Banco Central de Chile
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Central Bank of Chile
Working Papers

N° 271

Octubre 2004

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Working Papers of the Central Bank of Chile
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GENERAL EQUILIBRIUM DYNAMICS OF EXTERNAL SHOCKS AND POLICY CHANGES IN CHILE

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Resumen
En este trabajo se desarrolla un modelo macroeconómico de equilibrio general parametrizado para la economía chilena. Las relaciones básicas del modelo son derivadas del comportamiento optimizador intertemporal de un grupo de agentes racionales. El modelo también refleja algunas características claves del mundo real – como rigideces salariales de corto plazo y un grupo de agentes miopes – que genera desviaciones del equilibrio de empleo sin fricciones, consistente con el paradigma neoclásico irrestricto. El modelo es simulado numéricamente para ilustrar la dinámica de la economía chilena en respuesta a las perturbaciones externas y los cambios en política monetaria y fiscal que llevaron a la recesión de 1998-1999.

Abstract
This paper develops a macroeconomic general-equilibrium model fully parameterized for the Chilean economy. The model's basic relations are derived from intertemporal optimization by a group of rational forward-looking agents. The model also adds 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. The model is numerically simulated to illustrate the dynamics of Chile's economy in response to the external shocks and policy shifts that led to the 1998-99 recession.

We thank Roberto Ayala, Rómulo Chumacero, and participants at the 2002 Central Bank of Chile Conference on General Equilibrium Models of the Chilean Economy, the 2003 ECOMOD Istanbul Conference, and the Latin American Econometric Society meetings for valuable comments and suggestions on previous versions. The usual disclaimer applies.
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1. Introduction

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 micro-analytic foundations and its basic relations are derived from intertemporal optimization by a group of forward-looking agents endowed with rational expectations. Thus the economy's short-term equilibrium depends on the current and anticipated future paths of policy and external variables. However, 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 – the events associated to 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.

In essence, this is an extension of earlier work on macroeconomic dynamics for representative open economies and for Chile (Schmidt-Hebbel and Serven, 1994a,b, 1995, 1996, 2002). It adds to a scarce literature applying to developing countries non-linear dynamic macroeconomic models based on optimizing behavior under rational expectations, with well-defined short-term and stationary equilibrium properties.

Section 2 offers a brief summary of the model structure, its steady state, dynamics, stability, and solution procedure. Full details are given 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 and thus 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 3 describes the model's parameterization for the Chilean economy. The model's main structural equations are estimated econometrically, using quarterly data spanning the 1986-1997 period. This is complemented with calibration of all relevant variables to the model's base quarter (1997-2).

Section 4 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 during 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.

2. The model

2.1 Main features

The economy produces one single final good, which can be used for consumption and investment at home, or sold 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 (i.e., 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 inflationary finance of public deficits, we assume that its services yield utility to consumers. There are no restrictions to capital mobility and, in the absence of risk and uncertainty, all non-monetary assets are perfect substitutes. Hence their anticipated rates of return satisfy the corresponding uncovered parity conditions. In addition, the economy faces given world interest rates –the small-country assumption for financial markets. Both goods and asset markets clear continuously. In contrast, the labor market may not clear instantaneously due to real and/or nominal wage rigidity. Staggered wage setting along the lines of Calvo (1983) generates nominal inertia, with average wages indexed to a distributed lag of current and lagged consumer price inflation and reacting slowly to deviations from full employment.

Although in a simultaneous model such as ours no specific equation determines any particular variable, equality between demand and supply for the domestic good can be viewed as determining the real exchange rate. Given the latter, and with a fully flexible nominal exchange rate regime, money market equilibrium with an exogenously set money supply then determines the nominal exchange rate.

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. Thus, anticipated and realized values of the variables can only differ at the time of unexpected shocks or due to the arrival of new information about the future paths of exogenous variables.

Behavioral rules combine explicitly two benchmark specifications: neoclassical, intertemporally optimizing firms and consumers, and myopic firms and households, along with wage inflexibility.[1] Absent myopic agents and wage rigidity, the model would reduce to a standard open-economy neoclassical model of intertemporally-optimizing agents such as that of Servén (1995).[2]

Following the standard theory of investment under convex adjustment costs (Lucas, 1967, Treadway, 1969), neoclassical firms maximize their market value and link their investment decisions to Tobin's q (Tobin, 1969), i.e., the present value of the additional profits 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 intertemporal utility maximization in Ramsey fashion (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, i.e. 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 in the same way as neoclassical ones.

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 the Appendix.

2.2 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.

[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,b).

Thus, the government's budget must be balanced,[3] and the current account deficit must equal the exogenously given flow of foreign investment, which in turn is just sufficient to keep foreign equity holdings (in real per capita terms) unchanged.

Since the per capita real money stock is constant, long run inflation equals the rate of expansion of per capita nominal balances. With a constant real exchange rate, 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 rate of money growth are fully reflected in the inflation rate (and thus in the nominal interest rate) and in the rate of nominal depreciation.

By combining the model's equations, the steady-state equilibrium could be eventually reduced 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 relationship 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 (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.

In turn, 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: with the return on wealth being entirely consumed, *any* wealth stock is self-replicating.

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, and thus 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. Thus, the model exhibits hysteresis. This reflects the general result that forward-looking consumption behavior by infinitely-lived households with a

[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.

constant rate of time preference and facing perfect capital markets yields path-dependence of the steady-state (Giavazzi and Wyplosz 1984).

An important implication of the model's hysteresis property is that transitory disturbances generally have long-run effects. For the case of fiscal policy, this has been highlighted by Turnovsky and Sen (1991).[4] In our framework even transitory monetary disturbances can have permanent real effects,[5] although the quantitative importance of these effects turns out to be quite modest empirically.

2.3 Dynamics, Stability, and Model Solution

The model's dynamics combine predetermined variables (i.e., asset stocks) subject to initial conditions, and "jumping" variables (mostly asset prices). For the dynamic system not to explode, these non-predetermined variables have to satisfy certain terminal (transversality) conditions. Solving the model basically amounts to finding initial values for the non-predetermined variables such that, following 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,[6] but not for nonlinear systems such as the one at hand.[7] While a formal proof of stability cannot be provided, numerically the model was always found to converge 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 whose numerical solution several techniques exist (see e.g., Judd 1998, and Marimon and Scott 1999).[8]

Our solution method can be viewed as a combination of several approaches. Like with multiple shooting (Lipton et al. 1982), we "shoot" the model forward starting from an arbitrary guess about the initial values of the non-predetermined variables and choosing an arbitrary solution horizon (i.e.,

[4] Turnovsky and Sen (1991) use a non-monetary model with intertemporally optimizing consumers in which transitory fiscal disturbances have long-run effects. This conclusion depends critically on the endogeneity of 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] For example, if some consumers are myopic, so that they discount current taxes but not inflation, then a transitory increase in inflationary taxation matched by a reduction in direct taxes raises their perceived disposable income and consumption, leading to reduced wealth accumulation and eventually causing a fall in long-run wealth and a permanent real depreciation. Without myopia and absent the distorting effects of inflationary taxation, the experiment would just amount to a change in the composition of taxation between the inflation tax and direct taxes, without any effect on wealth, consumption or any other real variable. See Schmidt-Hebbel and Servén (1994c).

[6] See Blanchard and Kahn (1980) and Buiter (1984).

[7] In principle, we could linearize the system around a steady state to determine analytically the conditions under which the transition matrix possesses the saddle-point property. Given the large dimensionality of our system, however, this would be an intractable task.

a finite-time approximation to the infinite horizon problem). Once a solution has been found for the selected solution horizon, we then extend the horizon and recompute the solution path. We do this in order to prevent 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).[9] We keep extending the horizon in this fashion until the resulting changes in the solution trajectory of the endogenous variables fall below a certain tolerance, [10] at which time the process stops.

3. 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 1986-1997, a period of high growth and – likely – parameter stability. Model equations and budget constraints were calibrated to the second quarter of 1997 (1997.2), a base period of full employment that preceded the subsequent 1997-98 Asian and Russian crisis and 1998-99 domestic recession. Steady-state equilibrium conditions were imposed on the data for 1997.2, i.e., per capita state variables and relative prices are assumed to be constant for the purpose of our simulations.[11] Hence the first period of our counter-factual 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.

3.1 Quarterly database

The main database was assembled from various sources (Central Bank of Chile: *Boletín Mensual*, various issues; Central Bank of Chile, 1998; Budget Office, *Estadísticas de las Finanzas Públicas*, various issues; and Central Bank of Chile published data. For several variables we interpolated annual data to obtain quarterly time series. Standard interpolation techniques were used to generate quarterly data for physical and human capital stocks (full sample period)[12] and for

[8] 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, so that it is solved backwards starting from the *final* steady state.

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

[10] For the actual simulations, the model was made discrete, and we used a very strict convergence criterion, requiring that the maximum relative change between solutions in any variable at any time 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 (i.e., the slope of the augmented Phillips curve), and the magnitude of investment adjustment costs.

[11] This is a common assumption for rational expectations model simulations. It allows us to focus on the impact, transition, and steady-state effects of policy shifts "uncontaminated" by the non-stationary initial equilibrium of the economy. The slack variables for the two independent budget constraints were chosen to be total taxes and foreign transfers to the government

[12] We use the values calculated in Braun and Braun (1999) as a benchmark for 1995.4.

investment prices, consumption prices, and disposable private income (sub-sample before 1990). In the case of non-human capital, we build quarterly values using quarterly investment flows and a quarterly depreciation rate of 1.1%. In the case of human capital we use quarterly values of wages and labor force to construct quarterly observations. In the case of consumption prices, investment prices, and private disposable income, we use a modified Chow-Lin procedure.[13]

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.

3.2 Calibration of non-estimated 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) and the Harrod-neutral technical progress growth rate. In all cases we used the simple quarterly average for 1986-1997). The import content of investment (29%) is six times as large as the import content of consumption (5%); this agrees well with cross-country data reported in Servén (1999). 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, consistent with previous econometric estimations for Chile (Schmidt-Hebbel 1987, Arrau 1989) and with the log utility formulation in the model.

