# General Equilibrium Dynamics of Foreign Shocks and Policy Changes in Chile [#]

**Francisco Gallego ***

**Klaus Schmidt-Hebbel ****

**Luis Servén *****

JEL Codes: F41, F47

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 fraction of rational forward-looking agents. However, it also introduces critical real-world features – such as short-run wage rigidities and a fraction of myopic agents – that generate deviations from the frictionless full-employment equilibrium of the unconstrained neoclassical paradigm. The model is numerically simulated to account for the dynamics of Chile's economy in response to the foreign shocks and policy shifts that led to the 1998-99 recession.

Jan. 14, 2003

* M.I.T. ** Central Bank of Chile *** The World Bank.

## 1. Introduction

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

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 the 1998-99 recession. We simulate the individual and combined effects of the latter shocks to account for the latter 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). To our knowledge, this is the first attempt at constructing and using a non-linear dynamic macroeconomic model for a developing country based on optimizing behavior under rational expectations, with well-defined short-term and stationary equilibrium properties.

Section 2 spells out the model structure, its steady state, dynamics, stability, and solution procedure. 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 foreign shocks, the expansionary fiscal policy, and the contractionary monetary policy that were observed in Chile during 1997-99. Our simulations take account of most of the behavior variation in Chile's key macoreconomic variables during the 1998-99 recession. Brief conclusions close the paper.

## 2. Model features, steady state, dynamics, and solution

2.1 Model 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 foreign net 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. Wages are indexed to current and lagged consumer price inflation rates, and react 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 of the sectoral budget constraints, and the forward-looking behavior of private agents. Expectations are formed rationally and uncertainty is ruled out, which in effect amounts to assuming 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] Following the standard theory of investment under convex adjustment costs (Lucas, 1967, Treadway, 1969), neoclassical firms maximize their market value and link their investment

[1] Export demand and wage setting are the only behavioral equations in the model that do not follow (explicitly or implicitly) from first principles. Absent myopic agents and wage rigidity, the model would reduce to the standard intertemporal model of optimizing agents presented in Servén (1995).

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 installation cost (Hayashi, 1982). Classical consumers gear their augmented consumption (composed of goods consumption 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 the Tobin's q, i.e. the actual marginal productivity of capital minus the adjustment costs. Consequently, in the steady state –when disposable income equals permanent income and myopic version of Tobin's q equals classical Tobin's q—both kinds of myopic agents behave in the same way than the classical ones.

Technology and preferences are kept as simple as possible –mostly by assuming unit elasticities of substitution (although this specification could be easily generalized). Two-stage budgeting in consumption and investment allows separation between the determination 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 (1994a,b, 1995, 1996, and 2002). Sector flow budget constraints, market equilibrium conditions, and behavioral equations for firms, consumers, the public sector, and the external sector 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. Thus, the government's budget must be balanced,[2] 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,

[2] The government's budget must be balanced in terms of units of the effective labor force. This implies that the real value of asset stocks must increase at the rate of growth of the effective labor force, *g*.

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 per capita extended 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 de-accumulation 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. As noted by Giavazzi and Wyplosz (1984), this follows from the fact the assumption of forward-looking consumption behavior derived from intertemporal optimization by infinitely-lived households with a constant rate of time preference and facing perfect capital markets, yields path-dependence of the steady-state.

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).[3] In our framework even transitory monetary disturbances can have permanent real effects. For example, if some consumers are myopic, a transitory increase in inflationary taxation matched by a reduction in direct taxes raises disposable income and

[3] Turnovsky and Sen (1991) use a non-monetary model with intertemporally optimizing consumers in which transitory fiscal disturbances have long-run effects. It 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).

consumption, leading to reduced wealth accumulation and eventually causing a fall in long-run wealth and a permanent real depreciation.[4]

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,[5] but not for nonlinear systems such as the one at hand.[6] 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).[7]

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., 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).[8] 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,[9] at which time the process stops.

---

[4] 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).

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

[6] 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.

[7] In our case, path-dependence of the steady state rules out a number of solution methods –such as *reverse shooting* (Judd, 1999) 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.

[8] 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 (1999).

[9] 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)

Two leading examples are the "multiple shooting" method (Lipton et al. (1982)), and the "extended path" algorithm of Fair and Taylor (1983). We combine both techniques as follows. First, we solve the model over an arbitrarily chosen time horizon using multiple shooting. To prevent the solution from being distorted by the choice of too short a time horizon (which would force the model to reach the terminal conditions too early), we then extend the horizon and recompute the solution path; we keep doing this until the resulting changes in the solution trajectory of the endogenous variables fall below a certain tolerance at which time the process stops. In practice, the length of the simulation horizon required to converge is strongly affected by two parameters: the elasticity of real wages to employment (i.e., the slope of the augmented Phillips curve), and the magnitude of adjustment costs associated with investment.

## 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, a base period of full employment that preceded the subsequent 1997-98 Asian 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.[10] Hence the first period of our counter-factual simulations could be interpreted as 1997.3, if 1997.2 had been a stationary equilibrium period.

Table 1 reports our regression results and Table 2 presents the calibrated budget constraints for 1997.2. Tables 3 to 5 report structural coefficients and base-period values of pre-determined and endogenous variables from econometric estimations and calibration of budget identities. 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*

---

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.

[10] 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

*Públicas*, various issues; and the Central Bank of Chile Database). 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)[11] and for 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. 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.

All variables are expressed in labor force efficiency units to conform to the model specification.

### 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 1986-97). The import content of investment (29%) is six times as large as the import content of consumption (5%); this agrees well 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).

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 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 reported in Table 4 identify data samples and estimation techniques at the bottom of the table. For the estimations we pre-determined the values of capital depreciation,

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

steady-state growth, and the subjective discount rate. We have made occasional use of dummy variables to take account for special events or unexplained regression outliers.

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 70 % and 53%, respectively, substantially below the 100% share of the unconstrained neoclassical benchmark.[12]

### 3.4 Calibrated base-period values of predetermined variables

We fitted base-period (1997.2) values of predetermined variables in two stages:
a) adding regression residuals to the estimated intercepts to replicate observed values, and
b) forcing the budget constrains to hold with equality in 1997.2 at constant asset stocks (hence real stocks grow at the exogenous steady-state growth rate). We chose total foreign assets held by private sector and total taxes as the slack variables for the two independent budget constraints. The values are -1.9938% of GDP for the stock of foreign assets held by the private sector (the actual value was -1.8538% in 1997.2) and 13.2% of GDP for total taxes (the actual value was 16.3% in 1997.2). Table 2 reports all stocks and flows relative to GDP.

### 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 the actual values excepting taxes and foreign assets held by the private sector, as discussed above.

---

[12] Several studies have estimated, using various techniques, the share of constrained consumers ($\lambda_1$) in Chile and in other developed and developing countries. In the case of Chile, Corbo and Schmidt-Hebbel (1991) estimated $\lambda_1$ equal to 0.60 for the period 1968-88; Schmidt-Hebbel and Servén (1996) 0.45 for the 1963-1991 period; Villagómez (1997) 0.46 for the 1970-1989 period; Bandiera et al. (1999) 0.55 for the 1970-1995 period; and Bergoeing and Soto (2002) 0.75 for the 1986-1998 period. Finally, López et al. (2000), using a panel of developed and developing countries, found a share of constrained consumers of 0.40 for the whole sample, and 0.40 (0.61) for OECD (developing) countries.

## Table 1
## Econometric Estimations[13]

**1. Money Demand**

$$\log(\frac{hb}{c}) = 1.179 - 0.085 \log(\frac{i}{1+i})$$

(9.97)

**2. Real wage**

$$\ln(w) - \ln(w_{-1}) = 0.034 + 0.32 \ln(l) + 0.1365 \ln(\frac{pc}{pc_{-1}})) + 0.5699 \ln(\frac{pc_{-1}}{pc_{-2}}) + (1 - 0.1365 - 0.5699) \ln(\frac{pc_{-2}}{pc_{-3}})$$

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

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

**3. Production Function**

$$d\ln(\frac{y}{k}) = 0.177 + (0.397 - 1) d\ln(k) + 0.522\, d\ln(\frac{l}{k}) + (1 - 0.397 - 0.522)\, d\ln(\frac{mr}{k})$$

(5.60) (3.35) (4.14) (3.35) (4.14)

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

**4. Aggregate Private Investment**

$$inv = 0.136\{\frac{k}{15}\left(0.5299\, q_1 + (1 - 0.5299)\frac{0.397\frac{Y}{k}}{(0.0099 + 0.0108)} \Big/ p_k - 1\right) + (0.0099 + 0.0108)K)\} + (1 - 0.136)\, inv_{-1}$$

(3.10) (2.75)

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

**5. Aggregate Private Consumption**

$$dcp = (0.012 - 0.010) d(\frac{a}{p_C}) + (1 - 0.705)\left[\frac{wl - T + ef_p^* - (0.012 - 0.010)h}{p_C}\right] - \frac{im}{p_C}$$

(5.69)

$R^2$A=0.14 S.E.=3.602 LM (4)=0.54 LM (8)=0.65

**6. Export Demand**

$$d\ln(x) = 0.020 + 0.132\, d\ln(e\, px) + 0.683\, d\ln(yf) + 0.03\, d\ln(x_{-1})$$

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

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

Notes: The sample periods are 1986.1-1997.1. Estimation techniques and the dummy variables used in regressions are 1.Restricted cointegration. 2. TSLS, dummy variables are 1991-1992. 3. LS in first differences, dummy variables are 1990.1, 1992.3, and 1993.1. 4. LS with restricted adjustment cost parameter chosen to maximize adjusted $R^2$, dummy variables are 1994.4, and 1995.1.[14] 5. TSLS, dummy variables are 1992.3, 1995, and 1996.4. 6. TSLS in first differences.

