losses with very little improved market access. Theory, intuition, and experience indicate that preferential arrangements are unlikely to be implemented if the partner countries do not also expect to gain. Nonetheless, the gains for Chile remain substantial relative to unilateral free trade, if it could successfully negotiate these agreements with full market access.

Excluded regions are always estimated to lose from any of the preferential arrangements we consider. Thus, when partner countries gain from preferential arrangements, they do so at least partly at the expense of excluded regions.

The gains to the world from global free trade are estimated to be between \$199 billion and \$456 billion per year. This vastly exceeds the gains from any of the regional arrangements. These results emphasize the continuing importance of multilateral liberalization.

We estimate that Chile would gain from the Free Trade Agreement of the Americas (FTAA) if we assume that Chile starts from a status quo of no preferential trade agreements in the Americas. However, given that several agreements in the Americas are already in place, Chile would lose preferential access to markets in the Americas, such as Nafta and Mercosur. As a result the impact on Chile of the FTAA is ambiguous; it depends on how much preferential access Chile has in the markets of the Americas compared with other countries.

Since Chile starts with a relatively efficient uniform tariff of 11 percent, we estimate that it can obtain only small additional gains

5. The experience of some Mediterranean countries (namely, Morocco, Tunisia, and Turkey) in their preferential trade agreements with the European Union suggests that the highly protected agricultural sectors are likely to be excluded from such an agreement.

from improving the efficiency of its resource allocation by its unilateral reduction of its tariffs to 6 percent.⁶ The reduction in the tariff to 6 percent will have greater positive impact through the reduction in trade diversion involved in the regional arrangements.

We show that when a country starts with a uniform tariff, as in the case of Chile, the gains from joining a customs union are typically reduced if the country must adopt a nonuniform structure. Conversely, the gains are likely to be augmented if joining a customs union is a movement toward uniformity.⁷ In general, this result indicates that the relative uniformity of a country's preexisting tariff structure must be compared with the proposed common external tariff of any customs union on a case-by-case basis to ascertain whether welfare gains will actually be achieved.

We find that the benefits of trade liberalization or regional trade arrangements are considerably reduced if tariff revenue must be replaced by distorting alternative taxes. Similarly, our optimal tariff calculations indicate that unilateral trade liberalization can lead to lower tariff levels if efficient replacement taxes are in place.⁸

When there is an optimal tariff, as in this model, the amount by which a country can reduce its tariff is limited by the distortions of the replacement tax. Consequently, we produce an updated estimate of the collected VAT rates by sector in Chile.⁹ This exercise shows that Chile can reduce its legal VAT rates to about 50 percent of present levels and improve its welfare by 0.3 percent of GDP if it were able to eliminate evasion and collect the VAT uniformly.¹⁰ These gains are significant when compared with unilateral trade liberalization options.

6. This conclusion ignores dynamic gains from trade liberalization, which could lead to much larger gains.

7. Two other countries with uniform tariffs that may install the nonuniform tariff structure of a customs union are the Kyrgyz Republic and Estonia. The Kyrgyz Republic has a uniform tariff of 10 percent and has, in principle, agreed to join in a customs union with Russia, Belarus, and Kazakhstan. The Kyrgyz have not implemented the common external tariff, however, because of fears of the costs of the nonuniformity of the Russian tariff, which is the present common external tariff. See Michalopoulos and Tarr (1997) for details. Estonia has a uniform tariff of zero and is one of the five transition economies the European Union has designated as candidates for accession. Estonian authorities have considerable concerns, however, about the costs of imposing the European Union's common external tariff, especially in the highly protected sectors.

8. With low elasticities, however, an adverse terms-of-trade effect mitigates the welfare gains from reduced costs of trade diversion.

9. See Harrison, Rutherford, and Tarr (1997c).

10. We also eliminate the output tax that applies primarily to energy and beverages and tobacco.

We find that the optimal tariff in Chile is almost doubled under the current VAT collection rates, compared with a VAT that collects taxes at equal rates across sectors.

We perform systematic sensitivity analysis for the scenario of Chile forming a free trade agreement with Nafta and imposing a 6 percent tariff. Based on our sample of 3,500 simulations, we conclude that our result is robust to plausible uncertainty about the key elasticities of the simulation model.

Our analysis focuses on the impact of tariff changes in goods markets, which is the traditional focus of theoretical and applied analysis of regional trade arrangements. Regional arrangements may include other elements that we ignore, such as commitments to foreign investors in services sectors and the dynamic impacts of technology transfer.

The following section describes the model and data. Section 2 then presents and explains the policy results for Chile. Section 3 examines the impact on partner and excluded countries of Chile's agreements, as well as the impact of global free trade. In section 4 we present the results of our systematic sensitivity analysis, and the final section concludes.

1. A MULTIREGIONAL TRADE MODEL

The quantitative model developed to evaluate the trade policy options facing Chile is multiregional and multisectoral. It explicitly includes eleven regions or countries, with twenty-four sectors in each region or country.¹¹ The general specification of this model follows our earlier multiregional model of the effects of the Uruguay Round.¹² The most important differences are the inclusion of data for Chile, updated tariff rates for Argentina and Brazil, and more recent data

11. The eleven countries or regions are Argentina, Brazil, Chile, the rest of South America, Central America and the Caribbean, Mexico, Canada, the United States, the European Union (an aggregate of fifteen countries), Japan, and the rest of world. The twenty-four sectors are wheat; other grains; nongrain crops; meat products; milk products; other food products; beverages and tobacco; wool and other livestock; textiles, apparel, and leather products; chemicals, rubber, and plastics; fishing; forestry; lumber and wood; pulp and paper; energy products; mineral products; primary ferrous metals; nonferrous metals; fabricated metal products; machinery and equipment; transport industries; trade and transport services; other services; and a savings good.

12. Harrison, Rutherford, and Tarr (1997b). The website dmsweb.badm.sc.edu/glenn/ur_pub.htm provides access to the model and related publications.

for all other regions. We adopt a multiregion model, rather than a small open economy model, since we need to consider the possible effects on Chile of a reduction in Chile's import tariffs on other Mercosur members. Crucially, we also need to account for the market access effects on Chilean exports of a reduction of import tariffs by Mercosur, Nafta, or other regions with which Chile establishes a free trade agreement, either separately or collectively.

The general theory of the welfare effects of preferential trading arrangements allows for the impact of changes in partner country tariffs on the home country's terms-of-trade.¹³ Some empirical approaches to evaluating preferential trading arrangements ignore such impacts, however.¹⁴ Our framework allows us to explicitly evaluate the importance to Chile of improved market access to regions such as Mercosur and Nafta, as well as losses Chile may suffer as partner countries raise export prices to Chile.

An important feature of the Chilean economy is that its tariff rate is a uniform 11 percent across all traded sectors. The exception to this is the variable levy system for wheat, sugar, and edible oils. Estimates reveal that the variable levy system has resulted in an average level of protection for these three products in excess of 11 percent.¹⁵ We chose to ignore the variable levy system, as it would slightly bias downward our estimated gains from unilateral trade liberalization. Harrison, Rutherford, and Tarr (1997c) describe the key data that are important in the analysis.

Argentine tariffs are virtually identical to Brazilian tariffs. In the case of the United States, the tariff estimates include the tariff

13. See Wooton (1986); Harrison, Rutherford, and Wooton (1989, 1993).

14. An example is the approach adopted by Bond (1996). He develops a simple general equilibrium specification of the effects on Chile of these preferential trading arrangements, with an impressive level of detail with respect to tariff data. His results for Chile joining Nafta, however, differ significantly from ours because his CGE model does not incorporate the impact on Chile of access to Nafta markets.

15. The variable levy system is applied by examining monthly prices over the previous two and a half years for wheat and fifty months for sugar. The distribution is truncated at the top and the bottom by an equal percentage (about 15 percent). The range of the resulting truncated distribution determines the upper and lower bounds. A tariff surcharge or reduction of the tariff below the 11 percent rate is applied if the price in the present month is below or above the bounds. Since the system is not based on a domestic support price, its impact varies enormously from year to year. Valdés (1996) estimates that between 1985 and 1995, the nominal protection rate for sugar ranged from 6 to 98 percent, and the nominal protection rate for wheat ranged from -10 to 45 percent (see also Quiroz and Valdés, 1993).

equivalents of the nontariff barriers, which are quite important in sectors with high tariffs. If Chile forms a free trade area with Mercosur or Nafta, Chilean exporters will not face these tariffs, whereas outside exporters to these regions will. These data are thus crucial in assessing the value of the increased access that Chile might obtain from Mercosur and Nafta.

We have also estimated the rates of collected value-added tax in each industry and the tax on gross output. These rates were estimated using procedures explained in Harrison, Rutherford, and Tarr (1997c). The different VAT rates across sectors arise mainly because of evasion of the VAT. The two largest sectors in Chile—the trade and transport services sector and the other services sector—together account for 61 percent of value-added, yet they are the sectors with the lowest rate of collected VAT (about 3 percent as opposed to about 17 percent for most of Chilean manufacturing).

1.1 Formal Specification of the Model

The general specification of the model follows our earlier work on the Uruguay Round. We concentrate here on what we call our base model, which is static and assumes constant returns to scale. Except for the fact that imports and exports are distinguished by many regions, the structure of the model within any country is very close to the basic model of De Melo and Tarr (1992); the interested reader may consult their chapter 3 for a detailed explanation of the equations.

Briefly, production entails the use of intermediate inputs and primary factors (labor, capital, and land). Primary factors are mobile across sectors within a region, but they are internationally immobile. We assume constant elasticity of substitution (CES) production functions for value added, and Leontief production functions for intermediates and the value-added composite. Output is differentiated between domestic output and exports, but exports are not differentiated by country of destination.

Each region has a single representative consumer who maximizes utility, as well as a single government agent. In Harrison, Rutherford, and Tarr (1997c), we formally characterize the demand structure and elasticities that are critical to the results. Demand is characterized by nested CES utility functions for each agent, which allow multistage budgeting. Demand at the top level, for the composite Armington aggregate of each of the twenty-four goods, is Cobb-Douglas. Consumers first choose how much of each Armington

aggregate good to consume, such as wheat, subject to aggregate incomes and composite prices of the aggregate goods. The Armington aggregate good is, in turn, a CES composite of domestic production and aggregate imports. Consumers decide how much to spend on aggregate imports and the domestic good subject to the prior decision of how much income will be spent on this sector, and preferences for aggregate imports and domestic goods are represented by a CES utility function. Finally, consumers decide how to allocate expenditures across imports from the ten other regions based on their CES utility function for imports from different regions and income allocated to consumption on imports from the previous higher level decision.

Data and elasticities

Except for tariff data and the domestic tax data, the data employed to calibrate the model come primarily from the Global Trade Analysis Project (GTAP) database documented in Gehlhar and others (1996). We use the preliminary release of version 3 of this database, current as of May 1996. The eleven-region version of the model retains all regions of the GTAP database that are directly relevant to our policy simulations. The full GTAP database contains thirty-seven sectors.¹⁶

We generally assume that the lower-level elasticity of substitution between imports from different regions, σ_{MM} , is 30 and that the higher-level elasticity between aggregate imports and domestic production, σ_{DM} , is 15. We refer to these values as our central elasticities. Some econometric studies, such as Reinert and Roland-Holst (1992) and Shiells and Reinert (1993), suggest values that are lower than these. However, Reidel (1988) and Athukorala and Reidel (1994) argue that when the model is properly specified, the demand elasticities are not statistically different from infinity; their point estimates are close to the central elasticity values we have chosen. Moreover, elasticities would be expected to increase over time. This model presumes an adjustment of about ten years, a rather long period in the context of these econometric estimates.

16. When we aggregated to twenty-four sectors, we ensured that sectors with significant rates of protection (in the principal trading partners of Chile) were retained as individual sectors. That is, we aggregated sectors that are not important in trade or that have low rates of protection. Aggregation can significantly change the results in applied trade policy analysis, but this type of aggregation results in quite small aggregation bias.

A value of $\sigma_{MM} = 30$ means that if Chile tried to raise its prices by 1 percent on world markets relative to an average of aggregate imports, Chilean imports would decline relative to aggregate imports by 30 percent. Given that some economists may prefer lower elasticity estimates, we also perform most of our important policy simulations with $\sigma_{MM} = 8$ and $\sigma_{DM} = 4$. We refer to these as our low elasticities. A high elasticity scenario for a small open economy such as Chile would be a specification with still less market power for exports, such as would occur within the popular theoretical models of international trade where goods are homogeneous.

The output elasticity for each sector is not specified exogenously, but is determined endogenously from other parameters and data in the model. That is, each firm maximizes profits subject to its production function and input costs under constant returns to scale. An increase in the relative price of its output induces an output expansion, the elasticity of which depends on how fast its costs increase with an expansion of output. Analogous to the Armington assumption on imports, we assume that domestic output and exports are differentiated. The elasticity of transformation between exports and domestic production is assumed to be about four for each sector. Higher transformation elasticities would increase the elasticity of export supply. Elasticities of substitution between primary factors of production are taken from Harrison and others (1993) and generally reflect econometric estimates for the United States. These estimates are relatively low for primary goods, around unity for manufacturing goods, and elastic for tertiary goods. We assume fixed coefficients between all intermediates and value added.

Distortions

All distortions are represented as ad valorem price wedges. Border protection estimates combine tariff protection and the tariff equivalents of nontariff barriers. For Brazil and Argentina, these data were estimated by Reincke in Harrison, Rutherford, and Tarr (1997c). Otherwise these data are taken from the GTAP database. They are presented in Harrison, Rutherford, and Tarr (2001). Other distortions include factor taxes in production, value-added taxes, export subsidies, voluntary export restraints (represented as ad valorem export tax equivalents). These are also taken from the GTAP database, except for domestic distortion data in Chile. The latter were estimated for this exercise by Soloaga in Harrison, Rutherford, and

Tarr (1997c). Lump-sum replacement taxes or subsidies ensure that government revenue in each region stays constant at real benchmark levels. For Chile, however, we capture the marginal efficiency cost of the government having to raise extra revenues through a distortionary domestic tax system. For developing countries these costs could be quite significant, since the revenue losses from trade reform could be sizeable.

Solution algorithm

The model is formulated using the GAMS-MPSGE software developed by Rutherford (1999) and solved using the PATH algorithm of Ferris and Munson (2000). Although the model has 11 regions and 24 sectors, and is large by historical standards, it is smaller than our Uruguay Round model. Use of demand elasticities as high as those we employ could pose numerical problems in general, but this model solved without difficulty.

2. POLICY RESULTS FOR CHILE

We begin this section with a discussion of how Chile might replace the revenue it will lose from lowering its tariffs and the welfare implications of the different options. We then discuss the results regarding the preferential trade area policy options. Subsequently, we consider how Chile could use unilateral tariff reduction to optimize its trade policy. Finally, we examine the effects of Chile's strategy of additive regionalism.

2.1 The Role of the Replacement Tax

Chile reduces tariffs in most of our scenarios, which causes a revenue loss to the government. We impose an equal-revenue requirement in all simulations and stipulate explicitly how the additional tax revenue is to be generated. We employ either the existing VAT, a uniform VAT, or a lump-sum tax.

Welfare effects of the replacement tax

Collection of the existing VAT is not uniform in Chile. According to the estimates in Harrison, Rutherford, and Tarr (1997c), it ranges

from 0 to 18 percent across sectors. Raising revenue through the VAT therefore generates distortions: when the VAT is increased, resources move into less highly taxed sectors. This reduces any possible gains from the trade policy change. Results for welfare using the existing VAT are presented in column 1 of table 1.

We estimated the marginal cost of public funds of the existing VAT in Chile to be equal to 7.6 percent. This implies that consumers and producers have to be taxed 1,076 pesos for the government to receive 1,000 pesos. The 76 pesos are a welfare loss to the Chilean economy. We also calculated the marginal cost of public funds of the Chilean tariff; it equals 18.5 percent. Despite the fact that the tariff is uniform across sectors—and thus imposes no intersectoral distortion costs—the Chilean tariff imposes a higher distortion cost than the VAT because the tariff favors domestic production over imports.

In column 5 of table 1 we show the results of employing a lump-sum tax as the replacement tax. This tax avoids the distortions of a nonuniform VAT, since consumer income is taxed in a fixed amount independently of consumer choices. Hence, the revenue replacement tax instrument has no resource allocation effects. The results show that the VAT implies an added welfare cost relative to the lump-sum alternative.

Finally, column 3 of table 1 presents the results of using a uniform VAT. In these scenarios we first counterfactually create an equilibrium in which all other domestic taxes and subsidies are zero and the VAT is uniform. The impact we evaluate is then solely due to the trade policy change. Since all sectors are taxed and there is no labor-leisure choice, it is not possible to take an action that lowers the tax. In other words, there are no resource allocation effects and the uniform VAT is essentially equivalent to a lump-sum or distortionless tax in our model. In addition, any second-best interaction effects of distortions between the tariff and the existing VAT are removed if we start with a uniform VAT and no other distortions (for this reason the results for the lump-sum tax and the uniform VAT may differ). In these scenarios we equalize the VAT across sectors and solve for the level of the VAT that is required to compensate for the lost revenues.

Revenue effects

In column 2 of table 1, we present the equiproportional increase in the VAT required to keep government revenue constant. For example, assuming central elasticities, a free trade area with Mercosur would

Table 1. Welfare and Government Revenue Results for Chile's Trade Policy Options
 Percent of GDP

Policy simulation	Elasticity	Existing VAT			Replacement VAT ^a			Combined effect of uniform VAT and trade policy ^b		
		Change in welfare ^c	Change in VAT ^d	Change in welfare ^c	Tariff revenue	Lump-sum	Change in welfare ^c	Change in welfare ^c	Tariff revenue	
Free trade agreement with Mercosur	Central	-0.62	45	-0.40	1.7	-0.43	-0.19	1.8		
Customs union with Mercosur	Low	0.04	17	0.07	2.7	0.08	0.19	2.7		
Free trade agreement with Nafta	Central	-0.95	52	-0.74	1.3	-0.73	-0.62	1.2		
Zero tariffs on Nafta imports; no improved access	Low	-0.20	21	-0.22	2.5	-0.17	-0.14	2.5		
Free trade agreement with Mercosur; 6% external tariff	Central	0.82	48	1.03	0.9	1.04	1.23	0.9		
Free trade agreement with Nafta; 6% external tariff	Low	0.30	26	0.31	2.1	0.38	0.43	2.1		
External tariff reduced to 6%	Central	-1.11	62	-0.92	0.7	-0.83	-0.64	0.7		
External tariff reduced to zero	Low	-0.47	30	-0.45	2.0	-0.41	-0.33	2.0		
External tariff reduced to 8%	Central	0.12	49	0.44	1.7	0.35	0.61	1.7		
External tariff reduced to 6% External tariff reduced to zero	Low	0.06	38	0.11	1.7	0.13	0.21	1.7		
External tariff reduced to 8% External tariff reduced to zero	Central	1.46	45	1.72	1.1	1.70	1.89	1.1		
External tariff reduced to 6% External tariff reduced to zero	Low	0.41	41	0.45	1.4	0.49	0.55	1.4		
External tariff reduced to 8% External tariff reduced to zero	Central	0.02	16	0.12	2.9	0.10	0.41	2.9		
External tariff reduced to 6% External tariff reduced to zero	Low	-0.11	17	-0.08	2.7	-0.06	0.03	2.7		
External tariff reduced to 8% External tariff reduced to zero	Central	0.01	28	0.16	2.3	0.11	0.43	2.3		
External tariff reduced to 6% External tariff reduced to zero	Low	-0.18	30	-0.14	2.1	-0.14	-0.04	2.1		
External tariff reduced to 8% External tariff reduced to zero	Central	-0.26	76	-0.02	0	0.09	0.21	0		
External tariff reduced to 6% External tariff reduced to zero	Low	-0.54	72	-0.45	0	-0.42	-0.37	0		

Source: Authors' estimates.

a. In these scenarios, we first create an equilibrium with a uniform VAT with no other domestic taxes, then evaluate the pure effects of the trade policy.

b. These scenarios combine the impacts of the trade policy simulation with the move to a uniform VAT and the elimination of the domestic output tax; government revenues are held constant.

c. Change in Hicksian equivalent variation, as a percentage of GDP.

d. Required equiproportional increase in the VAT rate across all sectors to keep government revenues unchanged, as a percentage of GDP.

require a 45 percent increase in the VAT rate across sectors. If the collected VAT rate is 10 percent in a sector, the collected VAT rate would have to increase to 14.5 percent. With central elasticities, there is a strong substitution away from imports that pay tariffs in favor of imports from partner countries that are tariff free. The revenue requirements for the VAT are quite high in this case to compensate for the lost tariff revenues. With low trade elasticities, the revenue requirement for the VAT is much smaller: increases range from 17 to 26 percent in the three basic preferential trade arrangement scenarios presented in rows 1 through 3.

Columns 4 and 7 show tariff revenues collected in the new equilibrium as a percentage of GDP. In our initial equilibrium, tariff revenues are equal to about 3.6 percent of GDP, but they fall to between 0.9 and 2.7 percent of GDP in the preferential trade area scenarios (rows 1–3). This implies that tariff revenues drop to between 25 and 75 percent of original tariff revenues. The loss of tariff revenue is higher with Nafta (because Nafta is a larger share of Chilean imports than Mercosur) and higher with central elasticities (because of the greater trade diversion). The VAT revenues initially constitute about 9 percent of GDP. Depending on the preferential trade area and elasticities, the tariff loss is between 0.9 and 2.7 percent of GDP. Hence, if the VAT were employed as the replacement tax, it would be necessary for VAT revenues to increase by about 10 to 30 percent.

Some may question whether the implied increase in the VAT is too high. To provide intuition for the model implications for the VAT, we consider a particular scenario in which the lost tariff revenue is about 2.5 percent of GDP, as in row 6 with central elasticities. It is estimated in table 1 that the VAT rate would have to increase by 45 percent to a legal rate of about 26 percent. In 1994 the legal VAT rate of 18 percent generated VAT revenues of about 9 percent of GDP, so the legal rate was twice the collected rate. If we assume that the rate of VAT evasion does not change, then the VAT must be raised by 5 percent to generate 2.5 percent of GDP (that is, from 18 to 23 percent).

The model, however, predicts a required increase of the legal VAT rate to 26 percent, not 23 percent, because an increase in the tax would induce a shift away from the highly taxed sectors, together with an erosion of the tax base. Given our model parameters, increases in the VAT continue to generate additions in revenue within the range under consideration, but evasion of the VAT could potentially increase. The required legal VAT rate would then increase and

the distortion costs of revenue replacement would be still higher than we have estimated—or perhaps it is not feasible to generate considerably more revenue from the VAT without further reform in collection procedures.¹⁷

The revenue impact estimates depend heavily on σ_{MM} , the elasticity of substitution between imports from different regions.¹⁸ The estimated change in tariff revenue is considerably smaller in the low elasticity case.

Given the uncertainties over rates of evasion of VAT in Chile, these estimates should be taken as indicative of revenue requirements rather than as precise recommendations for the VAT rate. In fact, we emphasize the importance of uniformity of collections below.

2.2 Preferential Trade Area Options

The overall welfare results for the trade policy options are presented in table 1. More detailed results on output, imports, and exports for the main scenarios, with central elasticities, may be found in Harrison, Rutherford, and Tarr (1997c). Welfare impacts are presented as a percent of Chile's GDP. They represent changes on a recurring, annual basis, so a 1 percent welfare gain should be interpreted as a 1 percent increase in real income each year in the future.

In the first row of table 1, we present the results from the scenario in which Chile forms a free trade area with Mercosur. We assume that each of the Mercosur countries represented in the model (Argentina and Brazil) reduces its tariffs, export subsidies, or taxes on their trade with Chile to zero and that Chile does the same for its

17. To quantify these ideas, we simulated Chile's free trade area with Mercosur and Nafta, where we assume that the collected VAT rates in the services and trade and transportation sectors cannot be increased owing to evasion. These sectors have low rates of VAT collection, and evasion of the VAT may prevent additional collections. Together they produce about 65 percent of Chilean value-added. With central elasticities, the welfare loss in this case from the free trade area with Mercosur is increased to -0.60 percent of GDP and the gains from the free trade area with Nafta are reduced to 0.12 percent of GDP. As expected, the required rate of VAT increase jumps to about 75 percent.

18. The elasticity of substitution between domestic goods and aggregate imports, σ_{DM} , plays a relatively less important role in the revenue impact estimates. The preferential tariff reduction lowers the tariff-ridden composite price of imports and results in an increase in the quantity demanded of composite imports. This would imply additional tariff revenue from additional partner country imports. But the substitution effect between imports of different varieties dominates when we raise both elasticities.

trade with Mercosur. Chile does not adopt the common external tariff of Mercosur in this scenario.

The second scenario, shown in row 2, represents Chile joining Mercosur as part of the customs union. In addition to the requirements of the scenario in row 1, Chile adopts the common external tariff of Mercosur. Chile has not joined the Mercosur customs union and has no plans to do so, but we evaluate this scenario because it is a potential policy option. For simplicity, we assume that the common external tariff that Chile adopts is the import tariff structure that Brazil currently has with the countries that are not in Mercosur.¹⁹

The third scenario, in row 3, is Chile forming a free trade area with Nafta. In row 4, primarily to help understand the results, we evaluate the consequences of a free trade agreement between Chile and Nafta in which Chile does not obtain improved access to the Nafta market. After discussing these scenarios, we introduce further simulations to help explain the results and evaluate modified options.²⁰

The effects on welfare are dependent both on how Chile chooses to replace the lost tariff revenues and on assumed elasticities. Chile's preferential trade policy options with Mercosur lead to a loss of welfare with our preferred central trade elasticities and negligible gains or losses with low trade elasticities. The trade diversion costs of an agreement with Mercosur typically dominate the trade creation effects under central trade elasticities. Moreover, based on the Mercosur

19. This tariff structure is slightly different than the tariff structure shown for Argentina, for two reasons. First, there are exceptions to the common external tariff for Argentina and Brazil, as both countries continue to adapt their tariff schedules over time to the agreed common external tariff. Second, Argentina and Brazil could well have adopted exactly the same common external tariff at a detailed tariff-line level, but have different trade shares across these tariff lines. With the different trade weights, the rates that appear in the GTAP database at the twenty-four sector level reflect differences in these trade patterns, and need not reflect differences in the common external tariff at the detailed tariff-line level. For ease of comparison, we also assume in our "Chile customs union with Mercosur" scenario that Argentina adopts the tariff of Brazil as its common external tariff. This provides a clean representation of the Mercosur customs union for our purposes.

20. Higher elasticities result in higher gains for the free trade agreement with Nafta, but lower elasticities are better for the free trade agreement with Mercosur. The reason is that there is a welfare tradeoff with higher elasticities: they result in greater trade diversion costs in both agreements, and they result in increased gains from improved market access. The Nafta market is much larger, however, and the value of improved market access is worth more in the Nafta case than the increased trade diversion costs. The opposite is true for Mercosur.

external tariff, preferential access to the Mercosur markets is insufficient to overcome this welfare loss in Chile's markets. Welfare losses are lower with lower assumed elasticities because there is less trade diversion when Chile's consumers are less willing to substitute Mercosur's products for those of the rest of the world.²¹

The results indicate that the customs union with Mercosur is an inferior outcome for Chile relative to a free trade agreement with Mercosur. Mercosur's tariff structure is diverse compared with Chile's uniform tariff. Since the welfare costs of trade restrictions tend to increase disproportionately with the height of the tariff, Chile is better off with its own uniform tariff than with the common external tariff of the customs union.²² That is, part of the costs to Chile of joining a customs union with Mercosur derive from the loss of tariff uniformity. One advantage of a free trade agreement for Chile as opposed to a customs union is that only the customs union requires the adoption of a common external tariff.

In comparing our results in rows 1 through 3 regarding Chile's preferential trade area options, the most important result is that the free trade area with Nafta is beneficial to Chile while the other options are likely to present problems.²³ In order to ascertain the source of the gain to Chile from a free trade area with Nafta, we performed the simulation in row 4 in which Chile lowers its tariffs against imports from Nafta countries but does not obtain improved access in Nafta markets. Although this is not a policy option that Chile would adopt, the results of row 4 show that Chile loses from preferential reduction of its tariffs against Nafta countries without reciprocal access to Nafta markets, since the trade diversion dominates the trade creation.²⁴ Chilean access to the United States market in

21. These results are consistent with Donoso and Hachette (1996) and Muchnik, Errázuriz, and Domínguez (1996). Based on the results of Muchnik, Errázuriz, and Domínguez (1996), who focus on agriculture, Donoso and Hachette (1996) estimate that access to the Mercosur market would not offer significant gains to Chile. See also Valdés (1995) and Schiff and Sapelli (1996) for other views.