For a better characterization of the steady state we fixed the following parameter values: the labor force growth rate at an annual 1.6% (hence stationary annual output growth is 4%, the sum of the latter rate and a 2.4% rate of Harrod-neutral technical progress), the annual money growth rate at 7% (consistent with the annual steady-state inflation at the inflation target of 3% and stationary output growth at 4%), and the flow of foreign investment relative to output at 2%.

3.3 Econometric estimations

The estimation results for quarterly data are reported in Table 1. Data samples and estimation techniques are described at the bottom of the table. For the estimations we set exogenously the rates of capital depreciation, steady-state growth, and the subjective discount rate.[14] 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.

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[13] The modification makes use of quarterly data available since 1991 and applies the seasonal pattern of the 1991-1997 series to complement the traditional Chow-Lin method in constructing 1986-1990 data.

[14] Estimations are based on quarterly data; hence all oresent and estimated rates are defined on a quarterly basis.

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 (under instantaneous labor market clearing it would be infinity). Nominal wages are indexed to current CPI inflation and one and two-period lagged CPI inflation, with weights 14%, 57%, and 29%, 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 % and 53%, respectively, substantially below the 100% share of the unconstrained neoclassical benchmark.[15] Calibrated and estimated model parameters are reported in Table 2.

3.4 Calibrated base-period values of predetermined variables

We fitted base-period (1997.2) values of predetermined variables in two stages: first adding regression residuals to the estimated intercepts to replicate observed values, and then forcing budget constrains to hold with equality in 1997.2 at constant asset stocks (hence real stocks grow at the exogenous steady-state growth rate). Calibrated sector budget constraints are reported in Table 3. 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% of GDP for the stock of foreign assets held by the private sector (the actual value was -185% in 1997.2) and 13.2% of GDP for total taxes (the actual value was 16.3% in 1997.2). Base-period values of predetermined variables are reported in Table 4.

3.5 Calibrated base-period values of endogenous variables

Finally Table 5 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 taxes and foreign assets held by the private sector, as discussed above.

[15] Several studies have estimated, using various techniques, the share of constrained consumers (λ_C) in Chile and in other developed and developing countries. For Chile, Corbo and Schmidt-Hebbel (1991) estimate λ_C at 0.60 for the 1968-88 sample period, Schmidt-Hebbel and Servén (1996) report a value of 0.45 for 1963-1991; Villagómez (1997) reports 0.46 for 1970-1989, Bandiera et al. (1999) report 0.55 for 1970-1995, and Bergoeing and Soto (2002) 0.75 for 1986-1998. Finally, López et al. (2000), using a panel of developed and developing countries, found a share of constrained consumers of 0.40 for the world sample, and 0.40 (0.61) for OECD (developing) countries.

Table 1
Econometric Estimations

1. System Estimation of Money Demand and Aggregate Private Consumption

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

(3.20) (6.48)

$R^2A=0.25$ S.E.=0.047

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

(3.45)

$R^2A=0.19$ S.E.=0.03533

2. Real Wage

$$d\ln(w) = 0.034 + 0.3192\ \ln(l) + 0.1365\ d\ln\ (p_C) + 0.5699\ d\ln\ (p_{C,-1}) + (1-0.1365-0.5699)\, d\ln(p_{C,-2})$$

(4.13) (13.77) (1.30) (6.22)

$R^2A=0.66$ S.E.=0.011 LM (4)=0.38 LM (8)=0.45

3. Production Function

$$d\ln\left(\frac{Y}{K}\right) = (0.3969-1)d\ln(K) + 0.5218\, d\ln\left(\frac{l}{K}\right) + (1-0.3969-0.5218)d\ln\left(\frac{M}{K}\right)$$

(3.35) (4.14) (3.35) (4.14)

$R^2A=0.56$ S.E.=0.014 LM (4)=0.62 LM (8)=0.87

4. Aggregate Private Investment

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

(3.10) (2.75)

$R^2A=0.94$ S.E.=0.001 LM (4)=0.49 LM (8)=0.25

5. Export Demand

$$d\ln(X) = 0.0206 + 0.1320\, d\ln(e\, p_X^*) + 0.6830\, d\ln(Y^*) + 0.03\ \ d\ln(X_{-1})$$

(5.12) (2.40) (2.23) (0.22)

R^2A=0.46 S.E.=0.036 LM (4)=0.18 LM (8)=0.11

Note: At the bottom of each equation, but the system estimation, we report the adjusted R^2 (R^2A), the standard error of the regression (S.E.), and the p-values of Breusch-Godfrey serial correlation LM tests for 4 and 8 lags (LM (4) and LM (8), respectively). In general, seasonality of the variables was removed using X-11 ARIMA. The sample period is 1986.1-1997.1. Estimation techniques and the dummy variables used in regressions are the following. Equation 1: system estimation using weighted TSLS, dummy variables are 1992.3, 1995, and 1996.4. Equation 2: TSLS, dummy variables are 1991-1992. Equation 3: OLS in first differences, dummy variables are 1990.1, 1992.3, and 1993.1. Equation 4: TSLS with restricted adjustment cost parameter chosen to maximize adjusted R^2, dummy variables are 1994.4, and 1995.1. When adjustment costs are left unrestricted the estimation generates implausible values. To resolve this, we restricted the adjustment cost coefficient after doing a grid search for the value that maximized the adjusted R-squared. Equation 5: TSLS in first differences. In all cases, instrumental variables correspond to four lags of the endogenous variable.

Table 2
Structural Coefficients

Money Demand		**Private Investment Demand**	
Goods content of augmented consumption (β)	0.6337	Share of unconstrained firms (λ_1)	0.5299
Interest rate elasticity (σ)	0.078	Adjustment Costs to Investment (ϕ)	15
Wage Equation		Rate of depreciation of physical capital (δ)	0.0108
Employment elasticity (ω)	0.3192	**Share of domestic goods in investment (γ)**	0.7141
Indexation to current inflation (χ)	0.1365	**Private consumption demand**	
Indexation to 1-period lagged inflation (θ)	0.5699	Share of unconstrained consumers (λ_C)	0.6556
Production Function		**Share of domestic goods in consumption (η)**	0.9523
Constant (α_0)	0.4676	**Export Demand**	
Labor share (α_1)	0.5218	Constant (ε_0)	0.0206
Capital share (α_2)	0.3969	Real exchange rate elasticity (ε_1)	0.1320
		Foreign income elasticity (ε_2)	0.6830

Table 3
Sector Budget Constraints

Public Sector Budget Constraint

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

Simulated Initial Steady-State

$$[0.1018 + 1.75 * 0.0001 - 0.1045 - 1.1 * 0] + (0.0099 + 0.0074) * 0.3154 - (0.0123 - 0.0099) * 1.3138$$
$$+ (0.0123 - 0.0099) * 1.75 * 0.0640 = 0 - 0$$

External Sector Budget Constraint

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

Simulated Initial Steady-State

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

Private Sector Budget Constraint

$$\left[Y - p_K J - e\, p_M^*\, M + e\, f_P^* - T - p_C C\right] - d^* - \left(g + \frac{\dot{P}}{P} \right) m + (r - g) b$$

$$+ \left(r^* - g\right) e\, b_P^* = \dot{m} + \dot{b} - e\, FDI + e\, \dot{b}_p^*$$

Simulated Initial Steady-State

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

Table 4
Base-Period Values of Predetermined Variables

Income, Transfers, and Capital Flows		**Rates***	
Foreign transfers to the public sector (f_G^*)	0.0001	Real interest rate on foreign assets/liabilities (r^*)	0.05
Foreign transfers to the private sector (f_P^*)	0.0043	Rate of growth of the nominal money stock (μ)	0.07
Foreign income (Y^*)	1.0000	Harrod neutral technical progress (ν)	0.024
Foreign direct investment (*FDI*)	0.0200	Population growth (n)	0.016
Stocks		**External Prices**	
Domestic debt of the public sector (b_G)	1.3138	Intermediate imports (p_M^*)	1.0000
Foreign assets held by the public sector (b_G^*)	0.0640	Consumption imports (p_C^*)	0.9002
Goods Flows		Investment imports (p_K^*)	0.9002
Public national-goods consumption (G)	0.1045	Export-competing goods (p_X^*)	1.0000

* For clarity, rates are shown here in annual terms. The simulation model uses the equivalent quarterly values, which are also used in tables 3 and 5. The figures with simulation results below depict rates in annual terms.

Table 5
Initial Steady-State Values of Endogenous Variables

Income, Transfers, and Capital Flows	
Dividends (d)	0.1330
Taxes (T)	0.1018
Private disposable income (Y^D)	0.4274
Profit remittances abroad (d^*)	0.0436
Stocks	
Private sector total wealth ($a+h$)	187.4863
Non-human 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 imported-goods consumption (C^*)	0.0243
Private national-goods consumption (C^N)	0.4619
Gross domestic investment (J)	0.2836
Private national-goods investment (J^N)	0.2014
Private imported-goods investment (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

Employment (l)	1.0
Output (Y)	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

4. Simulation results

The model discussed above is useful to assess the dynamic adjustment to foreign shocks and domestic policy shifts in Chile because it is based on an explicit forward-looking and 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 during 1997-1998, which led to the 1998-1999 recession. We will also compare our simulation results to the actual response of Chile's macroeconomy in 1998-1999.

The simulated policy changes comprise an expansionary fiscal policy (that raises public consumption by 1.54 percentage points, from 10.5% to 12% of GDP) and a contractionary monetary policy (that reduces annual money growth from 7% to 4%). We also consider a composite adverse external shock, which combines a rise in the relevant foreign interest rate (by 1.2%), a decline in export prices (by 12%), and a reduction in foreign output growth (by 2.24%).[16] All shocks are temporary and assumed to last for 8 quarters. They are unanticipated at period zero, 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 during 1997-99 in Chile. Then we report and discuss our simulation results.

