

# GENERAL EQUILIBRIUM DYNAMICS OF EXTERNAL SHOCKS AND POLICY CHANGES IN CHILE

Francisco A. Gallego  
*Massachusetts Institute of Technology*

Klaus Schmidt-Hebbel  
*Central Bank of Chile*

Luis Servén  
*World Bank*

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.<sup>1</sup> 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).<sup>2</sup>

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.<sup>3</sup> 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.<sup>4</sup> 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.<sup>5</sup> 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.<sup>6</sup> 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).<sup>7</sup> 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.<sup>8</sup>

## **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.<sup>9</sup> 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.<sup>10</sup> 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).<sup>11</sup> 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.<sup>12</sup>

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.<sup>13</sup> 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.<sup>14</sup> 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).<sup>15</sup> 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.<sup>16</sup> 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, Bergoing 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 <sup>a</sup>	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 <sup>b</sup>	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**

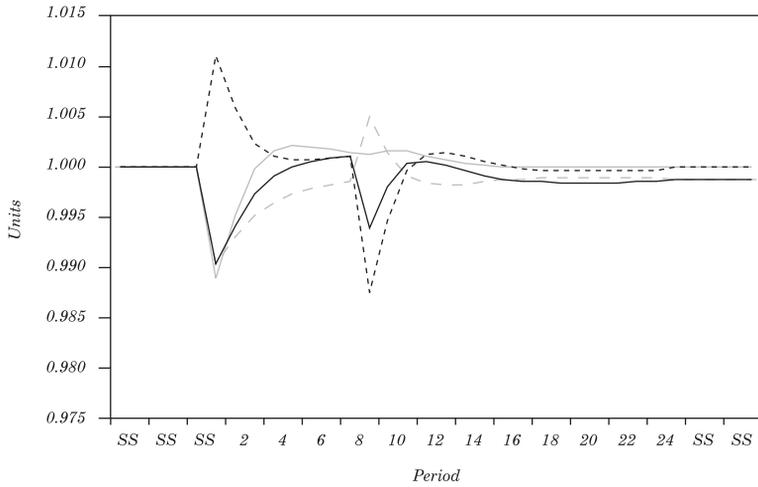
We simulate the effects of a temporary, debt-financed fiscal expansion that raises public consumption by 1.54 percentage points, from 10.5 percent to 12.04 percent of GDP. This policy shift causes the public debt stock to rise monotonically from 131 percent of GDP in the first quarter to 141 percent 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.

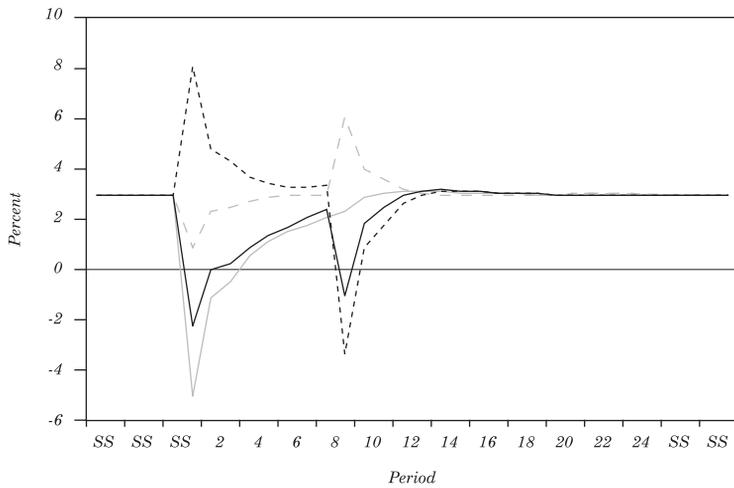
Since public consumption falls only on domestic goods, the fiscal shock raises aggregate demand for national goods. This causes on impact (that is, in the first period) a real exchange rate appreciation and an increase in investment, output, and employment. The real

