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Policy Shifts and External Shocks in Chile under Rational Expectations[*]

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Abstract

This paper develops a macroeconomic general-equilibrium model fully parameterized for the Chilean economy. The model's basic relations can be rigorously derived from intertemporal optimization by rational forward-looking agents. However, it also introduces critical real-world features – such as short-run wage rigidities and liquidity constraints – that generate deviations from the frictionless full-employment equilibrium of the unconstrained neoclassical paradigm. The model is numerically simulated to explore the effects of various permanent and temporary unanticipated policy shifts and foreign shocks. The experiments – a fiscal expansion, a monetary contraction, and adverse international oil price and interest rate shocks – reflect the policy changes and foreign shocks that Chile is likely to face at the turn of the millenium.

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1. INTRODUCTION

At the turn of the millenium, Chile is recovering from its first recession after 15 years of high uninterrupted growth. Sound macroeconomic and structural policies, a healthy banking system, and strong external indicators have led markets and policy makers to project a vigorous output and employment recovery for 2000-2001. Adoption of a conservative fiscal stance by the incoming government would allow a cyclical recovery of the budget balance and a return to fiscal surpluses in the medium term. Cautious monetary policy has allowed Chile to attain low inflation, consistent with a medium-term inflation target in the range of 2-4% per annum. However, the economy's small size, output specialization, and relatively high degree of integration into world goods and capital markets leave it very exposed to international trade and financial shocks. The Asian crisis and international financial turmoil of 1997-99, with their adverse effects on Chile's aggregate performance, provide a case in point.

This paper explores Chile's macroeconomic prospects using a general-equilibrium model fully parameterized for the Chilean economy. The model is firmly based on micro-analytic foundations, and its basic relations can be rigorously derived from intertemporal optimization by forward-looking agents. However, it also introduces critical real-world features – such as short-run wage rigidities and liquidity constraints – 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, the model is simulated to explore the impact, transition, and steady-state effects of shifts in policy and external variables. In essence, this is an application to Chile of earlier work on external shocks and fiscal and monetary policy in representative open economies (Schmidt-Hebbel and Serven, 1994a,b, 1995, 1996). To our knowledge this is the first attempt at constructing and using a dynamic macroeconomic model for a developing country based on optimizing behavior under rational expectations, and possessing well-defined short-term and stationary equilibrium properties.

The paper's plan is as follows. Section 2 spells out the model structure. The model distinguishes among three agents: the domestic private sector, the consolidated public sector, and the external sector. The private sector (households and firms) consists of one group of intertemporally optimizing agents and another of liquidity-constrained (or myopic) agents. The domestic economy produces a single good, while the rest of the world produces both an intermediate input and a final good; the three goods are imperfect substitutes. The one-sector assumption on the supply side implies that the model does not distinguish between the real exchange rate and the terms of trade, and that the latter are affected by domestic policies. Thus, resource allocation effects – say between traded and non-traded goods-producing sectors – are ruled out by our highly aggregated production structure. The asset menu distinguishes among (net) foreign assets, domestic government bonds, domestic equity, and domestic money. Asset markets, as well as the domestic goods market, clear instantaneously.

In contrast, the labor market can display real and/or nominal wage inertia, giving rise to persistent (but temporary) deviations from full employment. [1]

Section 3 provides a brief discussion of the model's 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. Transitory disturbances can therefore have permanent effects, whose magnitude depends on key parameters determining the speed of adjustment of the system.

Section 4 describes the model's parameterization for the Chilean economy. In essence, this entailed econometric estimation of the model's main structural equations, using quarterly data spanning the 1986-1997 period, complemented with calibration based on macroeconomic and financial magnitudes observed for the model's base quarter (1997-II).

Section 5 reports simulation results for various permanent and temporary unanticipated policy changes and foreign shocks. First we consider a fiscal expansion that raises government expenditure by 3 percentage points of GDP – consistent with proposals floated in the political arena – under different budget financing options. Then we report the results of a monetary contraction aimed at reducing inflation from 3% to 1.5% per annum. Next we simulate the economy's response to an international oil shock, similar in magnitude to the oil price increase observed in 1999. Finally we analyze the dynamics of a temporary increase in world interest rates by 100 basis points.

Section 6 draws brief conclusions and proposes further extensions.

[1] If borrowing-constrained agents and wage stickiness are ruled out, the analytical framework boils down to the neoclassical model analyzed by Serven (1995).

2. THE MODEL

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.

Domestic private agents hold four assets: money, domestic debt issued by the consolidated public sector (i.e., the government plus the central bank), foreign assets, and equity claims on the domestic capital stock. The public sector also holds foreign assets.[2] Money allows for inflationary finance of budget deficits. There are no restrictions to capital mobility and, in the absence of risk and uncertainty, all non-monetary assets are assumed to be perfect substitutes. Hence anticipated asset returns satisfy the corresponding uncovered parity conditions. Foreigners hold domestic equity but not domestic public debt.