4.1 The 1997-99 period

After 12 years of average high growth, Chile was hit in 1997-98 by adverse external shocks that, combined with an expansionary fiscal and a contractionary monetary policy, led to a mild recession in 1998-99. Annual GDP growth fell to 3.3% in 1998 and –1.1% in 1999.[17] The economy has recovered partly since 2000, at a pace of positive but relatively modest growth. Inflation fell quickly during the recession, from 6.5% in 1997 to 4.4% in 1998 and 2.5% in 1999. Hence convergence to low stationary inflation consistent with the long-term inflation target band was accomplished during the latter years. After continuing appreciation from the early 1990s through

[16] Previous papers have explored the dynamic macro 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 (1994a) analyze fiscal policy under alternative means of financing and Schmidt-Hebbel and Servén (1994b, 1995a) assess the impact of external shocks in a representative open economy. Schmidt-Hebbel and Servén (1994c) explore the macro-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) analyze the effects of contractionary monetary policies in Chile, and Schmidt-Hebbel and Servén (1995b) analyze the effects of fiscal policy in Chile. Servén (1995) explores analytically the impact of fiscal disturbances and foreign transfers in a non-monetary model closely related to ours.

[17] GDP data are measured at 1986 relative prices.

1998, the real exchange rate depreciated by 5% in 1999, 4.8% in 2000, and 12.7% in 2001. The current account deficit ratio to GDP, after peaking at 6.0% in 1998, fell to 0.2% in 1999.

What explains these developments? To our knowledge, only two papers have attempted an assessment of the causes of Chile's recent downturn. Corbo and Tessada (2001) find that the 1998-99 recession was a result of external shocks (lower terms of trade and reduced capital inflows) and monetary policy adjustment. The latter would have reflected the Central Bank's concern about higher inflation resulting from nominal exchange-rate depreciation and a very expansionary fiscal policy. In the second paper, Bergoeing and Morandé (2002) focus on the effects of labor market reforms. Using a calibrated model, they estimate that the expected increase in labor taxes explains much of the output decline.

Hence the few existing explanations for the 1998-99 recession can be divided into policy-related factors (fiscal expansion, monetary adjustment, 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. In what sense stylized? We do not attempt to match quarter by quarter the dynamics of Chile's key macroeconomic variables for four reasons. First, ours is a small structural model based on a parsimonious specification based on deep behavioral parameters that are largely derived from optimizing behavior, hence excluding ad-hoc but (possibly) empirically relevant right-hand side determinants. Thus the model's strength due to its simple structure and transparent dynamics and steady-state properties comes at a cost: it is not the ideal tool to track the short-run dynamics of any given endogenous variable. Second, we start from an initial simulation period (calibrated to be 1997.2) at which we assume, for expositional and simulation convenience, that the economy is at a stationary position – an obvious departure from reality. Third, 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 (8 quarters) and, when simulating their combined effects, we assume that they occur simultaneously. This was only approximately the case in Chile, as our subsequent data discussion illustrates.

Table 6 summarizes the actual behavior of key foreign and policy variables observed over periods roughly equal to 8 quarters, during 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 (not considered in the table) lower foreign capital inflows. Shortly before the start of the Asian crisis, fiscal policy was relaxed, as reflected by an increase of government consumption to GDP ratio by 1.5% of GDP during 1997.2-1999.1 As a reaction to the Asian crisis and fiscal relaxation, the Central Bank adopted a restrictive monetary stance, reflected in a 3.0% lower annual growth in M1. The final column reports the 8-quarter shocks – set quantitatively close to the actual shocks – that are used in the simulations below.

Table 6

Actual and Simulated Shocks

	Actual external and policy shocks observed in Chile			**8-quarter simulated shocks**
Variable	Initial period	Final period	Average change	Change
External Shocks				
Change in relevant external interest rate *	1997.2	1999.1	1.2%	1.2%
Change in export prices	1998.1	1999.4	-12%	-12%
Change in world GDP growth **	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%

* The relevant external interest rate is the sum of foreign real interest rate and country-risk premium.
** Change from HP trend growth.

Next we discuss the simulation results, first separately for the fiscal expansion, the monetary contraction, and the composite external shock (sections 4.2-4.4), and then by simulating the combination of all three shocks (section 4.5). Figure 1 depicts the dynamic response of all relevant endogenous variables to each of the four shocks, including the composite external shock. Figure 2 depicts in more detail the dynamic response of four key macro variables in reaction to the three individual external shocks that comprise the aggregate foreign shock.

4.2 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% to 12.04% of GDP. As a consequence of this policy shift, the public debt stock rises monotonically from 131 % of GDP in quarter 1 to 141% in quarter 8, with a further jump to 145% in quarter 9 (due to the high quarter-8 interest rate, discussed in more detail below) and stays at that level thereafter. Due to larger public debt, there is a small steady-state increase of tax revenues by of 0.03% of GDP (to meet the extra debt service) and a larger transitory increase in periods 9-12.

If all consumers were forward-looking, a temporary expansion in government consumption would lead to a transitory private consumption decrease, 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% of consumers who are myopic and hence 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. Thus, aggregate private consumption is lowered for 8 periods by less than under a permanent policy change but by more than what 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 (period 1) a significant real exchange rate appreciation and higher investment, output, and employment. Between periods 2 and 7, the real exchange rate gradually appreciates further, a reflection of the delayed wage reaction and the output contraction after period 1. The real exchange rate appreciation during the initial periods is reflected in the lower ex-ante domestic real interest rate in periods 1 to 4, as dictated by uncovered real interest parity.

Regarding investment, myopic investors (the 50% 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 1-3 and from period 9 to the new steady state. In contrast, neoclassical investors react to the temporary output boom in a different way: 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 declines during periods 1-8. Aggregating both kinds of investors, the private investment rate exhibits a slight increase in period 1 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 in private consumption. The consumption decline in period 1 lowers money demand, causing inflation to rise from 3% to 8% 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 1 and subsequently leads to overemployment, reflected by a rise in employment by 1.6% on impact.

The current account to output ratio shows a strong cycle, reflecting the pattern of consumption and investment, output, and the real exchange rate. The current account deficit increases marginally in the first period and thereafter improves as output expands and aggregate consumption and investment decline after period 1.

In order 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, i.e., before and after quarters 8-9. At the time of reversion of the temporary fiscal expansion in period 9, private consumption rises back to a level close to its initial steady-state value. At that time an expenditure switch back to imported goods takes place, consistent with the shift from public to private consumption, causing a 1.7 % real exchange rate depreciation (at quarterly rate). The exchange rate depreciation is fully anticipated and hence fully reflected by the domestic real interest rate, which increases to 12.4% (at annual rate).

In period 9, when the temporary fiscal expansion is reversed, inflation attains a through at -3.4%. Thereafter inflation returns toward its unchanged long-run level of 3%. Lower inflation in periods 10 to 12 raises real wages beyond levels consistent with full employment. Hence employment falls by 2.1% at quarter 9, deepening the recession induced by the decline in aggregate demand for national goods that takes place at quarter 9. The cyclical downturn of employment and output during quarters 9-11 is offset by overemployment and high output in quarters 12-16 – a reflection of the lagged effect of inflation on real wages.

It is important to note that the steady-state effects are almost negligible since the shock is temporary. Therefore 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 due to the model’s hysteresis.

4.3 Monetary contraction

Now we simulate the effects of a temporary monetary contraction that reduces money growth from 7% to 4%. Debt financing replaces seigniorage collection (public debt increases to a new steady-state level of 136% of GDP) – specifically its inflation tax component. That is because lower money growth leads to a drop in inflation during the first 10 periods (starting with a large initial decrease to -5.0%) that raises the stock demand for base money relative to annual output (during the first 10 quarters). Despite the rise in real money demand, the decline in nominal money growth leads to a decline in seigniorage from 0.9% of annual GDP to an average level of 0.5% of GDP on impact, matched by the above mentioned increase in public debt.

On impact private consumption of both unconstrained and constrained consumers is reduced. Classical consumers reduce their consumption levels in period 1 because of the interest rate spike in that period (prompted by the real exchange rate depreciation between quarters 1 and 2) and the myopic consumers do it because of the reduction in disposable income that results from the recession caused by the monetary crunch. The interest rate spike in quarter 1 also depresses private investment. Period-1 deflation in consumer prices raises real wages, hence 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 quarter 1, reducing output. However, given our model's parameter configuration, the supply contraction dominates the demand reduction, hence the relative price of national goods rises, as reflected by a real exchange rate appreciation on impact.

Starting in period 2 all variables reverse their previous pattern. A lower real interest rate prompts an aggregate demand response, and higher inflation reduces real wages, causing an increase in employment. Subsequently all variables start to converge toward their steady-state levels, some of them monotonically and others with some disruption around quarter 8, 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, and this leads to a temporary increase in interest rates, higher consumption and investment, and even overemployment between periods 4 and 14.

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 quarter 9 is anticipated early on, leading to a gradual rise in inflation to 3% in quarter 3 and thereafter, without any jumps occurring at the time of shock reversal.

4.4 External shocks

The third simulation is a composite external shock comprised by a rise in the relevant foreign interest rate by 1.2%, a decrease in export prices by 12%, and a decline of trend foreign output growth by 2.24%. We first analyze each shock by itself, depicting separately in Figure 2 their respective dynamic impacts on 4 key variables (output, inflation, real exchange rate, and the current account). Figure 1 presents the combined effect of the three external shocks.

First, the higher foreign interest rate involves a wealth loss for the domestic economy because of its net debtor position vis-a-vis the rest of the world. Classical consumers reduce their consumption level accordingly, leading to permanently lower aggregate demand and output levels and a more depreciated 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 9 and thereafter, their intertemporal spending pattern responds accordingly. With interest rates above their long run level (which is equal to consumers' subjective rate of discount), 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.

In response to the initial output slump, inflation rises to 3.2 % on impact, then starts to oscillate at levels close to 3% and converge close to 3% in quarter 12 and thereafter. The inflationary shock lowers real wages. However employment falls in response to the aggregate demand contraction, which also explains the drop of output (0.45% on impact and 0.1% in steady state). The opposite cycle of slight overemployment and overproduction is observed at quarters 8 through 10. Higher inflation at quarter 1 raises government revenue from seigniorage, so that public debt decreases on impact. The current account improves on impact reflecting a very sharp contraction of demand, which outweighs the higher service on foreign debt.

Now consider the second external shock. A lower export price has two first-round effects: a decline in income proportional to the loss in terms of trade (leading to lower private consumption) and a transitory reduction in the supply of exports (causing a transitory supply contraction and unemployment). As the change in export prices is temporary, the wealth effects for neoclassical consumers are relatively small and, therefore, their consumption declines only slightly during quarters 1 through 8.