**Figure 1. Dynamic Response of All Variables to All Shocks**

*A. Output*



*B. Inflation rate*

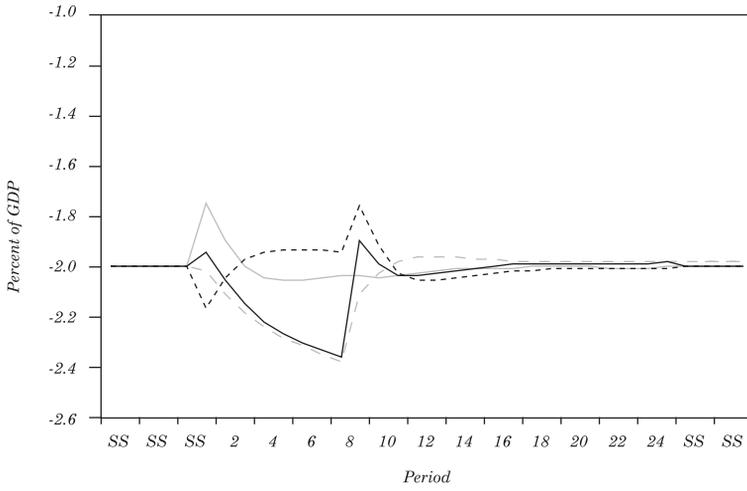


--- Adverse external shock    — Monetary adjustment    ... Fiscal expansion    -.- Combined shocks

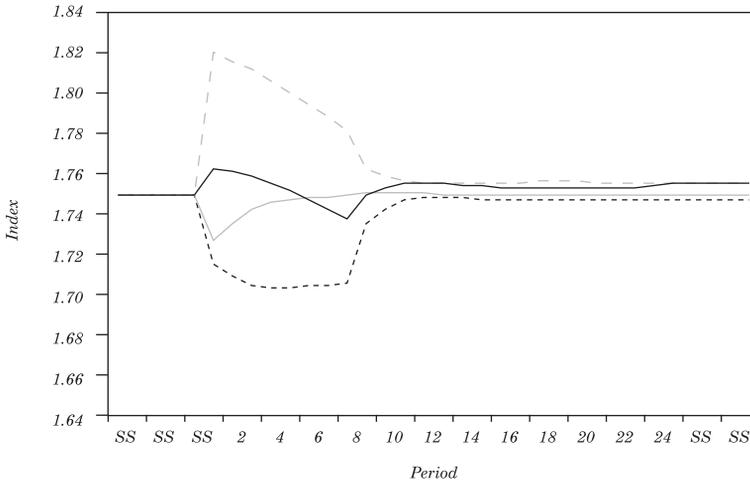
Source: Authors' calculations.