22. Ramsey-optimal tariffs vary inversely with the elasticity of demand. Typically, however, departures from uniformity do not conform with Ramsey-optimal rules, but rather with political economy considerations (see Panagariya and Rodrik, 1993).

23. Coeymans and Larraín (1994), Reinert and Roland-Holst (1992), and Hinojosa-Ojeda, Lewis, and Robinson (1995) also find that Chile would gain from a free trade area with Nafta.

24. We performed an analysis with Mercosur similar to the simulation in row 4 for Nafta. The impact with lump-sum tax replacement is also 0.83 percent of GDP. The trade creation and trade diversion effects are thus about the same for the agreement between Mercosur and Nafta.

nongrain crops (for which the tariff rate is 20 percent) is especially important.²⁵

These results demonstrate the importance of improved access emphasized by Wonnacott and Wonnacott (1981). Our results show that Chile can gain more from a free trade agreement with Nafta than it can from global free trade. Chile can expect to lose, however, from any of the preferential trade agreements we consider if access to partner country markets does not improve.

The importance of low, uniform tariffs

These results differ from several earlier numerical evaluations of preferential trading areas (for example, see Rutherford, Rutström, and Tarr, 1997; Harrison, Rutherford, and Tarr, 1997a). We speculate that part of the reason that trade diversion dominates trade creation in these estimates is that Chile has a low, uniform tariff. That

25. Although the GTAP database indicates that the U.S. tariff on nongrain crops is 47 percent, we lowered this to 20 percent in our benchmark equilibrium for two reasons. First, we prefer updated estimates where possible. The most important nongrain crop products for Chile are fruits and vegetables, and post–Uruguay Round tariff rates for these products in the U.S. market are the relatively modest figures cited below. The higher protection estimates for these products in the GTAP database, averaging 56 percent, were derived from an average of protection estimates in the 1989–1994 period. Second, the U.S. protection on these products varies with the season. We have assumed that Chilean fruits and vegetables would typically face U.S. tariffs that are in the low range of the seasonal tariffs applied by the United States, when they are ready for harvest and export to the United States. Products included in the nongrain crops category of the GTAP database, along with the estimated tariff and tariff equivalent of the nontariff barrier in the United States, are as follows, in percent: sugar, 67; oilseeds, including peanuts, 25; coffee, cocoa, and tea, 0; cotton, 31; vegetables (fresh, 0–25; frozen, 17.5–25.0; dried, 25–35; prepared and preserved, 13.6–14.7); fruits (fresh, 0–20; dehydrated, 0.6–2.2; frozen, 0.7–14.0; juices, 0–31.3; jams and pastes, 7.0–35.0; canned, 1.9–20.0); and other nonfood crops (tobacco, jute, and so forth), 19. The reduced estimates are closer to the estimates of Butelmann and Meller (1995), who report that Chilean fresh, frozen, and canned vegetables face most-favored-nation tariff rates in the United States ranging from 9.5 to 17.5 percent, with a reduction of a few percentage points for the former two categories where Generalized System of Preference treatment applies, and that Chilean fruits face U.S. most-favored-nation tariffs from 1 to 10 percent.

Since U.S. protection in milk products is also high, we examined the impact of denial of improved access in Nafta markets for Chilean products on both nongrain crops and milk products. Chile exports very few milk products, however, so the welfare result was only slightly more adverse for Chile (−0.60 percent of GDP with central elasticities and existing VAT replacement) relative to denial of Chilean access in nongrain crops alone.

is, the implementation of a preferential trade agreement in a country that starts with a dispersed tariff structure may result in a reduction in the dispersion of the tariff structure. Potential benefits from a reduction in tariff dispersion, however, are ignored in more aggregated analyses of preferential trade arrangements.²⁶ To verify this intuition, we counterfactually created an initial equilibrium in which Chile applies a 22 percent tariff on one-half of its imports and a zero tariff on all others; it then implements the policy scenarios in rows 1 through 4 of table 1, with existing VAT replacement and central elasticities. The sectors with the high tariffs were selected at random, and the experiment was repeated 206 times. The means of the distributions for welfare as a percent of GDP are as follows: free trade area with Mercosur, -0.56 percent; customs union with Mercosur, -0.44 percent; free trade area with Nafta, 1.47 percent; and free trade area with Nafta but without improved access, -0.52 percent.

The gains from the free trade area with Nafta are significantly larger when based on the hypothetical nonuniform initial tariff structure. Similarly, the losses from the free trade area with Mercosur are slightly smaller, reflecting a movement toward uniformity. Losses from a preferential reduction of tariffs toward the Nafta markets remain, however, if not accompanied by improved access to the Nafta market. These numerical results are consistent with the theoretical results of Hatta (1977), who finds that countries benefit from moving toward uniformity by simultaneously lowering the highest tariff and raising the lowest tariff.

In this hypothetical experiment, the ranking of the customs union with Mercosur versus the free trade area with Mercosur is reversed compared with the actual situation represented by table 1. Although Chile still loses from both preferential trade agreements with Mercosur, the customs union produces smaller losses than the free trade area because the common external tariff of Mercosur is more uniform than the hypothetical Chilean tariff. In the actual situation of table 1, the customs union with Mercosur represents a movement away from uniformity.

26. Further theoretical work into the generality of the impact of preferential arrangements on uniformity would be valuable. In our model elasticities are equal across sectors, so the Ramsey-optimal tariff is uniform. A useful exercise would be to evaluate the impact of a preferential trade arrangement, in which we start from randomly selected elasticities across sectors and see how often Chile gains from preferential trade agreements as we use a large number of distinct sets of elasticities.

2.3 Optimizing Chile's Trade Policy Options

We know from theory that Chile can reduce the trade diversion costs of preferential trade areas if it lowers its external tariff. A number of economists thus recommend that Chile reduce its external tariff in conjunction with establishing free trade agreements.²⁷ In rows 5 and 6, we evaluate the two free trade area options with a simultaneous reduction of the tariff to 6 percent. In rows 7 and 8, we examine the impact of lowering the external tariff to 8 percent and 6 percent, respectively, on a multilateral basis. We consider global free trade in row 9.

Chile may have a low optimal tariff despite being a small country, for the following reason. If Chilean exports are differentiated from the products of other countries so that Chile in aggregate faces a downward sloping demand curve for a product, even if individual Chilean producers do not perceive a downward sloping demand curve, then there is an optimal export tax that maximizes Chilean export profits. The height of the optimal export tax is inversely related to the elasticity of demand faced by Chile in its export markets, which is in turn determined by how substitutable Chile's products are with those of other countries.²⁸ In the limit, when Chilean products are perfect substitutes for products from all other countries in all its export markets, Chile has no ability to obtain a higher price by restricting its exports. In this case, the optimal export tax is zero.

Chile imposes virtually no export taxes, but the Lerner symmetry theorem shows that equilibrium import tariffs are generally equivalent to export taxes. The import tariff taxes all export sectors roughly uniformly. Market power on exports differs across sectors and destination markets, however, when the economy is characterized by many export sectors and product differentiation. Consequently, the import tariff is not as efficient an instrument as export taxes varied by sector and destination. Nonetheless, if export taxes are ruled out, there is a positive optimal import tariff. Given the existence of an 11 percent uniform tariff, we investigate both theoretically and numerically whether the optimal tariff is above or below the existing 11 percent tariff.

In our central elasticity scenarios, we assume that all countries have an elasticity of substitution between imports from different

27. For example, Schiff (1996); Corbo (1996); Leipziger and Winters (1996).

28. Individual competitive firms price at their marginal costs, but since the country as a whole must accept a lower price to sell more, there is an optimal export tax that equates the marginal revenue received from exports with the marginal costs. The more elastic the demand, the lower the optimal export tax.

countries (σ_{MM}) equal to 30. We show in Harrison, Rutherford, and Tarr (1997c) that the optimal tariff t^* is bounded below by

$$t^* = \left(\frac{\sigma_{MM}}{\sigma_{MM} - 1} \right) - 1$$

Thus, even with $\sigma_{MM} = 30$, the optimal tariff is over 3 percent, whereas it is over 14 percent in our low elasticity scenarios, with $\sigma_{MM} = 8$.

The preferential trade options in rows 5 and 6 generate the expected increase in the estimated welfare gains relative to rows 1 and 3, respectively. With central elasticities, welfare improves significantly compared with an 11 percent external tariff. With low elasticities, the adverse terms-of-trade effect of reducing tariffs mitigates the welfare gain from reducing the trade diversion costs. These results show that as long as Chile limits itself to a free trade area, it can profit from the increased access it obtains in its partner countries without excessive trade diversion costs, provided it lowers its external tariff sufficiently. In particular, the results in row 5 show that the free trade agreement with Mercosur can be expected to yield benefits when the external tariff is lowered to 6 percent. On the other hand, a comparison of rows 5 and 6 shows that an agreement with Nafta is worth a lot more than one with Mercosur, largely as a result of the superior market access of Nafta.²⁹

Rows 7 and 8 present our estimates of the welfare and replacement tax implications for Chile of unilaterally lowering its external tariff to 8 percent and 6 percent, respectively. With central elasticities and distortionless domestic taxes (either a lump-sum tax or a uniform VAT), unilateral reduction of the tariff to 8 percent increases welfare, and further gains are achieved from reducing tariffs from 8 percent to 6 percent. With the existing VAT as the replacement tax, reducing the tariff to 8 percent increases welfare. However, the distortion costs of the VAT are sufficiently high that, when combined with the small adverse terms-of-trade effects, no further gains are generated by reducing the tariff below 8 percent. With a distortionless

29. These additional gains to Chile with a 6 percent tariff from a free trade agreement with either Mercosur or Nafta derive primarily from the reduction in trade diversion costs, rather than from moving the tariff closer to an optimal tariff. This follows because the unilateral gains are only about 0.1 percent of GDP, whereas the preferential trading arrangements are worth about 0.8 percent of GDP more with the lowered external tariff.

replacement tax, reduction of the external tariff to zero produces positive welfare gains compared with the 11 percent tariff (row 9). The gains are less than in the case of reduction to 6 percent (row 8), which indicates that the optimal tariff is between 0 percent and 6 percent.³⁰

There is thus some limited scope for beneficial tariff reduction under existing VAT replacement and central elasticities. With higher elasticities, the optimal tariff is lower and the gains from tariff reduction greater.

2.4 Sectoral Impacts

In Harrison, Rutherford, and Tarr (1997c), we present the impacts on output, exports, and imports at the twenty-four-sector level of three of the principal trade policy options: the free trade area with Mercosur, the free trade area with Nafta, and unilateral reduction of the tariff to 8 percent. Here we focus on the percentage change in output under central elasticities. The sectors that expand significantly under the free trade agreement with Mercosur are transportation equipment (dramatically), machinery and equipment, iron and steel, and milk.³¹ In the case of the free trade agreement with Nafta, the sectors that expand more than 10 percent are iron and steel, transportation equipment, milk, nongrain crops, and textiles. With unilateral tariff reduction, the expanding sectors are transportation equipment, iron and steel, and, to a lesser extent, nonferrous metals and mining.

Iron and steel and transportation equipment expand under all three trade policy options, but the other expanding sectors differ. Iron and steel and transportation equipment are both small sectors in Chile; each sector produces less than 1 percent of Chilean value added. However, these are the two sectors that export the most intensively: both export over 90 percent of their output. Preferential or multilateral tariff reduction induces a depreciation of the real exchange rate, which

30. These are the results that the vice president of the Central Bank of Chile employed in his presentation before the lower house committee of the Chilean Parliament when he argued for a reduction of the tariff to 6 percent. In fact, we have separately calculated the optimum tariff with central elasticities at between 3 and 4 percent, and with the low elasticities about 14 percent, assuming lump-sum replacement of tariff revenues in each case.

31. Although the expansion of transportation equipment is dramatic in percentage terms, it is starting from a very small base. Thus the absolute increase is plausible.

makes exporting more profitable and gives a boost to sectors that export intensively.

With unilateral tariff reduction, the other sectors that expand (nonferrous metals and mining) also export a high percentage of their output. The real exchange rate impact and export intensity thus explain well the pattern of expanding and contracting sectors with unilateral nondiscriminatory tariff reduction.

Under a free trade agreement with Nafta, textiles, milk, and nongrain crops expand, in addition to the two or three most export intensive sectors, because the former three sectors obtain a substantial improvement in their terms-of-trade in the U.S. market. As discussed earlier, improved access to nongrain crops and milk is crucial to an improvement in Chilean welfare from Nafta, and these sectoral results are consistent with those welfare results.

Finally, the free trade agreement with Mercosur triggers an expansion of machinery and equipment and milk, in addition to transportation and iron and steel. Our data indicate that the former two sectors are among the most highly protected in Mercosur. These sectors obtain relatively greater improvement in their terms-of-trade after the implementation of a free trade agreement with Mercosur, which induces their expansion.

2.5 Additive Regionalism

Butelmann and Meller (1995) articulate the Chilean government's strategy: to negotiate bilateral free trade agreements with Mercosur, Nafta, and all of its significant and willing trading partners, including the European Union and the rest of South America.³² They argue that this strategy progressively lowers the effective average tariff, successively reduces trade diversion costs, and, crucially, helps to ensure stability of access to the markets of partner countries. The free trade agreement between Chile and Canada in late 1996, in which both countries agreed to eschew antidumping actions against each other, is regarded as a notable example of the advantages that the bilateral approach offers. An opposing view within Chile is offered by Donoso and Hachette (1996). They argue that the limited market

32. The percentage share of Chile's aggregate exports (imports) for its most significant trading partners are: the European Union, 32 (23) percent; Japan, 17 (10) percent; the United States, 14 (25) percent; Brazil, 5 (7) percent; Argentina, 5 (6) percent; and the rest of South America, 5 (5) percent.

access of bilateral agreements with southern countries (for example, Mercosur) is not worth delaying the benefits of opening up unilaterally, although agreements with the large markets of the United States, the European Union, or Japan would be worthwhile. Moreover, they fear that the Mercosur arrangement may restrict broader liberalization.

In table 2, we present estimates of the gains to Chile of progressively adding free trade agreements, where we use our central elasticities and a lump-sum tax as the replacement tax. Columns 1 and 2 are reproduced from the estimates in table 1. Column 3 shows that although the Mercosur agreement independently results in losses to Chile, it has a positive rather than negative impact when combined with an agreement with Nafta. The reason is that competition from Nafta producers greatly reduces the extent and impact of trade diversion.³³ Column 4 of row 1 shows that combining agreements with Nafta and Mercosur with an agreement with the European Union results in a large increase in the gains to over 5 percent of GDP. Finally, adding a free trade agreement with the rest of South America results in gains of 8.4 percent of GDP. These are enormous estimated gains for a constant-returns-to-scale model. In the last column of row 1, we exclude the United States from the agreement. This has only a small negative impact on Chile since the country obtains such substantial preferential access in the other markets.

Critics of the government's strategy argue that it is unrealistic to

33. Nafta and Mercosur combined produce gains of 1.48 percent of GDP, whereas the gains would be only 0.61 percent of GDP if the results of the Nafta and Mercosur agreements were merely additive (columns 1 plus 2). That is, we find that reduced trade diversion from the combined agreements accounts for 0.87 percent of GDP. Since this may appear to be too large a saving from reduced trade diversion, we use three additional simulations to verify our explanation: (1) Chile unilaterally eliminates tariffs on Nafta imports without improved access to Nafta; (2) Chile unilaterally eliminates tariffs on Mercosur imports without improved access to Mercosur; and (3) Chile unilaterally eliminates tariffs on Nafta and Mercosur without improved access to Nafta or Mercosur markets. If our explanation is correct, simulation 3 should result in reduced trade diversion costs of at least 0.87 percent of GDP, compared to additive losses from the first two simulations. The welfare impacts from these three simulations are as follows: (1) -0.83 percent of GDP; (2) -0.82 percent of GDP; and (3) -0.77 percent of GDP. If the losses of the preferential tariff reduction were additive, the total losses would be -1.65 (that is, -0.83 - 0.82). Since preferential tariff reduction against the two regions combined results in losses of only -0.77 percent of GDP, trade diversion costs are reduced by 0.88 percent of GDP by combining tariff reductions for the two regions.

Table 2. Welfare Results for Chile of Additive Free Trade Agreements^a
 Percent of Chilean GDP

External tariff rate and product coverage	Mercosur (1)	Partner countries or regions				
		Nafta (2)	Nafta and Mercosur (3)	Nafta, Mercosur, and the European Union (4)	Nafta, Mercosur, the European Union, and the rest of South America ^b (5)	Nafta, Mercosur, the European Union, and the rest of South America ^b (6)
11% tariff; all products included	-0.43	1.04	1.48	5.24	8.40	8.16
11% tariff; excluded products ^c	-	-	-	2.02	2.48	0.44
6% tariff; excluded products ^c	0.35	1.70	2.01	2.29	2.66	0.87
11% tariff; EU agricultural products excluded ^d	-	-	-	2.02	5.48	3.90
6% tariff; EU agricultural products excluded ^d	-	-	-	2.29	5.71	4.44

Source: Authors' estimates.

a. Chilean gains with central elasticities and lump-sum tax replacement.

b. The rest of South America includes all countries in the region except Argentina, Brazil, and Chile.

c. Excluded products in the agreement with the European Union (and their tariffs plus nontariff equivalents in the European Union, in percent) are: wheat (57), grains (74), nongrain crops (51), fishing (14), meat (63), and milk (129). Excluded products in the agreement with the rest of South America (and their tariffs, in percent) are nongrain crops (29), meat (51), milk (27), food (34), beverages and tobacco (55), textiles and apparel (46), chemicals, rubber, and plastics (31), fabricated metal products (43), and machinery (32). All products are included in the Nafta and Mercosur agreements in row 3.

d. Excluded agricultural products in the European Union are the same as in line 3. The other agreements include all products.

assume that the European Union would grant tariff-free access in its highly protected agricultural products as part of a free trade agreement with Chile. The European Union has steadfastly refused to do so in its association agreements with the Central and Eastern European countries and in its free trade and customs union agreements with Mediterranean countries such as Morocco, Tunisia, and Turkey. It is unlikely to offer concessions to Chile that it has refused to offer other countries from which it has more to gain geopolitically. Similarly, although more speculatively, tariff-free access in the most highly protected products is unlikely to be provided by the rest of South America, since (following Grossman and Helpman, 1995) the political economy interests that obtained such high protection would resist regional competition as well.

Row 2 of table 2 presents results that more realistically reflect possible outcomes by excluding highly protected agricultural products from the agreement with the European Union and products with tariffs above 25 percent in the rest of South America from that agreement. The results show, as expected, that the gains would be dramatically reduced without preferential access to these highly protected markets. The last column shows that the United States is crucial to the whole story. If the United States is not included in the additive agreements, the gains drop dramatically to 0.44 percent of GDP. The drop in welfare for Chile exceeds the gains from Nafta alone, showing that competition from (and in) the United States is important if Chile is to avoid the trade diversion costs of these agreements. Conversely, if Chile can get a free trade agreement with the United States as part of Nafta, then free trade agreements with Mercosur, the European Union, and the rest of South America each add about 0.5 percent to Chilean GDP. These gains accrue even when the European Union and the rest of South America exclude their most highly protected items from the agreements.

Proponents of the government's strategy maintain that the trade diversion costs of the free trade agreements would be diminished if Chile adopted a 6 percent external tariff. Moreover, while they concede that access to the European Union in highly protected agricultural products is unlikely, they maintain that Chile could possibly receive full access to the markets of the rest of South America, in view of the sustained trend toward open economies in Latin America. In row 3 of table 2, we evaluate the impact of a 6 percent external tariff with the same products excluded from the agreements with the European Union and the rest of South America as in row 2. There

are slightly larger gains to Chile from lowering the external tariff, but the United States remains important for substantial gains. In rows 4 and 5, we evaluate additive regionalism excluding only European Union agricultural products, so that full access to the rest of South America is obtained. Columns 5 and 6 show that obtaining tariff-free access to the highly protected markets of the rest of South America generates very substantial gains for Chile, with either a 6 percent or 11 percent external tariff.³⁴

If Chile succeeds in including a wide net of countries in its additive regionalism strategy, the estimates of the welfare gains range from 0.44 percent to 8.4 percent of Chilean GDP. In contrast, table 1 indicated that the gains to Chile from unilateral trade liberalization are only about 0.11 percent of GDP. The estimated gains to Chile from additive regionalism are thus between four and seventy-six times the gains from unilateral trade liberalization. On balance, it appears that Chile has little to lose by pursuing additive regionalism, especially given that additive regionalism is being combined with lowering the external tariff to about 6 to 8 percent.³⁵

3. THE IMPACT OF ADDITIVE REGIONALISM ON OTHER COUNTRIES AND A COMPARISON WITH GLOBAL FREE TRADE

Experience with regional trade arrangements has shown that if the agreement is not mutually beneficial to all parties, then it is unlikely to be effectively implemented or sustained (World Bank, 2000). Agreements may exist *de facto*, but they are not implemented effectively. The impact on Chile's partner countries in the trade agreements is thus relevant to the likely success of the strategy in the long run. Moreover, even if the agreements are beneficial to Chile and its

34. These results support the view that preferential access to highly protected markets provides the greatest benefits to Chile, especially if the markets are large.

35. Some critics of Chile's additive regionalism strategy argue that Chile will be unable to negotiate effective agreements with good partner countries if Chile's tariff is low. We are skeptical of this argument, since Chile has reached a tentative agreement with the United States despite lowering its tariff to 6 percent. Singapore has negotiated free trade agreements in recent years, despite having a free trade regime. Critics would maintain, however, that dispute resolution in free trade agreements, for policies such as nontariff barriers, would be difficult for a country with a low tariff, so the value of the agreements would not be great.

partners, if the benefits are derived from losses to countries that are excluded from the agreements, then the agreements would be unattractive from the perspective of the multilateral trading system. This section estimates the impact of Chile's additive regionalism strategy on partner and excluded countries and assesses the impact on the world in general. As a point of comparison, we also estimate the impact of global free trade on the countries and regions of our model.

Our estimates are presented in tables 3 and 4. Table 3 reports welfare gains as a percentage of own-country GDP, for both our central and low elasticity cases. Table 4 then gives the estimated welfare gains in millions of 1995 U.S. dollars, to facilitate a comparison of gains and losses across countries. The first five columns of the first row of table 4 reproduce the results for Chile's additive regionalism strategy that we presented in the first five columns of table 2. The remaining rows present results for the other ten countries or regions in our model. Column 6 presents results for the global free trade scenario.

3.1 Impact on Individual Countries and Regions

The first five columns of table 3 demonstrate that Chile is too small, or its trade pattern sufficiently different, for its regional agreements to have more than a trivial impact on about half of the countries and regions in the model.³⁶ This group includes Japan and the rest of the world (which are excluded from all the agreements evaluated in table 2), as well as the European Union and the United States (which are excluded in some of the arrangements in table 2 and included in others). Canada is also essentially unaffected by Chile's trade policy options.

The rest of South America and Central America, on the other hand, lose from all the agreements from which they are excluded, although the welfare loss is only about five one-hundredths of a percent of their GDP. These regions compete with Chile for the markets in Mercosur and Nafta, and they compete with producers from Mercosur and Nafta for the Chilean market. In both cases, they lose access to markets since the demand for their exports declines owing to preferential access arrangements between Chile and its partners; this adversely affects their terms of trade and welfare.³⁷

36. When we round welfare to the nearest one-hundredth of a percent of GDP, the impact is either zero or one one-hundredth of one percent.

37. This is consistent with the evidence of Winters and Chang (2000) who find that the price of imports from the US and Korea in Brazil fell after the formation of Mercosur.

Table 3. The Welfare Impact of Chile's Additive Free Trade Agreements and Global Free Trade^a
 Percent of each country's GDP

Country	Elasticity	Mercosur (1)	Nafta (2)	Nafta and Mercosur (3)	Partner countries or regions		
					Nafta, Mercosur, and the European Union (4)	Nafta, Mercosur, the European Union, and the rest of South America (5)	Nafta, Mercosur, the European Union, and Global free trade (6)
Chile	Central	-0.40	1.04	1.48	5.24	8.40	1.26
	Low	0.00	0.37	0.60	2.55	3.31	0.68
Argentina	Central	0.06	0.00	0.10	0.12	0.07	0.82
	Low	0.00	-0.01	0.02	0.02	0.01	0.60
Brazil	Central	0.02	-0.01	-0.04	-0.04	-0.02	0.94
	Low	0.00	-0.01	0.00	0.00	-0.01	0.24
Canada	Central	0.00	0.00	0.00	0.00	0.01	0.42
	Low	0.00	0.00	0.00	0.00	0.00	-0.36
Central America	Central	0.00	-0.06	-0.05	-0.04	-0.06	9.70
	Low	0.00	-0.03	-0.03	-0.05	-0.06	4.42
European Union	Central	0.00	0.00	0.00	0.00	0.00	2.74
	Low	0.00	0.00	0.00	0.00	0.00	1.17
Japan	Central	0.00	0.00	0.00	0.00	0.00	3.43
	Low	0.00	0.00	0.00	0.00	0.00	1.98
Mexico	Central	0.00	-0.02	-0.01	0.00	0.00	-1.38
	Low	0.00	-0.01	-0.01	0.00	0.00	-1.02
United States	Central	0.00	0.00	0.00	0.00	0.00	0.34
	Low	0.00	0.01	0.00	0.00	0.00	0.18
Rest of South America	Central	0.00	-0.03	-0.04	-0.04	-1.19	4.40
	Low	0.00	-0.02	-0.05	-0.05	-0.22	1.25
Rest of the world	Central	0.00	0.00	0.00	0.00	0.00	1.97
	Low	0.00	0.00	0.01	0.00	0.01	0.54

Source: Authors' estimates.

a. Lump-sum tax replacement and all products included in the agreements. The rest of South America includes all countries in the region except Argentina, Brazil, and Chile.

Table 4. The Welfare Impact of Chile's Additive Free Trade Agreements and Global Free Trade^a
 Millions of 1995 U.S. dollars

Country	Elasticity	Mercosur (1)	Nafta (2)	Partner countries or regions			
				Nafta and Mercosur (3)	Nafta, Mercosur, and the European Union (4)	Nafta, Mercosur, the European Union, and the rest of South America (5)	Nafta, Mercosur, the European Union, and the rest of South America (6)
Chile	Central	-291	414	590	2,090	3,350	504
	Low	-67	149	239	1,013	1,318	270
Argentina	Central	63	-1	222	264	147	1,832
	Low	44	-18	54	54	28	1,327
Brazil	Central	214	-42	-171	-161	-70	3,912
	Low	108	-36	15	-11	-21	1,004
Canada	Central	5	-20	-22	23	49	243
	Low	4	-15	-13	14	19	-2,058
Central America	Central	4	-37	-32	-23	-38	6,112
	Low	3	-21	-21	-29	-36	2,680
European Union	Central	-184	-156	-336	-88	-200	207,413
	Low	-28	-241	-317	156	86	88,720
Japan	Central	-58	-19	-30	81	-2	127,664
	Low	-30	-48	-69	-76	-91	73,711
Mexico	Central	13	-58	-44	-11	15	-4,539
	Low	1	-35	-35	-3	0	-3,315
United States	Central	-7	51	-29	138	60	19,972
	Low	-24	306	231	59	-11	10,833
Rest of South America	Central	-34	-56	-95	-73	-2,024	7,456
	Low	-28	-39	-75	-90	-376	2,110
Rest of the world	Central	92	-73	-50	-115	6	85,111
	Low	29	-89	-100	-229	-232	23,348

Table 4. (continued)

Country	Elasticity	Partner countries or regions				
		Mercosur (1)	Nafta (2)	Nafta and Mercosur (3)	Nafta, Mercosur, and the European Union (4)	Nafta, Mercosur, the European Union, and the rest of South America (5)
Sum for included countries	Central	-14	387	546	2,255	1,327
	Low	85	405	491	1,282	1,043
Sum for excluded countries	Central	-169	-384	-543	-130	-34
	Low	-73	-492	-582	-424	-359
Sum for all countries	Central	-183	3	3	2,125	1,293
	Low	12	-87	-91	858	684
						198,626

Source: Authors' estimates.

a. Lump-sum tax replacement and all products included in the agreements. The rest of South America includes all countries in the region except Argentina, Brazil, and Chile.