[13] At the bottom of each equation, but the monet demand, we report the adjusted $R^2$ ($R^2$A), the standard error of 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.

[14] When adjustment costs are left unrestricted the estimation generates implausible values. To resolve this, we restricted the adjustment cost coefficient after searching for the value that maximized the adjusted R-squared.

**Table 2**
**Sectoral Budget Constraints**

Public Sector Budget Constraint

$$[td + \mathrm{e\ ftrg\ - cng}] - (r-g)bg + (\mathrm{g} + \dot{\mathrm{P}}/\mathrm{P})hb + \mathrm{e(rf\ - g)\ fbg} = \mathrm{e\ f\dot{b}g} - \dot{bg} - \dot{hb}$$

*Simulated Initial Steady-State*

$$0.1018 + 1.75*0.004 - 0.1045 - (0.0123 - 0.0099)*1.3138 + (0.0099 + 0.0074)*0.3154$$
$$+1.75*(0.0123 - 0.0099)*0.0640 = 0$$

External Sector Budget Constraint

$$\left[\frac{x}{e} - pcmp\ cmp - pim\ \mathrm{im\ - pmr\ mr + ftrg + ftrp}\right] + (rf-g)[fbp + fbg] - \frac{prem}{e} = \left(f\dot{b}p + f\dot{b}g\right) - dfi$$

*Simulated Initial Steady-State*

$$\frac{0.2160}{1.75} - 0.9002*0.0242 - 0.9002*0.0753 - 1*0.0465 + 0.0043 + 0.0001 + (0.0123 - 0.0099)$$
$$*(0.0640 - 1.9938) - \frac{0.0436}{1.75} = -0.02$$

Private Sector Budget Constraint

$$[y - pi\ inv - pi\ iac - e\ pmr\ mr + e\ ftrp - td\ \mathrm{- pc\ cp}] - \left(g + \dot{P}/P\right)hb + (r-g)bg$$
$$-prem + (rf-g)e\ fbp = \dot{hb} + \dot{bg} - e\ dfi + e\ f\dot{b}p$$

*Simulated Initial Steady-State*

$$(1 - 1.25*0.2836 - 1.25*0 - 1.75*1*0.0465 + 1.75*0.0043 - 0.1317 - 0.9*0.4862)$$
$$-(0.0123 - 0.0099)*0154 + (0.0123 - 0.0099)*0.3217 - 0.0436$$
$$+(0.0123 - 0.0099)*1.75* - 1.9938 = 1.75* - 0.0200$$

**Table 3**
**Structural Coefficients**

| | | | |
|---|---|---|---|
| **Money Demand** | | **Private Investment Demand** | |
| Constant ($\phi_1$) | 1.179 | Share of unconstrained firms ($\beta_1$) | 0.5299 |
| Consumption Elasticity ($\phi_2$) | 1 | Adjustment Costs to Investment ($\mu$) | 15 |
| Interest rate Elasticity ($\phi_3$) | 0.085 | Rate of depreciation of physical capital ($\delta$) | 0.0108 |
| **Wage Equation** | | **Share of national goods in investment (**$\gamma$**)** | 0.7141 |
| Constant ($\phi_1$) | 0.034 | | |
| Employment elasticity ($\omega$) | 0.3192 | **Private Consumption Demand** | |
| Indexation to current inflation ($\theta$) | 0.1365 | Share of unconstrained consumers ($\lambda_1$) | 0.7049 |
| Indexation to 1-period lagged inflation ($\theta$) | 0.5699 | | |
| | | **Share of national goods in consumption (**$\eta$**)** | 0.9523 |
| **Production Function** | | **Export Demand** | |
| Constant ($\alpha_0$) | 0.4676 | Constant ($\rho_1$) | 0.2006 |
| Labor share ($\alpha_1$) | 0.5218 | Real exchange rate elasticity ($\rho_2$) | 0.1320 |
| Capital share ($\alpha_2$) | 0.3969 | Foreign income elasticity ($\rho_3$) | 0.6830 |
| Intermediate imports ($\alpha_3$) | 0.0814 | Lagged exports ($\rho_4$) | 0 |

**Table 4**
**Baser-Period Values of Predetermined Variables**

| | | | |
|---|---|---|---|
| **Income, Transfers, and Capital Flows** | | **Rates**[15] | |
| Foreign Transfers to the Public Sector (ftrg) | 0.0001 | Real interest rate on foreign assets/liabilities (rf) | 0.05 |
| Foreign Transfers to the Private Sector (ftrp) | 0.0043 | Rate of growth of the nominal money stock (nmg) | 0.07 |
| Foreign Income (yf) | 1.0000 | Harrod neutral technical progress (tg) | 0.024 |
| Direct Foreign Investment (dfi) | 0.0200 | Population growth (pg) | 0.016 |
| **Stocks** | | **External Prices** | |
| Domestic debt of the public sector (bg) | 1.3138 | Intermediate imports (pmr) | 1.0000 |
| Foreign assets held by the public sector (fbg) | 0.0640 | Consumption imports (pmc) | 0.9002 |
| | | Investment imports (pmk) | 0.9002 |
| | | Export-competing goods (px) | 1.0000 |
| **Goods Flows** | | | |
| Public national-goods consumption (cnp) | 0.1045 | | |

[15] For clarity, these rates shown here in annual terms. The simulation model uses the equivalent quarterly values.

**<u>Table 5</u>**
**<u>Initial Steady-State Values of Endogenous Variables</u>**

| | |
|---|---|
| **Income, Transfers, and Capital Flows** | |
| Operational Profits (op) | 0.3968 |
| Dividends (d) | 0.1330 |
| Taxes (td) | 0.1018 |
| Private disposable income (yd) | 0.4274 |
| Profit remittances abroad (prem) | 0.0436 |
| **Stocks** | |
| Private sector total wealth (a+hu) | 187.4863 |
| Non-human wealth of the private sector (a) | 10.7757 |
| Stock of domestic equity held by foreigners (fe) | 1.1368 |
| Domestic base money (hb) | 0.3154 |
| Human wealth of the private sector (hu) | 176.7107 |
| Physical Capital (k) | 13.7164 |
| Foreign assets held by the private sector (fbp) | -1.9938 |
| **Goods Flows** | |
| Private aggregate consumption (cp) | 0.4862 |
| Private imported-goods consumption (cmp) | 0.0243 |
| Private national-goods consumption (cnp) | 0.4619 |
| Gross domestic investment (inv) | 0.2836 |
| Private national-goods investment (in) | 0.2014 |
| Private imported-goods investment (im) | 0.0822 |
| Investment adjustment costs (iac) | 0 |
| Exports (x) | 0.2160 |
| Intermediate imports (mr) | 0.0465 |
| Total imports (m) | 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 Good Prices** | |
| Private aggregate consumption deflator (pc) | 0.9 |
| Aggregate investment deflator (pi) | 1.1 |
| **Other prices** | |
| Real exchange rate | 1.75 |
| Real equity price (Tobin's q) in units of domestic output | 1.2526 |
| Real wage per effective labor unit (rw) | 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 expansionary fiscal policy, adverse foreign shocks, and contractionary monetary policy that characterized 1997-98 and led to the 1998-99 recession. We will 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 (that raises public consumption by 1.5 percentage points, from 10.5% to 12% of GDP) and a contractionary monetary policy (that reduces money growth from 7% to 4%). We also consider a composite adverse external shock, composed by a rise in the relevant foreign interest rate (by 1.5%), a decline in export prices (by 15%), and a reduction in foreign output growth (by 3%).[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. The 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 in 1997-98 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 to the long-term inflation target band (formally adopted from 2001 onwards) was accomplished during the latter years. After continuing appreciation from the early 1990s through 1998, the real exchange rate depreciated by 5% in 1999,

[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) and Schmidt-Hebbel and Servén (1995b) analyze the effects of contractionary monetary policies 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.

4.8% in 2000, and 12.7% in 2001. The current account deficit ratio to GDP, after attaining 6.0% in 1998, fell to 0.2% in 1999.

What explains these developments? To our knowledge, only two papers have attempted to explain the causes of Chile's recent downturn. Corbo and Tessada (2001) find that the 1998-99 recession was a result of the effects of external shocks (lower terms of trade and reduced capital inflows) and a monetary policy adjustment. The latter is explained by 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), using a RBC model, estimate the effects of labor market reforms and that the increase in labor taxes explain 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, lower capital flows, etc).