**Figure 1. (continued)**

*C. Current account*



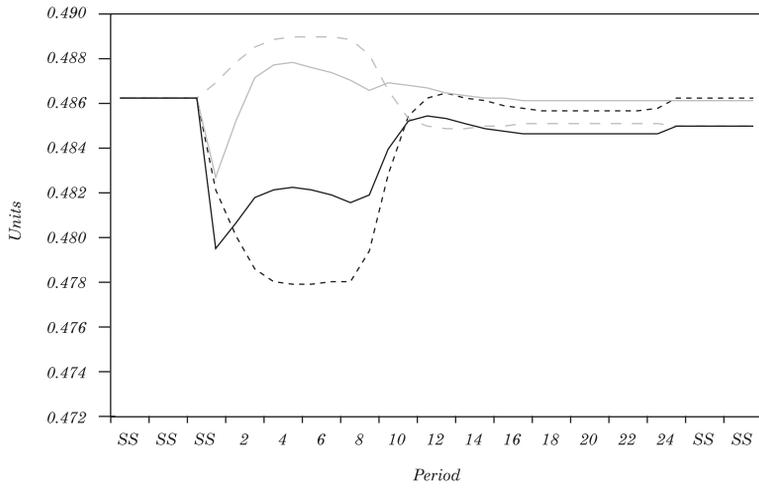
*D. Real exchange rate*



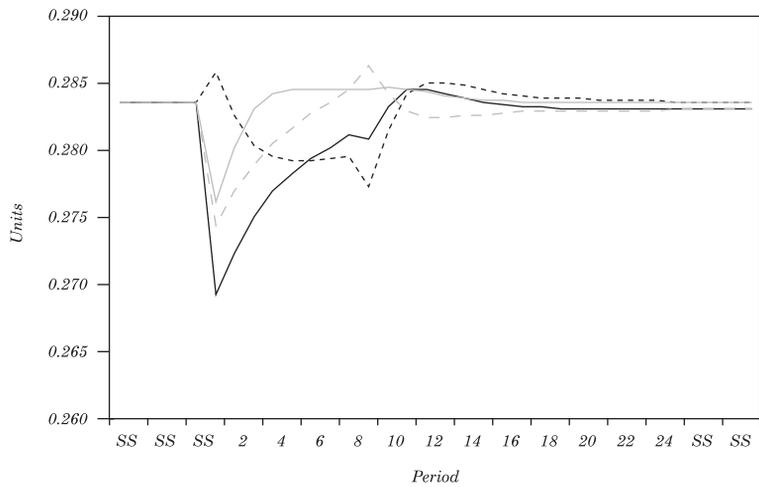
--- Adverse external shock    — Monetary adjustment    - - - Fiscal expansion    — Combined shocks

**Figure 1. (continued)**

*E. Private consumption*



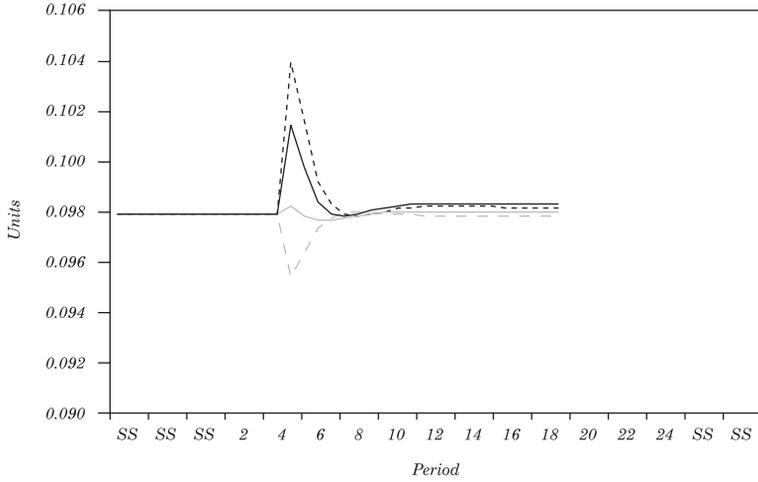
*F. Private investment*



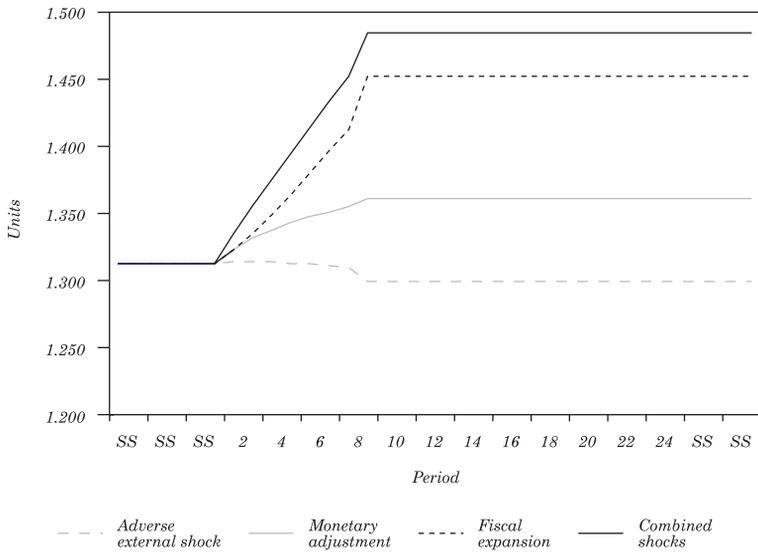
--- Adverse external shock    — Monetary adjustment    - - - Fiscal expansion    - · - Combined shocks