Both goods and asset markets clear continuously. In contrast, the labor market does not clear instantaneously due to real and/or nominal wage rigidity. Wages are indexed to current and past consumer price inflation, 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 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 unconstrained, intertemporally-optimizing firms and consumers, and Keynesian liquidity-constrained firms and households, along with wage inflexibility.[3] Following the standard theory of investment under convex adjustment costs (Lucas, 1967, Treadway, 1969), unconstrained 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 installation cost (Hayashi, 1982). Unconstrained consumers gear consumption to their permanent income, as derived from intertemporal utility maximization in Ramsey fashion (Ramsey, 1928). In contrast, constrained firms (consumers) gear their investment (consumption) expenditure to their current profits (disposable income).

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[2] Foreign assets held by the domestic private and public sectors are net assets (equal to gross foreign reserves plus other gross foreign assets less gross foreign liabilities) and therefore can have either sign.

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

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 introduced next, starting with sector flow budget constraints and market equilibrium conditions. Behavioral equations for firms, consumers, the public sector, and the external sector follow. Variable notation and definitions are summarized in Table 2.1. All stock and flow variables other than prices and interest rates are scaled to the labor force in efficiency units.[4] The model is written in continuous time. Dots over variables denote right-hand time derivatives.

2.1 Budget Constraints

There are three basic agents in the model: the consolidated public sector, the domestic private sector, and the external sector. The first includes the non-financial and financial (central bank) public sectors, the second aggregates private firms and consumers, and the third adds foreign investors, creditors, and trade partners. While some further disaggregation between firms and consumers is implicit below, we do not need it at this stage. The budget constraint for each of the three types of agents is written equating above-the-line current account surpluses with below-the-line increases in net real asset holdings per effective labor force unit. Therefore above-the-line interest flows are adjusted for the changes in real asset holdings per effective labor unit due to growth in effective labor (g) and inflation.

Public revenue includes conventional taxes, unrequited foreign transfers, growth-adjusted interest earnings from public assets held abroad, and seigniorage. The latter equals the sum of the inflation tax and the monetary revenue due to the growth of labor in efficiency units. Public expenditure includes public consumption, which is assumed to fall entirely on domestic goods, an investment subsidy paid to domestic firms (intended to replicate the effects of public capital expenditures),[5] and interest paid on the outstanding stock of domestic public debt. Revenues include direct taxes, interest on net foreign assets of the public sector, and the inflation tax. The resulting adjusted operational surplus of the consolidated public sector finances acquisition of foreign assets and retirement of base money and domestic debt:

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[4] Labor force in efficiency units is the actual labor force augmented by Harrod-neutral technical progress (see Table 1).

[5] Public sector ownership of the capital stock could be mimicked by introducing a tax on profits proportional to the cumulative volume of public investment. For simplicity, we do not pursue this option here. Also, we are implicitly assuming that public investment is a perfect substitute for private investment.

TABLE 2.1: NOTATION AND DEFINITION OF VARIABLES

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1. Labor and Employment

L	Absolute employment
$LF = LF_0 \exp(pg\ t)$	Absolute labor force
LF_0	Base-period absolute labor force
$N = L \exp(tg\ t)$	Absolute employment in efficiency units
$NF = LF \exp(tg\ t) = LF_0 \exp(g\ t)$	Absolute labor force in efficiency units
Pg	Population growth rate
Tg	Harrod-neutral technical progress rate
$g = pg + tg$	Growth rate of absolute labor force in efficiency units
$l = L/LF = N/NF$	Employment (relative to labor force)
Ld	Labor demand (relative to labor force)

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
Op	Operational profits
Td	Taxes
Yd	Private disposable income
$Prem$	Profit remittances abroad

External:

$ftrg$	Foreign transfers to the public sector
$Ftrp$	Foreign transfers to the private sector
Yf	Foreign income
Dfi	Direct foreign investment

TABLE 2.1 (Cont.)