The real exchange rate depreciates on impact by 0.6%. This causes a small decline in investment (because of higher prices of imported capital goods), giving rise to the output contraction discussed above. Output – which had contracted by 0.3% in period 1 – recovers partially to attain a new stationary level only 0.02% lower than that at the initial steady state. The gradual recovery in aggregate supply during periods 2 to 5 leads to a slight real exchange rate depreciation, which is largely undone in period 9 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% in period 1. Wage sluggishness precludes real wages from declining on impact to the level consistent with full employment. Hence employment declines on impact by 0.4%, contributing marginally to a deeper output contraction. The labor market normalizes after 3 periods, when the effects of the temporary inflation shock have faded away.

The export price shock reversion at quarter 9 leads to a subsequent recovery of most variables to levels close to initial values. A real exchange rate appreciation takes place in period 9 and a corresponding drop in the ex-ante real interest rate is observed, reflected in a 3.3% level in quarter 8. The latter raises Tobin's q which, in conjunction with a less depreciated exchange rate, now leads to an increase in private investment. The aggregate demand increase is reflected by a temporary output expansion and an increase in inflation to 4.5 % in period 9– leading to overemployment and reinforcing the output increase.

The current account deficit mimics the pattern of income and aggregate demand, especially consumption. It shows a higher deficit in periods 1 through 9, and converges subsequently to its stationary level.

The third external shock, lower 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. By coincidence, their quantitative effects are also very similar (The effects in Figure 2 are almost undistinguishable). Hence we will not discuss this shock separately.

The composite effect of the three external shocks combined (Figure 1) reflects roughly the relative intensity of each foreign shock separately.[18] The output drop is 1% on impact, inflation declines to 0.9% in quarter 1 (reflecting the positive effect of the foreign interest shock and the negative of the two shocks on exports), the real exchange rate depreciates by 4.0% on impact (mainly a result of the huge impact of the interest rate shock), and the current account deficit increases to 2.2% of output on average during quarters 1 to 8.

4.5 A comparative evaluation of the three shocks

As above, when the economy is affected by the composite external shocks and the two policy shocks at the same time, their combined effects are almost equivalent to adding the consequences of the three separate shocks.

Regarding output, the negative effect 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% during the first 24 quarters, while it is only 0.06% in the case of the monetary contraction. Regarding the fiscal shock, its positive cumulative effect on output is 0.7% during the first 24 quarters.

[18] There are second-order interaction and feedback effects that make the combined effects different from the simple sum of the effects of the three separate shocks.

Inflation falls well below 3% for 12 quarters, as a result of the large effect of the monetary contraction, a relatively smaller effect of the external shock, and, in periods 9-11, due to the reversion of the fiscal contraction. It is interesting to note that the monetary contraction has a persistent effect on inflation, a consequence of the forward-looking nature of the model. The main effects of the other shocks occur around quarters 1 and 9, that is, at the start and end of the temporary shocks.

The real exchange rate depreciates relative to its initial level during periods 1 to 8, mostly driven by the influence of the composite adverse external shock. Figure 2 suggest that the steady-state exchange rate depreciation is a consequence of the interest rate shock, due to the model's hysteresis. Finally, the current account deficit also increases during periods 1 to 8, mostly driven by the influence of the external shocks.

A relevant point that emerges from the latter results is that different shocks have different relative consequences for different variables. Clearly, the composite foreign shock – that represents the adverse consequence of the Asian and Russian crisis on the Chilean economy – 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 period 1.

The final question that we address is how well our simulations fit Chile's actual macroeconomic dynamics during 1997-1999. For this purpose we report in Table 7 mean deviations from trend of the four key macro variables in four consecutive 8-quarter windows, starting in 1997.3, 1997.4, 1998.1, and 1998.2, respectively. We chose the latter windows because the computed deviation is sensitive to the selected window, which is probably due to the large quarterly volatility of each variable. Then we report the simulation results for the same four variables, corresponding to the combined simulation (adverse external shock, fiscal expansion, and monetary contraction) depicted in Figure 1.

Table 7

(a) Actual and Simulated Quarterly Deviations of Key Macro Variables in Chile

Period	Output	Inflation	Real Exchange Rate	Current Account
		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%
Average 1997.3-2000.1	0.47%	-0.15%	0.54%	-0.43%
		Model Simulation		
8 quarters	-0.21%	-2.19%	0.15%	-0.42%

(b) Actual and Simulated Maximum Deviations

	Output	Inflation	Real Exchange Rate	Current Account
		Actual Data		
Maximum deviation from equilibrium	-3.80%	-2.90%	4.15%	-3.10%
(period)	(1999.2)	(1999.1)	(1998.1)	(1998.1)
		Model Simulation		
Maximum deviation from equilibrium	-0.96%	-5.20%	1.26%	-0.40%

(c) Actual and Simulated Changes over the Cycle

	Output (% change)	Inflation (change)	Real Exchange Rate (% change)	Current Account (change)
		Trough-to-Peak 1997.3-2001.1		
Model	1.08%	5.36%	1.04%	0.47%
	(6 quarters)	(13 quarters)	(4 quarters)	(1 quarter)
Data	3.39%	5.38%	5.49%	8.08%
	(6 quarters)	(7 quarters)	(4 quarters)	(8 quarters)
		Peak-to-Trough 1997.3-2001.1		
Model	-0.96%	-5.20%	-1.41%	-0.43%
	(1 quarter)	(1 quarter)	(8 quarters)	(7 quarters)
Data	-8.63%	-6.47%	-6.78%	-5.20%
	(6 quarters)	(5 quarters)	(6 quarters)	(3 quarters)

Panel (a) in Table 7 shows that the simulation results in terms of 8-quarter averages for the real exchange rate and the current account are reasonably close to the actual macroeconomic behavior (averaged across the four selected windows) observed in Chile. However the simulation results for output and inflation did not match well the actual response of both variables during 1997.3-2000.1.

The next two panels in Table 7 provide a different perspective on the comparison between actual and simulated response of the key variables, based on comparisons between maximum deviations (panel (b)) and through-to-peak and peak-to-through (panel (c)) cyclical changes. On the whole, two facts emerge. First, actual and simulated changes go in the same direction. Second, their magnitudes generally differ, with the exception of the inflation rate. Generally, the model tends to generate too little variation in real variables.

We attribute the differences between our out-of-sample simulations and the actual behavior of Chile's key macro variables to three factors. First, we do not simulate all shocks that hit the Chilean economy between 1997 and 2000. Second, our model is a parsimonious specification for Chile, largely based on dynamic optimizing behavior and consistent stock-flow relations but which did not attempt to match the quarterly dynamics of Chile's key macro variables during 1986-1997. Finally, it is likely that Chile's economy faced structural changes and restrictions in 1998-99 (including severe domestic credit constraints and stronger wage resistance to unemployment) that were not present in the preceding period and hence not captured by our model.

5. Conclusion

We have developed and applied in this paper a macroeconomic general-equilibrium model 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 borrowing constraints – that generate deviations from the frictionless full-employment equilibrium of the unconstrained neoclassical paradigm. The model was numerically calibrated to the second quarter of 1997. Then it was applied 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. The comparison between simulated and actual dynamics yields mixed results. They illustrate 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.