We use our model to simulate the response of the Chilean economy to most of the latter 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 five reasons. First, our model is based on a parsimonious specification, with deep behavioral parameters largely derived from optimizing behavior, hence excluding ad-hoc but empirically relevant right-hand side determinants. But the model's strength due to its structure and desirable dynamics and steady-state properties comes at cost: it is less able to track the short-run dynamics of any given endogenous variable. Second, we depart 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 this is known with certainty. 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. Finally, the magnitudes or our shocks differ somewhat from those observed in the data.

Table 6 summarizes the actual behavior of key foreign and policy variables observed for different 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, 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 the government consumption to GDP ratio by 1.5 pp. during 1997.2-1999.1 As a reaction to the Asian crisis and the 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[18] | 1997.2 | 1999.1 | 1.2% | 1.50% |
| Change in Export Prices | 1998.1 | 1999.4 | -12% | -15% |
| Change in World GDP growth[19] | 1997.4 | 1999.4 | -2.24% | -3.00% |
| **Domestic Policy Shocks** | | | | |
| Change in Government Consumption | 1997.2 | 1999.1 | 1.54% | 1.50% |
| Monetary Contraction[17] | 1998.1 | 1999.3 | -3.00% | -3.00% |

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 response 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 1.5 percentage points, from 10.5% to 12% of GDP.[20] As a consequence of this policy shift, the public debt stock rises monotonically from 131 % of GDP in quarter 1 to 141.19% in quarter

[18] The relevant external interest rate is the sum of foreign real interest rate and country-risk premium.
[19] Change from HP-trend growth
[20] Percentage points of GDP are denoted by pp here and below. Percentage point changes in variables that are themselves expressed as a percentage (e.g., interest rates) are noted as %.

8, with a further jump to 145% in quarter 9 (due to the high quarter-8 interest rate, discussed in more detailed bellow) 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 and a larger transitory increase in periods 9-12.

For the effects of temporary shocks like the one analyzed here, the role of myopic consumers and investors is crucial. If all consumers were forward-looking, a temporary expansion in government consumption would lead to a modest and transitory private consumption decrease, by an amount consistent with the wealth loss from the temporary fiscal expansion and the transitory increase in money services (caused by the increase in nominal interest rate and money holdings) which leads to substitution of goods consumption for money services. However 30% of consumers are myopic and hence respond to temporary changes in variables that affecting their disposable income. Therefore 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. In periods 2 to 7, the real exchange rate remains almost at the same level, a reflection of largely unchanged private consumption.

The real exchange rate appreciation at initial periods are fully reflected in the lower ex-ante domestic real interest rate in periods 1 to 4, as dictated by uncovered real interest parity. Another relevant asset price is Tobin's q, which falls on impact in response to the higher demand for capital, prompting the investment increase discussed below. Tobin's q remains at a lower level up to quarter 8, as a mirror of the real exchange rate appreciation.

Regarding investment, myopic investors (the 50% of investors who adjust their investment to contemporaneous marginal productivity of capital) causes investment to correlate strongly and contemporaneously with output. This is observed in periods 1-3 and from period 9 to the new steady state. In contrast, neoclassical investors respond to the lower Tobin's q by reducing their capital accumulation 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 moves according to the behavior of output, aggregate demand, and the real exchange rate.

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. This is because 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 12.24% (at annual rate).

In period 9, when the temporary fiscal expansion is reversed, inflation attains a through at -3.2%. 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 substitutes seigniorage collection (the public debt increases to a new steady-state level of 134.91% 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 -5.1%) 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 0.6% to an average level 0.5% of annual output on impact, matched by the above mentioned increase in public debt.

On impact private consumption of both unconstrained and constrained consumers is reduced. However the real value of the money services consumption declines from 0.21% to 0.16%, creating an incentive to intratemporally substitute real goods consumption for money services consumption. But 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.

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 same 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 evolution of variables. The gradual real exchange rate depreciation resulting from the upcoming monetary expansion is anticipated, leading to a temporary increase in interest rates, higher consumption and investment, and even overemployment between periods 4 and 10.

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 13 and thereafter.

### 4.4 External shocks

The third simulation is a composite external shock comprised by a rise in the relevant foreign interest rate by 1.5%, a decrease in export prices by 15%, and a decline of trend foreign output growth by 3%. We start by analyze each shock by itself, depicting in Figure 2 the dynamic effects of each shocks separately 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 3.7 % 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 (1.8% on impact and 0.3% in steady state). The opposite cycle of slight overemployment and overproduction is observed at quarters 6 through 11. High inflation at quarter 1 raises government revenue from seigniorage, so that public debt decreases on impact.

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). However as neoclassical consumers do not change their consumption levels, the ratio of consumption to output slightly during quarters 1 through 8.

The real exchange rate depreciates on impact by 0.7%. 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 in part to attain a new stationary level only 0.05% 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 undone in period 9 when export prices return to their initial level.

The export price shock and its derived output contraction causes a one-time inflation drop to 1.5% 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 0.5%, 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 3.0% level in quarter 8.

The latter raises Tobin's q which, in conjunction with a less appreciated 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 5 % in period 9– leading to overemployment and reinforcing the output increase.

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

Third, 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 indistinguishable). Hence we will not discuss the effect of lower foreign growth separately.

The composite effect of the three external shocks combined (Figure 1) reflects roughly the relative intensity of each foreign shock separately.[21] The output drop is 1.23% on impact, the inflation declines to 2.6% 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 5.1% on impact (mainly a result of the huge impact of the interest rate shock), and the current account deficit increases to 2.3% 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 of its higher degree of inertia and its effects on the economy's steady state. In fact, the cumulative output loss of the external shock is 5.1% during the first 24 quarters, while it is only 0.08% 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.

Inflation falls well below 3% for 11 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 other shocks have effects in quarters close to quarters 1 and 9, that is, at the start and end of the temporary shocks.

[21] 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.

The real exchange rate depreciates relative to its steady-state level during periods 1 to 8, mostly driven by the influence of the composite adverse external shock. The steady-state exchange rate depreciates as a consequence of the interest rate shock due hysteresis. Finally, the current account deficit also increases during periods 1 to 8, mostly driven by the influence of the external shocks.

An interesting 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 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. It also matters when each shock affects the domestic economy. 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 the model fits Chile's actual macroeconomic dynamics during 1997-1999. For this purpose we report in Table 7 average trend deviations of the four key macro variables in four subsequent 8-quarter windows, starting in 1997.3, 1997.4, 1998.1, and 1998.2, respectively. We chose the latter 3 windows because the data 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 2.

**Table 7**
**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% |
| | | **Model Simulation** | | |
| **8 quarters** | -0.33% | -2.37% | 1.07% | -0.28% |

Our average 8-quarter simulation results for three of the four variables are very close to the average macroeconomic behavior (across the four selected windows) that was observed in Chile. Our output contraction, real exchange rate depreciation, and current-account deficit reduction match approximately the behavior of Chile's macroeconomy between mid 1997 and early 2000. The exception is inflation, for which our simulated result is much larger than the reduction in (trend) inflation that was observed in Chile. This difference is very likely a consequence of non-instantaneous consumer price adjustment and inflation caused by price indexation and administrative price setting in Chile, while our model assumes instantaneous CPI adjustment.

Another interesting difference relates to the fact that the model fits approximately the actual data but it does at different historical periods. For example, the model fits approximately well the real exchange rate and the current account but not inflation and output in the first two 8-quarter windows, while the opposite occurs during the last two windows.

## 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 is numerically simulated to account for the dynamics of Chile's economy in response to the foreign shocks and policy shifts that led to the 1998-99 recession. The model replicates relatively well the medium-term (8-quarter) behavior of Chile's key macro aggregates.

## References

Arrau, P (1989): "Intertemporal Monetary Economics: Evidence from the Southern Cone of Latin America", Ph.D. Dissertation, University of Pennsylvania, Philadelphia.

Bandiera, O., G. Caprio, P. Honohan, and F. Schiantarelli (1999): "Does financial reform raise or reduce savings?", Policy Research Working Paper 2062. The World Bank.

Bergoeing, R. and R. Soto (2002): "Testing Real Business Cycles in an Emerging Economy". Manuscript, University of Chile and Pontificia Universidad Católica de Chile.

Bergoeing, R. and F. Morandé (2002): "Growth, Employment, and Labor Taxes: 1998-2001". Manuscript, University of Chile.

Blanchard, O. and C. Kahn (1980): "The Solution of Linear Difference Models Under Rational Expectations", Econometrica 48, 1305-11.

Braun, J. and M. Braun (1999): "Crecimiento Potencial: El Caso de Chile", Cuadernos de Economía 46 (107).

Brunner, M. and H. Strulik (2002): "Solution of perfect foresight saddlepoint problems: a simple methods and applications", *Journal of Economic Dynamics and Control* 26, p. 737-753.

Budget Office: Estadísticas de las Finanzas Públicas, various issues.

Buiter, W. (1984): "Saddlepoint Problems in Continuous Time Rational Expectations Models: A General Method and Some Macroeconomic Examples", Econometrica 52, 665-80.

Central Bank of Chile: Boletin Mensual, various issues.

_____________________ (1998): Cuentas Nacionales 1998.

Corbo, V. and K. Schmidt-Hebbel (1991): "Public policies and saving in developing countries", Journal of Development Economics 36.