While the rest of South America loses from being excluded by Chile, the biggest loss for this region by far occurs when the rest of South America is included with Chile in a free trade agreement (along with the European Union, Nafta, and Mercosur, as shown in column 5). The rest of South America has high protection on the products mentioned in the notes to table 2. To the extent that Chilean imports displace imports from other countries in the rest of South America, the rest of South America loses tariff revenue on imports. Although some trade creation results from tariff free access to Chilean imports in the rest of South America, the tariff loss dominates the trade creation owing to the high level of the tariffs.³⁸ Moreover, a comparison of columns 4 and 5 illustrates that the addition of the rest of South America to the coalition of Chile, the European Union, Mercosur, and Nafta results in an aggregate reduction in welfare for the partner countries. The gains to the other partners to this agreement are less than the losses to the rest of South America. The benefits are thus insufficient to allow the gainers to compensate the rest of South America for its losses.

For Mexico, competition from Chile for preferred access in the U.S. market results in a very small negative impact of including Chile in Nafta. Chile, however is too small to make a significant difference to Mexico in the U.S. market. When Chile combines an agreement with Nafta with an agreement with Mercosur, the diversification of Chilean exports results in still less displacement of Mexican exports in the United States, which reduces the negative impact on Mexico of Chile in Nafta. When Chile adds the European Union to its group of free trade agreements, the diversification of Chilean exports reduces the small negative impact on Mexico of Chile's preferential access to the United States to virtually zero. Mexican losses are substantial in our global free trade scenario discussed below, given the erosion of preferential access in U.S. markets from the whole world.

Brazil and Argentina both lose from Chile joining Nafta as a result of the erosion of preference margins in both Chile and Nafta markets. Both countries gain small amounts from a Mercosur free trade agreement with Chile. The latter fact is partly explained by improved access to the Chilean market for Mercosur producers. This result is probably also partially explained by the fact that

38. If the high tariff products mentioned above are excluded from the free trade agreement with Chile, the losses are reduced to about one-third of their level (to -0.36 percent).

Brazil and Argentina reduce the trade diversion costs of Mercosur when they add new partners. That is, Chile would compete with Brazilian producers in Argentine markets, which reduces Argentina's trade diversion costs from importing Brazilian products under the Mercosur agreement. Of course, Chile could displace imports from the rest of the world in Argentine markets, which could increase Argentine trade diversion costs. As more countries are added to a network of preferential trading arrangements, however, the trade diversion costs associated with earlier partners is reduced, especially if these are large countries that interject significant competition.³⁹ Brazil and Argentina both lose from Chile negotiating a free trade agreement with the rest of South America (see columns 4 and 5). This is likely due to a terms-of-trade loss in the markets of the rest of South America.

3.2 Aggregate Impact of Chile's Additive Regionalism Strategy

Even if Chile gains from an agreement or set of agreements, the question remains of whether Chile gains only because other countries lose. Table 4 converts the percentage gains and losses of table 3 into gains and losses in millions of 1995 U.S. dollars. This allows us to compare gains and losses across countries and arrive at a total for the world. At the bottom of the table, we sum the welfare effects, first, for countries that are included in the agreement. For example, Chile-Mercosur (column 1) includes Chile, Argentina, and Brazil in our model. We then sum the welfare effect for all countries that are not part of the agreement (for example, all countries other than Chile, Argentina, and Brazil in the case of Chile-Mercosur). The final row presents the sum of all countries.

The sum for included countries shows that the Chile-Mercosur agreement is dominated by trade diversion, to the extent that even the members of the agreement lose in aggregate. This is, however, the only agreement we consider that results in losses for the member countries. All the north-south agreements in table 4 (which all include the United States) result in aggregate net benefits for the member countries, even though at least one member loses in all of them. The inclusion of the United States means that significant com-

39. It is possible, however, that a new partner could divert imports from an excluded country and add to the trade diversion costs on balance.

petition is injected into the markets of participating members, which reduces the likelihood of trade diversion dominating.

The sum for excluded countries indicates that all of the preferential arrangements considered result in losses for the excluded countries or regions. These results are consistent with Winters and Chang (2000), who find, based on ex post data, that regional arrangements can have a very significant negative welfare effect on excluded countries (through negative terms-of-trade effects). In particular, they estimate that Mercosur induced losses for Chile, Germany, Japan, Korea, and the United States of about \$800 million per year, which was about 9 percent of the value of their exports to Mercosur.⁴⁰

For the world as a whole, assuming central elasticities, the agreement with Mercosur leads to losses for the world of \$183 million, primarily owing to the trade diversion costs for Chile and the terms-of-trade loss for the European Union. Independent of elasticities, the agreements in the first three columns result in essentially a zero impact for the world or for the three excluded regions outside of the Western Hemisphere (rounded to the nearest one-hundredth of a percent of their own GDP). Chile gains significantly when Nafta is involved, but the terms-of-trade loss for the excluded countries is almost as much as the gains to Chile, so the impact on the world is small.

The gains for the world become significant when either the European Union or the European Union and the rest of South America are added to Chile's network of agreements (see columns 4 and 5). The main reason behind these larger gains to the world is that the gains to Chile become very large when it obtains preferential access to the markets of the European Union and the rest of South America. Given the high protection on selected products in the rest of South America, however, the trade diversion costs in this region significantly reduce the gains to the world from including this region in Chile's network of free trade agreements.

3.3 Impact of Global Free Trade

The results for global free trade are presented in column 6 of tables 3 and 4. As expected the gains to the world vastly exceed

40. We estimate a very small negative effect for Central America as a result of Chile forming a free trade area with Nafta.

the gains from any regional arrangement. Even the included countries to any agreement gain more from multilateral global free trade than any individual regional arrangement (although the impact on Chile of an agreement with Nafta is close). These results emphasize the importance of moving toward lower trade barriers in the multilateral context.

Mexico is an exception (as is Canada in the low elasticity case). Mexico sees losses from global free trade owing to the erosion of favored access to the U.S. market.

3.4 Impact of the Free Trade Agreement of the Americas

We estimate that Chile would gain from a Free Trade Agreement of the Americas (FTAA) if we assume that Chile starts from a status quo of no preferential trade agreements in the Americas. The estimated gains are 1.25 percent of GDP under central elasticities and 0.53 percent under low elasticities.

Given that Chile already has several agreements in the Americas in place, Chile would lose preferential access to these markets, including Nafta and Mercosur. The FTAA's impact on Chile is therefore ambiguous; it depends on how much preferential access Chile has in the markets of the Americas compared to other countries.

4. SYSTEMATIC SENSITIVITY ANALYSIS

To calibrate the model, estimates of elasticities must be assembled for primary factor substitution, import demand, import source, and domestic demand. In the base model, all elasticity values are assigned *a priori* to values that we believe are plausible central tendency estimates. Since elasticity estimates are subject to a margin of error, our remedy for this problem, which is endemic to any large-scale model of this kind, is to undertake systematic sensitivity analyses of our major results with respect to plausible bounds on these elasticities. Even if we are unable to specify a point estimate with any precision, our prior assumptions over the likely bounds that these elasticities could take are quite strong. To the extent that our major conclusions are robust to

perturbations over these bounds, we do not see our uncertainty over specific values of these elasticities as a weakness of the model.⁴¹

Our sensitivity analysis employs the procedures developed by Harrison and Vinod (1992). These procedures essentially amount to a Monte Carlo simulation exercise in which a wide range of elasticities are independently and simultaneously perturbed from their benchmark values. These perturbations follow prescribed distributions, such as a *t* distribution with a specified standard deviation and degrees of freedom, or a uniform distribution over a specified range. For each Monte Carlo run, we solve the counter-factual policy with the selected set of elasticities. This process is repeated until we arrive at the desired sample size, which in our case is 3,500. The results are then tabulated as a distribution, with equal weight being given (by construction) to each Monte Carlo run. The upshot is a probability distribution defined over the endogenous variables of interest.

We focus solely on the welfare impacts of the scenario in which Chile joins Nafta and unilaterally imposes a 6 percent tariff on imports, using lump-sum taxes to replace any lost revenue. The point estimate of the welfare change for Chile from this scenario is 1.70 percent of GDP (see table 1). The issue for our sensitivity analysis is whether that result is robust to uncertainty over the elasticities.

The sensitivity analysis we undertake reflects a diffuse set of prior assumptions over the plausible elasticity values. Specifically, it assumes that elasticities are drawn from a probability distribution, typically uniform, over a specified interval. For the elasticity of substitution between primary factors in each sector, we assume a univariate normal distribution in each sector using the point estimate and standard errors from Harrison and others (1993) (the base model assumes the point estimates).⁴² For the elasticity of substitution between intermediate inputs and the value added composite in each sector, we assume a uniform distribution between 0 and 0.5 (the base model assumes 0). For the elasticity of substitution between domestic products and imported products, we assume a uniform distribution between 10 and 20 (the base model assumes 15). For the elasticity of substitution between imported prod-

41. These remarks should not be interpreted as denying the value of any new empirical work on generating such elasticities. On the contrary, any effort that could generate better bounds on these point estimates would be useful in generating policy conclusions that carry greater credibility, even if those conclusions are still probabilistic in nature. Moreover, we do not consider sensitivity analysis with respect to more general functional forms, even though we share concerns with the restrictiveness of some of the popular forms we employ.

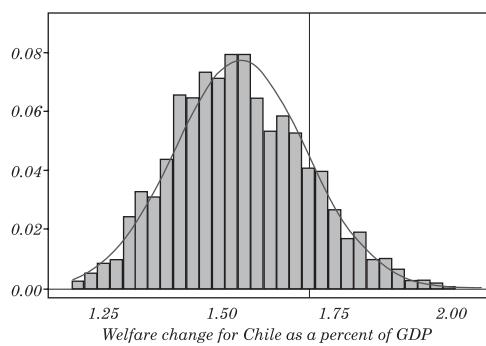
42. The distribution is truncated from below at 0 if need be.

ucts by source, we assume a uniform distribution between 20 and 40 (the base model assumes 30). For the elasticity of transformation between domestic and export markets, we generally assume a uniform distribution between 2 and 6 (the base model generally assumes 4).⁴³ Finally, for the elasticities of substitution between products in government demand and consumption demand for each household, we assume an interval between 0.5 and 1.5 (the base model assumes 1).

The results are reported in figure 1 in the form of a histogram of the solutions obtained. We also display a vertical line at the 1.7 percent point estimate, for comparison. The main welfare results for the base model are relatively robust to the range of elasticity perturbations considered here, although the point estimate of 1.7 percent is a slight overestimate of the true distribution of likely welfare impacts. The distribution of welfare impacts estimated with the sensitivity analysis has a mean of 1.54 percent, a standard error of 0.15 of a percentage point, a 90 percent confidence interval between 1.31 and 1.81 percent, and no values lower than 1.14 percent or higher than 2.05 percent. The point estimate is at the eighty-fifth percentile of the distribution of results, so 15 percent of the solutions generated welfare changes that were greater than 1.7 percent.

Our sensitivity analysis is local in the sense that we perturb trade elasticities around what we believe are plausible values. Since we

Figure 1. Change in Chile's Welfare when Joining Nafta and Imposing a 6 Percent Tariff
Fraction of solutions ($N = 3,500$)



Source: Authors' calculations.

43. The base model assumes a higher elasticity of transformation of 5 for three agricultural sectors (namely, wheat, other grains, and Nongrain crops). The uniform distribution varies the elasticity for these sectors between 3 and 7.

already know that the effects of the scenario are sensitive to the use of significantly lower short-run trade elasticities, there is little point including that in our formal sensitivity analysis. In other words, it is more informative to present results conditional on either short-run or long-run assumptions, and then undertake local sensitivity analysis around the precise numbers used to make either of those assumptions operational. Our primary conclusion, of significant welfare improvements for Chile from the policy of joining Nafta and setting a 6 percent import tariff, is thus robust to plausible uncertainty about the key elasticities of the simulation model.

5. CONCLUSIONS

Our results for Chile point to some general themes regarding regional trading arrangements. One clear theme is that improved market access in preferential trading areas is important. In the case of Chile, trade diversion costs dominate the welfare effects of bilateral agreements unless either sufficient market access is obtained in partner countries or third-country tariffs are lowered. The north-south agreements generally provide sufficient access to make them beneficial, but the south-south agreement we examined (namely, Mercosur) did not. Chile can reduce trade diversion costs and increase the net benefits of all agreements, however, by lowering its tariff to 6 percent. In the case of Mercosur, this agreement becomes beneficial with the reduction in the external tariff to 6 percent.

Absent its regional arrangements, unilateral reduction of the tariff to 6 percent conveys very small gains to Chile, whereas the regional arrangements are considerably more beneficial with the 6 percent tariff. Moreover, efficient replacement taxes are important with either regional or unilateral trade policy changes, and they provide greater scope for trade policy action. Finally, our range of estimates for the gains from additive regionalism indicate that Chile has little to lose by pursuing this strategy, and it may potentially gain many multiples of the gains from unilateral trade liberalization.

We find that the excluded countries lose from all of the regional arrangements that we examine. Partners to the preferential arrangements sometimes also lose. Chile's additive regional arrangements have an almost imperceptible impact on world welfare. In contrast, we estimate that global free trade generates gains to the world that are enormous in comparison, emphasizing the importance of moving toward lower trade barriers in the multilateral context.

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GENERAL EQUILIBRIUM ANALYSIS OF A FUEL TAX INCREASE IN CHILE

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Achieving economic growth has been an important issue for over half a century. More recently, developed countries have incorporated the need for a more equitable and environmentally balanced growth. The complexity of modeling an economy with all its interrelations, agents, and sectors, however, has led to the common practice of studying economic, social, and environmental policies in isolated form, in a context of partial equilibrium. Unfortunately, many measures that affect the environment also have an impact on economic growth, poverty, employment, or income distribution. Consequently, a full understanding of either the effects of macroeconomic policies on the environment or the impact of environmental or welfare policies on macroeconomic variables can only be achieved through the use of models that include the complex interrelations between the diverse sectors and agents of the economy. Significant developments have been made in the last fifty years with regard to the concepts and, more fundamentally, the analytic and computational tools for implementing such models.

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In the 1960s, growth and, more generally, economic development formed the central objective of economic planning. In 1966, Kuznets emphasized that achieving modern economic growth and the so-called industrialization of developing countries would require introducing drastic and systematic changes in the production structures, along with changes in demand, employment, investment, and international trade. He further warned of the relevance of carefully examining the velocity and schedule for these changes. Accordingly, in-depth planning of the process of growth, with an appropriate level of detail and disaggregation, was deemed fundamental.

The systematic and structural nature of the economic changes, and the great speed with which they were applied, generated consequences that crudely revealed that production sectors, trade structures, and the different markets and their participating agents could not be considered, analyzed, or intervened independently. Production bottlenecks, excesses in sectoral supply, unsatisfied demand, inefficient resource allocation, and the dependence of national policies and structural adjustments on international events increased the necessity of developing multisectoral models with increasing disaggregation. These were required to provide a useful framework for understanding and planning the structural changes, stressing the interrelations and interdependencies among production sectors, markets, agents, and so forth in a setting of general equilibrium.

In this context, input-output models were initially the main tools employed by those in charge of economic planning. They allowed the analysis of the linkages between sectors and the use of productive factors, mainly capital and labor. They were also helpful in understanding the different components of final demand and the value added of each particular sector and in facilitating a systematic comparison of them. These models suffer from serious limitations, however, such as their inability to incorporate market mechanisms or optimization processes, their fixed coefficients that impose fixed relative prices, their poor substitution possibilities, and their lack of social and environmental variables. Nevertheless, they were used for these purposes, based on the incipient development of computer sciences and mathematical techniques.

In the 1970s, exclusive concern with growth and development goals began to be perceived as insufficient. The debate about the need to balance economic growth and environmental impacts entered strongly starting in 1972, when the Club of Rome published *The Limits to Growth* (Meadows and others, 1972). Those in charge of generating social and economic policies and economic agents in general had to incorporate

new relevant variables into their decisionmaking process. Growth models increased in complexity, and the detailed definition of development strategies became even more necessary.

In 1987 the Brundtland Commission brought the concept of sustainable development into the mainstream discussion, defining it rather vaguely as development that "allows achieving the needs of the present generations without endangering future generations."¹ In practice, this definition has required that developing societies simultaneously meet economic, environmental, and social objectives for both the present and future generations (Pearce and Turner, 1990). Countrywide economic models therefore need to take into account a diversity of objectives associated with sustainable development. Economic objectives consider the need not only for economic growth, but also for increased equity and efficiency. Environmental objectives include concern about system integrity, bio-diversity, the capacity for assimilation, and global issues. Finally, social objectives encompass issues such as participation, social mobility, cultural identity, and institutional development. The debate on development continues with more or less conflicting positions, incorporating and trying to integrate economic and environmental variables in the most appropriate way.²

The complexity of the direct and indirect interrelations among economic, environmental, and social variables has increasingly called for models that allow the evaluation of policies that lead to sustainability. These models must take into account market mechanisms and optimizing behaviors, which determine the decisions of economic agents and the effectiveness of public policies. The prevailing economic paradigm requires eliminating the shortcomings of input-output models—such as the failure to incorporate price mechanisms—so they might contribute to planning processes.

Consequently, increasingly sophisticated policy analysis tools have been developed. These models are now able to capture the complex concept of sustainability, and they systematically and quantitatively analyze the evolution of the variables related to the three macroeconomic objectives of sustainability (namely, economic growth, equity, and environmental sustainability). In particular, applications based on computable general equilibrium (CGE) models were developed

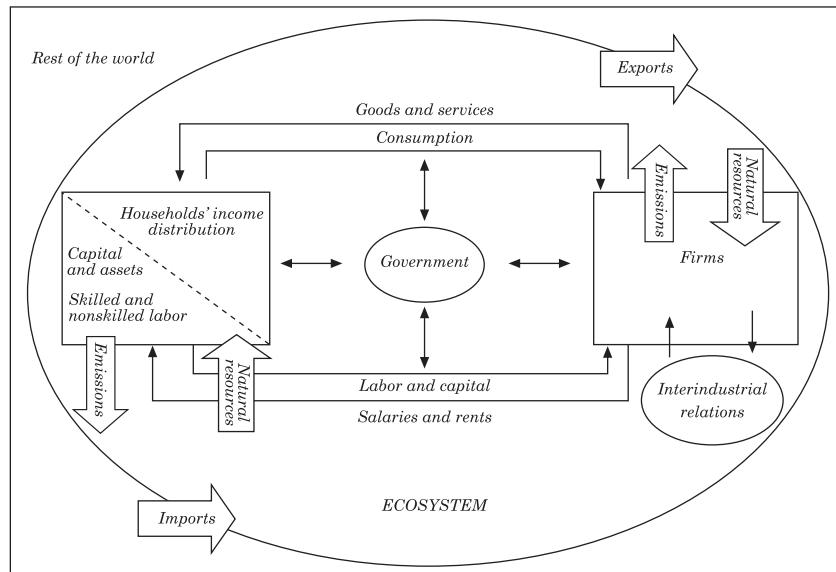
1. See the *Brundtland Report*, also known as *Our Common Future*, presented by The World Commission on Environment and Development at the 42nd Session of the U.N. General Assembly (A/42/427, 4 August 1987).

2. "Environmental Scares: Plenty of Gloom." *The Economist*, 20 December 1997; Dasgupta and Mäler (1998); Kneese (1998).

in the late 1970s and especially in the 1980s. These multisectoral models solve the limitations of the input-output models as evaluation instruments, representing the economy of a country more realistically by incorporating market mechanisms in the assignment of resources. They have also proved to be a useful instrument for describing the main relationships outlined and quantitatively evaluating *ex ante* the effects of different economic, social or environmental policies, in addition to the indirect side effects that in many cases evade the intuition.

Figure 1 schematically presents the relationships that can be modeled by means of a CGE model, based on the circular flow of the economy. It includes the main agents (that is, firms, households, and the government), flows of goods and services, payments to factors, international trade, and relationships with the environment. Each agent is modeled according to certain behavior assumptions; in particular it is common to assume optimizing producers (cost) and consumers (utility). Each market is modeled according to the specific reality of the economy—for instance, as a competitive or noncompetitive market or, in the case of the labor market, with or without full employment.

Figure 1. Circular Flow of the Economy



Source: Authors' elaboration.

These models simulate an economic Walrasian equilibrium by equating demand and supply in all markets, thereby obtaining equilibrium prices and quantities. A fundamental characteristic of the production sector in these models, as in the input-output models, is that it incorporates the demand for intermediate inputs, not just capital and labor. However, they differ from the rigid cost structure of the input-output models by allowing cost minimization by economic agents through substitution among production inputs (type and origin). The government sector is also modeled, as an agent that applies taxes, subsidies, and transfers.³

CGE models can be static or dynamic.⁴ Static models are normally used for analyzing interrelations throughout the economy and the linkages among sectors and agents. Moreover, they focus on stabilization policies and contingency issues. Dynamic models focus more on forecasting issues related to growth patterns and development strategies. Nevertheless, static models can deal with different temporal frameworks by altering parameters and elasticities. There are tradeoffs between analysis and forecasting. Good analysis can be done using many sectors, but it requires many assumptions and a large number of parameters. Alternatively, it is hard to make realistic forecast estimations in a dynamic framework with many sectors, and simpler models are preferred.

The goal of this paper is to show the potential of CGE analysis as a tool for policy evaluation in Chile. The paper is organized as follows. Section 1 presents the basic features, assumptions, and equations of the ECOGEM-Chile model. Section 2 then describes the data used for simulating with the model. Section 3 presents the economic, social, and environmental impacts of an increase in fuel taxes of 100 percent. A second scenario is also analyzed, in which this environmental policy

3. CGE models generally do not include endogenous optimizing behavior or any objective function for the public sector, for both technical and ethical reasons. The budget restriction, including both expenditures/transfers and tax revenues, is the main component of the policy simulations, and it is modified exogenously to explore different policy implications. It is also a key element for the domestic closure rules of the model. On the other hand, tax structure and the distribution of expenditures (coming from the social accounting matrix) represent an elected government decision, which must symbolize the preference of the majority of voters in a democracy. Finally, a public utility function that allows the endogenous modification of the public expenditure decisions in response to, say, an external shock must be supported by an ethical discussion and by the generally accepted economic thinking before the empirical results of the simulations.

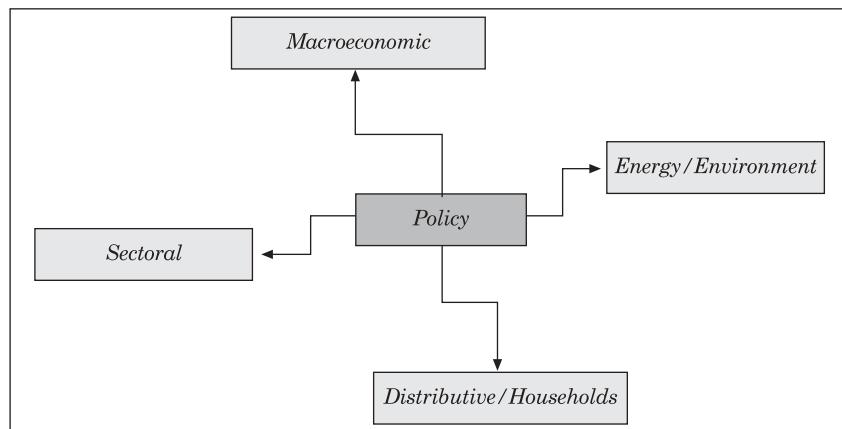
4. For a review of theory and applications of CGE models, see O’Ryan, De Miguel, and Miller (2000).

is combined with a trade policy financed by the increased public revenues. Finally, section 4 presents our main conclusions.

1. THE ECOGEM-CHILE MODEL

The ECOGEM-Chile model was developed to analyze, in a general equilibrium framework, different policies and their impacts on the various agents in the economy. It is capable of analyzing the impacts of a given economic, social, or environmental policy on macroeconomic, sectoral, and social variables and the environment (figure 2).

Figure 2. ECOGEM-CHILE Analysis



Source: Authors' elaboration.

1.1 Basic Features of the ECOGEM-Chile Model

The CGE model developed for Chile is a static model with multiple sectors, labor differentiation, income-group differentiation, trade partners, and specified productive factors, among other features.⁵ It is a neoclassical model, which is savings driven. It incorporates

5. The ECOGEM-Chile model was adapted by the Instituto de Asuntos Pùblicos (INAP) and the Centro de Economía Aplicada (CEA), both of the University of Chile, from a model developed by Beghin and others (1996) at the Organization for Economic Cooperation and Development (OECD). Basic features remain the same.

energy-input substitution to reduce emissions, as is common, because the emissions are related to the use of different inputs as well as to production and consumption levels.

The most important equations of the model are presented in this section, particularly those associated with environmental variables. The main indexes that will be used in the model's equations are as follows: production sectors or activities (i, j); types of work or occupational categories (l); household income quintiles (h); public spending categories (g); final demand spending categories (f); trade partners (r); and different types of pollutant (p).

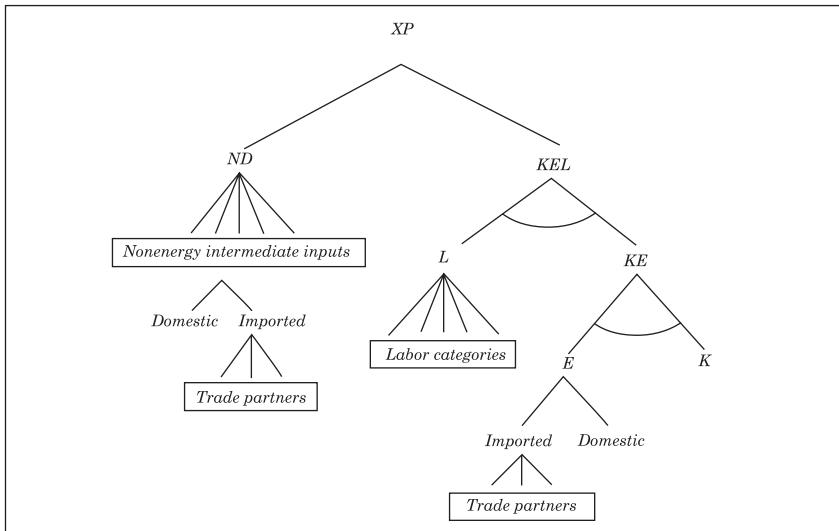
Production structure

Production is modeled by CES/CET nested functions (that is, constant elasticity of substitution and constant elasticity of transformation). If constant returns to scale are assumed, each sector produces while minimizing costs:

$$\begin{aligned} \min \quad & PKEL_i KEL_i + PND_i ND_i \\ \text{s.t.} \quad & XP_i = \left[\alpha_{KEL,i} KEL_i^\sigma + \alpha_{ND,i} ND_i^\sigma \right]^{1/\sigma}, \end{aligned}$$

where KEL is a composite good of capital, energy, and labor; $PKEL$ is the price of KEL ; ND is a composite good of nonenergy intermediate inputs; PND is the price of ND ; XP is total output; α is the share of input/factor use; and σ is the CES exponent related to the substitution elasticity.

Figure 3 presents the production function as a nested input/factor tree. In the tree's first level, decisions are made through a CES function to choose from a non-energy-producing intermediate input basket and a factor basket comprising capital, labor, and energy-producing inputs. To obtain the non-energy-producing intermediate input basket, a Leontieff function is assumed. On the factor side, a new CES function is used to split the elements into a capital-energy basket and labor and then to separate energy from capital, always assuming CES functions for substitution both between and within factors (types of labor, energy, and capital). Energy was modeled as a third factor to allow substitution among energy inputs, thus allowing sectors to adjust more realistically to environmental policies related to air emissions.

Figure 3. CES-nested Production Function

Source: Beghin and others (1996).