**Figure 1. (continued)**

*G. Tax revenues*

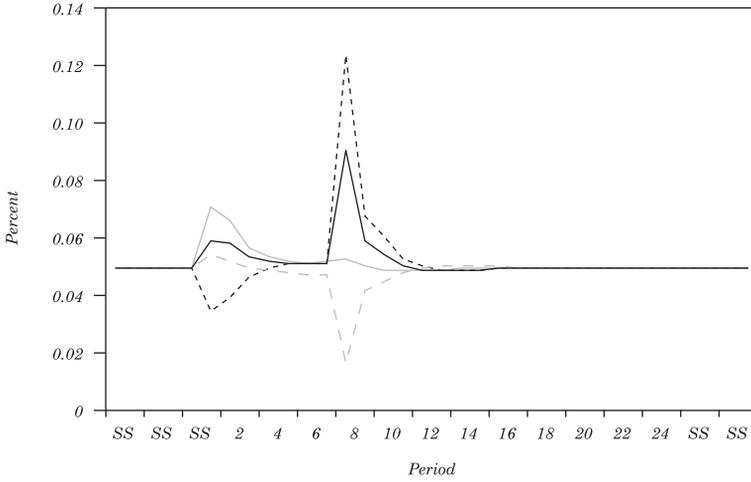


*H. Public debt stock*

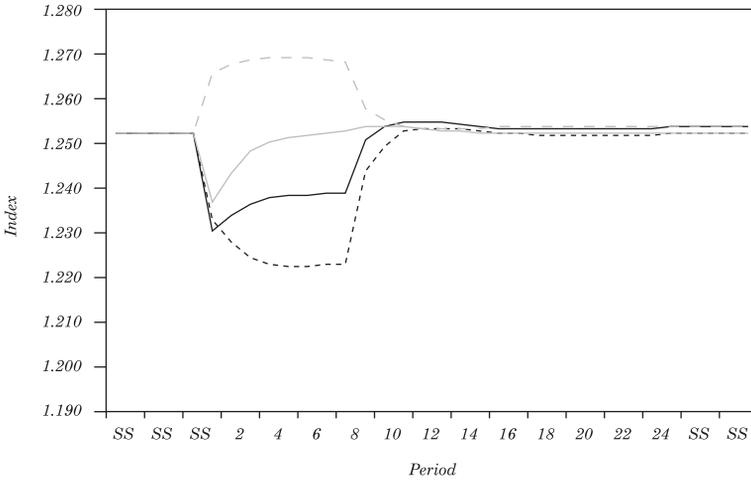


**Figure 1. (continued)**

*I. Real interest rate*



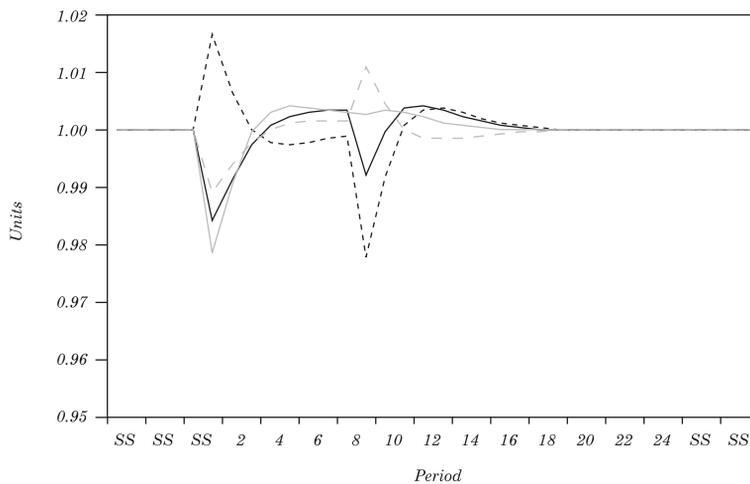
*J. Tobin's q*



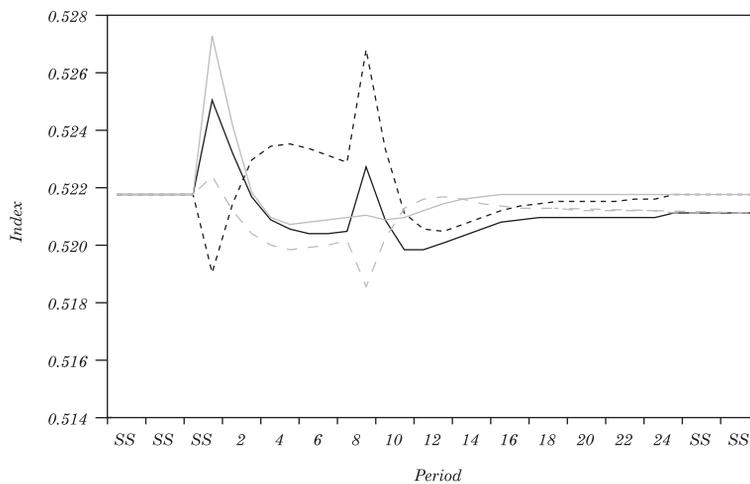