Corbo, V. and J. Tessada (2001): "Growth and Adjustmente in Chile: a look at the 90's". Manuscript, Pontificia Universidad Católica de Chile.

Fair, R. and J. Taylor (1983): "Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectations Models", Econometrica 51, 1169-85.

Giavazzi, F and C. Wyplosz (1984): "The Real Exchange Rate, The Current Account, and The Speed of Adjustment", in C. Bilson and R. Marston (eds.), Exchange Rates: Theory and Policy. Chicago, IL: Chicago University Press.

Hayashi, F. (1982): "Tobin's Marginal q and Average q: A Neoclassical Interpretation", Econometrica 50, 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, 1329-33.

Loayza, N. and F. Gallego (1999): "La Tasa de interés neutral en Chile: Marco conceptual y algunas estimaciones", manuscript, 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.

Lucas, R.E. (1967): "Adjustment Costs and the Theory of Supply", Journal of Political Economy 75, 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, 543-59.

Schmidt-Hebbel, K. (1987): "Foreign Shocks and Macroeconomic Adjustment in Small Open Economies", Ph.D. Dissertation, Massachusetts Institute of Technology, Cambridge, Mass.

Schmidt-Hebbel, K. and L. Servén (1994a): "Fiscal Policy in Classical and Keynesian Open Economies", PRD Working Paper No. 1299, The World Bank, May.

_____________________________ (1994b): "Dynamic Response to External Shocks in Classical and Keynesian Economies", PRD Working Paper No. 1300, The World Bank, May.

______________________________ (1994c): "Successful Structural Adjustment: Consumption and Growth in Chile", manuscript, The World Bank.

______________________________ (1995a): "Dynamic Response to External Shocks in Classical and Keynesian Economies", in D. Currie and D. Vines (eds.): North-South Linkages and International Macroeconomic Policy, Cambridge: Cambridge University Press.

______________________________ (1995b): "Hacia una Menor Inflación en Chile: Contracción Monetaria bajo Expectativas Inflacionarias", in F. Morandé and F. Rosende (eds.): Análisis Empírico de la Inflación, Universidad Católica- ILADES/Georgetown. Santiago, Chile.

______________________________ (1996): "Ajuste Fiscal y Tipo de Cambio Real a la Luz de un Modelo de Expectativas Racionales", in F. Morandé y R. Vergara (eds.).: Análisis Empírico del Tipo de Cambio en Chile, CEP - ILADES/Georgetown. Santiago, Chile.

______________________________ (2002): "Policy Shifts and External Shocks in Chile under Rational Expectations". Manuscript, Central Bank of Chile and World Bank.

Seater, J. (1993): "Ricardian Equivalence", Journal of Economic Literature XXXI, 142-90.

Servén, L. (1995): "Capital Goods Imports, the Real Exchange Rate, and the Current Account", Journal of International Economics.

Servén, L. (1999). "Macroeconomic Uncertainty and Private Investment in Developing Countries: An Empirical Investigation". Manuscript, World Bank.

Tobin, J. (1969): "A General Equilibrium Approach to Monetary Theory", Journal of Money, Credit and Banking 1, 15-29.

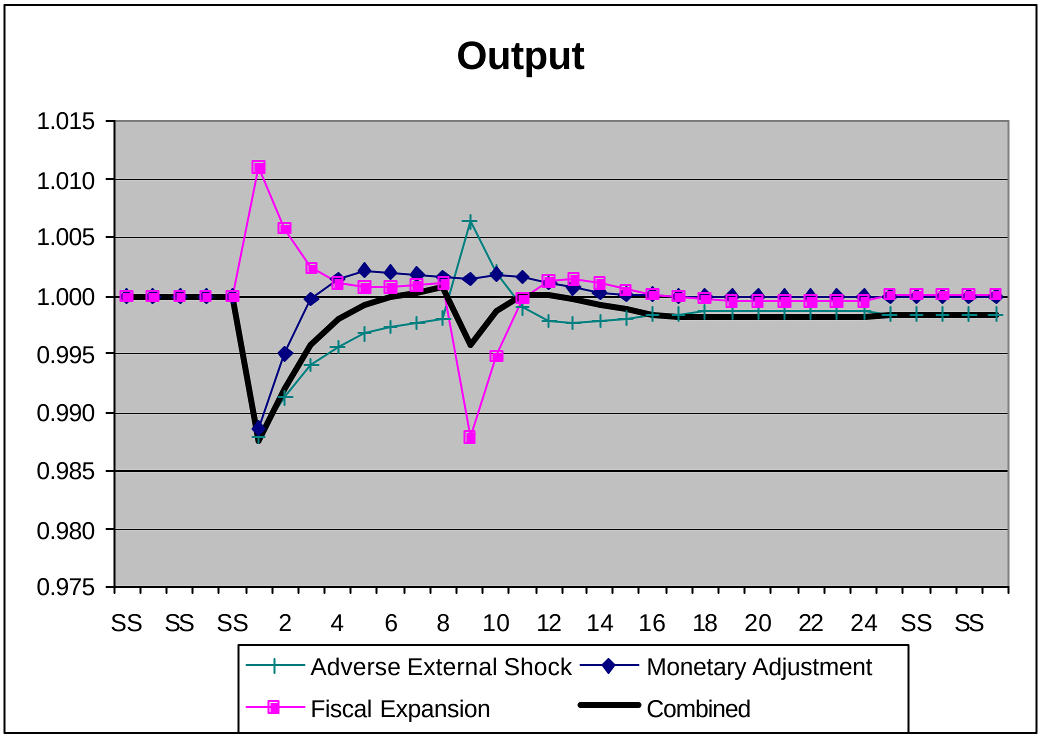
Treadway, A. (1969): "On Rational Entrepreneurial Behaviour and the Demand for Investment", Review of Economic Studies 36, 227-39.

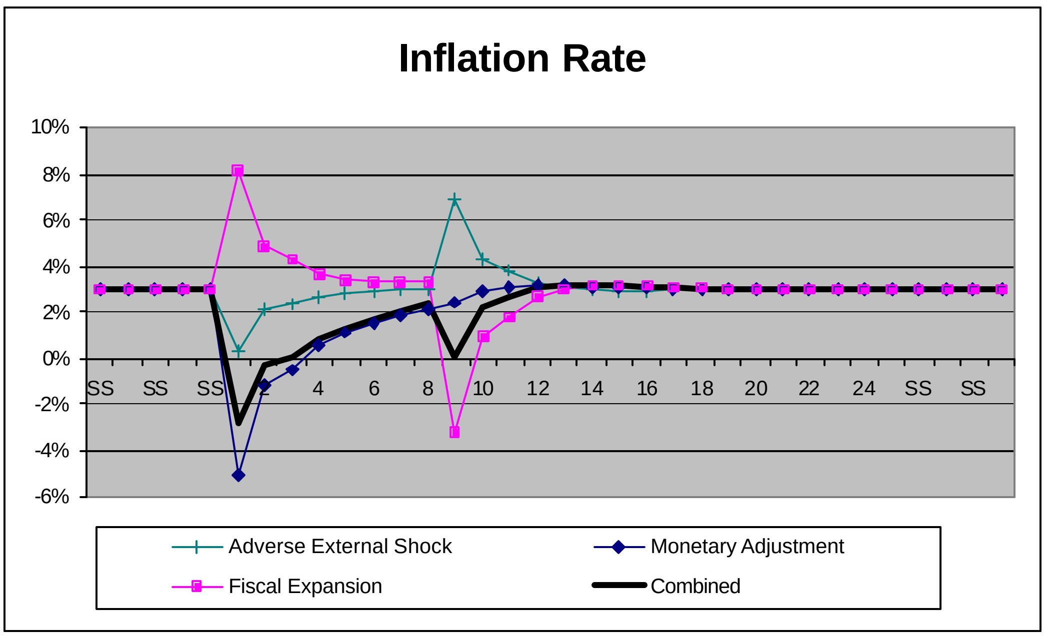
Turnovsky, S. and P. Sen (1991): "Fiscal Policy, Capital Accumulation, and Debt in an Open Economy," Oxford Economic Papers 43, 1-24.