Consumption

Households use their income for consumption and savings. Their decision process is modeled by an extended linear expenditure system (ELES).⁶ This utility function also incorporates a minimum subsistence-level consumption independent from the level of income.

$$\max \quad U = \sum_{i=1}^n \mu_i \ln(C_i - \theta_i) + \mu_s \ln\left(\frac{S}{CPI}\right), \text{ subject to}$$

$$\sum_{i=1}^n PC_i C_i + S = YD \text{ and}$$

$$\sum_{i=1}^n \mu_i + \mu_s = 1 ,$$

6. The way in which savings are included (divided by a price index of the other goods) partially neutralizes the substitution between consumption and savings, because the savings price is a weighted price of all the other goods. In this sense, savings represent future consumption.

where U represents the consumer's utility; C_i is the consumption of good i ; θ is the subsistence-level consumption; S is saving; CPI is the price of savings; and μ is the marginal propensity to consume each good and to save.

Other final demands

In addition to intermediate demand and household demand, the model includes the rest of final demand: investment, government consumption, and trade margins. These demands are modeled through fixed shares of the total final demand.

Public finances

The model considers different types of taxes and transfers. The following direct taxes are defined in the model: labor tax (differentiated by occupational category), taxes on firms, and taxes on income (differentiated by quintile). The model also defines import tariffs and subsidies, as well as export taxes and subsidies (by sector). Value-added tax (VAT)—for domestic and imported goods and by sector—and specific taxes are also included.

Foreign sector

To incorporate the foreign sector, we use the Armington assumption to break down goods by place of origin, allowing imperfect substitution between domestic and imported goods and services. As with production, a CES function allows substitution between the imported and domestic baskets. Domestic supply gets a similar treatment as demand, now including a CET function to distinguish the domestic market from exports. For imports,

$\min \quad PD \cdot XD + PM \cdot XM$, subject to

$$XA = [\alpha_d XD^\rho + \alpha_m XM^\rho]^{1/\rho},$$

where PD and PM are the prices of domestic and imported goods, respectively, while XD and XM are the respective quantities. XA represents the good made up of both imports and exports, that is, the Armington good. Parameter ρ is related to the substitution elasticity between both goods.

For exports,

$$\min \quad PD \cdot XD + PE \cdot XE, \text{ subject to}$$

$$XP = \left[\gamma_d XD^\lambda + \gamma_e XE^\lambda \right]^{1/\lambda},$$

where PE is the price of the exported good and XE is the respective quantity. XP is the sector's total production. Parameter λ is related to the substitution elasticity between the domestic and exported goods.

Factor market equilibrium conditions

To achieve labor market equilibrium, labor supply and demand are made equal for each occupational category, where supply is determined on the basis of real wages. As for the capital market, a single type of capital is assumed to exist, which may or may not have sector mobility depending on the imposed elasticity.

Closure conditions

The model allows two alternative closure conditions for public finances. In the first, government savings are defined as fixed and equal to the original level prior to any simulation; an adjustment is allowed through some tax or government transfer to achieve government fiscal target. In the second alternative, government savings are allowed to vary, while taxes and transfers are kept fixed. The second option was chosen in the application developed in this paper.

As is usual in these models, the value of the demand for private investment must equal the economy's net aggregate saving (from firms, households, government, and net flows from abroad). The final closing rule refers to balance-of-payments equilibrium. This equation is introduced into the model through Walras Law.

1.2. Environmental Specifications in the Model

The model allows three possibilities for reducing emissions of pollutants in the economy. They all introduce some kind of tax or policy that alters the economic players' decisions in their profit- or benefit-maximizing processes. The first is the most traditional and common mechanism in general equilibrium models, namely, lowering production in the most highly polluting sectors. The second involves

substitution among different energy inputs that may be more or less polluting. The third possibility is to reduce emissions through the use of end-of-pipe technologies (such as filters and treatment plants). This last possibility is in the experimental stage and thus is not included in the results of our simulations.

The model does not include the possibility of technological change—stemming from investment processes based on relative returns—toward new, less polluting technologies, because this would require the use of a dynamic model. Moreover it is currently possible to change substitution elasticities to simulate more flexible technologies for less polluting processes. Also left out of the players' utility function is the environmental quality as a good for which there is a willingness to pay, which alters consumption decisions on the rest of the goods and their equilibrium prices.

Lowering production

Introducing a tax on emissions raises production costs. All things equal, this causes an increase in the price of the good produced by the polluting industry (which pays for the tax). The industry thus becomes less competitive at both the national and international levels, and the demand for the good and production both fall, at least in the long run. In the case of environmental regulation that sets a limit on emissions, the company will be forced to reduce its level of production.

These mechanisms are essentially based on making prices endogenous in the general equilibrium model, together with the possibility of reallocating factors and resources among the various production sectors (a CES function), substitution between different goods at the level of final demand (an ELES function), and substitution between the domestic and the foreign markets (a CET-Armington function).

Substitution among inputs

The use of each type of input in either production or final consumption causes a certain level of emissions independently of the production process. Therefore, another way to reduce emissions is to substitute less polluting inputs for the more polluting ones. In the case of a tax on emissions, the costs associated with using a more polluting input are indirectly increased, such that its use becomes relatively more costly and its substitution is encouraged.

In the case of a new emissions regulation, a constraint on optimization is introduced both in the domestic economy and in firms. Continuing to use the same volume of polluting inputs leads to a suboptimal situation that converges toward the original optimum to the extent that substitution occurs toward less polluting or noncontaminating inputs.

The model basically differentiates between energy-producing and non-energy-producing inputs. Non-energy-producing inputs are used in the production function with fixed coefficients. Substitution between energy-producing inputs or between these and other productive factors (capital and labor) is determined by CES functions nested within the production function.

Energy-producing inputs (that is, coal, petroleum-based fuels, electricity, and natural gas) are associated with the emission of up to thirteen types of pollutants (not all of which are discharged by the energy-producing inputs) through emission factors. These emission factors link the use of each money unit spent on the input to the amount of emissions of each pollutant in physical units. The total volume of emissions in the economy for each type of pollutant is therefore determined by the following equation:

$$E_p = \sum_i v_i^p \cdot XP_i + \sum_i \pi_i^p \cdot \left(\sum_j XAP_{ij} + \sum_h C_{ih} + \sum_f XAFD_f^i \right),$$

where v and π are the output- and input-based emissions coefficients, respectively; XP is total output; XAP is intermediate consumption; and $XAFD$ other total final demands (from investment and government consumption). In other words, the total volume of emissions equals the sum of all the emissions of the pollutant, p , caused by all the production sectors, i and j , of the input-output matrix (seventy-four sectors for Chile) generated in their production processes per se, independently of the emissions associated with the use of polluting inputs, plus all the emissions derived from the use of both energy-producing and non-energy-producing polluting intermediate inputs: a) in the production processes of all the sectors, b) in households' consumption, h , and c) by other components of the final demand, f .

1.3 Further Development in the ECOGEM-model

The model can be improved in many directions to support a more complete analysis of policy options. This subsection discusses some specific improvements, including the creation of a dynamic version of the model, the inclusion of a new abatement sector in the specification,

and the incorporation of a valuation of environmental quality in the utility function.

The dynamic version

Dynamics can be incorporated in the model through either a new dynamic forward-looking model or a recursive dynamic model based on the static ECOGEM-Chile model. The latter is accomplished by solving the model for several stages (periods) and linking them through the capital accumulation equation. Thus investment in period T becomes capital stock for period $T + 1$. Capital is then assigned among sectors according to the relative rates of return. Calibration requires a baseline scenario for the growth path, which is usually called the business-as-usual scenario. Population, labor force, depreciation, and GDP growth rates are exogenous, and the type of technical process must be chosen (the capital-labor efficiency ratio). If alternative scenarios to the base line are simulated, the technical efficiency parameter becomes constant and capital growth is determined endogenously by the saving-investment relation.

Abatement possibilities

The reduction of emissions through new end-of-pipe technologies can be incorporated in the model by introducing a new production sector that the other sectors can use to reduce their emissions. This new sector then becomes the abatement technology sector.⁷ This requires a CES function that allows substitution between the abatement sector and the other sectors producing non-energy-producing intermediate inputs. The result is reflected on the following equations:

$$\begin{aligned} AB_j &= \alpha_{ABj} \cdot \left(\frac{P_{ABNDj}}{P_{ABj}} \right)^{\sigma_{ABND}^j} \cdot ABND_j , \\ ND_j &= \alpha_{NDj} \cdot \left(\frac{P_{ABNDj}}{P_{NDj}} \right)^{\sigma_{ABND}^j} \cdot ABND_j , \text{ and} \\ P_{ABNDj} &= \left[\alpha_{ABj} \cdot (P_{ABj})^{1-\sigma_{ABND}^j} + \alpha_{NDj} \cdot (P_{NDj})^{1-\sigma_{ABND}^j} \right]^{\frac{1}{1-\sigma_{ABND}^j}} , \end{aligned}$$

7. Abatement technology is the current expenditure in technology to comply with an environmental regulation or to avoid paying an environmental tax.

where AB represents the abatement expenditure, ND is expenditures for the rest of non-energy-producing inputs, and $ABND$ is the nest that includes both. Parameters α_{AB} and α_{ND} are the shares of each input, and σ_{ABND} is the substitution elasticity between the two inputs. P_{AB} , P_{ND} , and P_{ABND} stand for the respective prices of each input and the price of the compounded input.

Total emissions in the economy are now also determined by the existing expense in abatement. The coefficients that determine emissions are weighted by the reduction factor associated with the abatement technologies used:

$$E_p = \sum_i v_i^p \cdot X P_i + \sum_j \sum_i \pi_i^p \cdot X_{ij} + \sum_i \pi_i^p \left(\sum_h C_{ih} + \sum_f X AFD_f^i \right).$$

For each sector and each pollutant,

$$\pi^* = \pi - \left(\frac{G_{AB}}{\theta} \right)^{\frac{1}{\omega}} \cdot \frac{1}{\sum_i X_{ij}} \text{ and}$$

$$v^* = v \cdot \frac{\pi^*}{\pi},$$

where G_{AB} is the sector's expenditure in abatement technologies, X_{ij} is the intermediate demand of sector j for sector i , θ and ω are parameters from the emission cost reduction functions, and v and π are the emission coefficients associated with the production and use of intermediate inputs, respectively.

To introduce this mechanism into the model, it is necessary to disaggregate the data for the abatement sector, calculate parameters θ and ω for each sector, and create their market. The demand is then made up of the sum of the demand of each and every sector in the input-output matrix, while the supply is determined by a new sector generated from the sectors that produce the abatement technologies, or by a proportion thereof.

Environmental quality in the utility function

Individuals value environmental quality, and they experience damage from emissions. Environmental quality should therefore be incorporated in the utility function to fully represent individuals' behavior and preferences. It allows us to endogenously assess the real costs and benefits of an environmental (or other) policy and to obtain

the final welfare when agents are able to choose between traditional goods and services and environmental ones.

Although there is a large literature on the valuation of environmental damages, few CGE models incorporate environmental valuation endogenously (Perroni and Wigle, 1994, 1997; Tsigas and others, 1999), and the key parameters cannot be directly estimated. The relationship between emissions and environmental damage is usually modeled by a damage function. Current environmental quality is equal to the difference between endowments of environmental quality and damage. Thus, the individuals' valuation of environmental quality depends on the level of environmental quality and on the consumption of other goods and services. A CES utility function can model the decisions between environmental quality and the consumption nest (which, in turn, is modeled by the ELES utility function). The elasticity of substitution should be related to the income elasticity of the environmental quality valuation; the degree of responsiveness of the marginal valuation of environmental quality to an increase in damage depends on the size of the environmental quality endowments. Estimation of parameters and data on environmental quality are required in this area of development. An "environmental utility function" is not included in the CGE model presented here; consequently, our results do not consider benefits from environmental quality improvements. The cost of any environmental policy is thus overestimated. On the other hand, benefits from economic policies are also overestimated when environmental damage increases.

2. THE DATA

A very important component of any general equilibrium model is the data used. These data include information for the base year, usually an input-output matrix or a social accounting matrix, and substitution and income elasticities for each sector. Elasticities can be estimated through econometric regressions if enough information is available, or if not, other previous data can be used. The data requirements and number of parameters used make it necessary to ensure that the information is of good quality and that it is constantly updated.

2.1 Economic quality data

As in any applied general equilibrium model, the main source of information is the social accounting matrix (SAM). The matrix for

Chile was built based on the 1996 input-output matrix provided by the Central Bank of Chile (2001). The 1996 SAM is the most recent available information for Chile; it was developed by De Miguel and others (2002) based on the methodology applied by Alonso and Roland-Holst (1995) and the framework built by Venegas (1995). Data from official surveys on social variables, labor, and consumption were used, as well as foreign trade information provided by the Central Bank. This SAM has seventy-three sectors, twenty labor categories (ten rural and ten urban), ten income groups (divided by deciles), and twenty-eight trade regions.

The social accounting matrix for Chile was aggregated to enable a better mathematical convergence for the model. In the simulation exercise presented on section 3, the SAM includes eighteen economic sectors.⁸ Labor is divided into skilled and unskilled, the foreign sector is not differentiated by origin, and household income is disaggregated into five quintiles. The matrix is measured in billions of 1996 pesos, although units of measure and amounts are less relevant in this type of exercise than the variables' ratio accuracy (relative weight).

Income, substitution, and other elasticities can be varied to realistically model the timing of the adjustment process. The choice of short-, medium- or long-term elasticities, as used in the relevant international literature, thus provides different degrees of flexibility according to the objective of the policy exercises. Capital accumulation processes as a function of relative returns are not included, however, as this is a static model. Intersectoral capital mobility and long-term substitution elasticities may minimize this flaw.

2.2 Emission Factors

For the Chilean case, five input-output matrix sectors are considered in the set of energy-producing inputs: oil and natural gas production, which a priori considers the extraction of petroleum and natural gas in their mining phase; coal mining; oil refining, which includes all production of heavy petroleum, gasoline, and kerosene; electricity; and gas production and distribution.

The two types of emission coefficients are input based and output related. The input-based coefficients associate emissions with the use of polluting goods that generate emissions, such as coal, gas, and oil products. The output-related coefficients tie emissions to the total

8. The specific sectors are described in appendix A.

output of each sector. Among the thirteen types of air, water, and land pollutants with available emission coefficients, we selected those related to the air pollution problem in Santiago for the simulations. These are sulfur dioxide (SO_2), nitrogen dioxide (NO_2), volatile organic compounds (VOC), carbon monoxide (CO), and suspended particulates (specifically, particulate matter ten micrometers in diameter or smaller, or PM10).

The emission factors associated with output are obtained independently of the inputs used by each sector. We used the national SAM figures to extrapolate the data to Chile, thereby obtaining the emissions levels on the basis of the valued amount of the inputs used.⁹

2.3 Further Developments in Data

The model also includes land and water emission factors, but they have not been incorporated at this point. Further research is needed to adapt them to the local features before they can be included for Chile.

Similarly, abatement technologies cannot be included without introducing a new sector—namely, the abatement sector. It is also necessary to build cost-of-abatement curves to model the reductions stemming from the use of these end-of-pipe technologies. Both elements have been developed but not yet calibrated in the model, with the new 1996 SAM.

3. POLICY SIMULATIONS

The objective of this section is to illustrate the model's potential by analyzing a specific policy. We first perform a simple exercise of increasing fuel taxes to twice their current rate. We then highlight the model's ability to combine different policies by pairing the same fuel tax increase with a policy to reduce trade barriers.

3.1 Increased Fuel Taxes

For this exercise, we chose a restrictive tax policy that increases taxes on fuel (namely, oil refinery products) to double the current tax

9. To examine the procedure followed to calculate emissions, together with the estimation results, see Dessus, Roland-Holst, and van der Mensbrugghe (1994).

rate (that is, a 100 percent increase).¹⁰ We assume that the revenues obtained from this tax policy are not recycled, so government savings are increased.¹¹ New public savings are channeled to the market, thus increasing liquidity for investment. This policy represents an environmental policy in which contaminating fuels are taxed in order to reduce emissions. For this simulation, no capital mobility is allowed and substitution elasticities are quite flexible.¹² Sectoral adjustment will therefore tend to occur within the sector (factors/inputs) rather than between sectors.¹³ Consequently, the results reflect a short- to medium-run response to the shocks.

Several impacts can be identified in this scenario. The main macroeconomic effects of increasing fuel taxes involve a decrease in basically all macroeconomic variables except investment, owing to higher fuel prices in the economy. Chile is not an oil producer, so the tax increase has important effects on production (-1 percent), consumption (-1 percent), imports (-1.5 percent), and exports (-1.6 percent). This causes a fall in real GDP of 0.5 percent. Capital immobility triggers a rougher adjustment because it impedes intersectoral reallocations, and a restricted equilibrium is achieved where macroeconomic effects are enhanced. However, the growth of investment (0.5 percent) owing to the boost in government savings reduces the overall impact by half. Real government savings increase by over 11.4 percent, from roughly 2.5 to 2.75 percent of GDP. Corporate savings, however, fall by 0.9 percent.

Sectoral impacts are perhaps the most significant in the model. Table 1 shows the impacts on sectoral output, employment, exports, and imports. The sectors that are negatively affected are those involved in the extraction or refinery of oil products, as well as the transport-related sectors, which directly depend on oil. The substitutes electricity and coal are now relatively cheaper, and their output thus increases. The construction sector also benefits from the policy

10. The results presented in this section do not pretend to be real and useful for policy application, but rather are intended to show the possibilities of the model. Real applications require a deep analysis.

11. Other options are also possible. For example, the revenue can be used to offset another inefficient tax, which is modeled in section 3.2.

12. The elasticities used in the present simulation are similar to those assumed by other studies for Chile (Coeymans and Larraín, 1994; Beghin and others, 2002; Harrison, Rutherford, and Tarr, in this volume). In another paper, we undertake a sensitivity analysis in which we use the same model to show differences in the model when assuming other elasticities (O’Ryan, Miller, and De Miguel, 2003).

13. Appendix B presents the same simulation assuming full capital mobility across sectors.

Table 1. Sectoral Effects

Percent

<i>Sector</i>	<i>Production</i>	<i>Labor</i>	<i>Exports</i>	<i>Imports</i>
Renewables	-1.0	-0.3	-2.5	0.4
Nonrenewables	-0.8	-0.5	-1.0	-0.4
Oil and gas extraction	-11.5	-14.0	-14.3	-29.2
Coal	2.1	3.7	-3.0	5.3
Food industry	-0.6	-0.2	-1.0	-0.2
Textiles	0.0	0.3	0.0	-0.1
Wood products	-0.9	-0.7	-1.4	-0.2
Chemicals	-0.5	0.0	-0.8	-0.3
Oil refinery	-26.8	-31.8	-67.4	6.3
Manufactures	-0.1	0.3	-0.3	0.0
Electricity	0.6	3.2	-	3.6
Gas	-1.2	1.6	-	-
Hydraulic	-0.1	0.3	0.5	-0.3
Construction	0.4	1.2	-	0.8
Commerce	-0.5	-0.3	-0.6	-0.4
Road transport	-3.6	0.1	-15.7	0.9
Other transport	-3.5	-2.8	-4.8	-1.3
Services	-0.1	0.2	0.7	-0.3

Source: Authors' calculations.

as a result of the higher level of investment, which has its origin in the increased public savings. Employment (labor demand) by sector follows the same path as production, increasing when output grows and decreasing otherwise.

The remaining sectors, which are mainly primary and industrial, experience minor negative effects on their output, which leads to an overall reduction in the economy's production. The main reason is the increase in production costs owing to higher energy costs. This also causes a decrease in wages, as some jobs are cut. This reduces the household income, as shown below.

Imports and exports also vary by sector. The greatest impacts correspond to the sectors that were most strongly affected by the policy, as expected. Most sectors reduce both their imports and exports, although some imports are increased as a result of lower production costs elsewhere. The overall effect is a reduction in trade activity, with a decrease in both total imports and total exports.

All households are negatively affected. In terms of income and prices, the effect is roughly the same for all income groups (see table 2). Real income falls almost 1 percent. The effects on welfare may vary, however. If the utility level is used to measure the welfare effects, the poorest groups are more negatively affected than groups with a higher income. This is due to the definition of the utility function, which

Table 2. Impacts on Households and Welfare
Percent

Variable	Household income quintile				
	First	Second	Third	Fourth	Fifth
Real income	-1.0	-1.0	-1.0	-1.0	-0.9
Income	-0.6	-0.6	-0.6	-0.6	-0.6
Prices	0.4	0.4	0.4	0.4	0.4
Utility	-1.0	-1.0	-0.9	-0.8	-0.4

Source: Authors' calculations.

considers a decreasing marginal utility. Furthermore, the tax increase has a direct impact on the minimum subsistence consumption (heating, transportation, and so forth), and this represents a greater share of poorer consumption baskets.

Finally, the model identifies the environmental effects of increasing fuel taxes. The basic effect on emissions is clearly positive, since the emission levels of all pollutants are reduced. One of the main pollution problems in Chile is PM10 emissions in Santiago. With this policy, they are reduced by 15.8 percent. SO₂ and NO₂ emissions are also reduced significantly, by 17.3 percent and 17 percent, respectively. Smaller reductions are observed for carbon monoxide (5.9) and volatile organic compounds (2.9).

3.2 Increased Fuel Taxes and a Tariff Reduction

The model allows the combination of different policies. The simulation presented in this subsection combines an environmental policy linked to fuel taxation and a policy that reduces trade barriers. We thus use the same increase in fuel taxes modeled above, but this time the government applies a tax substitution in which the revenues are channeled to finance tariff reductions. Government savings remains constant at the initial level.¹⁴ The exercise incorporates the same technical characteristics and assumptions as the previous simulation.

The macroeconomic variables are less affected by the rise in fuel taxation than in the previous simulation. The decrease in tariffs partially compensates the recessive effect of the environmental taxation by encouraging trade and reducing the prices of imported goods and

14. Different fiscal policies can be simulated when the government wants to maintain public revenues in the face of tariff reductions linked to free trade policies. Here, we use the fuel tax, but VAT, specific taxation, income taxation, transfers/subsidies, and so forth can also be explored and compared.

services for production and consumption. These variables still fall, but the impact is smaller with the trade policy: production (-0.9 percent, versus -1 percent in the last simulation), consumption (-0.6 percent versus -1 percent), imports (-0.6 percent versus -1.5 percent), and exports (-0.7 percent versus -1.6 percent). Consequently, the effect on real GDP is also smaller, at -0.4 percent (versus -0.5 percent above). Public savings remain constant, since revenues from fuel taxation are used to compensate shrinking revenues from tariffs. Aggregate corporate savings experience a small impact (-0.2 percent), although strong differences are seen at a sectoral level depending on trade orientation and the intensity of fuel use. Because aggregate savings remain almost constant, investment also essentially remains constant (0.1 percent). Tariff revenues drop by roughly 14.5 percent.

At the sectoral level, most sectors improve their situation relative to the previous simulation (see table 3). In fact, most of the negative results involve exports, whereas imports and employment now experience a positive impact. Production also benefits from the tariff reductions. Local energy production (oil and gas extraction and coal) is reduced further since these substitutes are bought in from abroad in response to the lower tariffs, and construction is not affected since investment does not increase.

Table 3. Sectoral Effects

Percent

Sector	Production	Labor	Exports	Imports
Renewables	-0.7	0.0	-1.6	2.3
Nonrenewables	-0.5	0.1	-0.5	1.2
Oil and gas extraction	-11.7	-14.6	-12.2	-28.1
Coal	1.5	2.6	-1.2	7.3
Food industry	-0.3	0.1	0.0	2.0
Textiles	0.1	0.4	1.8	1.3
Wood products	-0.6	-0.3	-0.5	1.7
Chemicals	-0.4	-0.2	1.0	0.9
Oil refinery	-26.0	-31.6	-65.7	10.1
Manufactures	-0.1	0.0	2.3	0.5
Electricity	0.7	2.9	-	3.1
Gas	-0.7	1.6	-	-
Hydraulic	0.0	0.3	1.5	-0.4
Construction	0.1	0.5	-	-0.3
Commerce	-0.4	-0.2	0.5	-0.7
Road transport	-3.2	0.2	-13.5	0.7
Other transport	-2.7	-1.8	-3.6	-1.0
Services	0.0	0.2	1.4	-0.5

Source: Authors' calculations.

Table 4. Impacts on Households and Welfare
Percent

Variable	Household income quintile				
	First	Second	Third	Fourth	Fifth
Real income	-0.7	-0.6	-0.6	-0.6	-0.6
Income	-0.6	-0.6	-0.6	-0.6	-0.6
Prices	0.1	0.0	0.1	0.1	0.0
Utility	-0.7	-0.6	-0.6	-0.5	-0.3

Source: Authors' calculations.

Table 4 shows the negative impact on all households. The price effect is now smaller, however, so both utility and real income improve relative to our previous simulation. The regressive effect remains.

The positive environmental effects decrease slightly for all emissions. PM10 emissions are reduced by 14.5 percent (versus 15.8 percent in the simulation without the trade policy), SO₂ by 16 percent (versus 17.3 percent), NO₂ by 15.7 percent (versus 17 percent), carbon monoxide by 4.4 percent (versus 5.9 percent), and volatile organic compounds by 2.5 percent (versus 2.9 percent).

In summary, the simulated combination of environmental and trade policies seems to have more benefits than the environmental policy alone: the environmental effects are still strong, but the macroeconomic and social impacts are smoother. At a sectoral level, the degree of the impact depends on the intensity of fuel use and relations with foreign markets.

4. CONCLUSIONS

This paper presents an empirical application of the computable general equilibrium ECOGEM-Chile model using the latest available economic information for Chile (1996). The model is very flexible and comprehensive, and it permits an analysis of the impact of policies and external shocks on different economic agents. It includes detailed disaggregations by sector (seventy-two sectors), labor (twenty categories), trade partner (twenty-seven countries), and household (ten income groups). It incorporates energy-input substitution possibilities and input-based emissions of up to thirteen different pollutants. It can analyze the effects on macroeconomic, sectoral, social, and environmental variables. ECOGEM-Chile is thus a useful tool for analyzing policies and external shocks that may affect the most important economic agents in Chile.

To illustrate some of the model's features, we simulated the impact of a 100 percent increase in fuel taxes. The results of this simulation show negative impacts on aggregate variables such as consumption, production, trade, and GDP. We assumed that government expenditure does not vary, so public savings increase. This generates a rise in investment, which partially offsets the fall in GDP. An analysis of the sectoral impacts pointed to winning and losing sectors. The winners from the policy are those sectors that provide alternative energy products, such as electricity (mainly hydropower) and coal. Construction also benefits as a result of the higher levels of investment. The losing sectors identified are oil extraction and production and the transport sector. Other sectors are also affected, mainly negatively, but to a lesser degree.

Households are also negatively affected by the policy, partly through an increase in domestic prices and partly through a decrease in income. The latter results from sectors laying off workers, which reduces the average wage. All households are affected at the same rate. Finally, we observe the positive impacts related to an important emission reduction for all pollutants, which reaches 17 percent in the case of SO₂ and NO₂ and 15 percent in the case of PM10 emissions. The environmental benefits were not valued, and thus the impact on economic welfare is uncertain.

We also simulated a mix of environmental and trade policies to show the benefits from policy coordination and to discuss alternative closure rules. Here, real public savings remain constant, and all revenues from fuel taxation are compensated by equivalent reductions in trade tariffs. Sectors now suffer from two shocks: an increase in fuel taxes and a reduction in tariffs. The results show that most impacts on macroeconomic, social, and environmental variables are smoothed, thereby achieving better average results. These results depend, however, on each sector's energy pattern and trade orientation.

No capital mobility was allowed in either of the simulations presented, and the results thus represent a short- to medium-term adjustment. Sectoral impacts would increase with capital mobility, as capital flows from less to more profitable sectors. Additionally, the model has ample flexibility for simulating reductions in other taxes (such as VAT or corporate taxes), as well as a reallocation of the increased public revenues to subsidies, transfers, or public expenditure.

The main aim of this paper is to show the potential of general equilibrium analysis. Consequently, the results should not be seen as conclusive for future fuel tax or trade policies. The model results

should be considered as only part of any policy analysis, which generally also requires an in-depth examination of the results obtained by sectoral specialists. Several improvements could enhance the model's capabilities for environmental analysis—in particular, the development of a dynamic version, the inclusion of an “environmental utility function,” and the simulation of policy exercises applying the equations related to abatement technologies presented in this paper. Similarly, natural gas needs to be integrated as an important energy input in the Chilean economy; it is only partially included in the 1996 input-output matrix because natural gas became available in significant volumes only in 1997. Despite these limitations, the present core model considers most of the economic features of the CGE literature, it has a huge level of economic detail and data desegregation, and it includes useful environmental and energy characteristics.