--- Adverse external shock    — Monetary adjustment    ..... Fiscal expansion    — Combined shocks

**Figure 1. (continued)**

*K. Employment*



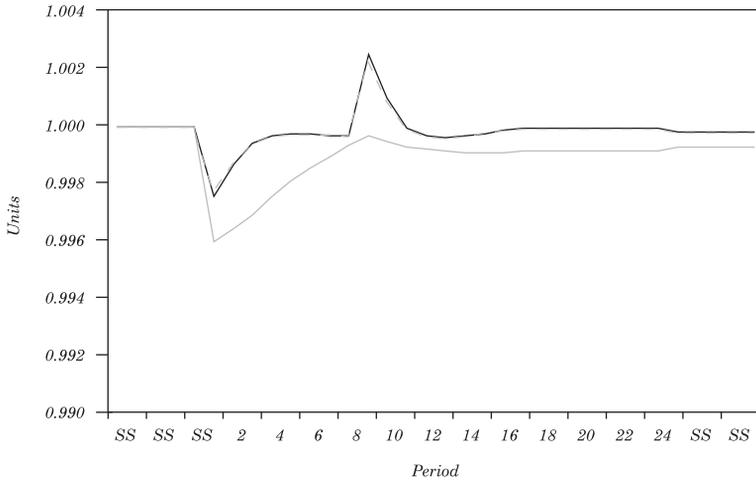
*L. Real wage*



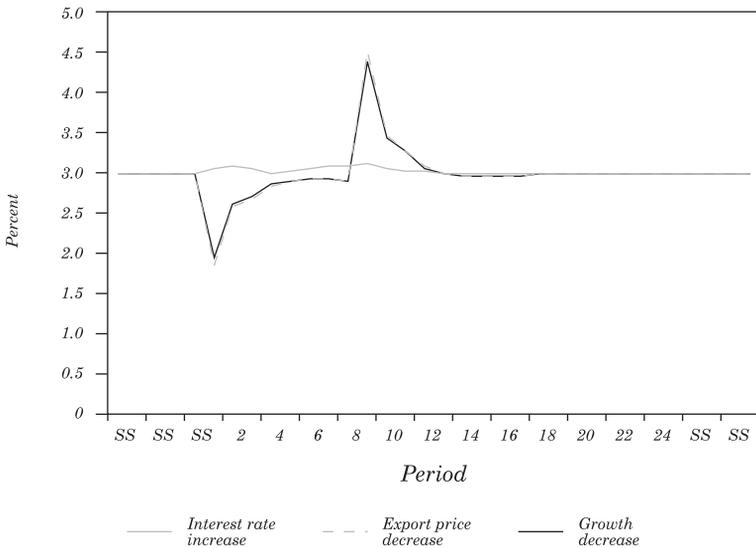
--- Adverse external shock    — Monetary adjustment    - - - Fiscal expansion    - · - Combined shocks