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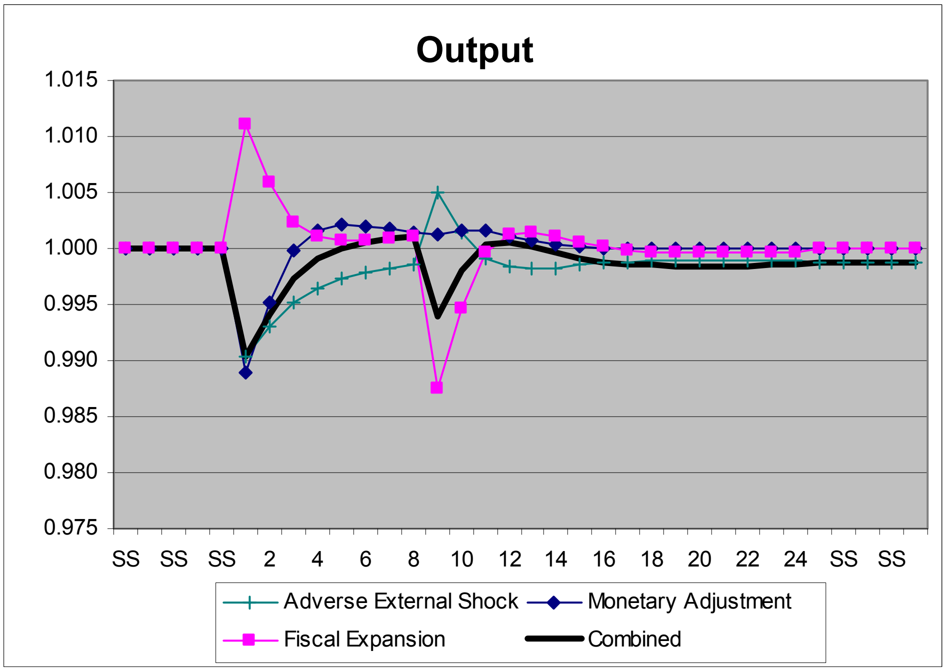
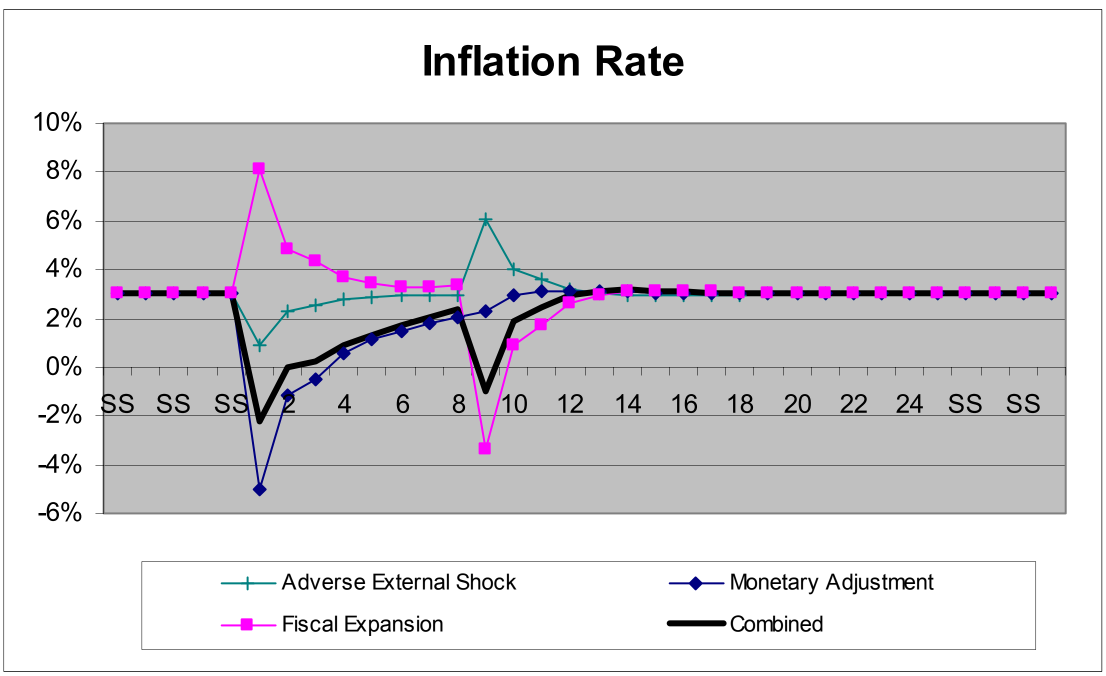
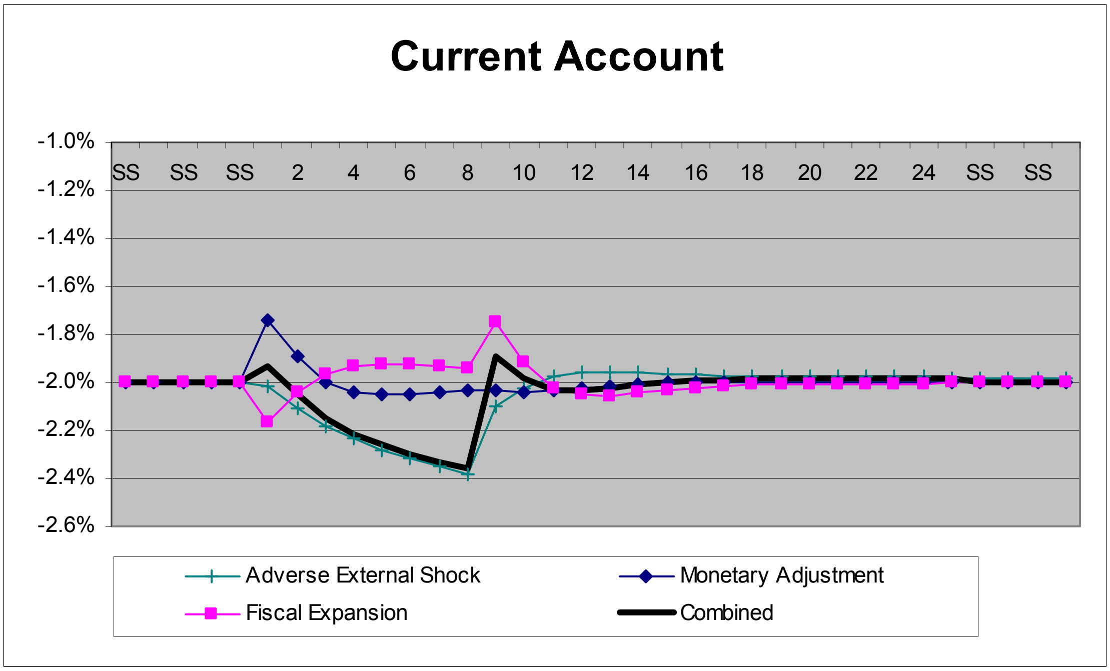
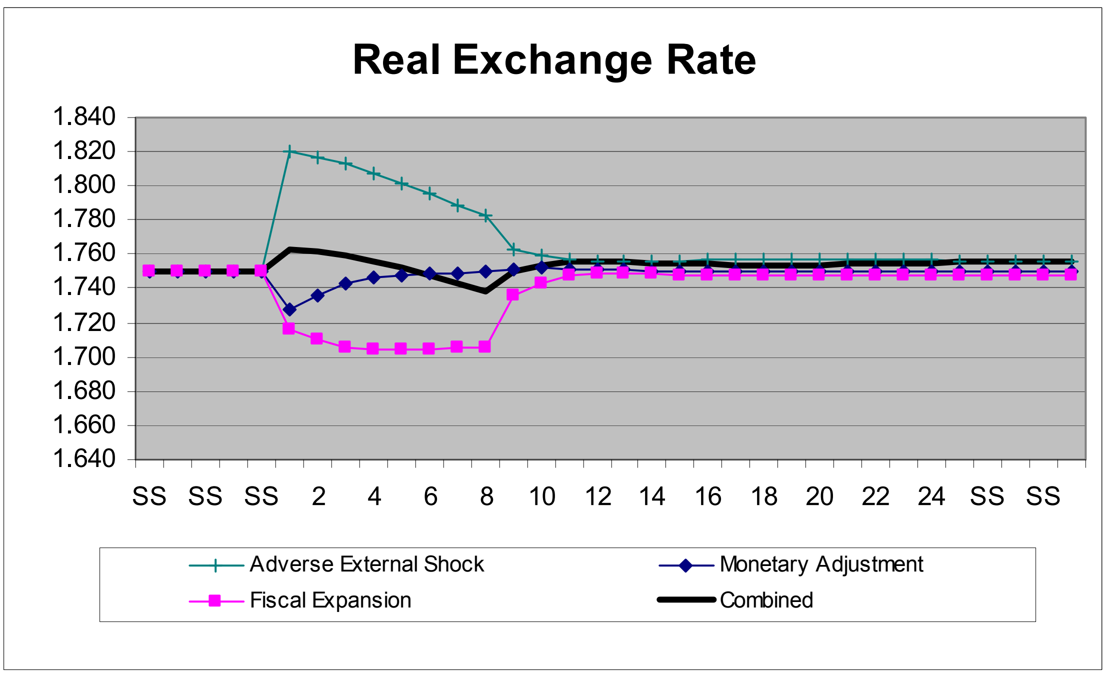
Figure 1

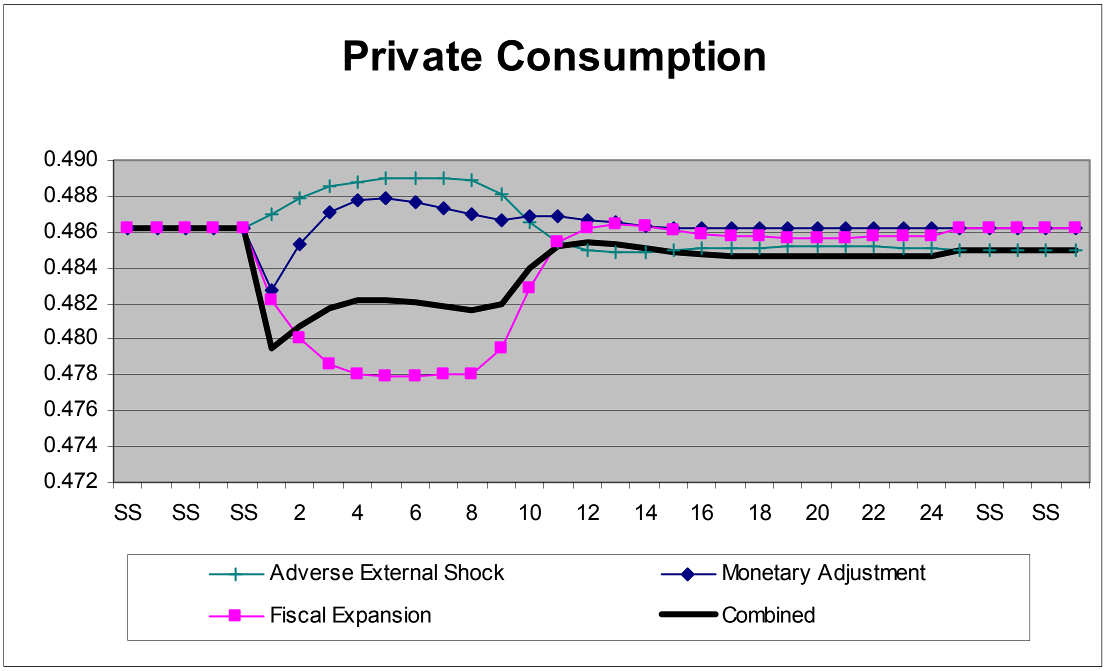
Dynamic Response of All Variables to All Shocks

