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]

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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 macroeconometric 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

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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 macroeconometric 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 macroeconometric 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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