Finally, the results show that the model is highly effective for systematically and holistically analyzing different policies and their impact on Chile's economy. The model can evaluate external price shocks, trade policies, tax reforms, social and environmental policies, and other policies, together with their separate impacts on different income groups and production sectors and their aggregate impacts.

APPENDIX A

Sectors Used

<i>Aggregate sector</i>	<i>1996 input-output matrix code</i>	<i>Description</i>
Renewables	1–5	Agriculture, fruit, livestock, forestry, fisheries
Nonrenewables	8–10	Copper, iron, other minerals
Oil and gas extraction	7	Oil and gas extraction
Coal	6	Coal
Food industry	11–25	Meat, dairy, preserves, seafood, oils, bakery, milled products, sugar, other foods, animal feed, beverages, wine, liquor, beer, tobacco
Textiles	26–29	Textile, clothes, leather, shoes
Wood products	30, 31, 46	Wood products, furniture, pulp and paper
Chemicals	32, 34–38	Printing, chemicals, other chemicals, rubber, plastics, glass
Oil refinery	33	Oil refinery
Manufactures	39–45, 47	Nonmetallic minerals, iron and steel, nonferrous metals, metal mechanics, nonelectric machinery, electric machinery, transport materials, other manufactures
Electricity	48	Electricity
Gas	49	Gas
Hydraulic	50	Hydraulic
Construction	51	Construction
Commerce	52–54	Commerce, restaurants, hotels
Road transport	56, 57	Freight transport, passenger transport
Other transport	55, 58–60	Railways, sea transport, air transport, other transport
Services	61–74	Communications, banking, insurance, leasing, services to firms, real estate, public education, private education, public health, private health, entertainment, other entertainment, other services, public administration

Source: Authors' elaboration and Central Bank of Chile (2001).

APPENDIX B

Comparison of Impacts with and without Capital Mobility

Table B1 compares the results of a specification assuming full capital mobility across sectors with one featuring zero capital mobility. As the table indicates, the impact on sectoral output is much higher under full capital mobility than under zero capital mobility. This is due to the possibility of installing and uninstalling capital, which allows the sectors to adjust their production at a lower cost. This has a negative impact on households, however: since the winning sectors no longer require a high amount of additional labor, the average wage falls slightly.

From a macroeconomic perspective, full capital mobility generates a slightly higher impact on GDP, consumption, and investment and a relatively lower impact on production and trade. The latter arises from the possibility of switching capital from one sector to another, leading to increased output in winning sectors. Finally, the environmental impacts are also slightly higher, owing to the growth of a cleaner energy sector.

Table B1. The Effect of Capital Mobility across Sectors
Percent

<i>Variable</i>	<i>No capital mobility</i>	<i>Full capital mobility</i>
Macroeconomic		
Production	-1.00	-0.80
Consumption	-1.00	-1.20
Investment	0.50	0.80
Exports	-1.60	-1.50
Imports	-1.50	-1.20
Real GDP	-0.50	-0.60
Absorption	-0.50	-0.50
Real government savings	11.40	14.20
Corporate savings	-0.90	-1.10
Sectoral production		
Renewables	-1.00	-1.80
Nonrenewables	-0.80	3.30
Oil and gas extraction	-11.50	-14.50
Coal	2.10	11.10
Food industry	-0.60	-0.80
Textiles	0.00	0.70
Wood products	-0.90	-2.10
Chemicals	-0.50	0.00
Oil refinery	-26.80	-32.60
Manufactures	-0.10	1.10
Electricity	0.60	10.10
Gas	-1.20	0.30
Hydraulic	-0.10	0.70
Construction	0.40	0.70
Commerce	-0.50	-0.50
Road transport	-3.60	-5.30
Other transport	-3.50	-13.60
Services	-0.10	0.40
Real income		
First quintile	-1.00	-1.30
Second quintile	-1.00	-1.30
Third quintile	-1.00	-1.30
Fourth quintile	-1.00	-1.20
Fifth quintile	-0.90	-1.10
Environment		
SO ₂	-17.30	-19.90
NO ₂	-17.00	-19.60
CO	-5.90	-3.80
VOC	-2.90	-3.00
PM10	-15.80	-17.90

Source: Authors' calculations.

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IMPERFECT LABOR MOBILITY, URBAN UNEMPLOYMENT AND AGRICULTURAL TRADE REFORM IN CHILE

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A component of agricultural policy in Chile is the use of price bands to stabilize domestic price movements in selected agricultural crops and processed agricultural commodities. In the 1990s, the use of price bands for wheat, fats and oils, and sugar resulted in the equivalent of roughly a 22 percent tariff on these commodities. Depending on the result of pending discussions with the WTO following a complaint by Argentina and of ongoing discussions regarding Chile's participation in the North American Free Trade Agreement, constraints could be imposed on Chile's use of price bands to protect its agricultural economy.

The prospect of agricultural trade policy reform in Chile raises a number of related policy concerns. One of these is rural-urban income divergence, which remains at high levels. Rural wages are roughly one-third of the average wage in Chile's large cities (1996 Casen Survey). Carter (1997) notes the implications for political stability. Another

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consequence of income divergence is rural-urban migration (Harris and Todaro, 1970). Urban populations grew faster than rural populations throughout the 1990s. A closely related issue that became increasingly prominent in the recent economic slowdown is the emergence of high levels of urban unemployment.

A question of considerable interest, then, involves the effect that these developments might have on the economic analysis of the outcome of trade liberalization. Several recent applied general equilibrium studies undertake the quantitative modeling of the likely effect of Chilean trade liberalization (Harrison, Rutherford, and Tarr, 1997; Benjamin and Pogany, 1998). The existing literature, however, uses aggregated models of a strongly neoclassical flavor. As the preceding discussion indicates, the Chilean economy exhibits certain features closely associated with the development literature—namely, rural-urban migration, urban unemployment, and imperfect labor mobility. Since these economic features can have important consequences for the analysis of the effect of a number of different policies including trade reform, it seems appropriate to consider Chilean agricultural reform in the context of a model that incorporates them. That is task addressed in this paper.

The paper is organized as follows. In section 1 we briefly discuss the policy background. Section 2 uses a formal general equilibrium model to illustrate some important agricultural trade policy consequences of urban unemployment and imperfect labor mobility. This formal model also highlights the underlying structure of a large (fifty-sector) numerical general equilibrium model, which we describe in section 3. In section 4, we present the results of simulations designed to quantify the effects of removing the price bands in Chile under the assumption of dual labor markets with imperfect labor mobility, and we discuss policy implications. Accounting for the second-best implications of urban unemployment and limited labor mobility is shown to affect outcomes of agricultural reform. A key result is that removing price bands results in modest net welfare gains, but the welfare gains turn negative with a more comprehensive removal of all agricultural and food tariffs. This is a consequence of predicted increases in urban unemployment and declines in rural wages. Section 5 contains our concluding comments.

1. POLICY BACKGROUND

Overall economic growth in Chile has been very uneven, and the division between rural and urban economies remains significant. Many

analysts note Chile's inability to integrate the poor rural regions with the rapidly growing industrial economy. Other researchers focus on the phenomenon of rural-urban migration in response to rural-urban income differentials. These differentials persist in the face of high rates of unemployment in Chile's major urban centers.

There is considerable debate over the importance of different factors as determinants of migration responses. The general economic framework postulates that migrants make rational economic choices, in which they consider the real income adjusted for the probability of obtaining employment at the destination and the costs of migration. Costs may include transportation, job search (expenses and opportunity cost), lodgings, and the like. They may include so-called upskilling costs, such as education and training necessary to obtain urban employment. They may also include less immediately obvious, but nonetheless real, opportunity costs such as giving up locational preferences and attachments to existing arrangements. These costs may be offset by chain effects—the availability of information through networks of previous migrants.

While labor migration may lead to a more efficient allocation of resources in a first-best framework, in a second-best framework, migration may worsen problems of urban congestion and unemployment, significant levels of which developed in urban Chile in the early 2000s. In Santiago, the rate of unemployment in 2001 was more than 10 percent.

Chile thus displays a number of important economic developments: high rates of urban unemployment; continuing flows of migrants from rural to urban areas in search of better income opportunities; and the attendant mix of urban congestion and poverty. Into this heady mix of domestic economic issues comes Chile's bid to join the North American Free Trade Agreement, which will clearly entail further reform of its external (trade) policy. The remainder of the paper explores the consequences of agricultural trade reform in Chile given the domestic problems of urban unemployment and rural-urban migration.

2. THEORETICAL FRAMEWORK

To reinforce the structure of the numerical model we describe in section 3, we present a formal derivation of some key results concerning agricultural liberalization in a model with rural-urban migration, and we demonstrate how these may be altered by imperfect

labor mobility. Consider a developing economy with distinct rural and urban regions. An industrial good, X , is produced in the urban region and exported. An agricultural good, Y , is produced in the rural region. Full employment of labor prevails in the rural region, but a rigid wage in the urban region creates unemployment. Following Harris and Todaro (1970), migration occurs between the two regions until the expected urban wage is equal to the actual rural wage. Capital is fully mobile. To keep things simple, world prices and factor endowments are exogenous. A compact algebraic description of the model is

$$c_X(\bar{w}, r) = 1 , \quad (1)$$

$$c_Y(w, r) = p_Y , \quad (2)$$

$$w = \pi \bar{w} , \quad (3)$$

$$a_{XL}X + \pi a_{YL}Y = \pi \bar{L} , \quad (4)$$

$$a_{XK}X + a_{YK}Y = \bar{K} , \text{ and} \quad (5)$$

$$G(p_Y, \bar{K}, L_X, L_Y) + (p_Y - p_Y^*)M_Y = E(p_Y, u) . \quad (6)$$

Equations (1) and (2) are zero profit conditions (we chose p_X as numéraire), which can be solved for the factor prices. Once these are known, Shepherd's lemma enables us to derive the optimal input-output coefficients (a_{ij}). Equation (3), the Harris-Todaro labor market equilibrium condition, can be solved for the equilibrium rate of employment, π . Equations (4) and (5) are the factor market constraints, which can then be solved for output levels. Finally, equation (6) is the budget constraint expressed in terms of the gross national product (GNP) and expenditure functions, which can be solved for the welfare level. All the usual assumptions apply; production functions are homogeneous of degree one, continuous, and strictly concave; and the utility function is continuous, quasi-concave, and increasing in consumption of both goods. To guarantee stability, we assume that X is capital intensive (the Neary condition). Now, totally differentiating the budget constraint yields

$$dW = (p_Y - p_Y^*)dM_Y + \bar{w}dL_X + \pi \bar{w}dL_Y , \quad (7)$$

where $dW \equiv E_u du$, and an asterisk designates a world price. Following Corden and Findlay (1975), we define the total urban labor force as L_U and then $dL_X = \pi dL_U + L_U d\pi$. Substituting into equation (7) we have

$$dW = (p_Y - p_Y^*) dM_Y + \bar{w} L_U d\pi , \quad (8)$$

where we have simplified by making use of the fact that $dL_U + dL_Y = 0$. The incremental change in welfare is thus the sum of a Harberger effect and the effect of changes in the probability of employment. As is well known, free trade is suboptimal, since $dW \neq 0$ when $p_Y = p_Y^*$ (only the first term drops out).

Let t be a tariff imposed on Y , such that $p_Y^*(1+t) = p_Y$. Using this and dividing both sides of equation (8) by dt , we have

$$\frac{dW}{dt} = tp_Y \left(\frac{dM_Y}{dt} \right) + \bar{w} L_U \left(\frac{d\pi}{dp_Y} \right) \left(\frac{dp_Y}{dt} \right) , \quad (9)$$

which is the basic decomposition of the welfare effect of an agricultural import tariff. The first term reflects the deadweight loss, and it is negative. However, $dp_Y/dt = p_Y^* > 0$, and a sufficiently small tariff will thus raise social welfare if it raises the probability of employment.

By construction, factor prices are determined entirely by goods prices, and so logarithmically differentiating equations (1) and (2) and solving yields

$$\hat{w} = \frac{\hat{p}_Y \theta_{KX}}{\theta_{LY} \theta_{KX}} , \quad (10)$$

where a circumflex denotes a proportional change, θ_{ji} is the cost share of factor j in industry i , and

$$\hat{p}_Y = \left(\frac{p_Y^*}{p_Y} \right) dt > 0 .$$

It is clear from equation (1) that the return to capital is fixed. Now from equation (3), we know that $\hat{\pi} = \hat{w} - \hat{w}$, and hence the probability of finding urban employment improves with a small tariff on Y . Reversing the arguments indicates that liberalizing agricultural trade may lower welfare.

The preceding analysis has cast the neoclassical Harris-Todaro model of the developing economy in a slightly different light, since the model is generally used to illustrate the negative welfare consequences of restricting imports of capital-intensive goods. Less frequently emphasized is the positive welfare effect of agricultural export subsidies, and the clearly implied (second-best) role for agricultural protection.

Three recent papers attempt to incorporate imperfect labor mobility into the Harris-Todaro framework (Parai and Beladi, 1997; Gilbert and Mikic, 1998; Gilbert and Wahl, 2001). The latter two introduce the concept of the elasticity of labor migration. Consider a situation in which there is a differential between the rural wage and the expected urban wage, ρ ; hence equation (3) becomes $w = \pi\bar{w} - \rho$. The variable ρ is positive and may represent locational preferences, attachments to existing arrangements, a high cost of relocation, and the effect of a restrictive government policy, as discussed in section 1. The elasticity of labor migration can then be defined in a natural way as

$$\varepsilon = \frac{\hat{L}_U}{\hat{\rho}},$$

which is the proportional change in the total urban population induced per proportional change in the expected wage differential ($0 < \varepsilon < \infty$). All other equations remain unchanged, as does the fundamental welfare derivation for a tariff on Y , given equation (9). The proportional change in the probability of employment, however, is now

$$\hat{\pi} = \frac{\varepsilon w\hat{w} + \rho(\hat{a}_{XL} + \hat{X})}{\varepsilon\pi\bar{w} + \rho}, \quad (11)$$

which is of ambiguous sign, in general.

A full analytical description of the properties of this model, while interesting, is beyond the scope of this paper. However,

$$\lim_{\varepsilon \rightarrow 0} \hat{\pi} = \hat{a}_{XL} + \hat{X},$$

which in the case of a tariff on Y (discussed above) can be shown to have negative welfare effects. Hence, the less labor movement is

allowed, the greater is the potential for gains from agricultural liberalization. Moreover,

$$\lim_{\varepsilon \rightarrow \infty} \hat{\pi} = \left(\frac{w}{\pi \bar{w}} \right) \hat{w},$$

such that this model converges to the standard Harris-Todaro case. There is clearly also a critical value of ε (such that $\hat{\pi} = 0$) beyond which the model will behave in the same manner (qualitatively) as the standard Harris-Todaro model.

The intuition behind the result is quite straightforward. An agricultural tariff in the standard Harris-Todaro model draws labor and capital out of the urban region, but because agriculture is labor intensive, more labor is drawn than capital. The end result is an improvement in urban employment. In the limiting case of no labor migration, the rural wage rises as before and agricultural output expands, but now labor cannot move to fill the needs of agriculture. A reduction in production of X then leads to higher urban unemployment, and welfare subsequently declines. Hence, the degree of labor mobility, in addition to the prevalence of urban unemployment, become important variables when evaluating the consequences of agricultural trade liberalization in a developing economy.

3. AN APPLIED GENERAL EQUILIBRIUM MODEL

The simplified framework described above, while helpful in formalizing the issues involved, makes a number of major abstractions in the interest of tractability. The most obvious include the dimensions of the model and the effect of other policy distortions on the equilibrium system, which can have important second-best implications. While it is difficult if not impossible to take all of these factors into account within the constraints of an abstract formal model, an applied general equilibrium (AGE, also known as computable general equilibrium, or CGE) model is well suited to the task. Such models take data from an actual economy or set of economies and combine them with a structural description of the behavior of agents within the system and the constraints that they face. The system can then be solved numerically, and the effect of policy interventions can be quantitatively examined within a consistent framework that accounts for important market interrelationships.

In this section we describe an applied counterpart to the formal model analyzed above. Our notation uses the Greek alphabet to denote free and calibrated parameters, lower case letters to denote policy variables, and bars to denote those variables fixed by the closure assumptions. The sets used are as follows: g represents agents; sectors are defined as $i(j) \subset g$; urban sectors are $u \subset i$; endowment commodities are f , and underemployed endowments are $m \subset f$. Full definitions are presented in the appendix. The basic structure is the well-established single-country Armington trade model.¹

The production block consists of a set of constant elasticity of substitution (CES) production functions, with intermediates used in fixed proportions:

$$Q_i = \frac{\alpha_i^Q}{1 - \sum_j a_{ji}} \left(\sum_f \theta_{fi}^Q FD_{fi}^{-\rho_i^Q} \right)^{-1/\rho_i^Q}. \quad (12)$$

Equation (13) represents the corresponding demand functions for primary factors. A subset of factors have prices fixed exogenously in a subset of sectors, corresponding to the rigid urban wages of the Harris-Todaro specification:²

$$PF_{fi} = PN_i \left(\frac{\alpha_i^Q}{1 - \sum_j a_{ij}} \right) \left(\sum_f \theta_{fi}^Q FD_{fi}^{-\rho_i^Q} \right)^{-1/\rho_i^Q-1} \theta_{fi}^Q FD_{fi}^{-\rho_i^Q-1}, \quad (13)$$

where $PF_{mu} = \bar{P}F_{mu}$ and $PF_{fi} = PF_f$, with $f \notin m$. This implies unemployment of that subset of factors, with the rate of employment defined by equation (14)

$$ER_m = \frac{\sum_i FD_{mi}}{\sum_i FD_{mi} + UN_m}. \quad (14)$$

1. We present only brief details of the Armington trade model. For a full description, see, for example, Devarajan and Lewis (1990).

2. There is no government-imposed wage floor in Chile, so our characterization of unemployment as arising from downward inflexible wages is a simplification. Other explanations (such as search costs) are plausible. Furthermore, labor classified as unemployed in this model does not contribute to net social welfare, whereas in reality these workers are likely to be involved in the informal sector (although their marginal productivity may well be very low). For both of these reasons, our model probably presents what can be interpreted as worst-case scenarios for unemployment.

Equation (15) specifies our modified Harris-Todaro factor market equilibrium conditions:

$$PF_{mi} = ER_m \overline{PF}_{mu} - COST_m , \quad (15)$$

where $i \notin u$. Equation (16) introduces an inelastic migration response, as in our simplified model above:³

$$\sum_u FD_{mu} + UN_m = \alpha_m^M COST_m^{\varepsilon_m} . \quad (16)$$

Finally, equation (17) defines the factor market constraints:

$$\sum_i FD_{fi} = \overline{END}_f - UN_f . \quad (17)$$

The demand block consists of two levels. At the first level, households maximize a Stone-Geary linear expenditure system (LES), the objective function of which is equation (19), subject to their income as defined in equation (18). At the second level, the household optimizes domestic and imported goods (see equation 24).

$$NDI = \sum_i Q_i PN_i + \sum_i tm_i \overline{PWM}_i \sum_g M_{ig} \overline{XR} + \sum_i tx_i PD_i X_i - \sum_i ty_i PD_i Q_i - \sum_{ig} C_{ig} P_{ig} - \overline{CA} \cdot \overline{XR} , \quad (18)$$

where g represents the government or investors as appropriate, and

$$U = \alpha \prod_i (C_{ig} - \lambda_i)^{\theta_i^C} , \quad (19)$$

where g represents households. Equation (20) defines the corresponding household demand functions:

$$C_{ig} = \lambda_i + \left(\frac{\theta_i^C}{P_{ig}} \right) \left(NDI - \sum_j \lambda_j P_{jg} \right) , \quad (20)$$

where g represents households.

3. The Harris-Todaro specification of labor market equilibrium is often interpreted as implying a competitive auction in each period, with each worker having an equal chance of obtaining employment. As in all models, this is a stylized description—we interpret equation (16) only as meaning that once the dust has settled, any new equilibrium will have the familiar Harris-Todaro characteristics.

Firms demand final goods in fixed proportions to their output:

$$C_{ij} = \sum_j a_{ij} Q_j . \quad (21)$$

Final demands for government consumption and investment are fixed in quantity terms by equations (22) and (23):

$$C_{ig} = \bar{G}_i , \quad (22)$$

where g represents the government, and

$$C_{ig} = \bar{I}_i , \quad (23)$$

where g represents investors.

Having allocated their expenditure across the commodities, all agents then choose the optimal combination of imports and domestic production (the Armington composite). This is reflected in each agent's demands for domestic production (equation 24) and imports (equation 25).⁴ The introduction of product differentiation via this mechanism is the major departure of the model from models of standard trade theory.

$$D_{ig} = \frac{\alpha_{ig}^{A-1} \left[PD_i / (1 - \theta_{ig}^A) \right]^{\sigma_i^A} C_{ig}}{\left[\theta_{ig}^A \left(PM_i / \theta_{ig}^A \right)^{\sigma_i^A \rho_i^A} + (1 - \theta_{ig}^A) \left[PD_i / (1 - \theta_{ig}^A) \right]^{\sigma_i^A \cdot \rho_i^A} \right]^{-1/\rho_i^A}} \quad (24)$$

and

$$M_{ig} = \left(\frac{\theta_{ig}^A}{1 - \theta_{ig}^A} \right)^{\sigma_i^A} \left(\frac{PD_i}{PM_i} \right)^{\sigma_i^A} D_{ig} . \quad (25)$$

Equations (26) through (30) describe the price equations of the model, and they have straightforward interpretations. Equation (28) defines the price of a composite of imports and domestic production; it is derived from the assumption of CES Armington aggregation. Similarly, we use constant elasticity of demand (CED) functions to describe how world prices respond to changes in the trade volume (equation 30). Equation (29) defines net prices. The nominal exchange rate is the chosen numéraire for the system (all prices in the model are relative prices).

4. Allowing each agent to independently make import decisions along Armington lines is known as the SALTER specification.

$$PM_i = \overline{PWM}_i (1 + tm_i) \overline{XR} , \quad (26)$$

$$PD_i = \frac{PWX_i \overline{XR}}{1 + tx_i} , \quad (27)$$

$$P_{ig} = \alpha_{ig}^{A-1} \left[\theta_{ig}^{A\sigma_i^A} PM_i^{(1-\sigma_i^A)} + (1 - \theta_{ig}^A)^{\sigma_i^A} PD_i^{(1-\sigma_i^A)} \right]^{1/(1-\sigma_i^A)} , \quad (28)$$

$$PN_i = PD_i (1 + ty_i) - \sum_{j=1}^N a_{ji} P_{ji} , \quad (29)$$

$$X_i = \alpha_i^X PWM_i^{\epsilon_X} . \quad (30)$$

Lastly, we impose equilibrium conditions on the model. Equation (31) defines the familiar material balance conditions, and equation (32) the balance of trade. The current account balance is set exogenously. Since Walras Law implies the equilibrium conditions are not independent, any one of them can be dropped.

$$Q_i = X_i + \sum_g D_{ig} , \quad (31)$$

$$\sum_i \overline{PWM}_i \sum_g M_{ig} + \overline{CA} = \sum_i PWX_i X_i . \quad (32)$$

To summarize, the AGE model presented here incorporates the key features of our formal modeling: institutionally rigid urban wages and corresponding urban unemployment, rural-urban migration in response to expected wage differentials, and an imperfectly elastic migration response. It also makes a number of extensions. It can accommodate many endowment factors, each of which may be fully or partially employed, fully or partially mobile, or specific to a given economic activity. It can accommodate many sectors, each of which can be classified as rural or urban and traded or nontraded. The model incorporates product differentiation, thereby accommodating simultaneous export and import activities in the same sector and varying domestic versus import preferences among agents. Finally, the model incorporates a complete set of trade taxes and subsidies to ensure accounting for the second-best implications of policy interventions.

The GTAP4 database (McDougall, Elbehri, and Truong, 1998) is the primary source for the production, protection, and trade data used

in the model, as well as for many of the free parameters.⁵ The base year of the data is 1995. Although virtually all of the now-extensive applied general equilibrium literature based on the GTAP4 database employs the GTAP model described in Hertel (1997), or derivatives thereof, it is a straightforward procedure to extract the information necessary to construct a single-economy model such as that used here. Also, because we are using a single-country model, we are able to work at a much greater level of detail than most of the GTAP-based literature (we use fifty sectors, of which four are nontraded and forty-six are traded—the full GTAP4 disaggregation). Using the GTAP4 data ensures not only that our starting point is consistent with much of the existing research, but also that the data are widely available to other researchers who wish replicate our results.

We supplement the GTAP4 data with rural and urban labor force counts from the 1996 National Socioeconomic Survey (Casen) database, which we use to estimate rural and urban wages consistent with the GTAP4 payments data. Agricultural and resource-based industries (forestry, fishing, and mining), along with processing activities that are generally located close to a raw material source (food production, lumber production, and so forth) are assumed to be rural activities, while textiles, heavy manufactures, and services are classified as urban. In this model the urban region represents the cities of Santiago, Concepción, and Valparaíso. The rest of Chile is represented as rural. The initial (baseline) urban unemployment rate of 7.35 percent is from the Casen survey. The implied expected urban-rural wage differential in 1995 is nearly 200 percent (that is, the rural wage is just over one-third of the expected urban wage)—which reflects the substantial impediments to labor mobility that remain a feature of the Chilean economy. Since estimates of the elasticity of labor migration are not available, we use two limiting values: low (0.1) and high (10). The model is implemented in the General Algebraic Modeling System (GAMS) and solved in levels form. The following section presents the results of our policy simulations.

4. RESULTS AND POLICY IMPLICATIONS

The results of the simulations are presented in tables 1 through 4. Table 1 summarizes the recent history of commodity price bands in

5. The calculation of model parameters is specified in GAMS code for the Chile model. The code and the model are available from the authors on request.

Chile in terms of tariff equivalents. Table 2 presents some important economywide summary statistics for the estimated effects of removing the agricultural price bands followed by estimated effects of removing all tariffs on agricultural and food commodities. The first column gives the estimated change in welfare, measured as the equivalent variation in millions of 1995 dollars. The second column is the estimated rate of urban employment (one minus the rate of urban employment gives the rate of urban unemployment). Finally, the third column gives the rural labor wage as a percentage of the urban labor wage. Table 3 presents estimated percent changes in baseline agricultural production, while table 4 presents the estimated percent changes in baseline agricultural imports. Changes in trade and quantity supplied occur in all other sectors, as well; we do not report those results in this paper, but they are available from the authors.

Table 1. Chile: Equivalent Total Tariffs for Products with Price Bands, 1990–1999

Percent

Year	Wheat	Refined sugar	Coarse soja oil
1990	53.7	6.1	25.4
1991	42.1	12.3	24.3
1992	19.7	21.5	29.0
1993	18.1	28.8	23.3
1994	15.3	12.3	6.0
1995	7.0	2.6	1.4
1996	5.3	16.5	15.2
1997	15.1	28.1	17.1
1998	47.1	49.0	6.1
1999	49.9	77.4	33.5

Source: Ministry of Agriculture, Office of Agrarian Policies and Studies (Odepa).

Table 2. Summary Statistics

Simulation	Welfare change (millions of dollars)	Employment rate (percent)	Rural wage (percent of urban wage)
<i>Low Mobility</i>			
Initial equilibrium	–	92.57	32.5995
Price band removal	6.28	92.63	32.5935
No agricultural tariff	-7.10	92.62	32.4339
<i>High Mobility</i>			
Initial equilibrium	–	92.66	32.5668
Price band removal	3.03	92.67	32.5777
No agricultural tariff	-17.73	92.56	32.4590

Source: Authors' calculations.