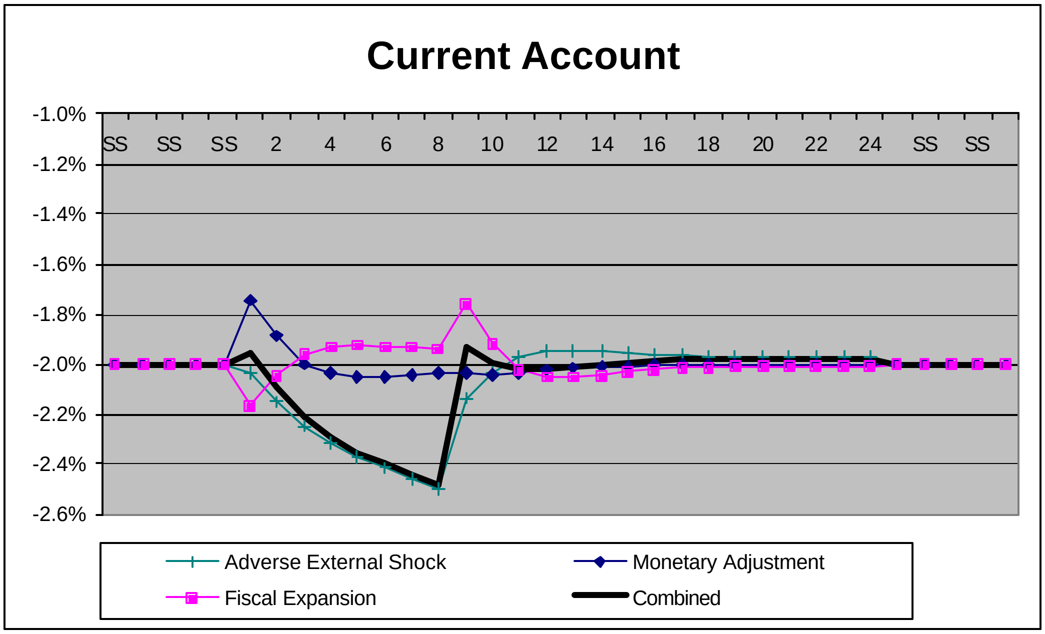
Villagómez, A. (1997): "Private saving, interest rates and liquidity constrians in LDCs: recent evidence", *Applied Economics* 29.

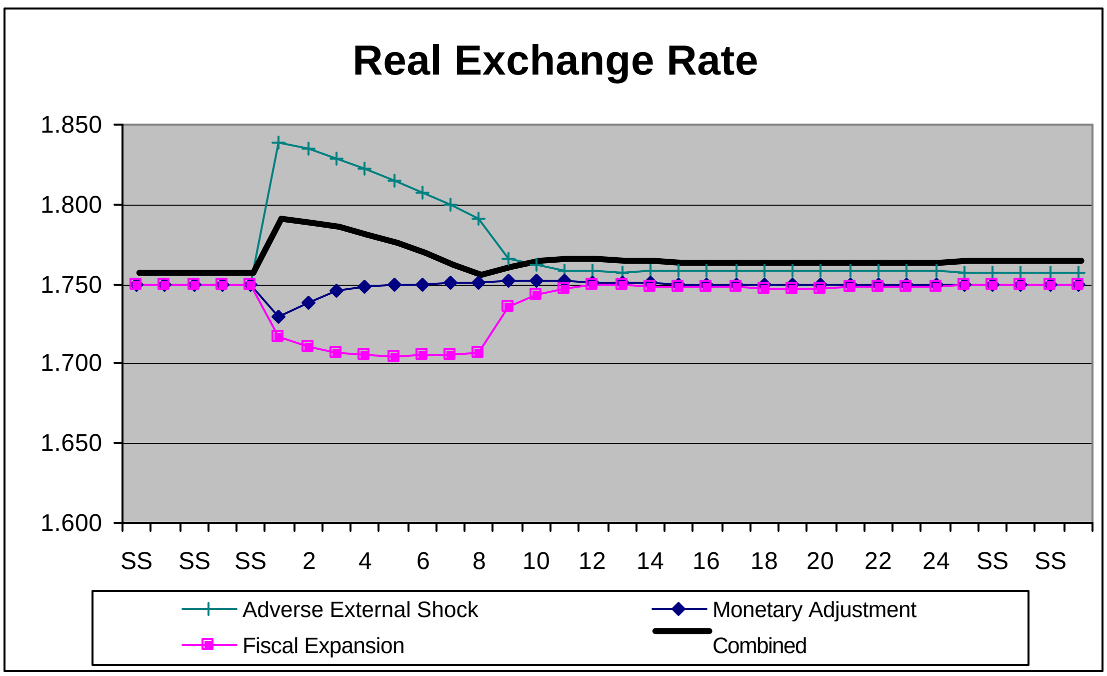
**Figure 1**

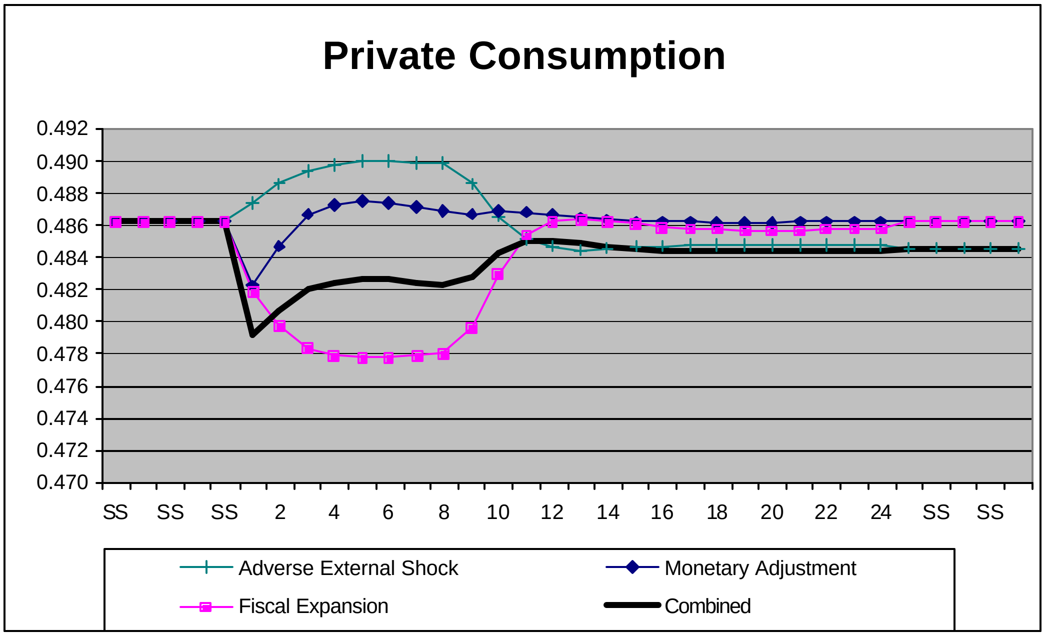
**Dynamic Response of All Variables to All Shocks**