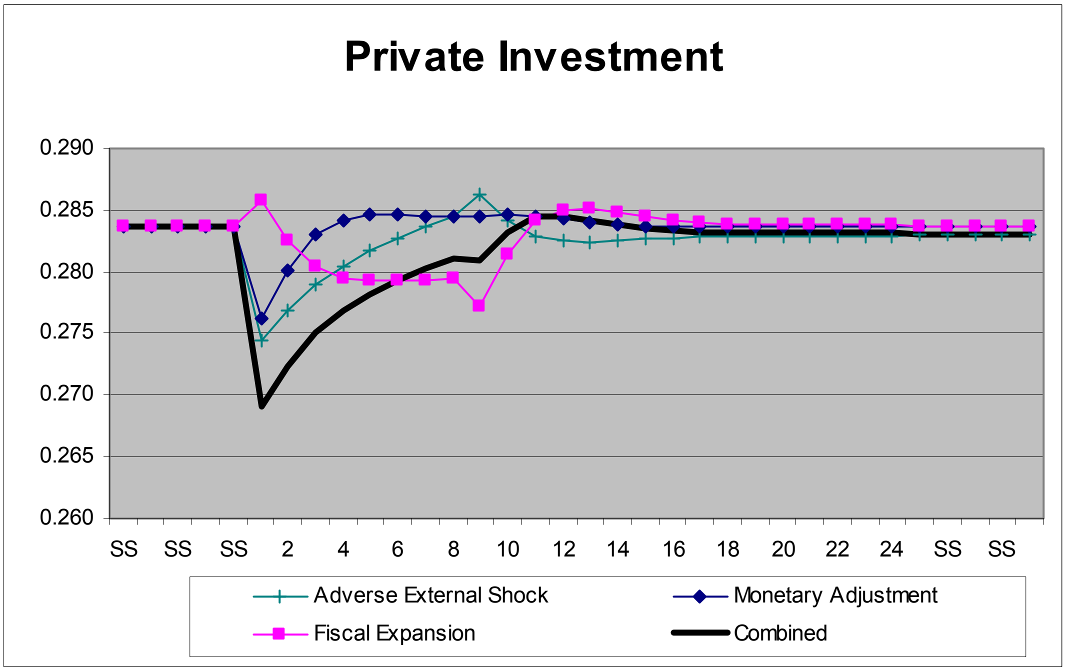


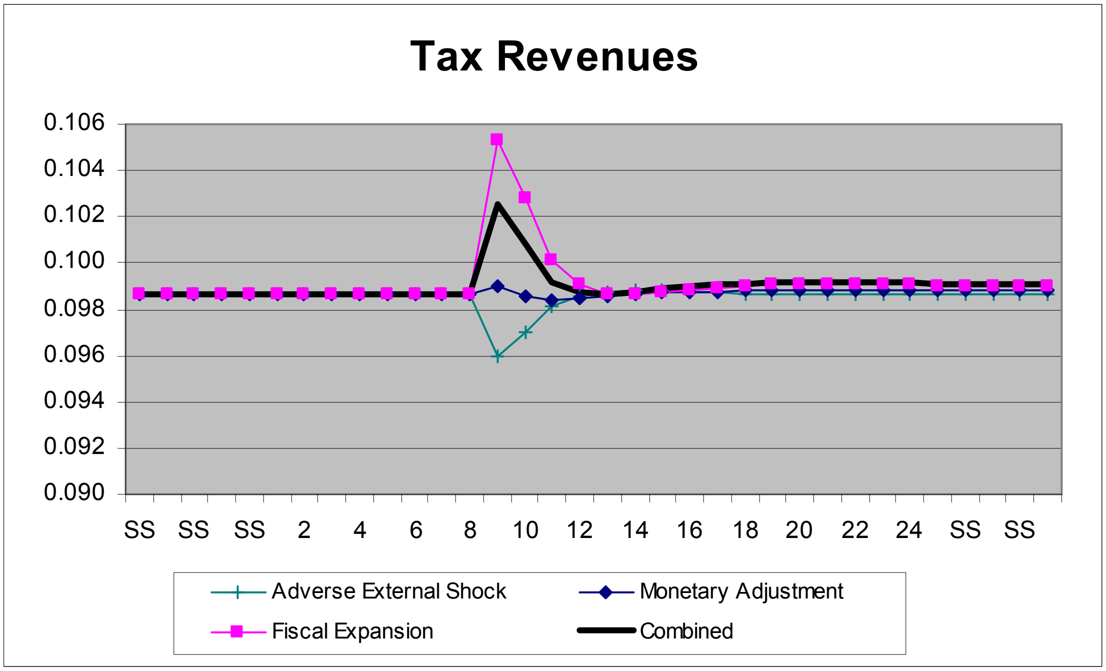



Current Account
-1.0%
-1.2%
-1.4%
-1.6%
-1.8%
-2.0%
-2.2%
-2.4%
-2.6%
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

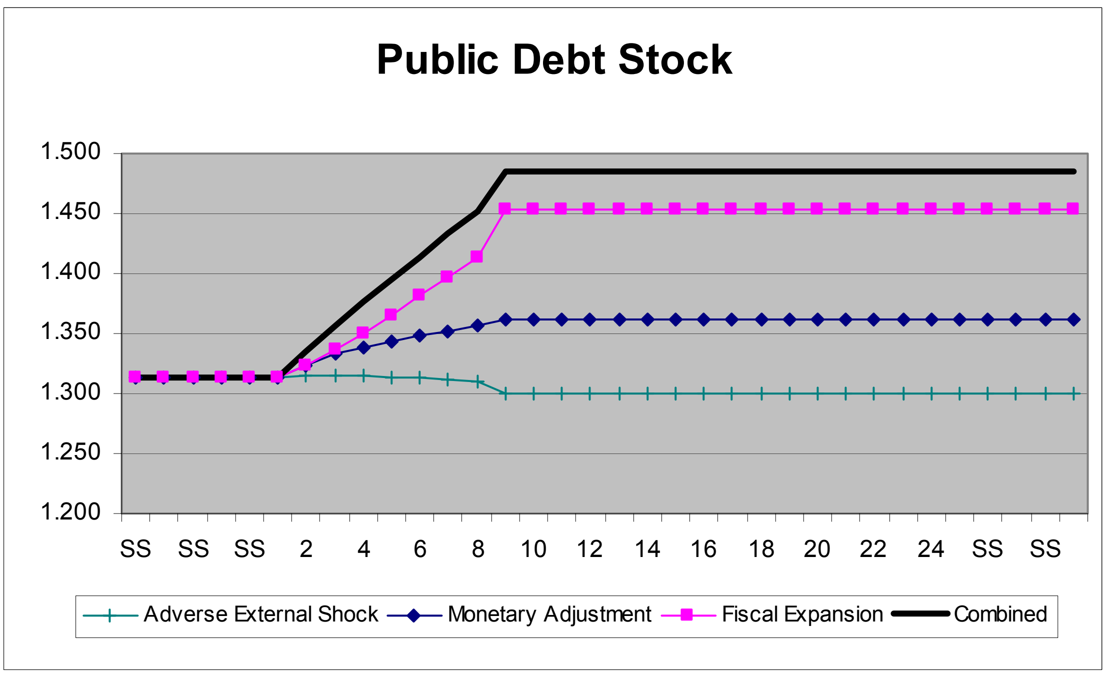

Real Exchange Rate
1.840
1.820
1.800
1.780
1.760
1.740
1.720
1.700
1.680
1.660
1.640
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined


Private Consumption
0.490
0.488
0.486
0.484
0.482
0.480
0.478
0.476
0.474
0.472
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

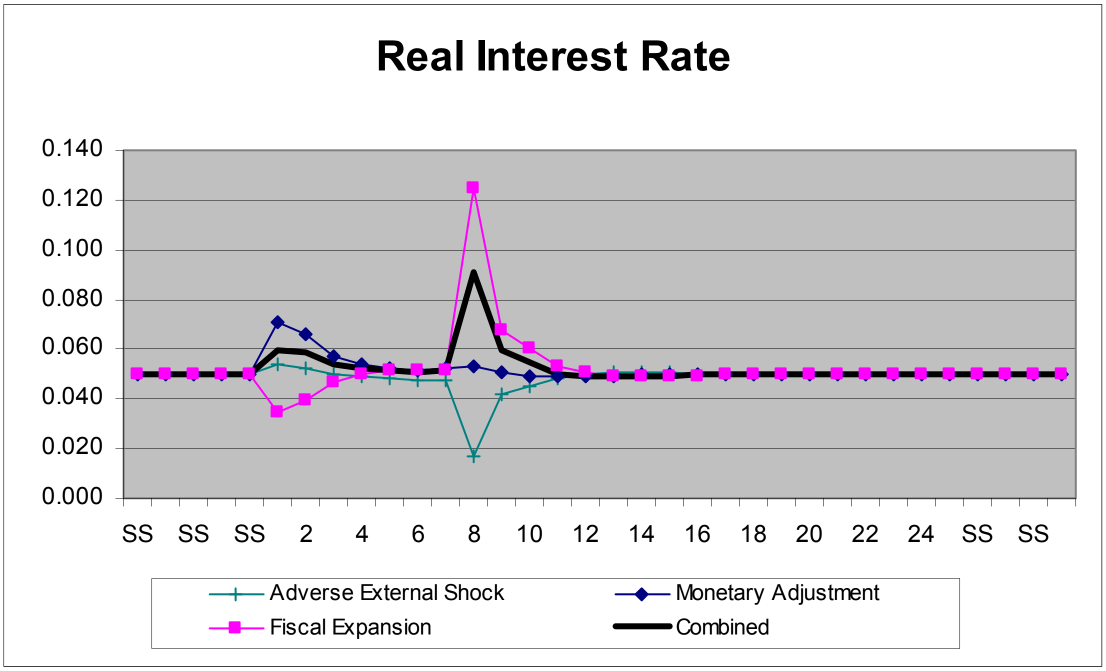

Private Investment
0.290
0.285
0.280
0.275
0.270
0.265
0.260
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