**Figure 2. Dynamic Response of Main Variables to External Shocks**

*A. Output*



*B. Inflation rate*

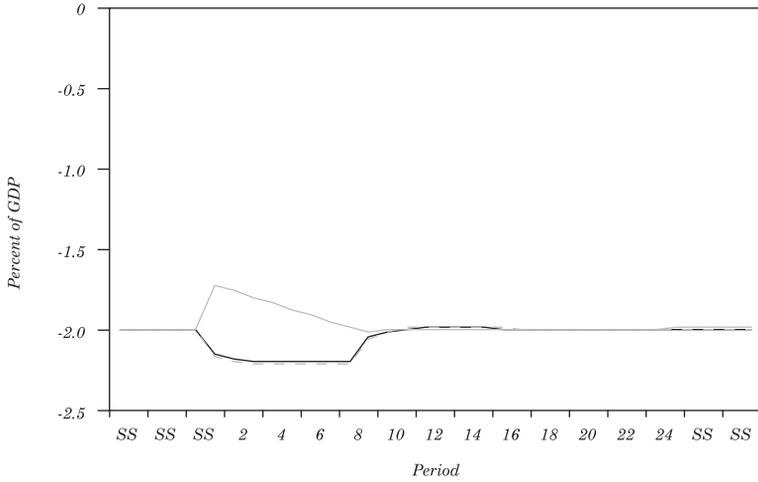


—— Interest rate increase
- - - Export price decrease
—— Growth decrease

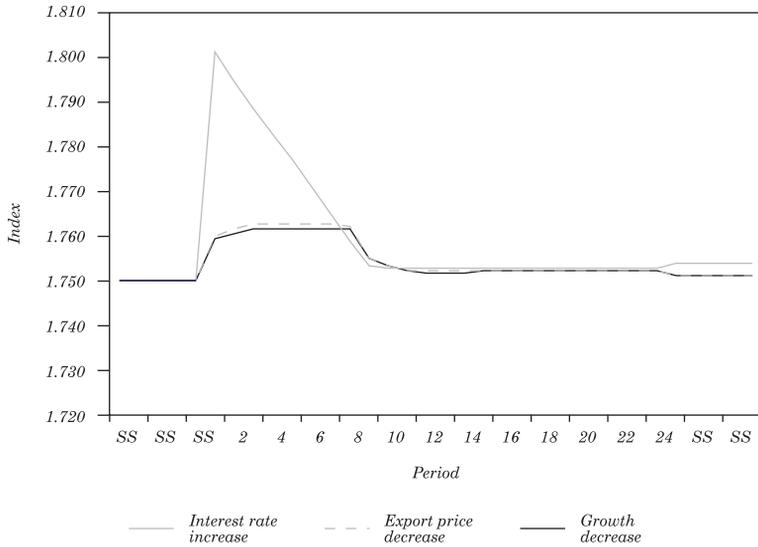
Source: Authors' calculations.

**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.<sup>17</sup> 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
$l$	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
$\mu$	Growth rate of the nominal money stock
$\rho$	Consumers' subjective discount rate

$\delta$	Depreciation rate of physical capital
$x$	Fraction of equity owned by domestic agents
$\lambda_C$	Share of intertemporally optimizing consumers
$\lambda_I$	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
$\Omega$	Weighted average of current and lagged consumer prices
$P^C$	Nominal private consumption deflator

### **Real exchange rate**

$e = (E P^*)/P$  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:

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

Augmented consumption deflator:

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

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:

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

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:

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

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:

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

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:

$$\left( \frac{X}{e} - p_C^* C^* - p_K^* J^* - p_M^* M + f_p^* + f_G^* \right) + (r^* - g)(b_p^* + b_G^*) - \frac{d^*}{e} = \left( \dot{b}_p^* + \dot{b}_G^* \right) - FDI \quad (28)$$

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:

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



### Real Wage

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

$$d\ln(w) = \underset{(4.13)}{0.034} + \underset{(13.77)}{0.3192} \ln(I) + \underset{(1.30)}{0.1365} d\ln(p_C) \\ + \underset{(6.22)}{0.5699} d\ln(p_{C,-1}) + (1 - 0.1365 - 0.5699) d\ln(p_{C,-2})$$

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

### Production Function

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

$$d\ln\left(\frac{Y}{K}\right) = \left( \underset{(3.35)}{0.3969} - 1 \right) d\ln(K) + \underset{(4.14)}{0.5218} d\ln\left(\frac{I}{K}\right) \\ + \left( 1 - \underset{(3.35)}{0.3969} - \underset{(4.14)}{0.5218} \right) d\ln\left(\frac{M}{K}\right)$$

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

### 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  $R^2A$ . The estimation includes dummy variables for 1994:4 and 1995:1.