Table 3. Estimated Effects on Production of Key Agricultural/Food Commodities

Commodity	Initial output value (millions of dollars)	Percent change in volume			
		Low mobility		High mobility	
		No band	No tariff	No band	No tariff
Paddy rice	46	-3.33	-3.37	-3.34	-3.39
Wheat	971	-2.11	-2.44	-2.12	-2.48
Other grains	367	0.40	0.66	0.38	0.61
Vegetables and fruit	3,424	0.08	0.14	0.07	0.08
Oil seeds	37	-3.15	-3.17	-3.16	-3.22
Sugar cane and beets	344	-3.64	-3.73	-3.65	-3.77
Plant-based fibers	10	0.02	-2.08	-0.01	-2.13
Other crops	302	-0.01	-0.05	-0.02	-0.11
Cattle	712	0.07	-0.80	0.06	-0.84
Other agriculture	995	0.11	-0.29	0.10	-0.33
Raw milk	352	0.26	-2.09	0.26	-2.11
Meat from cattle	1,086	0.09	-0.98	0.07	-1.03
Other meat products	1,298	0.06	0.01	0.05	0.01
Vegetable oils	69	-19.06	-16.29	-19.07	-16.34
Dairy products	943	0.35	-2.95	0.35	-2.27
Processed rice	53	-7.76	-7.54	-7.77	-7.57
Sugar	436	-4.90	-5.07	-4.91	-5.11
Other food products	7,072	2.05	1.38	2.03	1.33
Beverages and tobacco	2,072	0.26	-1.85	0.24	-1.91

Source: Authors' calculations.

Consider first the effect of removing the price bands on wheat, fats and oils, and sugar. When labor movement is relatively inelastic, welfare is estimated to rise by just over \$6.28 million. When a high level of labor mobility is assumed, the gains drop by over \$3 million but are still positive. This result confirms the importance of the migration elasticity parameter. As our simple abstract model indicated would be the case, when labor is relatively immobile, the removal of price bands improves the urban unemployment problem. When labor is more mobile, however, price band removal leads to expanded migration to urban areas and thus to expanded urban unemployment relative to the low-mobility scenario. This has a detrimental effect on the net welfare gains from liberalization.

When labor is relatively immobile, price band removal improves urban unemployment because more capital than labor shifts to the

Table 4. Estimated Effects on Imports of Key Agricultural/Food Commodities

Commodity	Initial output value (millions of dollars)	Percent change in volume			
		Low mobility		High mobility	
		No band	No tariff	No band	No tariff
Wheat	25	80.97	75.37	80.98	75.42
Other grains	93	2.07	-1.38	2.07	-1.38
Vegetables and fruit	50	1.17	9.23	1.17	9.25
Oil seeds	4	-21.69	7.08	-21.69	7.05
Sugar cane and beets	20	-17.45	-18.87	-17.44	-18.83
Plant-based fibers	62	-0.27	0.62	-0.27	0.59
Other crops	137	0.02	10.19	0.01	10.17
Cattle	9	-0.63	58.21	-0.60	58.38
Other agriculture	16	-0.31	36.77	-0.29	36.87
Meat from cattle	152	-0.08	13.92	-0.07	13.96
Other meat products	16	-0.38	27.31	-0.35	27.43
Vegetable oils	119	13.77	12.87	13.77	12.84
Dairy products	71	-1.49	53.40	-1.48	53.46
Processed rice	12	24.69	22.47	24.69	22.49
Sugar	38	69.26	66.26	69.28	66.33
Other food products	255	-1.89	38.43	-1.89	38.44
Beverages and tobacco	98	-0.64	61.96	-0.62	62.07

Source: Authors' calculations.

urban economy, and the increased capital allows more urban labor to be employed at the fixed wage. In the case of high mobility, the urban employment rate still goes up, and the rural wage goes up relative to the base line. This is because more of the rural labor force has moved to the urban labor force, allowing the rural wage to be bid up for the remaining labor. The welfare gain is lower in the case of high mobility, however, because of the increase in urban unemployment.

The estimated effect of the reform scenarios on Chile's pattern of food and agricultural production, as well as imports, is presented in tables 3 and 4.⁶ Two main patterns emerge. First, removal of the price

6. The GTAP4 data (1995) on vegetable oils no longer represent the current situation in Chile. The data indicate a small domestic oil industry with small imports, but the domestic crushing industry has since disappeared, as has production of edible oil seeds, which have been replaced by imports of edible oil.

bands leads to substantial expansion of imports of the directly affected commodities, as we might expect. Second, the next-most-substantial changes in import volumes (which are negative) are for commodities that are inputs into the production of the directly affected commodities, such as sugar beets in the case of sugar. For example, the removal of the price band on sugar leads to an increase in sugar imports of 69 percent (table 4.) and a fall in sugar production of nearly 5 percent (table 3).⁷ With reduced sugar production, the inputs into domestic sugar production—such as sugar beets—are likewise reduced (table 3).

In the case of a full removal of agricultural tariffs, the policy leads to a loss in welfare that increases as the elasticity of labor migration increases. The reduction in agricultural supply is more pronounced the more labor mobility is allowed (table 2). With high labor mobility, the urban employment rate falls relative to the baseline. The rural wage declines as capital and labor are drawn out of rural areas, reflecting the relative reduction in capital in the rural region resulting from increased international competition. The result is a falling employment rate in the urban area, increased unemployment in the urban area, and reduced wages in the rural area. While total returns to capital do increase, the harm inflicted on rural workers and the worsening of urban unemployment offset the efficiency gains from cheaper imports and result in a net welfare loss. In the case of low mobility, the loss in welfare stems mainly from the reduction in the rural wage relative to the urban wage. In this scenario, the urban employment rate manages to increase relative to the baseline, but urban unemployment increases and the overall change in welfare is negative.

The results of the model thus generate some valuable policy lessons. The most important point is that in a general equilibrium model that accounts for imperfect labor mobility and urban unemployment, the removal of the price bands on wheat, sugar, and fats and oils increases welfare, but the net effects of total agricultural tariff elimination are estimated to be negative. The elimination of all agricultural

7. The production functions used in the model assume quasi-concavity and continuity. The assumption of continuity becomes somewhat tenuous in a sector like sugar, which is characterized by only a few processing plants that require a minimum output level to remain viable. In this case, reduction of production below a given threshold would result in the collapse of the industry. From this point of view, our prediction of a 5 percent reduction in sugar production may be conservative and dependent on a continuity assumption that may not be true. Some observers of Chilean agriculture feel that the sugar industry would collapse completely without the protection of the price band.

and food tariffs generates sufficient urban unemployment so as to negate the positive welfare effect stemming from lower agricultural and food prices. Chile's labor policy needs to be closely coordinated with possible trade liberalization. If reform results in significant harm to the agricultural sectors increases in urban unemployment will mitigate the beneficial economic efficiency effects.

5. CONCLUDING COMMENTS

As in all economic models, the applied general equilibrium techniques used in this paper are based on a highly stylized structural framework, and this raises a number of issues. One problem with the approach used here is that it is difficult to separate rural and urban activities cleanly along sectoral lines. Another is that the single-country specification means we are unable to account for the effect of Chile gaining access to other markets or the effect of Chile's liberalization on other economies. With regard to the latter issue, several recent studies develop global general equilibrium models, so there is little need to add to that literature. Most of the gaps that remain to be filled involve Chile-specific issues, and more detailed single-country models are an appropriate analytical tool. With respect to the former, to paraphrase Whalley (1985), applied general equilibrium models increase the level of understanding of how institutions affect outcomes, tell a story that is consistent with a set of stylized facts, and provide a consistent framework for the policy debate. The results presented in this paper should be interpreted in this context.

Our findings also suggest that given the existence of urban unemployment and its second-best implications, policies harmful to agriculture and other rural-based industries should be approached with caution if they are likely to provoke worsening terms of trade for the rural sectors. The gains from lower natural resource prices are likely to be offset by worsening rural-urban income divergence and urban unemployment.

Finally, the analysis in this paper examines only the removal of agricultural and food product tariffs. More comprehensive trade liberalization would also remove existing export and output barriers, taxes, and subsidies—not only on agriculture, but also on other portions of the economy. It is quite possible that the net effect of complete liberalization would result in economywide adjustments that would substantially improve overall welfare, but that is another study.

APPENDIX

Notation Used in the Model

This appendix provides the full definition of all the variables and parameters used in the model presented in section 3 (equations (12) through 32). An asterisk at the end of the definition indicates parameters that are independent of the base year data (free) and are supplied independently; other parameters then follow by calibration.

Variables

PM_i	Importable price
PD_i	Domestic price
PWX_i	World price of exportables
P_{ig}	Domestic-import aggregate price
PN_i	Net prices
PF_f	Factor returns
Q_i	Gross output
FD_i	Factor demands
ER_f	Employment rate ($= 1/f \notin g$)
UN_f	Unemployment ($= 0/f \notin g$)
$COST_f$	Cost of migration ($= 0/f \notin g$)
U	Utility level
C_{ig}	Total agent consumption
NDI	Household income
M_{ig}	Imports
D_{ig}	Domestic demand
X_i	Exports

Parameters

a_{ij}	Input-output coefficients
PWM_i	World price of importables
END_f	Factor endowments
PF_g	Institutionally rigid factor returns

\bar{I}_i	Investment
\bar{G}_i	Government expenditure
\bar{CA}	Current account balance
\bar{XR}	Exchange rate
tm_i	Import taxes/subsidies
tx_i	Export taxes/subsidies
ty_i	Output taxes/subsidies
α_i^Q	Production function shift
θ_{fi}^Q	Production function share
σ_i^Q	Production elasticity*
ρ_i^Q	$(1/\sigma_i^Q) - 1$
α	Utility function shift
θ_i^C	Utility function share parameter
λ_i	Subsistence consumption level
α_{ig}^A	Armington shift parameter
θ_{ig}^A	Armington share
σ_i^A	Armington elasticity*
ρ_i^A	$(1/\sigma_i^A) - 1$
α_i^X	Export demand shift
ε_i^X	Export demand elasticity*
α_g^M	Migration function shift
ε_f^M	Migration elasticity*

The following parameters do not appear in the model, but they are used in the calibration process of the Stone-Geary utility function (to determine the subsistence parameters). The Frisch parameter (minus the reciprocal of the marginal utility of income) scales the price elasticities.

η_i	Income elasticity of demand*
ϖ	Frisch parameter*

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LABOR MARKET DISTORTIONS, EMPLOYMENT, AND GROWTH: THE RECENT CHILEAN EXPERIENCE

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From 1984 to 1998, the Chilean economy grew at a rate of 5.4 percent per capita, putting it among the world's most successful economies in the past twenty years. This performance can undoubtedly be attributed to the market-oriented structural reforms that took place in the 1970s, 1980s, and early 1990s. This route was far from easy, however. The period of substantial growth was preceded by a profound crisis in the early 1980s that led to an accumulated decline in per capita output of around 20 percent for 1982–1983.¹ Chile then grew steadily, and it regained its trend level in 1990.² In the years

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1. The Chilean crisis of 1982–1983 is considered one of the worst in the twentieth century (see Kehoe and Prescott, 2002).

2. In this study, we use output per working-age population to analyze growth processes in the Chilean economy and a 2 percent annual rate as trend. Output per working-age population (that is, the population from sixteen to sixty-four years of age) is the appropriate indicator of per capita output in the context of the theoretical economy we use, in which the entire working-age population is capable of working. The 2 percent rate used as a proxy for trend growth corresponds to average annual growth in this variable from 1960–2002 in Chile.

that followed, the growth rate held steady at around 6 percent, bringing per capita output 30 percent above its 1980 trend level by 1998.

In the past few years, however, the Chilean economy has experienced a sharp drop in its growth rate. From 1998 to 2002, the per capita growth rate averaged a mere 0.63 percent per year. Different hypotheses have been put forth to explain this period of stagnating growth. In particular, analysts have mentioned external factors associated with the decline in the terms of trade and reduced access to external capital flows that started with the Asian crisis. The recent recession affecting the world economy—which deteriorated further after the September 11 terrorist attack—is said to have contributed to worsening the outlook for the terms of trade and dampening investors' appetite for risk. Others have argued that this fall could be the result of the excessively restrictive monetary policy stance applied by the Central Bank in mid-1998 to reduce the impacts of the Asian crisis, which were just becoming apparent at the time. The effects of this policy, combined with the direct impact of the Asian crisis itself, may have proved more lasting and harder to turn around than originally foreseen, even with the openly expansionary monetary policy that has been applied for several quarters since.

Still others argue that the country's difficulties with returning to growth rates like those of the past decade go beyond the explanations of a normal cycle. These analysts suggest that recent results reveal a decline in the economy's potential for growing at more than 3 to 4 percent annually. Furthermore, until very recently, the economy was unable to create new jobs at rates comparable to those previously observed. The combined phenomena of stagnant growth and low job creation coincided not only with an external scenario that is extremely complex for emerging economies, but also with a range of policy actions, including legal reforms, that affect production costs. Among these, two stand out: the 30 percent increase in the minimum wage implemented between 1998 and 2000 and the so-called labor code reform. The latter was passed in October 2001, but only after two years of parliamentary debate that left the impression that the reform would increase labor hiring costs by much more than it actually did. Other relevant policy changes include reforms to reduce tax evasion, which were passed toward the end of 2000, and reforms to reduce the tax burden on individuals but gradually increase the burden on companies, which were approved in mid-2001. In an opposite direction, reforms were passed in late 2001 to liberalize the capital market; these should reduce investment and capital costs in the future.

The present article focuses on the third of these hypotheses, that is, that the decline in growth and job creation are linked to changing production costs, mainly associated with more expensive labor. Taking Bergoeing and others (2002) and Bergoeing and Morandé (2002) as our starting point, we analyze the role of factor accumulation and the efficiency with which these factors were used over the past twenty years in Chile, placing output fluctuations in the context of a simple neoclassical growth model. The analysis shows that the fall in employment has been the primary determinant of the observed decline in growth in recent years. This contrasts sharply with the crisis in the early 1980s and the recovery and strong economic growth phase that followed and lasted through 1998, when the efficiency of factor use was the main engine driving economic activity.

1. GROWTH ACCOUNTING

In the context of the neoclassical model, lower growth may be the result of a decline in labor factor accumulation, stemming from changes in implicit or explicit taxes that make it more expensive to hire labor and thus increase production costs. Kehoe and Prescott (2002) show that most crises during the twentieth century were the consequence of drops in the efficiency of factor use or labor contribution. In Chile from 1981 to 1998, the main source of growth was the efficiency with which labor and capital were used; since then, fluctuations in activity levels have resulted fundamentally from changes in employment.

To determine the contribution of factor accumulation and the efficiency of factor use to the change in output per working-age population, we break down the change in the latter by changes in total factor productivity (TFP), the capital-to-output ratio, and hours worked per person of working age. This breakdown is based on a Cobb-Douglas aggregate production function, that is,

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha},$$

where Y_t is output, K_t is capital, L_t is total hours worked, and A_t is TFP.³ In this context,

$$A_t = \frac{Y_t}{K_t^\alpha L_t^{1-\alpha}}. \quad (1)$$

3. Appendix A provides a complete description of the data used and sources.

When TFP grows at a constant rate, that is, when $A_t = Ag^{(1-\alpha)t}$, the neoclassical growth model is characterized by a unique balanced growth path in which output and capital per worker grow at the same constant rate, $g - 1$. In this study, we analyze the behavior of output relative to this trend. The 2 percent trend in output per working-age person used for Chile also fits the United States data very well throughout most of the twentieth century. Kehoe and Prescott (2002) argue that this trend growth represents evidence that the world stock of useable knowledge has grown smoothly over time and is not country specific: countries differ in their institutional structures.

Labor and output series are available directly from national accounts. To obtain A_t , however, we must choose a value for the capital share in output, α , and generate aggregate capital series, K_t . Information from national accounts indicates that the labor compensation share of Chile's output is almost 0.5. This, in a competitive context, corresponds to $1 - \alpha$, so the capital share is 0.5. This fraction is stable over time and similar to many developing countries. Labor's share is much higher in developed countries, with α fluctuating around 0.3. Gollin (2002) shows that if we correct for labor's share in developing countries to allow for the underestimation of independent workers, then labor's contribution rises significantly and tends toward levels observed in developed countries—that is, 0.7. A second reason for using this figure and not the information from national accounts is that in the latter case, the growth model predicts a marginal productivity for capital that is unrealistically high.⁴ The sensitivity exercises included in appendix B show that the results of the study would not be substantially different if we assumed a value of α close to that arising from the national accounts (for example, 0.45). The fraction of output attributed to the labor factor only affects the distribution of changes in output between TFP and capital; it does not affect the labor factor's contribution, which is the main element behind the behavior of output in 1998–2002. We therefore assume that $\alpha = 0.3$, particularly given that this paper centers precisely on the changes to production costs stemming from legal reforms (namely, labor laws).

Taking logarithms in the production function, we have

$$\log\left(\frac{Y_t}{N_t}\right) = \frac{1}{1-\alpha} \log A_t + \frac{\alpha}{1-\alpha} \log\left(\frac{K_t}{Y_t}\right) + \log\left(\frac{L_t}{N_t}\right),$$

4. If $\alpha = 0.45$, for example, the before-tax rate of return on capital would average 23 percent from 1960 to 2002. With $\alpha = 0.30$, however, this rate is 15 percent.

where L_t/N_t is the number of hours available for work per person of working age.⁵ We then break this expression down to separate out changes in real output per working-age population for period t and $t+s$, as follows:

$$\begin{aligned} \frac{\log\left(\frac{Y_{t+s}}{N_{t+s}}\right) - \log\left(\frac{Y_t}{N_t}\right)}{s} &= \frac{1}{1-\alpha} \frac{\log A_{t+s} - \log A_t}{s} \\ &\quad + \frac{\alpha}{1-\alpha} \frac{\log\left(\frac{K_{t+s}}{Y_{t+s}}\right) - \log\left(\frac{K_t}{Y_t}\right)}{s} \\ &\quad + \frac{\log\left(\frac{L_{t+s}}{N_{t+s}}\right) - \log\left(\frac{L_t}{N_t}\right)}{s}. \end{aligned}$$

The first term on the right-hand side of the equation represents the contribution of TFP to growth; the second term is the contribution from changes in the capital-output ratio; and the third term is the contribution from changes in hours worked per person of working age. The empirical evidence reveals that in the long term, both the capital-output ratio and employment remain constant. In the short term, however, factor accumulation can be very important to growth.

Table 1 provides the breakdown of output per working-age population (henceforth per capita output) for the Chilean economy from 1980 to 2002. These data reveal that employment was the most relevant factor behind the level of economic activity in 1998–2002, which contrasts with the period of sustained growth from 1983 to 1998.⁶ Employment explains an average annual decline in per capita output of around 2.31 percent in the more recent period.⁷ Per capita

5. We obtain N_t by multiplying the population aged sixteen to sixty-four years by the number of hours available for work in the year, assuming a hundred hours per week for fifty-two weeks; L_t corresponds to the number of people working in Chile for the average number of hours worked in Greater Santiago. This breakdown is based on Hayashi and Prescott (2002).

6. During the crisis in the early 1980s, employment and TFP accounted for similar percentage drops in per capita output.

7. We are using a logarithmic approximation of growth. This allows us to carry out an additive decomposition of growth factors.

output rose, however, by an average of 0.63 percent per year during this period because TFP was 1.51 percent and the capital-output ratio contributed 1.42 percent. In previous years, TPF appears to have been the main determinant of growth.

Table 1. Growth Accounting in Chile, 1981–2002

<i>Period</i>	<i>Total change in Y/N</i>	<i>Contribution of TFP</i>	<i>Contribution of K/Y</i>	<i>Contribution of L/N</i>
1981–1983	-10.93	-7.81	5.26	-8.38
1983–1998	4.76	3.36	-0.34	1.73
1998–2002	0.63	1.51	1.42	-2.31

Source: Authors' calculations.

Alternative calculations for the growth accounting confirm our main finding, namely, that the drop in per capita output in 1998–2002 is mostly explained by a fall in the contribution of labor (see table 2). This result is robust to different specification for capital and labor: our results remain qualitatively unchanged if we use capital utilization instead of capital stock or the number of workers instead of hours worked.

Table 2. Growth Accounting in Chile, 1998–2002: Robustness to Alternative Measures

<i>Indicator</i>	<i>Total change in Y/N</i>	<i>Contribution of PTF</i>	<i>Contribution of K/Y</i>	<i>Contribution of L/N</i>
Base case	0.63	1.51	1.42	-2.31
Number of people	0.63	1.04	1.06	-1.61
Capital utilization and number of people	0.63	1.29	0.81	-1.61

Source: Authors' calculations.

2. DETERMINISTIC GROWTH MODEL

This section uses a simple deterministic version of the neoclassical growth model, which considers a single good that is

consumed or used in investment. The representative household solves the following problem:

$$\begin{aligned} \max & \sum_{t=1980}^{\infty} \beta^t [\gamma \log C_t + (1-\gamma) \log (N_t - L_t)], \\ \text{s.a. } & C_t + K_{t+1} - K_t = (1 - \tau_t^l) w_t L_t + (1 - \tau_t^k)(r_t - \delta) K_t + T_t, \end{aligned}$$

where C_t is consumption, $N_t - L_t$ is leisure, r_t is the real return on capital before taxes, w_t is real wages, τ_t^l is the labor tax rate, τ_t^k is the tax on net capital minus depreciation, and T_t is a transfer that the government pays the consumer. Moreover, $\beta \in (0, 1)$ is the discount factor, and δ is the depreciation rate.

The representative firm solves the problem,

$$\max \Pi_t = A_t K_t^\alpha L_t^{1-\alpha} - r_t K_t - w_t L_t.$$

The government's problem is to balance its budget, that is,

$$T_t = \tau_t^l w_t L_t + \tau_t^k (r_t - \delta) K_t. \quad (2)$$

Finally, the equilibrium requires market clearing:

$$C_t + K_{t+1} - (1 - \delta) K_t = A_t K_t^\alpha L_t^{1-\alpha} = Y_t. \quad (3)$$

The consumer's problem is characterized by a condition requiring intertemporal optimization for consumption and an intratemporal consumer-leisure optimization condition. These are represented, respectively, by the following equations:

$$\frac{C_{t+1}}{\beta C_t} = 1 + (1 - \tau_{t+1}^k)(r_{t+1} - \delta) \text{ and} \quad (4)$$

$$\frac{C_t(1-\gamma)}{\gamma} = w_t (1 - \tau_t^l)(N_t - L_t). \quad (5)$$

The problem of firms is characterized by conditions of equality between marginal productivity and factor prices:

$$r_t = \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha} = \alpha \frac{Y_t}{K_t} \text{ and} \quad (6)$$

$$w_t = (1 - \alpha) A_t K_t^\alpha L_t^{-\alpha} = (1 - \alpha) \frac{Y_t}{L_t}. \quad (7)$$

Equations (2) through (7) are necessary and sufficient to completely characterize the equilibrium. To simulate the model, we must parameterize our theoretical economy. The parametric specification is given by $\beta = 0.98$, $\delta = 0.05$, and $\gamma = 0.28$. We specified the discount factor and the depreciation rate using the values typically assigned in the literature. The parameter for labor disutility, γ , was calibrated according to equation (8), assuming zero labor tax and considering an average value for the 1960–1998 period consistent with data for consumption, employment, and output. This parameter thus implicitly includes distortions associated with the labor market, and it is consistent with the values reported by McGrattan (1994) for the United States and Bergoeing and Soto (in this volume) for Chile. To evaluate the plausibility of an increase in distortions in the consumption-leisure decision associated with labor market policies, we calibrate the labor tax for equation (8) so as to replicate the behavior of employment in 1998–2002 in Chile. The capital tax is calibrated in equation (9), given β and δ .

$$\gamma = \frac{C_{t+1}}{C_t + w_t(N_t - L_t)(1 - \tau_t^l)} \text{ and} \quad (8)$$

$$\beta = \frac{C_t}{C_{t-1} [1 + (1 - \tau_t^k)(r_t - \delta)]}. \quad (9)$$

Finally, C_t corresponds to total private and governmental consumption and exports.

3. SIMULATIONS

We used the growth model described above to carry out five simulation exercises, which serve as the basis for analyzing whether changes in factor prices resulting from distortionary tax policies were relevant to Chile's recent economic growth performance. Each exercise consists of simulating the model from 1980 to infinity using actual values for TFP and different values for taxes, associated with unexpected reforms.⁸ We then report the impacts of TFP, the

capital-output ratio, and the ratio of employment to the working-age population on growth for the 1980–2002 period, in a manner consistent with the growth accounting breakdown presented in the previous section. The first simulation consists of solving the equilibrium with a capital tax of 49 percent for the entire period under analysis. The second exercise takes into consideration the income tax reforms implemented in Chile in the mid-1980s, which is simulated as a fall in the capital tax from 49 percent to 18 percent in 1987.⁹ These values were calibrated for the periods 1960–1980 and 1987–2002, respectively, based on the consumption-investment decision implicit in the data—that is, using equation (9). Because the decline in the capital tax rate is unexpected, the equilibrium of the simulation remains unchanged for the first six years. The actual income tax rates in Chile during this period underwent a reduction from 45 percent to 10 percent in 1985 and then an increase to 15 percent in 1991. The capital tax rates calibrated from the data using equation (9), while they represent the set of distortions implicit in the consumption data, are surprisingly similar to the rates actually observed during this period.

The third simulation is perhaps the most interesting for the purposes of this paper. It assumes that the debate about changes to labor legislation that started in 1999 and the significant hike in the minimum wage increased the likelihood of labor becoming more expensive, which is expressed as a hiring tax in the model. This tax is calibrated so as to replicate the decline in employment's contribution to growth as observed in the previous four years and is maintained from then on.

The two final exercises consist of calibrating the capital tax and TFP, respectively, for the 1998–2002 period so as to replicate the observed decline in employment (thereby assuming away the hiring tax of the third exercise).

Table 3 presents our results. The simulation of an economy without capital tax reform significantly underestimates output growth from 1983 to 1998 and overestimates it for the next four years. The main reason for the underestimation is that the drop in the capital-output ratio and employment is overestimated. The opposite occurs in the last four years of the sample period: the

8. From 2003 on, we assume that TFP grows at the same average rate as it did in 1960–2002.

9. Although the reform started in 1985, it wasn't fully implemented until 1989.

model underestimates the increase in capital and the drop in the fraction of total hours worked. The fall in employment is so dramatic that output growth in this period is overestimated by about 1.9 percent.

Table 3. Growth accounting in Chile: Simulations with $\alpha = 0.30^a$

<i>Period and source of change in Y/N</i>	<i>Data</i>	<i>Simulation</i>	<i>Simulation</i>	<i>Simulation</i>	<i>Simulation</i>	<i>Simulation</i>
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
1981–1983						
Total change in Y/N	-10.94	-9.20	-9.20	-9.20	-9.20	-9.20
Contribution of TFP	-7.81	-7.81	-7.81	-7.81	-7.81	-7.81
Contribution of K/Y	5.25	5.60	5.60	5.60	5.60	5.60
Contribution of L/N	-8.38	-6.98	-6.98	-6.98	-6.98	-6.98
1983–1998						
Total change in Y/N	4.76	2.80	4.05	4.05	4.05	4.05
Contribution of TFP	3.36	3.36	3.36	3.36	3.36	3.36
Contribution of K/Y	-0.34	-1.12	-0.33	-0.33	-0.33	-0.33
Contribution of L/N	1.73	0.56	1.02	1.02	1.02	1.02
1998–2002						
Total change in Y/N	0.63	2.53	1.81	0.74	0.20	-6.72
Contribution of TFP	1.51	1.51	1.51	1.51	1.51	-8.02
Contribution of K/Y	1.42	1.11	1.28	1.54	0.99	3.60
Contribution of L/N	-2.31	-0.72	-0.98	-2.31	-2.31	-2.31

Source: Authors' calculations.

a. Simulation 1, our base case, considers a capital tax and no reforms. Simulation 2 includes a capital tax reduction to 18 percent as of 1987. Simulation 3 adds to simulation 2 a labor tax of 6.17 percent as of 1999. Simulation 4 adds to simulation 2 a capital tax increase to 35.16 percent as of 1999. Simulation 5 replicates the exercise in simulation 4, but TFP in 1998–2002 is calibrated to replicate the observed fall in employment (specifically, TFP falls by 5.6 percent annually).

Incorporating the capital tax reform significantly improves the results for the 1983–1998 period. This time, capital falls almost as much as in the data, and the underestimation of employment is only 0.7 percentage points. For the 1998–2002 period, however, the increase in output is overestimated, mainly because the model doesn't capture the fall observed in employment.