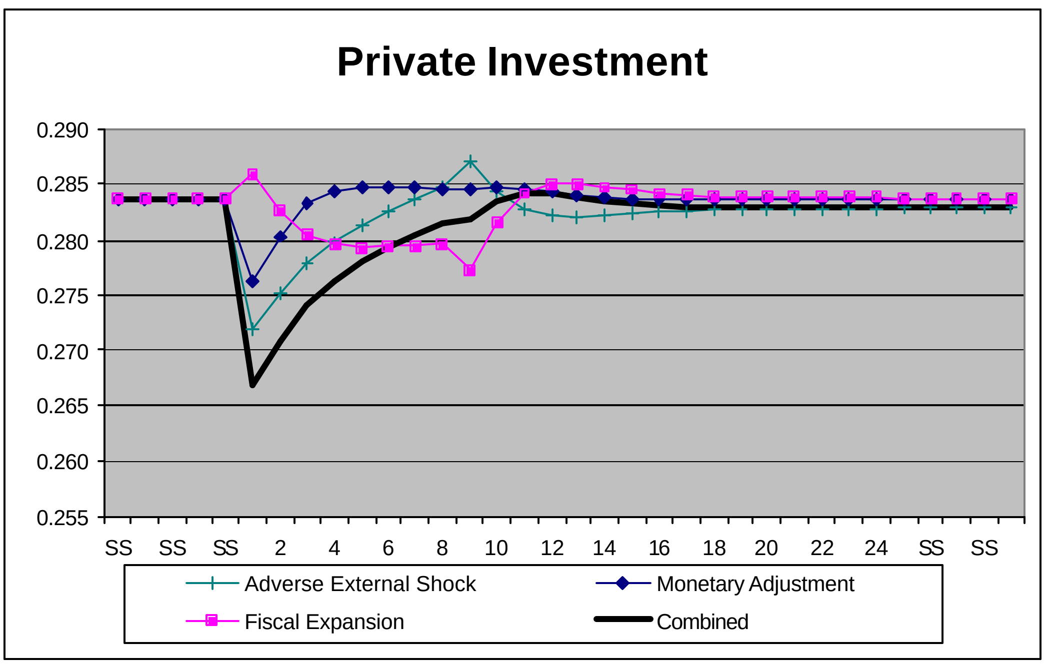


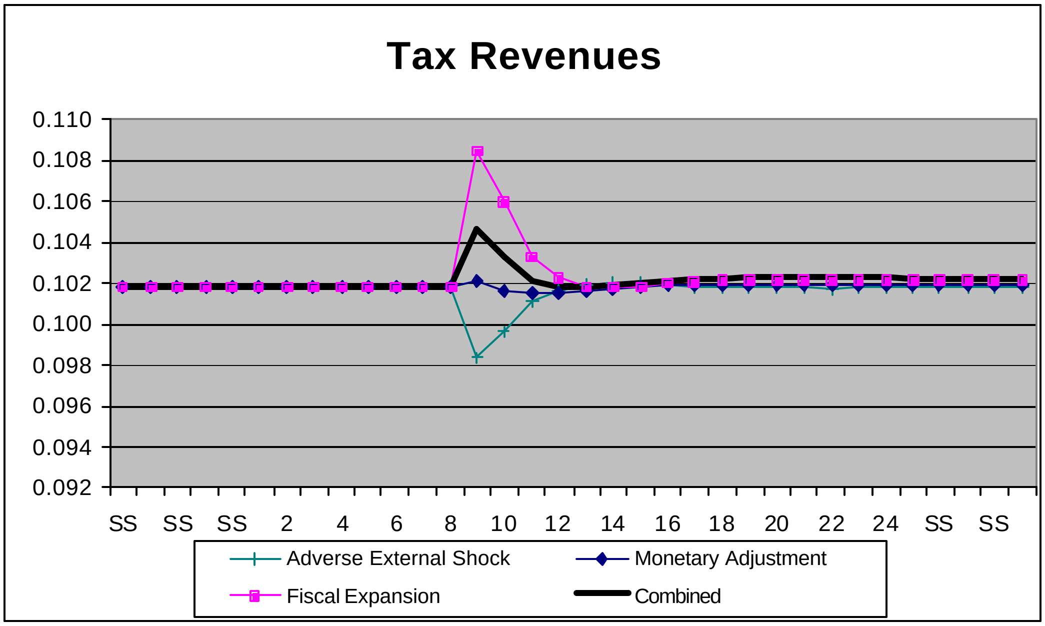



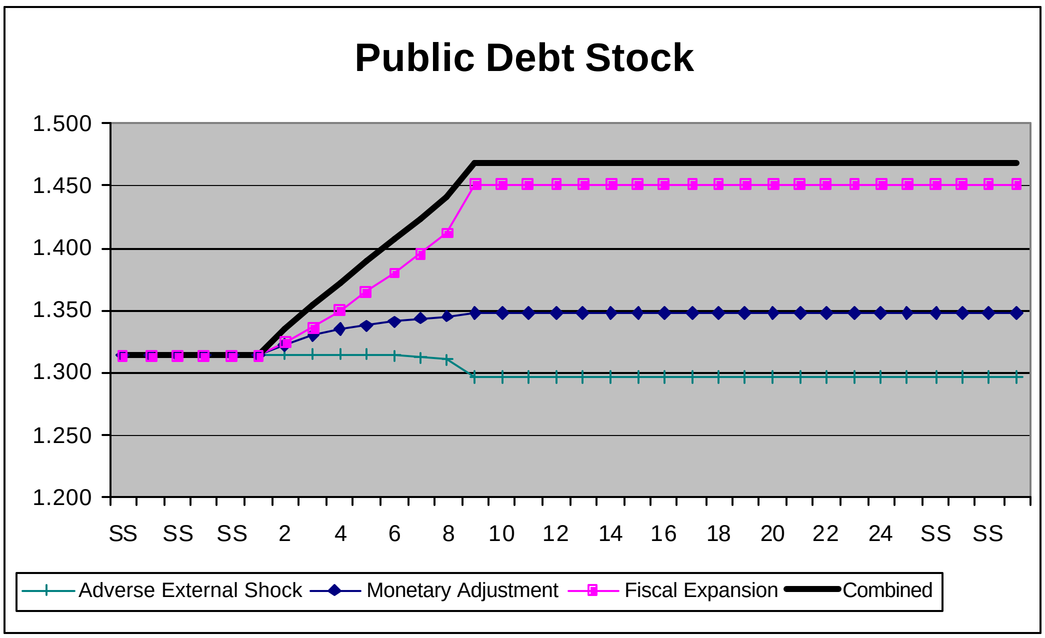

Current Account
-1.0%
-1.2%
-1.4%
-1.6%
-1.8%
-2.0%
-2.2%
-2.4%
-2.6%
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

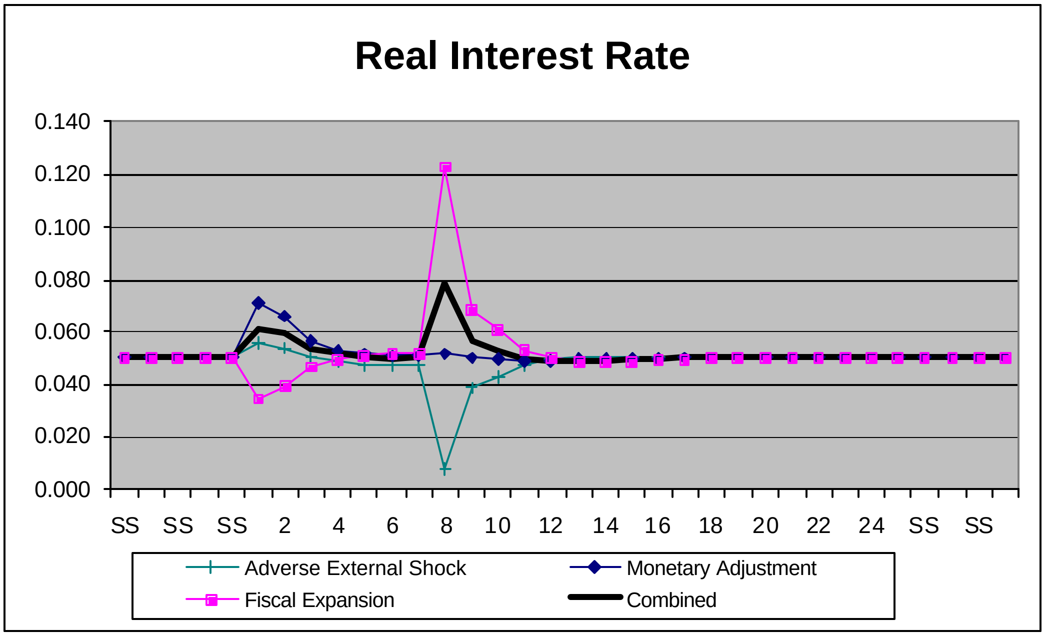

Real Exchange Rate
1.850
1.800
1.750
1.700
1.650
1.600
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

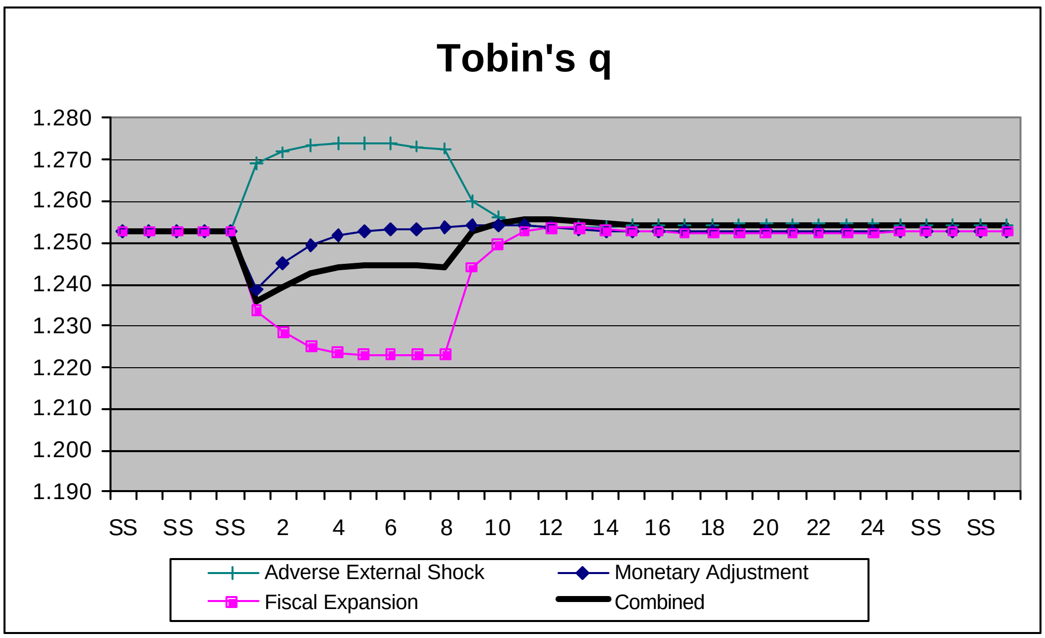

Private Consumption
0.492
0.490
0.488
0.486
0.484
0.482
0.480
0.478
0.476
0.474
0.472
0.470
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