$$I = \underset{(3.10)}{0.136} \frac{K}{15} \left\{ \left[ \underset{(2.75)}{0.5299} q_1 + (1 - 0.5299) \frac{0.397(Y/K)}{(0.0099 + 0.0108)} \right] - 1 \right\} \\ + \underset{(3.10)}{0.136} (0.0099 + 0.0108) K + (1 - 0.136) I_{-1}$$

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

## **Export Demand**

Estimated using 2SLS in first differences:

$$\begin{aligned} d\ln(X) = & 0.0206 + 0.1320 d\ln(ep_X^*) \\ & \quad (5.12) \quad (2.40) \\ & + 0.6830 d\ln(Y^*) + 0.03 d\ln(X_{-1}), \\ & \quad (2.23) \quad (0.22) \end{aligned}$$

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

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 ( $\beta$ ): 0.6337

Interest rate elasticity ( $\sigma$ ): 0.078

Wage equation

Employment elasticity ( $\omega$ ): 0.3192

Indexation to current inflation ( $\chi$ ): 0.1365

Indexation to one-period lagged inflation ( $\theta$ ): 0.5699

Production function

Constant ( $\alpha_0$ ): 0.4676

Labor share ( $\alpha_1$ ): 0.5218

Capital share ( $\alpha_2$ ): 0.3969

Private investment demand

Share of unconstrained firms ( $\lambda_1$ ): 0.5299

Adjustment costs to investment ( $\phi$ ): 15

Rate of depreciation of physical capital ( $\delta$ ): 0.0108

Share of domestic goods in investment ( $\gamma$ ): 0.7141

Private consumption demand

Share of unconstrained consumers ( $\lambda_C$ ): 0.6556

Share of domestic goods in consumption ( $\eta$ ): 0.9523

Export demand

Constant ( $\epsilon_0$ ): 0.0206

Real exchange rate elasticity ( $\epsilon_1$ ): 0.1320

Foreign income elasticity ( $\epsilon_2$ ): 0.6830

**Calibration of the sector budget constraints**

The public sector budget constraint is defined as follows:

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

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:

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

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

Rates<sup>18</sup>

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

Growth rate of the nominal money stock ( $\mu$ ): 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 ( $l$ ): 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

## REFERENCES

- Arrau, P. 1989. "Intertemporal Monetary Economics: Evidence from the Southern Cone of Latin America." Ph.D. dissertation, University of Pennsylvania.
- Bandiera, O., G. Caprio, P. Honohan, and F. Schiantarelli. 1999. "Does Financial Reform Raise or Reduce Savings?" Policy research working paper 2062. Washington: World Bank.
- Bergoeing, R. and F. Morandé. 2002. "Crecimiento, empleo e impuestos laborales: Chile 1998–2001." *Cuadernos de Economía* 39(117): 157–74.
- Blanchard, O. and C. Kahn. 1980. "The Solution of Linear Difference Models under Rational Expectations." *Econometrica* 48(5): 1305–13.
- Braun, J. and M. Braun. 1999. "Crecimiento potencial: el caso de Chile." *Cuadernos de Economía* 36(107): 479–517.
- Brunner, M. and H. Strulik. 2002. "Solution of Perfect Foresight Saddlepoint Problems: A Simple Method and Applications." *Journal of Economic Dynamics and Control* 26(5): 737–53.
- Budget Office. Various issues. *Estadísticas de las finanzas públicas*. Santiago: Ministry of Finance of Chile.
- Buiter, W. 1984. "Saddlepoint Problems in Continuous Time Rational Expectations Models: A General Method and Some Macroeconomic Examples." *Econometrica* 52(3): 665–80.
- Calvo, G. 1983. "Staggered Contracts in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 383–98.
- Central Bank of Chile. Various issues. *Boletín Mensual*. Santiago.
- . 1998. *Cuentas Nacionales*. Santiago.
- Corbo, V. and K. Schmidt-Hebbel. 1991. "Public Policies and Saving in Developing Countries." *Journal of Development Economics* 36(1): 89–115.
- Corbo, V. and J. Tessada. 2002. "Growth and Adjustment in Chile: A Look at the 1990s." In *The Challenges of Economic Growth*, edited by N. Loayza and R. Soto. Santiago: Central Bank of Chile.
- Fair, R. and J. Taylor. 1983. "Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectations Models." *Econometrica* 51(4): 1169–85.
- Giavazzi, F. and C. Wyplosz. 1984. "The Real Exchange Rate, the Current Account, and the Speed of Adjustment." In *Exchange Rates: Theory and Policy*, edited by C. Bilson and R. Marston. University of Chicago Press.