Consequently, the third and fourth simulations apply increases in taxes on employment and capital, respectively, to replicate the behavior observed in employment. These exercises test the hypothesis that higher production costs may be responsible for the

lower growth observed in Chile in the recent past. The simulations demonstrate that increasing the labor tax from zero to 6.17 percent or the capital tax from 18.0 to 35.2 percent can produce this effect. The second tax, however, worsens the overall prediction while improving the approximation of output performance. In particular, the unreformed model from 1999 overestimates the fall in the capital contribution, so that a higher capital tax worsens the model simulation even further.

Our final simulation imposed a TFP during the 1998–2002 period so as to replicate the observed fall in employment. The rationale for this exercise is that TFP may be mismeasured as a result of unobserved shocks to the economy. The simulation shows that a fall in TFP like the one considered generates a deep fall in output per capita, similar to that observed in 1981–1983, whereas the data show that output per worker actually increased during the period, albeit slightly.

The labor tax option thus appears to be the most plausible explanation for what occurred in Chile after 1998. This labor tax could imply that economic agents perceived an increase in hiring costs as a result of both the large increase in the minimum wage between 1998 and 2000 and the debate surrounding labor reforms.¹⁰ This perception of an increase in the relative price of labor was apparently enough to generate a significant drop in short-term growth in Chile.¹¹ Labor markets were also reformed in Chile in 1992, when an increase in the required severance pay raised the cost of firing. Labor did not fall, however, the way it did in the last four years of the sample period. The macroeconomic scenario was dramatically different, as the economy was growing at a much faster rate and capital inflows were booming.

We modeled the increased cost of hiring labor as the result of several labor market distortions associated with the observed debate on the labor code and the actual increases in the minimum wage that occurred in Chile in 1999–2002. Our simulations fully

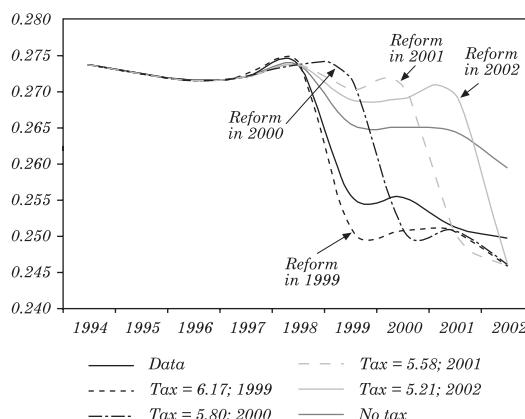
10. Cowan and others (2003) also document the effect of the minimum wage on employment in 1999 and 2000, using a very different approach. In addition, Martínez, Morales, and Valdés (2001) show that a structural break in the labor demand occurred in Chile in 2000. That is, given the aggregate production and relative prices, the Chilean economy demanded less employment at the end of 2000 than in previous years. This downward displacement in labor demand could be explained by an increase in hiring costs, as mentioned above.

11. Beyer (2001) finds that the expected cost of layoffs associated with the new labor structure would rise by about 16 percent.

incorporate the higher cost of labor as of 1999, however. When we simulated this policy distortion as being perceived to happen some periods in the future, the increases in the cost of labor needed to replicate the observed fall in employment were smaller than if the reform was fully implemented in 1999. This simulation captures the timing of the discussion generated in Chile during the period and the uncertainty with respect to the period in which the authority would implement the labor reform. Our results show that the labor tax required to match the fall in employment drops as the expected date of implementation moves farther into the future. Specifically, if the reform is expected to be implemented in 1999, a 6.17 percent tax is required to replicate the actual fall in employment; the required tax falls to 5.8 percent when the reform is expected to occur in 2000, 5.58 percent for 2001, and 5.21 percent for 2002. In a dynamic general equilibrium model with no frictions, agents substitute intertemporally to optimize. Since the reform is expected to become binding in the future, firms decide to temporarily increase their hiring of labor until their labor costs effectively increase.

Figure 1 shows the equilibrium paths of employment for alternative scenarios with respect to the date when the reform is expected to be fully in place. The plotted lines illustrate the actual data for the proportion of hours worked between 1998 and 2002, the simulated

Figure 1. Future Taxes and the Fall in Employment, 1998–2002
Proportion of hours worked



Source: Authors' calculations.

path in the economy without labor taxes, and the employment paths calibrated for labor reforms implemented at alternative dates in the future. If the reform is expected to be binding in the future, the simulated economies with the required taxes match the average fall in employment for the period, but it occurs later than actually happened. Moreover, as discussed above, the further away the expected reform, the lower is the required increase in the cost of labor needed to match the fall in employment.

These results crucially depend on the assumption of fully flexible labor markets until the reform is effectively implemented. Another possibility is that labor markets have frictions—as a result of firing costs, for instance—so that even when the reform is expected several years in the future, the fall in employment is observed in the present. This possibility is not considered here since our simulations in which the reform is assumed to be expected immediately and markets are fully flexible (table 3) generate the same equilibrium as that obtained when the reforms are expected in the future and rigidities are binding in the present.

Our model simplifies reality on several dimensions, one of which is potentially relevant to the analysis. By using a closed economy, we do not explicitly take into account the effect of changes in the terms of trade or other external variables that may be relevant in the case of a small, open economy like Chile. These variables mainly affect what is referred to here as TFP, that is, the residual that remains after considering the accumulation of labor and capital (in other words, all other input factors).¹² The data for 1998–2002 show, however, that the decline in employment, rather than TFP, was the dominant element behind trends in per capita output. Moreover, our exercises include actual TFP, thus capturing the impact of the terms of trade on output. In this context, the relation between growth and employment is not dependent on the assumption of a closed economy. Finally, when we generated the observed fall in employment based exclusively on a drop in TFP (the fifth simulation of table 3), the induced changes in per capita output and the capital-to-output ratio were inconsistent with the observed patterns: the simulation generates a fall in either variable, whereas the data show that both increased.

12. Appendix C demonstrates that our closed-economy model captures fluctuations in the terms of trade through the TFP parameter, A_t . Comparing 1983–1998 with 1999–2000 shows that the contribution of TFP to per capita growth fell by almost 50 percent. This fall is undoubtedly the result of the lower terms of trade since 1998.

4. CONCLUSIONS

This study suggests that the recent decline in economic activity in Chile may have been the result of the increased cost of hiring labor perceived by economic agents, here simulated as a labor tax of 6.17 percent. This perception may have stemmed from the combination of the substantive increase in the minimum wage between 1998 and 2000 and the debate that started in 1999 over the labor code reform. The final bill passed by Congress in October 2001 did include provisions that increased the cost of hiring.

Although establishing a connection between the recently observed fall in employment in Chile and the perception of an increase in the hiring cost of labor requires further analysis, this study shows that small expected changes in relative input prices may generate a large substitution of inputs, causing a detriment to short-term economic growth. If the expected increases in input prices remain over time, the fall in economic activity may reduce long-run growth.

APPENDIX A

Data Sources and Description

For the 1981–2002 period, the gross domestic product series is taken from the Central Bank of Chile. The investment series is from gross capital formation and inventory changes in the International Monetary Fund's *International Financial Statistics*. Capital was generated using the investment series, corrected for the assumed depreciation rate. The working-age population corresponds to people from sixteen to sixty-four years of age, as reported by the World Bank's *World Development Indicators*. Employment series are from the National Statistics Bureau (INE). Finally, total hours worked were calculated using employment per average hours worked in urban Santiago, according to results from the employment and unemployment survey carried out by the Universidad de Chile's Economics Department.

For the 1998–2002 robustness simulations in table 2, we use employment from INE and capital utilization from the Central Bank of Chile.

APPENDIX B

Alternative Simulation

Table A1 provides the results of growth accounting for the data and for each of the five simulation exercises presented in table 3, assuming $\alpha = 0.45$. Simulations were carried out using $\beta = 0.98$, $\delta = 0.05$, and $\gamma = 0.33$. Capital tax rates, calibrated in equation (9), were in this case $\tau_t^k = 0.71$ until 1986 and $\tau_t^k = 0.53$ thereafter. The labor tax that replicates employment's contribution (fall) in 1999–2002 is $\tau_t^l = 0.0469$.

Table A1. Growth Accounting in Chile: Simulations with $\alpha = 0.45^a$

Period and source of change in Y/N	Data	Simulation	Simulation	Simulation	Simulation	Simulation
		1	2	3	4	5
1981–1983						
Total change in Y/N	-10.94	-10.15	-10.15	-10.15	-10.15	-10.15
Contribution of TFP	-12.58	-12.58	-12.58	-12.58	-12.58	-12.58
Contribution of K/Y	10.03	10.20	10.20	10.20	10.20	10.20
Contribution of L/N	-8.38	-7.76	-7.76	-7.76	-7.76	-7.76
1983–1998						
Total change in Y/N	4.76	2.08	3.86	3.86	3.86	3.86
Contribution of TFP	3.66	3.66	3.66	3.66	3.66	3.66
Contribution of K/Y	-0.64	-2.19	-0.99	-0.99	-0.99	-0.99
Contribution of L/N	1.73	0.60	1.18	1.18	1.18	1.18
1998–2002						
Total change in Y/N	0.63	1.12	1.46	0.80	0.26	-8.02
Contribution of TFP	0.22	0.22	0.22	0.22	0.22	-13.60
Contribution of K/Y	2.71	1.66	2.53	2.88	2.34	7.90
Contribution of L/N	-2.31	-1.04	-1.29	-2.31	-2.31	-2.31

Source: Authors' calculations.

a. Simulation 1, our base case, considers a capital tax and no reforms. Simulation 2 includes a capital tax reduction to 53 percent as of 1987. Simulation 3 adds to simulation 2 a labor tax of 4.69 percent as of 1999. Simulation 4 adds to simulation 2 a capital tax increase to 60.35 percent as of 1999. Simulation 5 replicates the exercise in simulation 4, but TFP in 1998–2002 is calibrated to replicate the observed fall in employment (specifically, TFP falls by 5.6 percent annually).

As with the case reported in the text ($\alpha = 0.30$), the simulations without tax reforms (columns 1 and 2 in the table) considerably underestimate growth in output per person of working age during

the period of sustained growth and overestimate this output during the period beginning in 1998. The capital tax reform that began in 1987 allows us to accurately replicate the factor accumulation process observed in the data. Finally, the labor tax rate necessary to replicate actual employment trends from 1998–2002 is almost equal to the result of the simulation exercise reported in table 3.

From a qualitative point of view, therefore, the results reported in table A1 do not differ from those presented in table 3. The sole difference lies in the relevance of capital and TFP in each case. Nonetheless, $\alpha = 0.45$ is not only implausible from an empirical perspective (see Gollin, 2002), but also suggests an annual before-tax return on capital averaging 23 percent in 1960–2002. This rate of return is too high.

APPENDIX C

Terms of Trade and TFP in a Closed-Economy Growth Accounting

Assume a small open economy that produces two types of goods: exportable and importable. The aggregate production function in terms on importable goods would then be as follows:

$$Y_t = A_t^M K M_t^{\alpha_M} L M_t^{1-\alpha_M} + P_t^X A_t^X K X_t^{\alpha_X} L X_t^{1-\alpha_X}, \quad (\text{C.1})$$

where $K M_t$ and $L M_t$ are employment and capital in the importable sector and $K X_t$ and $L X_t$ are employment and capital in the exportable sector. P_t^X is the relative price of exports and imports (terms of trade), which is exogenously determined since the economy is assumed to be small. To calculate TFP as in equation (1)—that is, assuming that there is only one good—the actual production function is given by equation (C.1). We thus obtain

$$A_t = \frac{Y_t}{K_t^\alpha L_t^{1-\alpha}} = \frac{A_t^M K M_t^{\alpha_M} L M_t^{1-\alpha_M}}{K_t^\alpha L_t^{1-\alpha}} + \frac{P_t^X A_t^X K X_t^{\alpha_X} L X_t^{1-\alpha_X}}{K_t^\alpha L_t^{1-\alpha}}, \quad (\text{C.2})$$

where $K_t = K M_t + K X_t$ is the aggregate capital stock measured in terms of the importable good and $L_t = L M_t + L X_t$ is total employment expressed in hours of work. Equation (C.2) can then be presented as

$$A_t = A_t^M w_t^M + A_t^X w_t^X P_t^X, \quad (\text{C.3})$$

$$\text{where } w_t^M = \frac{K M_t^{\alpha_M} L M_t^{1-\alpha_M}}{K_t^\alpha L_t^{1-\alpha}} \text{ and } w_t^X = \frac{K X_t^{\alpha_X} L X_t^{1-\alpha_X}}{K_t^\alpha L_t^{1-\alpha}}.$$

Equation (C.3) shows that the changes in TFP estimated under this assumption include not only the actual changes in the productivity level in the economy (given by A_t^M and A_t^X), but also the efficiency gains or losses stemming from input reallocations (measured by w_t^M and w_t^X) and changes in the terms of trade.

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TAX INCENTIVES FOR RETIREMENT SAVINGS: SIMULATION RESULTS IN THE PRESENCE OF LIQUIDITY CONSTRAINTS AND HETEROGENEOUS CONSUMERS IN AN OLG-GE MODEL

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The overlapping generations general equilibrium (OLG-GE) framework constitutes an important tool for policy evaluation. One of its strengths is that it considers that at any given time the population is composed of workers of different ages and, therefore, with different time horizons. This has two advantages. First, the assumption of a realistic distribution of time horizons and budget constraints among the population allows the analyst to realistically model the evolution of the equilibrium path of the economy given a certain policy. Second, modeling the different generations in detail supports making meaningful welfare comparisons across generations. These advantages make the framework attractive for policy evaluation, since it can help determine cohort-based compensatory policies that may be crucial for making a certain policy feasible.

This paper uses an OLG-GE model to assess the impact of the recently approved tax incentive mechanisms for retirement savings in Chile. The purpose is to determine the extent to which different groups of workers may take advantage of the incentives, the potential aggregate impact in the steady state, the transition path of the economy to the new steady state, and the welfare implications of the reform.

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The OLG-GE framework is particularly attractive for studying this reform because the reform triggers more than one transition. One is a transition in individual savings decisions. The fact that workers are at different stages in their life cycle implies that the final aggregate impact on capital accumulation will arise only when all living generations have faced the same conditions during their working lives. The second is an important fiscal transition. Taxes are deferred, which means that the public sector will have to make some kind of transitory adjustment until income tax collection returns to a stationary level.

The model used in this paper incorporates two important improvements with regard to previous versions, which are crucial for the problem at hand. First, it models an income tax structure with increasing marginal rates. Solving the consumption and savings problem in this context provides new insights into the impact of income taxes on savings. Moreover, it is crucial for the model to provide a realistic prediction of the impact of tax incentives on savings behavior. Second, the population is modeled with heterogeneity in income levels. This provides the necessary environment for welfare evaluation, since the benefits of the policy under study vary with income level.

The paper is organized as follows. The first section introduces the tax incentive mechanism recently approved in Chile for voluntary savings for retirement. Section 2 describes the model and section 3 its parameterization. Section 4 presents partial equilibrium results, showing optimal policies for voluntary savings for different agents. Steady-state comparisons are presented in section 5, while section 6 shows the results for the transitions. A final section summarizes the main findings and presents paths for future work.

1. TAX INCENTIVE MECHANISMS FOR VOLUNTARY SAVINGS FOR RETIREMENT (VSR)

The incentive mechanism consists of allowing a deduction from the income tax base equal to the savings for retirement made during a year up to a maximum. These savings can only be accessed at retirement, at which time the withdrawals are subject to income tax. Withdrawals take the form of either annuities or monthly pension payments. In the latter case, the amount of the payments

is determined via the phased withdrawal rules that apply to normal pensions, which try to secure a constant pension throughout retirement. In addition, a certain amount can be withdrawn tax-free in lump-sum payments, provided that the monthly pension is above a certain level.

An incentive scheme like this has been in place in Chile since the current pension system was implemented in 1981. A reform implemented in March 2002 introduced the following changes to the scheme:

- Maximum monthly voluntary contributions were raised from 48 UF to 50 UF a month;¹
- Tax-free withdrawals after retirement were limited to 2,100 UF² (there was no limit before the reform);
- Withdrawals before retirement were allowed, subject to a penalty of 3 percent of the withdrawal plus one-tenth of the marginal income tax rate that corresponds to the income level of the worker (the penalty thus varies between a minimum of 3 percent and a maximum of 7.3 percent);
- The type of institution allowed to provide the service was expanded to include banks and insurance companies; and
- Providers were allowed to charge a fee.

Taken at face value, the effect of the legal changes on the amount of voluntary savings is ambiguous. The limit on tax-free withdrawals and the provider fee have a direct adverse pecuniary effect that makes VSR less attractive, whereas the higher monthly contributions and the possibility of early withdrawal make the mechanism more attractive (although the change in contributions is small and early withdrawal does not generate a direct pecuniary effect).

The crucial point of the legal modification, however, is that competition for VSR is now open to new players. These new entities can be expected to undertake a large marketing effort to encourage workers to participate in the system. Recent findings show that long-term savings are highly sensitive to framing and arrangements that reduce transaction costs (Choi and others, 2001). Marketing efforts should help to place retirement savings on the “path of least resistance”, expanding the use of existing programs.

1. The *Unidad de Fomento* (UF) is a CPI-indexed unit of account widely used in the financial sector in Chile. It varies daily.

2. Limit is defined as 1,200 *Unidades Tributarias Mensuales* (UTM), another CPI-indexed unit of account, which varies monthly. 1 UTM = 1.75 UF approximately.

2. THE MODEL

The base model is the OLG-GE model with credit constraints developed by Cifuentes and Valdés-Prieto (1997) which, in turn, is an expanded version of Auerbach and Kotlikoff (1987). The main difference with the latter is that Cifuentes and Valdés-Prieto model the case of liquidity constraints. This is extremely important for the present case. In the absence of liquidity constraints, savers would take advantage of the full tax incentive, without considering preferences for consumption. Consumption would be maximized independently with total wealth as the only input. Liquidity constraints prevent this: the extent to which the tax advantage is used depends on both the income profile and time preferences.

The model has three sectors: households, firms, and the government. Households are endowed with an age-related path of units of labor. In this paper, I further consider three different types of household, according to the level of education attained by the head. Different levels of educational attainment imply different levels of productivity, so this is modeled as different amounts of labor units.

Households accumulate savings that are offered to the productive sector (firms) as capital and to the government as demand for bonds. This means that households own all the factors in the economy, and capital is owned homogeneously among households of similar characteristics. Firms demand factors with a profit-maximizing objective. Government, in turn, must finance expenditures through taxes and public debt issuances. There is no uncertainty of any sort in the model, and agents are assumed to have perfect foresight.

2.1 Households

Households are assumed to have an economically active life of sixty years, which represents a worker who offers labor in the market between ages twenty-one and sixty-five and is retired from age sixty-six through death at age eighty. The supply of labor typically increases with age or presents a hump shape, as a result of the effects of experience on productivity for different types of worker. The section on calibration shows the particular profiles for labor productivity used in this paper.

Factor prices and labor endowment are given. Each type of household maximizes a constant intertemporal elasticity of

substitution (CIES)—or constant relative risk aversion (CRRA)—utility function to find the optimal path of consumption and savings:

$$\max U = \frac{1}{1-1/\gamma} \sum_{a=a_1}^{80} (1+\delta)^{-(a-a_1)} c_a^{e^{1-1/\gamma}}, \quad (1)$$

subject to

$$F_{at}^e = [w_t l_a^e (1 - \tau_t^{ss}) + r_t F_{a-1,t-1}^e + p_{at}^e] (1 - \tau_t^y) + F_{a-1,t-1}^e - c_a^e (1 + \tau_t^c) \quad (2)$$

for $a = a_1, \dots, 80$,

$$F_{at} \geq 0 \text{ for all } a \in \{21, \dots, 80\} \text{ and} \quad (3)$$

$$F_{20,t}^e = 0 \text{ for all } e \text{ and } t, \quad (4)$$

where

$$p_{at}^e = p_{t-a}^e = \begin{cases} 0 & \text{for } a = 21, \dots, 65 \\ \frac{\sum_{i=21}^{65} w_{t-a+1} l_{i,t-a+1}^e \tau_{t-a+1}^{ss} \prod_{j=i+1}^{65} (1+r_j)}{\sum_{i=1}^{15} (1+r_{t+i-1})^{-i}} & \text{for } a = 66, \dots, 80 \end{cases} \quad (5)$$

and where δ is the discount rate or time preference parameter, γ is the elasticity of intertemporal substitution (or the inverse of the coefficient of risk aversion), a indicates age, t represents chronological time, e is education level, and a_1 is the age at which the consumer is maximizing.

Equation (2) is the budget constraint in flow terms. F_{at}^e indicates the stock of financial assets at the end of period t , l_{at}^e is the labor supply, w_t is the wage rate at year t , c_a^e is net consumption, τ^y and τ^c are income tax and value-added tax (VAT) rates, respectively, τ^{ss} is the social security contribution rate, and p_{at}^e is the pension benefit. As indicated in equation (5), pension is assumed to be a constant during retirement; therefore, $p_{at}^e = p_{t-a}^e$, which means that the pension does not depend on age, but on the cohort to which the worker belongs.

Equation (3) imposes credit constraints by requiring that financial assets can not be negative. Equation (4) indicates that workers do not own assets at the beginning of their working life.

Choices regarding consumption and saving plans are time consistent throughout the worker's life. This means that if maximization were to be revised later in life, the consumer would choose to stick to the original plan. Each worker thus optimizes only once, with $a_1 = 21$. However, optimization may change in the face of unanticipated changes in the evolution of the workers' environment. In this case, all agents have to re-optimize at the moment of the reform, and the optimization can be based on starting assets greater than zero.

The maximization problem so defined implies that households have perfect knowledge of factor prices and tax rates from the age at which they maximize until the end of life. The outcome of the maximization is a path of household consumption, asset holdings, and taxes paid.

Finally, I define the evolution of mandatory retirement assets, A , as

$$A_{at}^e = w_t l_{at}^e \tau_t^{ss} + (1 + r_t) A_{a-1,t-1}^e - p_{at}^e \text{ for } a = 21, \dots, 80, \text{ and}$$

$$A_{20,t}^e = 0 \text{ for all } e \text{ and } t.$$

2.2 Aggregation

To move from individual data to aggregate macroeconomic variables, I sum across all individuals alive at a given time, t . This implies summing across age and educational levels. I assume that population grows at an annual rate of n percent. Aggregate supply of capital in year t is

$$K_t^S = \sum_{e=1}^3 \left[\sum_{a=21}^{80} F_{at}^e \cdot (1+n)^{-a} + \sum_{a=21}^{80} A_{at}^e \cdot (1+n)^{-a} \right]. \quad (6)$$

In equilibrium, capital supply should equal capital demand by the productive sector plus total public debt, which is the demand for capital by the public sector.

Total labor supply is the sum of labor endowments of workers of different ages and educational levels alive in a given year:

$$L_t = L_t^S = \sum_{e=1}^3 \left[\sum_{a=21}^{80} l_{at}^e \cdot (1+n)^{-a} \right]. \quad (7)$$

In contrast with capital, labor supply is fixed. Factor prices adjust until full employment of labor is reached. The implicit assumption with regard to productivity growth is that each generation is born with a profile of labor endowments that is x percent higher than the previous generation for every age. This introduces productivity growth, in that it benefits only new generations that join the labor market. In terms of the notation introduced,

$$\frac{I_{a,t+1}^e}{I_{at}^e} = (1 + x) \text{ for all } a, e, \text{ and } t.$$

2.3 Firms

Firms use a constant elasticity of substitution (CES) technology to produce. They maximize profits taking factor prices as given, as described in the following expression:

$$\max \Pi = \left[\alpha L^{(\sigma-1)/\sigma} + (1 - \alpha) K^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} - \phi K - r K - w L, \quad (8)$$

where the subscript t has been dropped from the expression for simplicity, since all variables refer to the same time, t ; σ represents the elasticity of substitution in production; and ϕ is the depreciation rate. First-order conditions of maximization imply that factors are hired until price equals marginal productivity:

$$\frac{\partial Y}{\partial K} = r + \phi; \quad \frac{\partial Y}{\partial L} = w.$$

Factor demands can be obtained from the first-order conditions:

$$L^D = w^{-\sigma} \alpha^\sigma Y^{\sigma/(\sigma-1)} \text{ and} \quad (9)$$

$$K^D = (r + \phi)^{-\sigma} (1 - \alpha)^\sigma Y^{\sigma/(\sigma-1)}. \quad (10)$$

2.4 Government

Government must finance exogenously given expenditures. This can be done by issuing debt or imposing taxes. By definition, the balanced budget implies

$$G_t + r_t B_t = T_t + B_{t+1} - B_t,$$

where G_t is total government expenditures, B_t is the outstanding public debt, and T_t is the tax collection, which equals

$$T_t = (w_t L_t + r_t F_t + p_t) \tau_t^y + c_t \tau_t^c,$$

where F_t is total voluntary assets held at time t , p_t represents total pension payments at time t , and c_t is aggregate net consumption at time t . All three aggregates are determined according to the following relation:

$$z_t = \sum_{e=1}^3 \left[\sum_{a=21}^{80} z_{at}^e \cdot (1+n)^{-a} \right].$$

The no-Ponzi-game condition implies that the present value of taxes should equal the present value of expenditure plus the initial stock of debt. This condition implies that the growth rate of debt cannot exceed the interest rate.

In practice, for a given path of public expenditures, fiscal budget can be balanced by an infinite number of combinations of paths for public debt and each of the taxes. In this paper I assume that public debt and income tax rates are fixed *ex ante* by rules and that the VAT rate is adjusted to attain equilibrium in fiscal budget. In particular, I assume that public debt is fixed as percentage of GDP. This guarantees that the no-Ponzi-game condition is always satisfied. The income tax schedule follows a rule that is described in the next section.

2.5 Equilibrium

Equilibrium is found using a Gauss-Siedel algorithm. The first step is to conjecture an initial path for the level of the aggregate stock of capital (K_t^D). Given that the path for labor (L_t) is known and fixed, paths for factor prices (r and w) consistent with the conjecture

can be derived using equations (9) and (10). A path for the parameter that balances the fiscal budget is also conjectured. Given these paths, households decide consumption and savings. Individual variables are aggregated to determine capital supply and the level of the variable that adjusts the public sector finances. The equilibrium delivers new values for the conjectured variables. If these new values are the same as the initial conjecture, then an equilibrium has been found. This typically is not the case in the first rounds. When magnitudes differ, a new conjecture is used to simulate the model, typically a path between the previous conjecture and the previous outcome of the model. A solution is found after a few iterations. In formal terms, the equilibrium condition I am looking for is

$$K_t^D + B_t = K_t^S \text{ for all } t,$$

which says that capital demanded in the economy, from the production side (K_t^D) and from the government (B_t), should equal capital supply (K_t^S).

In the case of a transition, the algorithm is the same except that convergence is assumed to reach a maximum 180 years after the introduction of the reform that triggered the transition. This involves assuming that all relevant prices in the economy are fixed from that year on at the value they reach that year. This assumption is usually not binding, since the economy typically converges in shorter time spans.

3. PARAMETERS

This section presents the parametrization of the model, with special attention to the tax scheme and the income profiles. It also discusses the strategy followed to determine the optimal savings policy in the presence of tax incentives for retirement savings.

3.1 Tax Scheme

Previous versions of the model consider single-rate income tax schemes. The incentive mechanisms under study here, however, have their greatest impact with income tax schemes in which the marginal tax rate increases with income, as is the case of Chile. This paper models the Chilean income tax structure (see table 1).

Table 1. Income Tax Rates in Chile, 2002

<i>Income range (UFs per month)^a</i>	<i>Marginal tax rate (percent)</i>
0–23.6	0
23.6–52.5	5
52.5–87.5	10
87.5–122.5	15
122.5–157.5	25
157.5–210.0	33
210.0–262.5	39
262.5 and over	43

Source: Internal Revenue Service.

a. Tax brackets are defined in UTMIs in the tax code. Here they are presented in UFs to facilitate presentation.

Incorporating this tax scheme has two implications for the model. First, the government budget is adjusted via the consumption or value-added tax. Adjusting marginal income tax rates introduces noise with regard to the object of study, which is precisely the fact that the effective marginal income tax rate can be changed through retirement savings. If I allowed the tax scheme to change over time in order to adjust the government budget, I would not be able to measure the additional savings generated by the tax incentive.