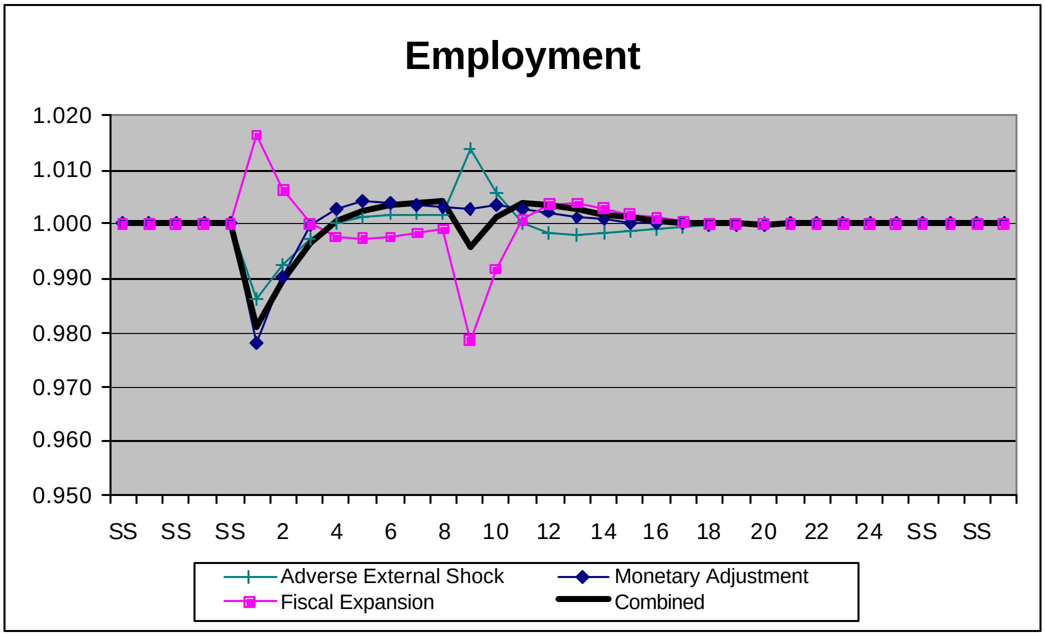

Private Investment
0.290
0.285
0.280
0.275
0.270
0.265
0.260
0.255
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined


Tax Revenues
0.110
0.108
0.106
0.104
0.102
0.100
0.098
0.096
0.094
0.092
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

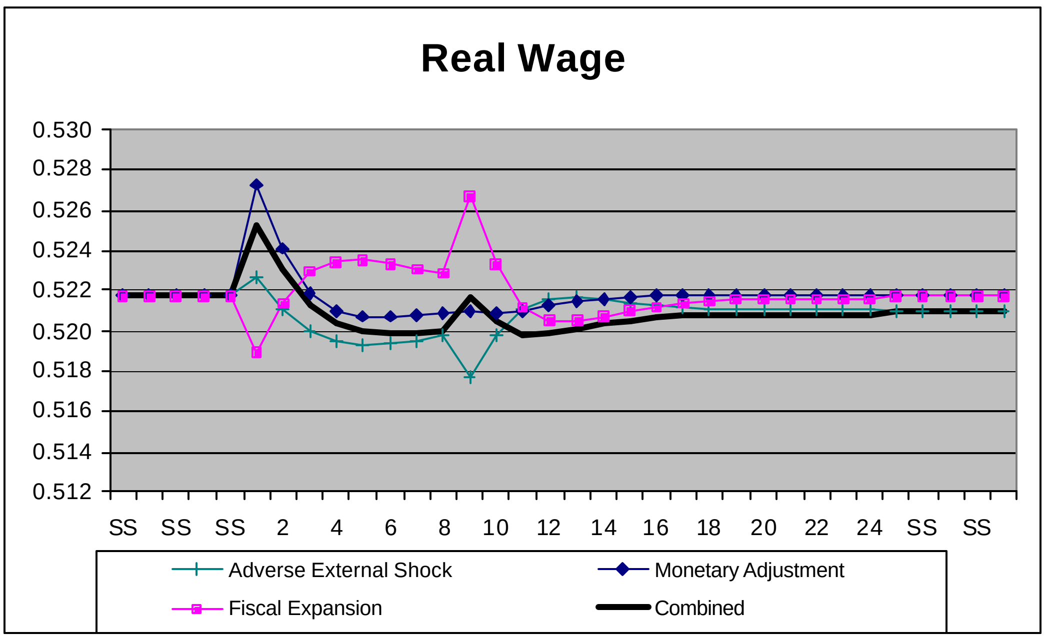
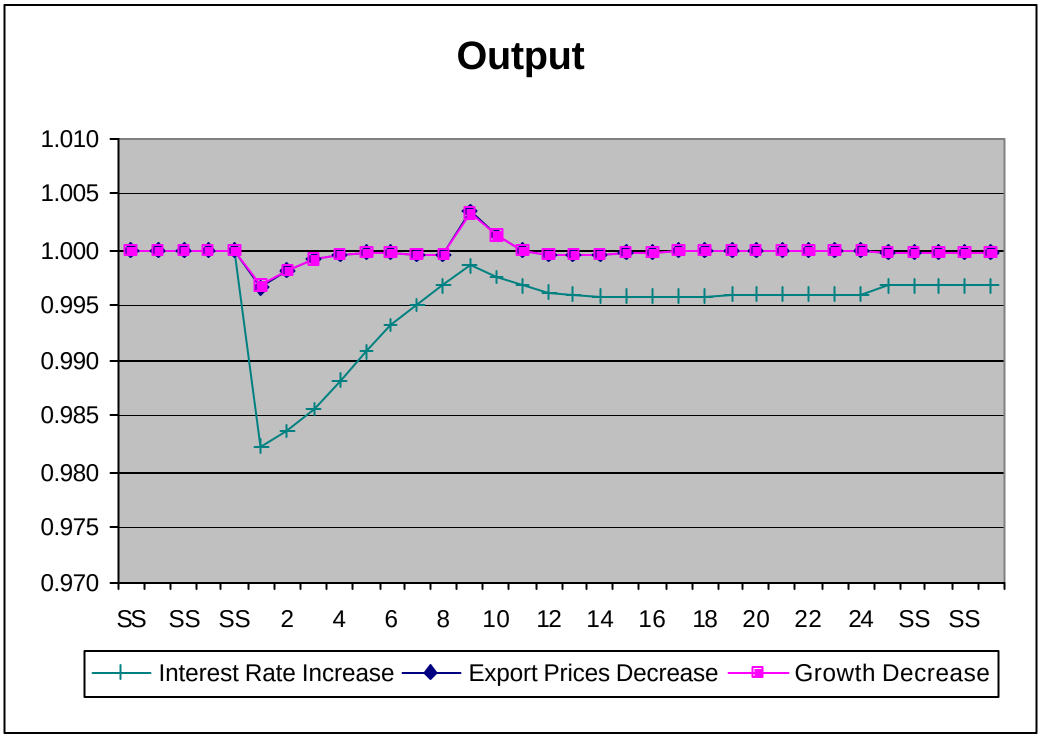
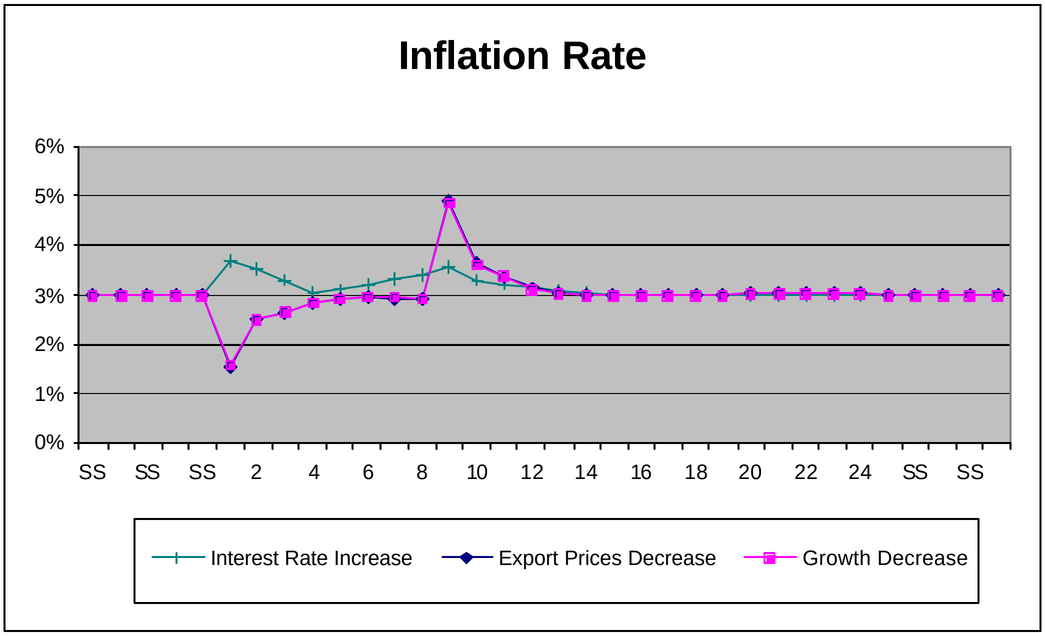
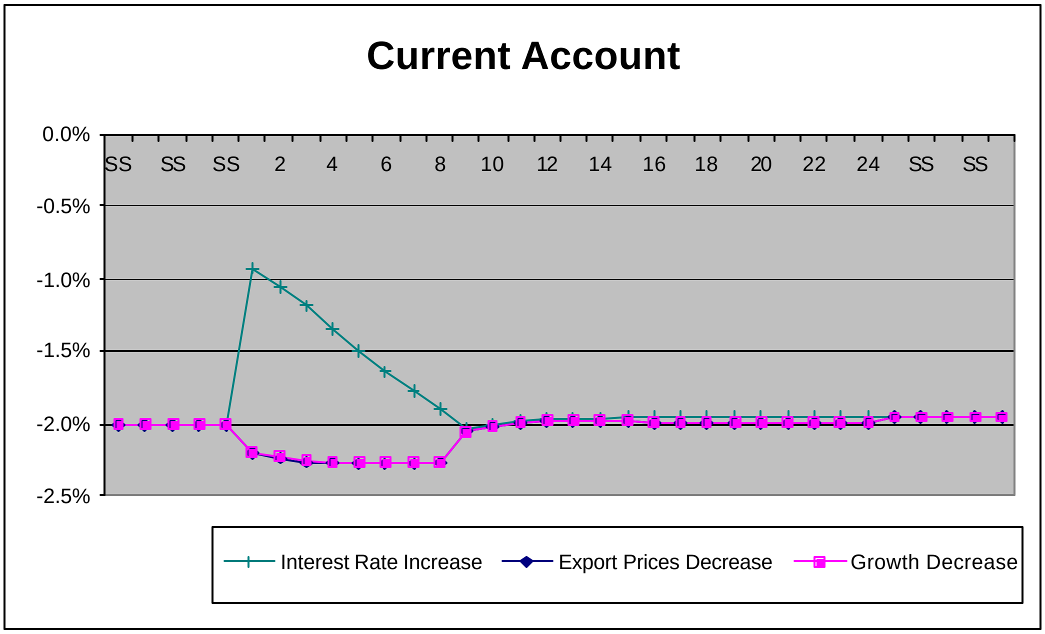
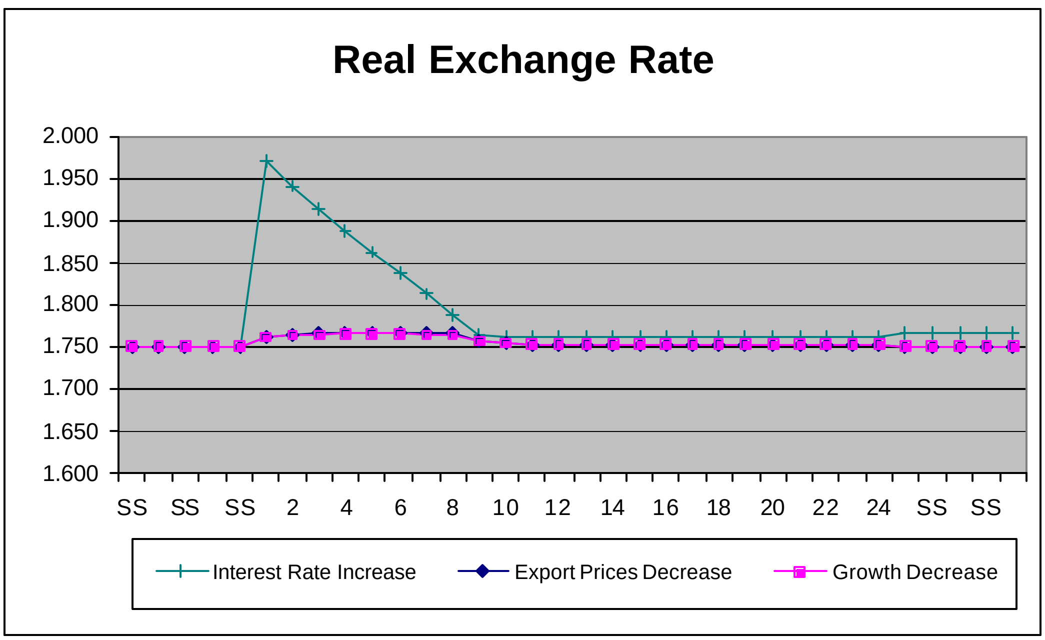