- Hayashi, F. 1982. "Tobin's Marginal  $q$  and Average  $q$ : A Neoclassical Interpretation." *Econometrica* 50(1): 215–24.
- Judd, K. 1998. *Numerical Methods in Economics*. MIT Press.
- Lipton, D., J. Poterba, J. Sachs, and L. Summers. 1982. "Multiple Shooting in Rational Expectations Models." *Econometrica* 50(5): 1329–33.
- Loayza, N. and F. Gallego. 1999. "La tasa de interés neutral en Chile: marco conceptual y algunas estimaciones." Unpublished paper. Santiago: Central Bank of Chile.
- López, H., K. Schmidt-Hebbel, and L. Servén. 2000. "How Effective is Fiscal Policy in Raising National Saving?" *Review of Economics and Statistics* 82(2): 226–38.
- Lucas, R.E. 1967. "Adjustment Costs and the Theory of Supply." *Journal of Political Economy* 75(4): 321–34.
- Marimon, R. and A. Scott, eds. 1999. *Computational Methods for the Study of Dynamic Economies*. Oxford University Press.
- Ramsey, F. 1928. "A Mathematical Theory of Saving." *Economic Journal* 38(152): 543–59.
- Schmidt-Hebbel, K. 1987. "Foreign Shocks and Macroeconomic Adjustment in Small Open Economies." Ph.D. dissertation, Massachusetts Institute of Technology.
- Schmidt-Hebbel, K. and L. Servén. 1994a. "Dynamic Response to External Shocks in Classical and Keynesian Economies." Policy research working paper 1300. Washington: World Bank.
- . 1994b. "Fiscal Policy in Classical and Keynesian Open Economies." Policy research working paper 1299. Washington: World Bank.
- . 1994c. "Successful Structural Adjustment: Consumption and Growth in Chile." Unpublished paper. Washington: World Bank.
- . 1995a. "Dynamic Response to External Shocks in Classical and Keynesian Economies." In *North-South Linkages and International Macroeconomic Policy*, edited by D. Currie and D. Vines. Cambridge University Press.
- . 1995b. "Hacia una menor inflación en Chile: contracción monetaria bajo expectativas inflacionarias." In *Análisis empírico de la inflación*, edited by F. Morandé and F. Rosende. Pontificia Universidad Católica de Chile and ILADES/Georgetown. Santiago, Chile.
- . 1996. "Ajuste fiscal y tipo de cambio real a la luz de un modelo de expectativas racionales." In *Análisis empírico del tipo de cambio en Chile*, edited by F. Morandé and R. Vergara. Centro de Estudios Públicos and ILADES/Georgetown. Santiago, Chile.

- . 2002. "Policy Shifts and External Shocks in Chile under Rational Expectations." Unpublished paper. Central Bank of Chile and World Bank.
- Servén, L. 1995. "Capital Goods Imports, the Real Exchange Rate, and the Current Account." *Journal of International Economics* 39(1-2): 79-101.
- . 1999. "Macroeconomic Uncertainty and Private Investment in Developing Countries: An Empirical Investigation." Policy research working paper 2035. Washington: World Bank.
- Tobin, J. 1969. "A General Equilibrium Approach to Monetary Theory." *Journal of Money, Credit, and Banking* 1(1): 15-29.
- Treadway, A.B. 1969. "On Rational Entrepreneurial Behaviour and the Demand for Investment." *Review of Economic Studies* 36(106): 227-39.
- Turnovsky, S. and P. Sen. 1991. "Fiscal Policy, Capital Accumulation, and Debt in an Open Economy," *Oxford Economic Papers* 43(1): 1-24.
- Villagómez, A. 1997. "Private Saving, Interest Rates and Liquidity Constraints in LDCs: Recent Evidence." *Applied Economics* 29(5): 607-15.