The second implication is more troublesome. In a context of productivity growth, keeping the income tax scheme of table 1 constant over time implies that the economy will only reach a stationary equilibrium when the entire population is in the highest income bracket. Consequently, a model economy will be in a very long transition path until this happens. Such a simulation is feasible, but it is highly intensive in computational capacity—and the main question is whether it is a meaningful exercise. In such a transition, distortions increase over time as the median marginal income tax rate increases (and the VAT or other tax rates decreases if the size of the government is to be kept constant). Income tax becomes the main source of revenue for the government.

That context clearly is not a reasonable scenario for policy evaluation. Agents in the economy will not allow the level of distortions to follow whatever path the dynamics of growth might determine. A more sensitive scenario is to assume that a decision has been made about the level of distortions that agents in the economy find optimal

and then to keep that level of distortions constant, except for the consequences of the specific tax reform under study.

The practical way to keep the level of distortions constant is to adjust the threshold of each income tax bracket increase in line with productivity in the economy. Each generation will face the same scheme in relative terms, and a stationary equilibrium can be attained. While such adjustments do not occur on a yearly basis in reality, the strategy adopted here seems to provide a reasonable assumption regarding medium- and long-run tax policy dynamics.

3.2 Income Profiles

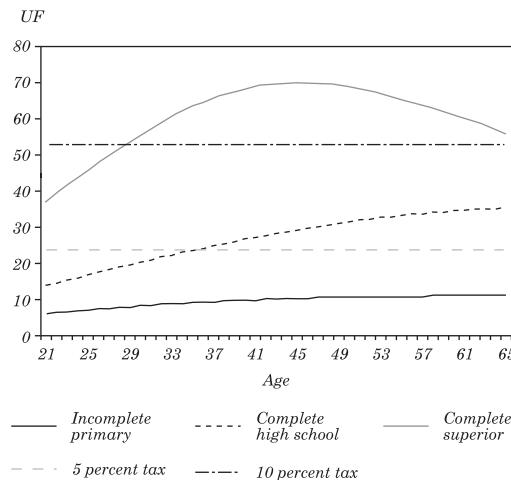
Recent studies on the effects of age on income include Larrañaga and Paredes (1999) and Butelmann and Gallego (2001). The former paper estimates an average age-income profile using synthetic cohorts from a long series of panels (1957 to 1996) from the employment survey in Greater Santiago. Having data for various years allows them to isolate cycle effects properly. This profile is longitudinal, that is, it represents the income profile faced by individuals or cohorts throughout their lifetime. Butelmann and Gallego (2001), in turn, report cross-sectional age-income profiles. In principle, longitudinal profiles can be derived from cross-sectional ones based on assumptions about the evolution of productivity growth between generations. However, longitudinal profiles cannot be derived from the Butelmann-Gallego data using reasonable assumptions of productivity growth. This may be due to the fact that year effects affect their estimates.

Butelmann and Gallego (2001) report profiles for different levels of educational attainment, while Larrañaga and Paredes (1999) derive only one profile representing the population average. Assuming that year effects do not substantially affect the relative differences in income across workers with different educational attainment, I can use Butelmann and Gallego (2001) profiles to derive income profiles by educational attainment from Larrañaga and Paredes (1999). I determine this by imposing the condition that at every age, income levels for the three income categories have to keep the relative distances found in Butelmann and Gallego (2001), while averaging the level of Larrañaga and Paredes (1999). Weights are reported in Butelmann and Gallego (2001).

Figure 1 shows the income profile thus derived. The income profile of the worker with the lowest level of education never

reaches the first income bracket with positive income tax. This implies that tax incentives for VSR will never be relevant for this group. In fact, they can only reduce welfare for this group, since these workers do not obtain any benefit from the tax incentives and the lower liquid income at working ages may heighten financial constraints. Population shares of different groups by educational attainment are as follows: incomplete primary school: 53.2 percent; complete high school: 25.2 percent; and complete superior education: 21.6 percent.

Figure 1. Income Profiles by Level of Educational Attainment^a



Source: Author's calculations based on Butelman and Gallego (2001) and Larrañaga and Paredes (1999).
 a. Based on monthly income in 2001.

3.3 Other Parameters

Table 2 shows the value used in the simulations of the other variables of the model. Data on public debt and public expenditure are Chile averages for the period 1993–2000. Public debt considers Central Bank long-term debt plus recognition bonds. It is not relevant for the model whether the issuer is the Treasury or the Central Bank, as in Chile. What is captured by the model is the crowding-out effect of public debt on investment, and this effect occurs independently of the issuer.

Table 2. Simulation Parameters

<i>Variable</i>	<i>Value</i>
Public debt over GPD	19.6 percent
Public expenditure over GPD	17.6 percent
Contribution rate to mandatory pension fund	5 percent
Production function (CES)	
Sigma	0.8 and 1.2
Alfa	0.53 and 0.75
Time preference	1, 3, and 10 percent
Intertemporal elasticity of substitution	0.9
Population growth rate	1 percent

Source: Central Bank of Chile and author's estimates.

With regard to public expenditure, what is relevant for the model is the part that is financed with taxes. This provides the measure of the government's impact on the budget constraints of private economic agents. Thus, public expenditures financed by means other than taxes (such as return on assets, asset sales, and income from public companies) is treated as part of the private economy in this model.

The mandatory contribution to pension funds is assumed to be 5 percent. The mandatory level in Chile is actually 10 percent, but because the model assumes a worker starts working at the age of twenty-one and contributes continuously until he/she is sixty-five, the amount accumulated in the personal account is usually very large. The model does not consider more realistic features of contribution histories, such as periods of unemployment, independent employment, or absence from the labor force, as it is not the purpose of the model to incorporate such features. Instead, their relevant impact on lifetime budget constraints is fully captured via a lower contribution rate.³

The parameters of the production function are chosen to generate a reasonable macroeconomic environment. Sigma captures the elasticity of substitution in production in the CES function; this is chosen in the vicinity of 1, the Cobb-Douglas case. Alpha, in turn, is set to generate a share of labor in GDP between 66 and 68 percent, which is an appropriate value for the Chilean economy. Finally, among the combinations of sigma and alpha that match this requirement, I choose those that generate a real interest rate around 5 percent, a reasonable benchmark for returns on long-term savings.

3. The accumulation of large balances in individual accounts can be avoided through early retirement. This can easily be included in the model.

3.4 Simulation Strategy

Tax incentives affect the consumer's maximization problem because wealth increases if income is transferred from periods with high marginal tax to periods with low marginal tax. The practical implication of this is that the income profile and the path of taxes cease to be exogenous and become a consequence of workers' savings decisions. This would not be a problem in the absence of borrowing constraints: workers would take full advantage of the tax benefit, and the resulting shape of the income profile would not have any material consequence, since workers would be able to follow any consumption stream they wanted. In other words, tax incentives would only have a wealth effect. In the presence of credit constraints, however, reallocations of income along the lifecycle can have important welfare effects if they change the extent to which credit constraints are binding. The combination of credit constraints and an endogenous income profile sets up a problem that is difficult to solve in a general way in the context of the Auerbach and Kotlikoff framework. A general solution can be found by modeling a dynamic programming problem as in Cifuentes (2000). Within the Auerbach and Kotlikoff framework, a good approximation to the solution can be found simplifying the space of possibilities available to the worker and selecting the optimal consumption and savings paths by numerical search. The simplifying assumptions are the following:

- Active life (twenty-one to sixty-five years of age) is divided into five periods of nine years each. I assume that the savings rate in voluntary retirement savings mechanisms is constant within each of these periods.
- Saving rates in voluntary retirement savings mechanisms are restricted to values that are multiples of 2.5 percentage points.
- Withdrawals take the form of annuities. This is reasonable considering that the optimal strategy should be similar to this. Withdrawing funds all at once triggers higher marginal tax rates.
- Strategies that consider withdrawal of funds from voluntary retirement savings accounts before retirement are discarded a priori. In a context of perfect certainty about income levels, withdrawing voluntary retirement savings before retirement would make sense only if income in some future period is sufficiently lower than current income such that taxes plus penalty in the future are lower than current marginal taxes. That situation never happens in this exercise given the shape of the income profiles used.

4. PARTIAL EQUILIBRIUM RESULTS

This section explores the optimal use of tax incentives for retirement for different types of agents. Given a tax structure for income taxes, the optimal use of voluntary retirement savings mechanisms is affected by four main factors:

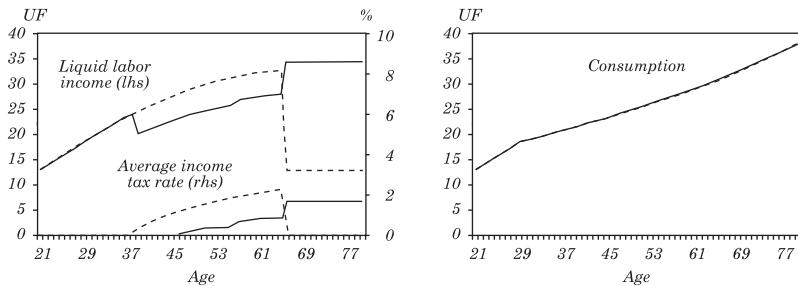
- The shape of the income profile. A steep income profile implies that liquidity constraints are strongly binding in early periods, and the voluntary retirement savings mechanisms are less likely to be used in those periods.
- The presence of a mandatory retirement savings program. This is straightforward: if a portion of income is already being set aside for retirement, with no possibility of early withdrawal of the funds, then workers' desire to reserve more income for the future is reduced, despite the benefits provided through the incentives.
- Time preferences. As mentioned earlier, the presence of liquidity constraints means that the use of the tax advantage is not independent of preferences. A high discount rate lowers the degree to which workers take advantage of voluntary retirement savings mechanisms.
- Income level. Workers' income determines their relative position with regard to income tax brackets. This, in turn, determines the extent to which there is a tax-arbitrage opportunity.

Figure 2 shows the optimal policy with regard to voluntary retirement savings for the case of a worker with a complete high school education and intertemporal preferences (δ) of 1, 3, and 10 percent, respectively. All cases consider a 4 percent real interest rate (net of fees). Dotted lines show the situations without the voluntary retirement savings mechanisms.

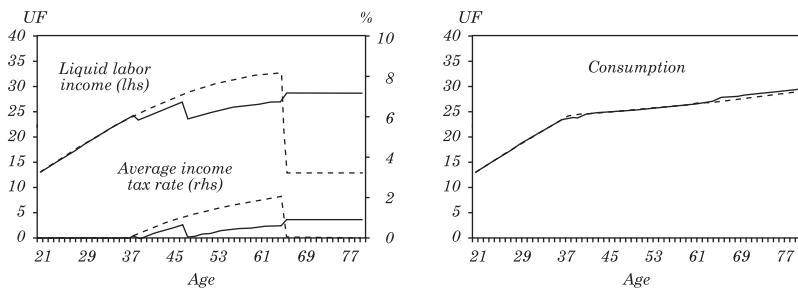
In the case of $\delta = 1$ percent (figure 2.A), optimal policy consists of a voluntary savings rate of 17.5 percent between ages of thirty-nine to fifty-six and 15 percent between fifty-seven and sixty-five. The new path for liquid income closely tracks the optimal consumption path. The new consumption path is above the previous in all years starting around the age of forty. The slope of consumption paths is not the same throughout the life cycle because the marginal income tax rate varies along the life cycle, changing the first-order condition for consumption. This is clear in the consumption path without voluntary retirement savings at the retirement age, when the marginal tax rate goes to zero. The consumption path steepens, which is why both

Figure 2. Liquid Labor Income, Consumption, and Average Income Tax Rate Profiles^a

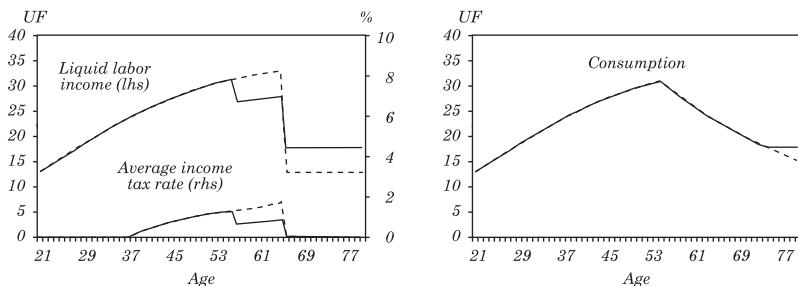
A. Time preference (δ): 1 percent



B. Time preference (δ): 3 percent



C. Time preference (δ): 10 percent



Source: Author's calculations.

a. The graphs show the case of a worker with complete high school education; the continuous line represents the case with voluntary retirement savings, and the dotted line, the case without it.

consumption paths intersect at the end of life. The figure also shows the average tax rate, which illustrates how taxes are reduced and a portion of them deferred toward retirement age.

The case of $\delta = 3$ percent shows a lower use of voluntary retirement savings mechanisms vis-à-vis the previous exercise (see figure 2.B). Here optimal rates are 5 percent for ages thirty-nine to forty-seven and 17.5 percent from forty-eight to sixty-five. The consumption path is lower in the new situation between ages thirty-eight and forty, but this sacrifice is compensated with larger consumption at retirement.

Finally, figure 2.C shows the case of a worker with a high intertemporal preference. Optimal policy is to save voluntarily for retirement at a rate of 15 percent between ages fifty-seven and sixty-five. Consumption is reduced between ages of fifty-five and fifty-nine relative to the previous situation, but it then becomes higher between the ages of seventy-five and eighty.

From the cases described above, I infer that the optimal policy consists of taking advantage of tax incentives subject to keeping the original consumption path attainable. This explains, for example, the apparent paradox that the optimal savings rate for ages fifty-seven to sixty-five is higher for the consumer with a higher discount rate when comparing the cases of $\delta = 1$ percent and $\delta = 3$ percent. A higher savings rate at those ages causes the original consumption path to become unfeasible for the agent with $\delta = 1$ percent. This result is not absolute, however, since very small reductions in the consumption path can be tolerated.

Table 3 summarizes the optimal savings policy for the different agents and time preferences. Workers with complete superior education have their highest savings rates earlier in life than workers with complete high school. This is a consequence of the shape of their respective income profiles, which have a hump earlier in life for the former worker than for the latter.

5. GENERAL EQUILIBRIUM RESULTS: THE STEADY STATE

Table 4 presents the impact of voluntary retirement savings mechanisms on the steady state given four different parameterizations. In all cases, the capital stock increases, with a subsequent increase in output and fall in the interest rate. The increase in the capital stock is higher in the cases with lower elasticity of substitution in

Table 3. Optimal Savings Rate in Retirement Accounts with Tax Incentives

<i>Educational attainment and time preference</i>	<i>21 to 29</i>	<i>30 to 38</i>	<i>Age 39 to 47</i>	<i>48 to 56</i>	<i>57 to 65</i>
Incomplete primary					
1 percent	0	0	0	0	0
3 percent	0	0	0	0	0
10 percent	0	0	0	0	0
Complete high school					
1 percent	0	0	17.5	17.5	15.0
3 percent	0	0	5.0	17.5	17.5
10 percent	0	0	0	0	15.0
Complete superior					
1 percent	0	15.0	20.0	0	0
3 percent	0	5.0	15.0	5.0	5.0
10 percent	0	0	0	0	5.0

Source: Author's calculations.

production ($\sigma = 0.8$). In this case, capital increases on the order of 4.8 percent, while output increases 1.6 percent. In the higher elasticity case, these figures are 2.7 percent and 0.8 percent, respectively.

In the new steady state, the VAT rate and the level of collection of VAT and income taxes change only slightly. In the case of the income tax, payments have been deferred from active life to retirement. This move will make sense for a worker only if the present value of taxes paid falls, so tax collection in the steady state should be lower. However, labor income rises as a result of the increase in salaries in response to higher capital accumulation. This implies that all income profiles shift upward and are subject to higher marginal tax rates. This is analogous to saying that the average tax rate increases. On the capital income side, the fall in returns is compensated with an increase in the capital stock, leaving the total effect close to null. This is verified by the small change in the relative share of factor income in GDP.

Summing the change in collection rates on the two taxes yields a small reduction. This reflects the fact that the fall in the interest rate implies lower payment for public debt, such that fewer funds need to be collected.

Pension funds (both voluntary and mandatory) grow considerably. Their share of total assets in the steady-state economy jumps from 50 percent to 80 percent. The increase in total capital is on the order of

Table 4. Impact of Tax Incentive Mechanisms for Voluntary Retirement Savings

Variable	$\sigma = 0.8, \alpha = 0.53$			$\sigma = 1.2, \alpha = 0.75$		
	Without incentives	With incentives	Change ^a	Without incentives	With incentives	Change ^a
Productivity growth = 0 percent						
Real interest rate	5.01%	4.69%	-0.32	4.57%	4.45%	-0.12
Gross investment rate	17.7%	18.2%	0.56	17.5%	17.8%	0.32
Capital-output ratio	3.9	4.0	3.1%	3.9	4.0	1.8%
Capital-labor ratio	9.8	10.2	4.8%	6.6	6.8	2.7%
Output-labor ratio	2.5	2.5	1.6%	1.7	1.7	0.8%
Share of labor in GDP	66.6%	66.9%	0.26	68.7%	68.6%	-0.09
VAT rate	22.6%	22.6%	0.01	24.5%	24.7%	0.21
VAT collection / GDP	14.6%	14.5%	-0.12	15.9%	16.0%	0.06
Income tax collection / GDP	3.8%	3.8%	0.06	2.4%	2.3%	-0.08
Pension fund / Total assets	50.3%	81.1%	30.8	47.6%	81.2%	33.6
Pension fund / GDP	207.1%	343.8%	136.7	194.4%	337.3%	142.9
Productivity growth = 1 percent						
Real interest rate	5.51%	5.16%	-0.35	4.97%	4.83%	-0.14
Gross investment rate	20.7%	21.3%	0.66	20.2%	20.6%	0.42
Capital-output ratio	3.7	3.9	3.2%	3.7	3.7	2.1%
Capital-labor ratio	9.1	9.6	4.9%	6.1	6.2	3.0%
Output-labor ratio	2.4	2.5	1.6%	1.7	1.7	0.9%
Share of labor in GDP	66.2%	66.5%	0.27	69.0%	68.9%	-0.10
VAT rate	23.6%	23.6%	0.07	25.4%	25.7%	0.32
VAT collection / GDP	14.6%	14.4%	-0.11	15.8%	15.9%	0.10
Income tax collection / GDP	3.7%	3.8%	0.05	2.4%	2.3%	-0.12
Pension fund / Total assets	49.2%	77.0%	27.8	46.9%	77.7%	30.8
Pension fund / GDP	194.0%	312.9%	119.0	180.9%	180.9%	124.7

Source: Author's calculations.

a. Percentage points or percent change, as indicated.

2–3 percent, so this large increase in pension funds mainly represents a transfer from other types of savings to these with tax advantages.

The impact on the total amount of funds is thus considerable despite the fact that the tax incentive mechanism is only relevant for workers with relatively high incomes. Two caveats must be kept in mind, however, when drawing conclusions from these numbers. First, all the demand for assets in this economy is based on lifecycle motives, whereas in reality, agents hold wealth with other purposes. The effects of changes in lifecycle savings thus tend to be amplified. Second, uncertainty may reduce incentives to voluntarily lock savings until retirement.

6. GENERAL EQUILIBRIUM RESULTS: THE TRANSITION PATH

Transition paths reveal key features with regard to the evolution of variables over time that are not possible to determine from steady-state comparisons. This is particularly true when the shocks that generate the transition take the form of changes in the tax regime or other dimensions of fiscal policy. In the particular case studied here, transition analysis is key to verifying that the evolution between steady states is not monotonic.

In addition, OLG models help determine the specific welfare change of the different generations affected by a reform. This is crucial, since policy reforms may look very positive based on a comparison of the steady states, but only the study of the transition will indicate whether there are costs and if so, how they are distributed among different groups.

The previous section showed that output is higher in the new steady state and that income tax revenue is similar in the initial and final steady states. Given the nature of the reform, however, income tax should fall during the transition, such that other taxes should rise. Transition analysis provides an indication of the magnitude of the changes, the time it will take the economy to reach the new steady state, and the costs that different generations must bear while this is happening.

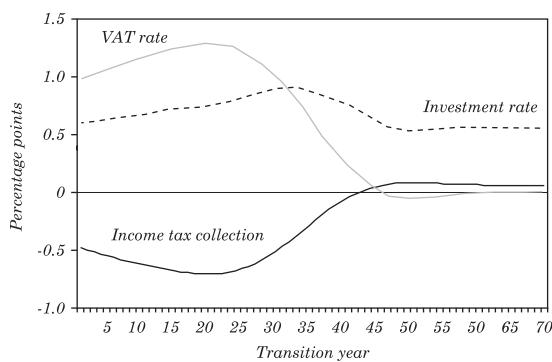
The results are summarized in figures 3 and 4. Figures 3 shows the evolution of the macroeconomic equilibrium for each case of elasticity of substitution in production and $x = 0$ percent. This can be summarized by the evolution of income tax collection, which drives the fiscal adjustments, and the evolution of the gross investment rate,

which summarizes the accumulation process and thus gives an indication of the evolution of factor prices. The VAT rate is also shown for completeness.

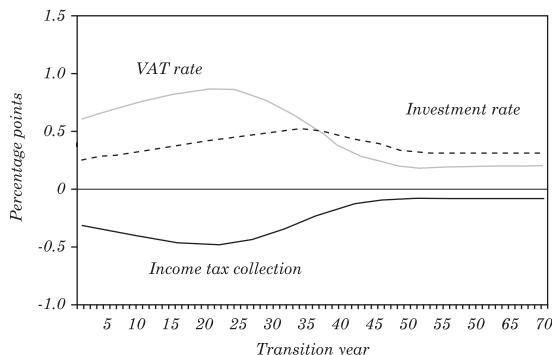
The two graphs have the same scale on the vertical axis to facilitate comparison. Variables are shown as changes from their initial steady-state values. Demand for capital in the case of low elasticity of substitution in production (figure 3.A) is such that the

Figure 3. Change with Respect to Steady-state Values

A. *Elasticity of substitution in production (σ): 0.8*



B. *Elasticity of substitution in production (σ): 1.2*



increase in investment rates is larger than in the high elasticity case (figure 3.B) for all the periods after the shock. This implies that this economy moves to an equilibrium with higher capital and therefore greater output. Income tax collection falls initially (to a greater extent under low elasticity of substitution), but in both cases it recovers to slightly above the initial percentage of GDP in the final steady state. The necessary increase in the VAT rate is larger in the case of low elasticity of substitution, rising above 1 percentage point for 30 years.

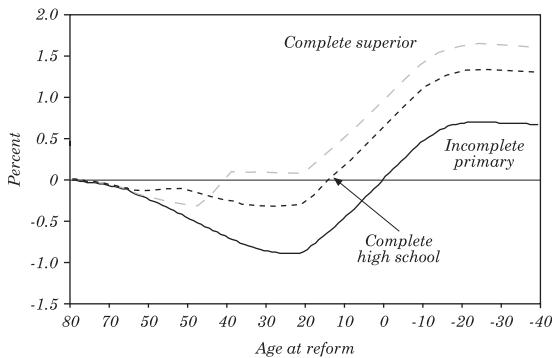
The path of aggregate macroeconomic variables is monotonic, as suggested by the evolution of the investment rate. These are increasing for thirty-two to thirty-four years, and then they decline until they converge to a level above the previous steady state by 0.55 and 0.31 percentage points in the first and second case, respectively. Capital stock, wages, and pension funds grow monotonically between steady states, a transition that takes fifty years.

Figure 4 shows the welfare impact of the reform for each of the transitions studied. Each transition features three types of agent, one for each of the educational levels considered. All three have the same time preference of 3 percent. The welfare impact is driven by two factors. The first is a set of macroeconomic factors, such as the prevailing level of wages, interest rates, and taxes for a given generation. The higher VAT of the initial years of the transition imply lower welfare for the generations that are alive in this period, while the higher wages that result from the increased accumulation of capital raise the welfare of the generations born after the reform. The second factor is the extent to which workers participate in the tax incentive scheme. Workers who are alive in the years of higher VAT may be able to counter this negative effect by exploiting the tax incentive mechanism and increasing their wealth.

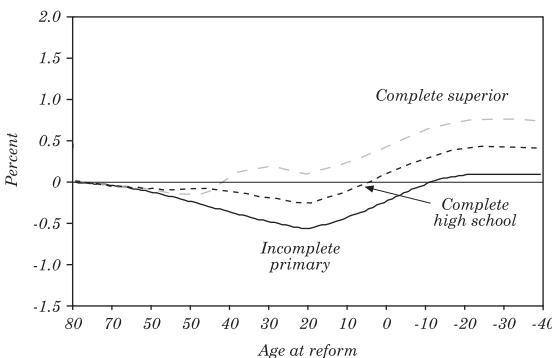
These two factors help explain the welfare impact shown in figure 4. Welfare is measured in terms of equivalent variations, which is the percentage change in lifetime consumption that is equivalent in welfare terms to the impact of the reform. Workers with the higher educational levels always benefit the most from the reform, since they take advantage of the tax incentive mechanism. The welfare differential is constant for generations that were not in the labor force at the time of the reform. For generations that were in the labor force at the time of the reform, the welfare effect depends on the extent to which they use the tax incentive mechanism.

Figure 4. Welfare: Equivalent Variations

A. Elasticity of substitution in production (σ): 0.8



B. Elasticity of substitution in production (σ): 1.2



Source: Author's calculations.

Agents with the lowest level of education do not benefit from the tax incentive mechanism, so they do not have any direct means of offsetting the increased VAT. Welfare for this type of agent starts improving when VAT rates start decreasing and capital accumulation drives wages up. In the case depicted in figure 4.A, the welfare of this group starts to improve with the generation that is born exactly in the year of the reform. This generation starts its active life in the

twentieth year of the transition. Figure 3.A indicates that VAT rates are at their highest twenty years after the reform and that they remain above the steady-state level for twenty-five more years. However, at the same time wages are higher and increasing for the next twenty-five years, and this evolution compensates that of taxes in welfare terms.

For workers who are over forty-five years of age at the reform, those with complete high school are better off than those with complete superior education. The reason for this can be seen in table 3, which shows that the former type of worker has a higher voluntary retirement savings rate in this age group than the latter. For younger workers (that is, those below forty-seven at the time of the reform), the savings rate is higher for the group with complete superior education than for the group with complete high school, and the welfare ranking is also higher. In fact, university-educated workers younger than forty years of age at the moment of the reform do not suffer any loss of welfare.

7. CONCLUSIONS

This paper has shown that tax incentive mechanisms to promote voluntary retirement savings have the potential to increase both savings and output in the long-run equilibrium of the economy. This change stems from a shift in the payment of income taxes from active life to retirement. Thanks to this shift, workers can reduce the total amount of taxes paid by reallocating income from periods in which marginal tax rates are high to periods in which they are low. This raises the capital accumulation in the economy. The increase in capital prevails in the new equilibrium, while tax collection returns to its original composition.

The increase in capital, however, has not come without a cost. The delay in tax payments implies that other taxes will have to be raised during a transition period. The paper shows how this burden is distributed among groups with different income levels. The impact is regressive, in that the lower income groups are the most affected because they have to suffer the tax increase without being able to exploit the new benefits of the system. In the long run, future generations of all income levels benefit, but the groups with the highest income levels benefit the most.

The impact on capital accumulation described in the paper is high. This is a consequence of assumptions and features of the model that

need to be addressed. An important assumption, for example, is that all workers participate in the system. An alternative exploration of the issue should incorporate independent and informal workers into the model, which was beyond the scope of this paper.

Another important element that should be explored is the impact of uncertainty. In the model, agents can perfectly anticipate the tax payments generated by different paths of savings and withdrawals, and they optimize accordingly. Uncertainty makes this less clear. If the realization of an adverse shock makes it necessary for workers to access the funds in their voluntary retirement savings accounts before retirement, they will have to pay a penalty. The tax saved on making deposits will have to be higher than the expected penalty for early withdrawal if voluntary retirement savings are to continue to be attractive. This implies that voluntary retirement savings will be lower than in the certainty case. Exploring this issue will be highly informative for assessing the optimal conditions of access to funds before retirement.

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