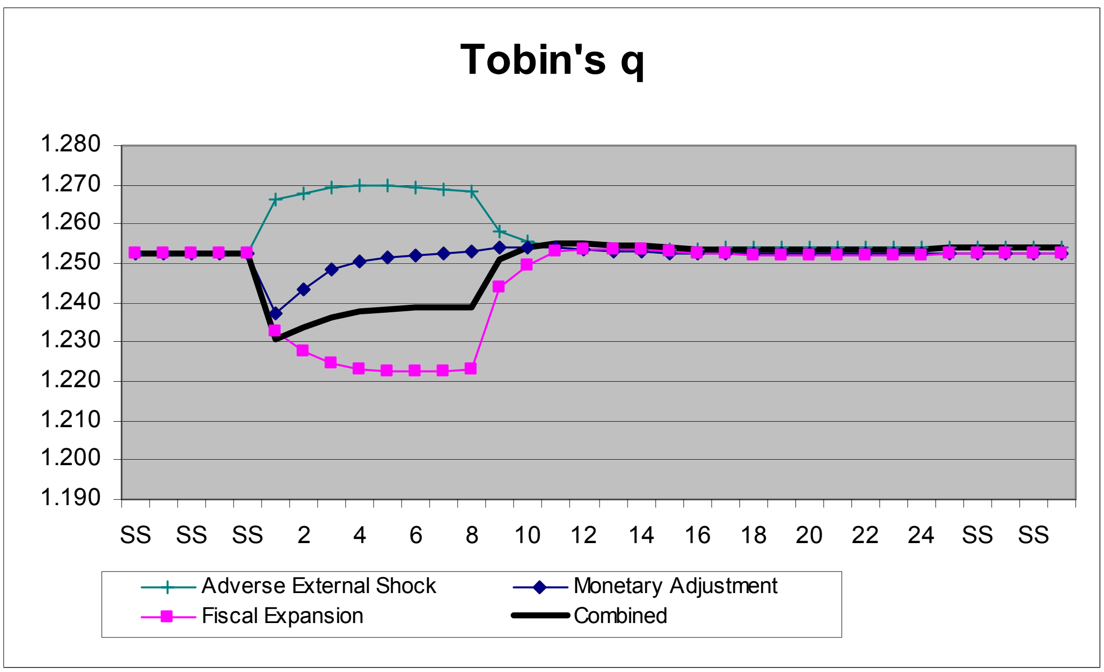


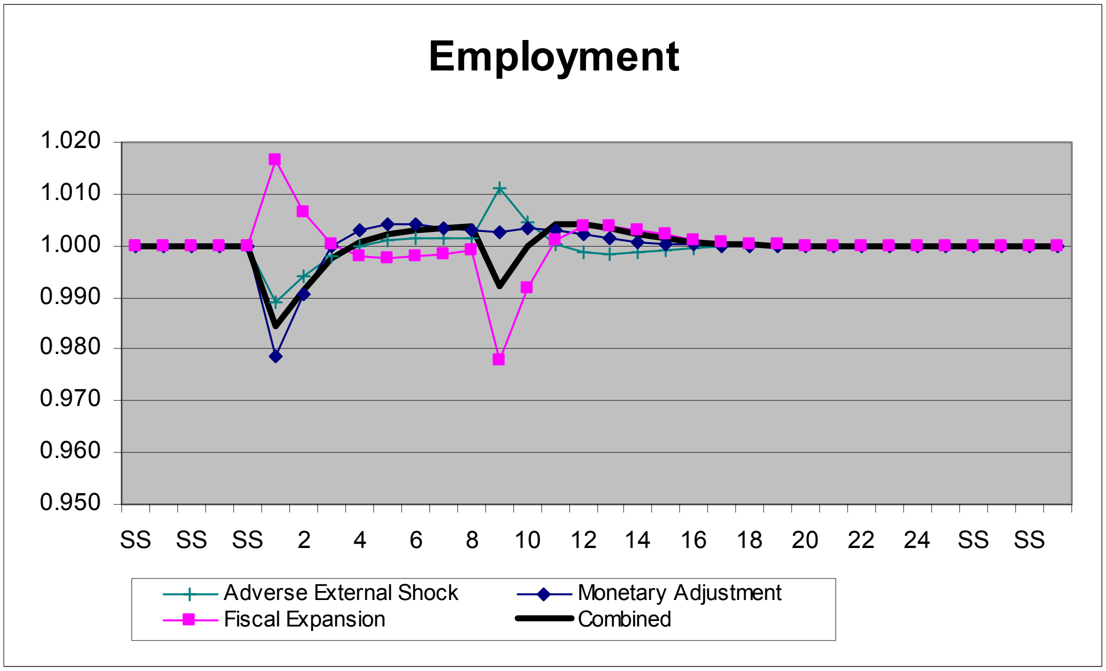
Tax Revenues
0.106
0.104
0.102
0.100
0.098
0.096
0.094
0.092
0.090
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined



Public Debt Stock
1.500
1.450
1.400
1.350
1.300
1.250
1.200
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined


Real Interest Rate
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined


Tobin's q
1.280
1.270
1.260
1.250
1.240
1.230
1.220
1.210
1.200
1.190
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined


Employment
1.020
1.010
1.000
0.990
0.980
0.970
0.960
0.950
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

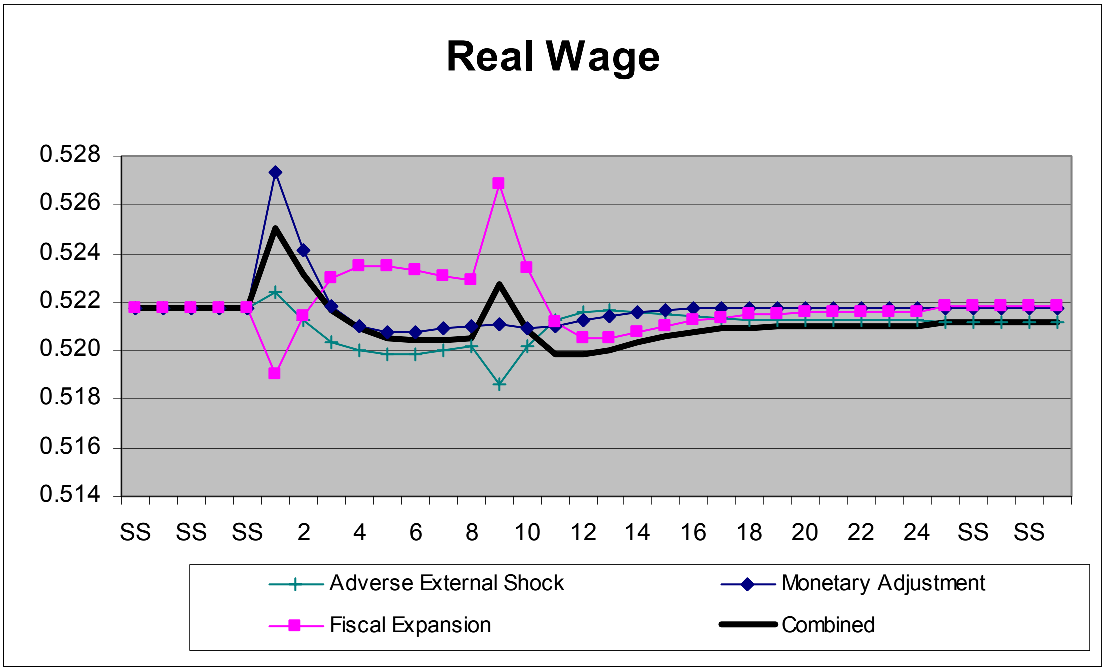
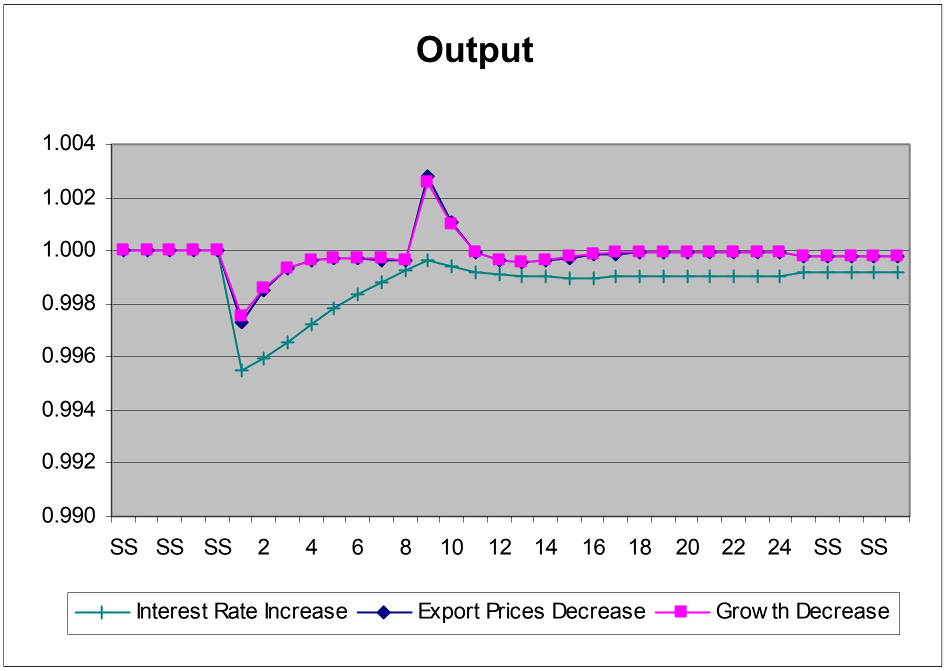
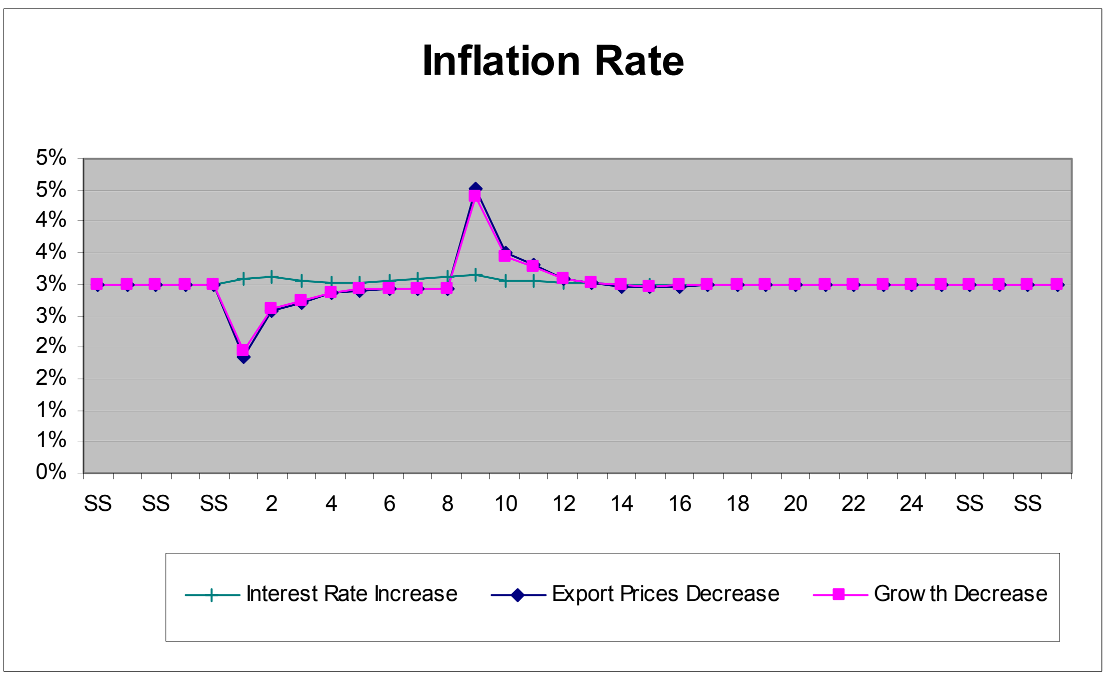
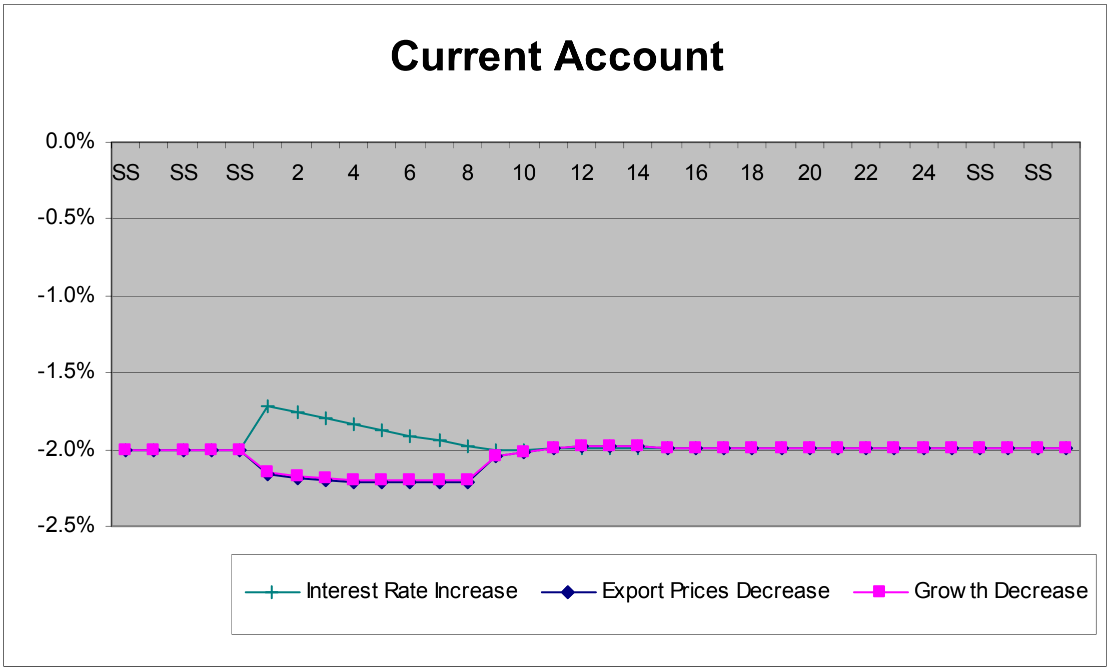
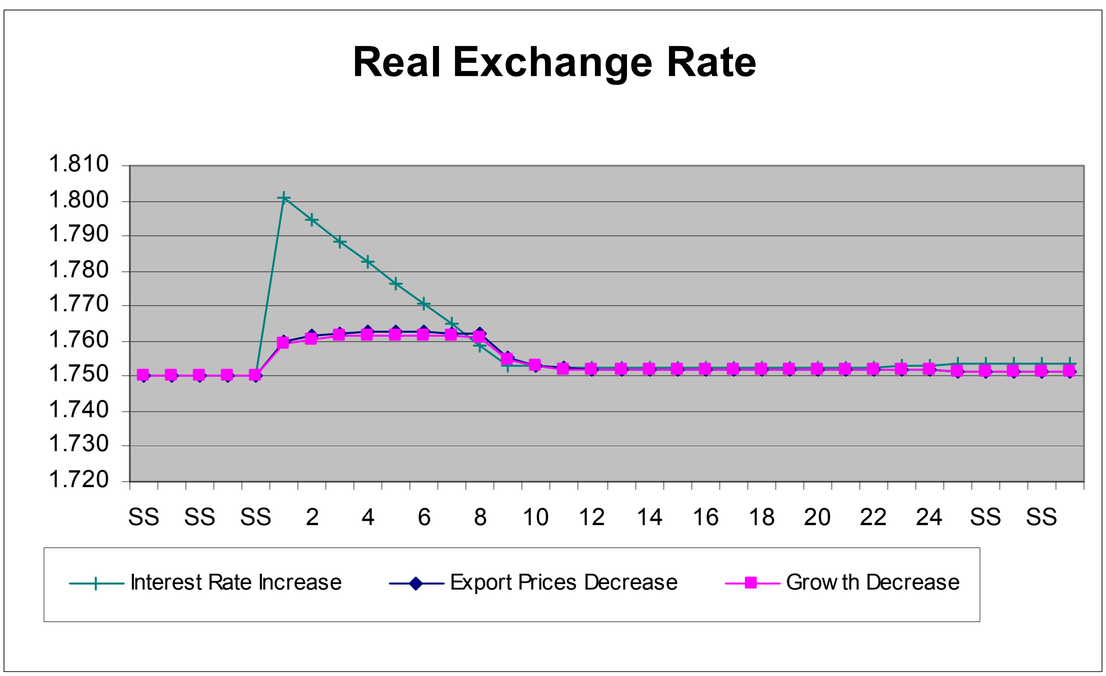