Real Wage
0.530
0.528
0.526
0.524
0.522
0.520
0.518
0.516
0.514
0.512
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Adverse External Shock
Monetary Adjustment
Fiscal Expansion
Combined

**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
Growth Decrease


Real Exchange Rate
2.000
1.950
1.900
1.850
1.800
1.750
1.700
1.650
1.600
SS SS SS 2 4 6 8 10 12 14 16 18 20 22 24 SS SS
Interest Rate Increase
Export Prices Decrease
Growth Decrease

## Appendix: Model Variables and Equations

### A. NOTATION AND DEFINITION OF VARIABLES

---

#### 1. Labor and Employment

| | |
|---|---|
| $N$ | Population growth rate |
| $n$ | Harrod-neutral technical progress rate |
| $g = n + n$ | Growth rate of labor force in efficiency units |
| $L$ | Employment (relative to labor force in efficiency units) |

#### 2. 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. A dot over a variable denotes its right-hand time derivative.

#### 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 |
| $K$ | Physical capital |
| $x$ | Fraction of equity owned by domestic agents |
| $(1-x)$ | Fraction of equity owned by foreigners |

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) |
| $I$ | Installation of new capital |
| $J^N$ | Investment in domestic goods |
| $J^*$ | Investment in foreign goods |

| | |
|---|---|
| $I_G$ | Public investment subsidy |
| $X$ | Exports |
| $M$ | Intermediate imports |

6. Various Rates

| | |
|---|---|
| $i$ | Nominal interest rate on domestic public debt |
| $r$ | Real interest rate on domestic public debt |
| $r^*$ | Real interest rate on foreign assets/liabilities |
| $m$ | Rate of growth of the nominal money stock |

7. Goods Prices

Domestic (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 |
| $p_K$ | Investment deflator |

External (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. Other Prices

Domestic Prices:

| | |
|---|---|
| $q$ | Tobin's marginal $q$ (in units of domestic output) |
| $w$ | Real wage per effective labor unit |
| $W$ | Nominal wage per labor unit |
| $P^C$ | Nominal private consumption deflator |

Real Exchange Rate:

| | |
|---|---|
| $e = (E\, P^F)/P$ | 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 scaled to the labor force in efficiency units.[22]

**Consumers utility function**

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

**Augmented consumption deflator**

(2) $p_Z = [bp_C^{1-s} + (1-b)i^{1-s}]^{\frac{1}{1-s}}$

**Goods consumption deflator**

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

**Consumers budget constrain**

(4)
$$\left(wl + e\, f_P^* - T\right) + xd - \left(g + \dot{P}/P\right)m + (r-g)b + \left(r^* - g\right)e\, b_P^*$$
$$= \left(ep_C^* C^* + \dot{p}_C^N C^N\right) + m + \dot{b} + e\, \dot{b}_P^* + v\, \dot{x}$$

**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) $C = (r-g)\dfrac{a}{p_C} + (1 - l_C)\left[\dfrac{wl - T + ef_p^* - (r-g)h}{p_C}\right] - \dfrac{im}{p_C}$

**Base money market equilibrium**

[22] Labor force in efficiency units is the actual labor force augmented by Harrod-neutral technical progress.

(10) $m = (1 - l_C)C\dfrac{(1-b)}{b}\left(\dfrac{p_c}{i}\right)^s$

**Private national goods consumption demand**

(11) $C^N = hp_C C$

**Private imported goods consumption demand**

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

**Production function**

(13) $Y = a_o \; l^{a_1} K^{a_2} M^{(1-a_1-a_2)}$

**Definition of investment**

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

**Evolution of capital stock**

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

**Definition of dividends**

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

**Labor demand**

(17) $l = a_1 \dfrac{Y}{w}$

**Imported materials demand**

(18) $M = (1 - a_1 - a_2)\dfrac{Y}{ep_M^*}$

**National goods aggregate investment demand**

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

**Imported goods aggregate investment demand**

(20) $J^* = J \; p_K' = (1-g)\dfrac{p_K J}{ep_K^*}$

**Intertemporal Tobin's q**

(21) $q_1 = \int \exp\{-(r+d)t\}\left[a_2 \dfrac{Y}{K} - p_K \dfrac{f}{2}\left(\left(\dfrac{I_1}{K_1}\right)^2 - (g+d)^2\right)\right]dt$

**Myopic Tobin's q**

$$(22)\quad q_2 = \frac{\left[ a_2 \frac{Y}{K} - p_K \frac{f}{2}\left( \left( \frac{I_2}{K_2} \right)^2 - (g+d)^2 \right) \right]}{(r+d)}$$

**Aggregate investment demand**

$$(23)\quad I = \frac{K}{f}\left( \frac{l_I q_1 + (1-l_I)q_2}{p_K} - 1 \right) + (g+d)K$$

**Public sector budget constraint**

$$(24)\quad \left[ T + ef_G^F - G - p_K I_G \right] - (r-g)b + (r^* - g)eb_G^* = e\dot{b}_G^* - \dot{b}^G - m\, m$$

**Export demand for national imports**

$$(25)\quad X = (e\, p_X^*)^{e_1}\, y^{*e_2}$$

**Foreign investors' per-capita holdings of equity**

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

**Total volume of dividends earned by foreign investors**

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

**Balance of payments identity in real (foreign currency)**

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

**Goods market equilibrium**

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

**Nominal wage setting rule**

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

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

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

**Real wage per-effective labor unit**

$$(32)\quad \frac{\dot{w}}{w} = w(l-1) \quad + c\,\frac{1-q}{q}\left(\frac{\ddot{\Omega}}{\Omega} + \frac{\dot{p}_C}{p_C}\right) \; +(c-1)\frac{\dot{P}}{P}$$