Real Wage
0.528
0.526
0.524
0.522
0.520
0.518
0.516
0.514
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

Figure 2
Dynamic Response of Main Variables to External Shocks






Current Account
0.0%
-0.5%
-1.0%
-1.5%
-2.0%
-2.5%
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Interest Rate Increase
Export Prices Decrease
Grow th Decrease


Real Exchange Rate
1.810
1.800
1.790
1.780
1.770
1.760
1.750
1.740
1.730
1.720
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Interest Rate Increase
Export Prices Decrease
Grow th Decrease

Appendix: Model Variables and Equations

A. Notation and Definition of Variables

1. General Notation

All stock and flow variables other than interest rates are defined in real terms. Current-price domestic (external) income and transfer flows and prices are deflated by the price of the domestic good (external price deflator). All stock and flow variables other than prices and interest rates are defined in terms of units of effective labor force. Domestic (external) relative prices are measured in real domestic (external) currency units. Time is denoted by t. One dot over a variable denotes its right-hand time derivative and two dots denote the second time derivative. The exponential function is denoted by exp and the natural logarithm is denoted by log.

2. Population, Labor, and Employment

n	Population growth rate
ν	Harrod-neutral technical progress rate
$g = \nu + n$	Growth rate of effective labor force
l	Employment (relative to effective labor force)

3. Income, Transfer, and Capital Flows

Domestic:

d	Dividends
d^*	Profit remittances abroad
T	Taxes

External:

f_G^*	Foreign transfers to the public sector
f_p^*	Foreign transfers to the private sector
Y^*	Foreign income
FDI	Direct foreign investment

4. Stocks

Domestic:

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

External:

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

5. 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

6. Rates and Shares

i	Nominal interest rate on domestic public debt
r	Real interest rate on domestic public debt
r^*	Real interest rate on foreign assets/liabilities

μ	Rate of growth of the nominal money stock
ρ	Consumers' subjective discount rate
δ	Rate of depreciation of phisical capital
x	Fraction of equity owned by domestic agents
λ_C	Share of unconstrained consumers
λ_I	Share of unconstrained firms

7. <u>Goods Prices</u>

Domestic prices (all relative to the price of the domestic final good):

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

External prices (all 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

8. <u>Other Prices</u>

Domestic Prices:

q_1	Intertemporal optimizing firms' Tobin's marginal q
q_2	Myopic firms' Tobin's marginal q
w	Real wage per effective labor unit
W	Nominal wage per labor unit
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)

B. Equations

All stock and flow variables other than prices and interest rates are scaled to the labor force in efficiency units.

Consumers' utility function

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

Augmented consumption deflator

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

Goods consumption deflator

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

Consumers' budget constraint

(4) $$\left(wl + e\,f_P^* - T\right) + xd - \left(g + \dot{P}/P\right)m + (r-g)b + \left(r^* - g\right)e\,b_P^*$$

$$= \left(ep_C^* C^* + p_C^N C^N\right) + \dot{m} + \dot{b} + e\,\dot{b}_P^* + v\,\dot{x}$$

Human wealth

(5) $h = \int_0^\infty \exp\{(g-r)t\}\left(wl + ef_p^* - T\right)dt$

Total wealth

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

Nominal interest rate

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

Uncovered interest rate parity

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

Private aggregate consumption demand

(9) $C = (\rho - g)\dfrac{a}{p_C} + (1-\lambda_C)\left[\dfrac{wl - T + ef_p^* - (\rho - g)h}{p_C}\right] - \dfrac{i\,m}{p_C}$

Base money market equilibrium

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

Private domestic goods consumption demand

(11) $C^N = \eta p_C C$

Private imported goods consumption demand

(12) $C^* = (1-\eta)\dfrac{p_C C}{ep_C^*}$

Production function

(13) $Y = \alpha_o \; l^{\alpha_1} K^{\alpha_2} M^{(1-\alpha_1-\alpha_2)}$

Total investment

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

Capital stock accumulation

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

Dividends

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

Labor demand

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

Imported materials demand

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

Domestic goods aggregate investment demand

(19) $J^N = J[p_K - ep_K^* p_K'] = \gamma p_K J$

Imported goods aggregate investment demand

(20) $J^{*} = J\, p_K{}' = (1-\gamma)\dfrac{p_K J}{e p_K^{*}}$

Intertemporal Tobin's q

(21) $q_1 = \int_0^{\infty} xp\{-(r+\delta)t\}\left[\alpha_2 \dfrac{Y}{K} - p_K \dfrac{\phi}{2}\left(\left(\dfrac{I_1}{K_1}\right)^2 - (g+\delta)^2\right)\right]dt$

Myopic Tobin's q

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

Aggregate investment demand

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

Public sector budget constraint

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

Export demand for national imports

(25) $X = (e\, p_X^{*})^{\varepsilon 1}\, y^{*} \exp^{\varepsilon 0}$

Accumulation of foreign investors' per-capita holdings of equity

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

Dividends earned by foreign investors (profit remittances abroad)

(27) $d^{*} = (1-x)d$

Balance of payments identity in real foreign-currency units

(28)

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

Goods market equilibrium

(29) $Y = C^{N} + J^{N} + G + X$

Nominal wage setting rule

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

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

$$(31)\quad \frac{\dot{\Omega}}{\Omega} = \frac{\theta}{1-\theta}\left(\frac{\dot{P}_C}{P_C} - \frac{\dot{\Omega}}{\Omega}\right)$$

Real wage per effective labor unit

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

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