4. Stocks

Domestic:

A	Non-human wealth of the private sector
Bg	Domestic debt of the public sector
Fe	Stock of domestic equity (shares in domestic firms) held by foreigners
Hb	Domestic base money
Hu	Human wealth of the private sector
K	Physical capital
Pvig	Present value of government investment subsidy
Pvihb	Present value of cost of holding money

External:

Fbg	Foreign assets held by the public sector
Fbp	Foreign assets held by the private sector

5. Goods Flows

y	Gross output of final goods
cp	Private aggregate consumption
cmp	Private imported-goods consumption
cnp	Private national-goods consumption
cng	Public national-goods consumption
inv	Gross domestic investment
in	Private national-goods investment
im	Private imported-goods investment
ig	Public investment subsidy
iac	Investment adjustment costs
x	Exports
mr	Intermediate imports

6. Various Rates

Domestic (External) Rates:

i (if)	Nominal interest rate on public debt (foreign assets/liabilities)
r (rf)	Real interest rate on public debt (foreign assets/liabilities)
i-r (if-rf)	Anticipated domestic (external) inflation rate
Nmg	Rate of growth of the nominal money stock

TABLE 2.1 (Cont.)

7. Goods Prices

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

pc	Private aggregate consumption deflator
pi	Aggregate investment deflator

External (all relative to the price of the foreign final good):

pcmp	Private imported-goods consumption deflator
pim	Imported-goods investment deflator
pmr	Intermediate imports deflator
px	Deflator of export-competing goods

8. Other Prices

Domestic Prices:

q	Real equity price (Tobin's q) in units of domestic output
v	Real wage per effective labor unit
W	Nominal wage per labor unit
PC	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
P^*	Nominal external deflator (foreign price level)

(1) $$\left[td + eftrg - cng - pi\ ig\right] - \left(r - g\right)bg + \left(g + \dot{P}/P\right)hb + e\left(rf - g\right)fbg = e\dot{fbg} - \dot{bg} - \dot{hb}$$

The external sector budget constraint -- the balance of payments identity -- reflects trade in goods and non-factor services, unrequited transfer payments to both the public and private sectors, loans from both domestic sectors, and foreign investment flows toward the private sector as well as profit remittances from the latter. Therefore, the external adjusted current account surplus and its financing, for convenience written in constant-price foreign currency units, is the following:

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

The private sector budget constraint reflects the assumption that private firms do all production and make all investment decisions, own the economy's entire capital stock, and benefit from a public investment subsidy. Firm ownership is split between domestic consumers and foreigners. The consolidated domestic private sector (firms and consumers) budget constraint is given by:

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

2.2 Market Equilibrium Conditions

Equilibrium conditions are specified for goods, asset, and labor markets. Continuous market clearing at equilibrium goods prices and asset returns contrasts with sluggish wage adjustment observed in the labor market.

Goods Markets

The single good produced domestically can be used for consumption and investment at home, or sold abroad. Thus there is no distinction between production for domestic and export markets. The domestic good is an imperfect substitute for the foreign final good. However, the economy is small in its import markets by assumption. Equilibrium in the market for domestic goods can be expressed:[6]

(4) $$y = cnp + cng + in + pi\ iac + x$$

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[6] Note that gross output y differs from conventional national-accounts value added or GDP for two reasons: y is defined as gross of the value of intermediate imports (*e pmr mr* in our notation) and gross of the value of investment adjustment costs (*pi iac*).

Under continuous market clearing, this can be interpreted as an implicit equation for the real exchange rate.

Asset Markets

Asset market equilibrium conditions are specified for base money, domestic bonds, and equity claims on the fixed capital stock. They reflect three features: perfect capital mobility, external interest rate determination in international markets (the small country assumption for financial markets), and absence of uncertainty (no risk premia). Imperfect substitutability between base money and other assets is reflected by a conventional transactions-based demand for base money. Domestic and foreign bonds, as well as equity, are assumed perfect substitutes; hence their anticipated rates of return must be equalized at each point in time.

Base money market equilibrium assumes standard Cagan-type money demand (Cagan, 1956):[7]

(5) $$hb = f_1 \; y^{f_2} \; \exp(f_3 \, i)$$

where $f_1, f_2 \geq 0, f_3 \leq 0.$

Arbitrage between domestic and foreign bonds leads to the uncovered interest parity condition

(6) $$r = rf + \frac{\dot{e}}{e}$$

Similarly, arbitrage between equity and domestic public bonds is reflected by the following market equilibrium condition for equity prices (Tobin's q):

(7) $$\dot{q} = r\,q - \frac{d}{k}$$

Finally, the nominal interest rate is defined by the standard Fisher equation:

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

[7] One way to rationalize (5) would be to assume that individuals' utility function is additively separable in consumption and the transaction services of money, with the latter increasing with real money and decreasing with the overall volume of transactions as measured by real output. This kind of formulation rules out distortionary effects of inflationary taxation, which in our framework is a convenient feature given that taxes are likewise assumed non-distortionary.

Labor Market

In the general case, wage rigidity (nominal and/or real) prevents the labor market from clearing instantaneously. We follow the conventional assumption that employment is determined by labor demand:

(9) $l = ld$

The labor market follows a wage-setting rule, which states that nominal wages are indexed to current and lagged consumer price inflation (with weights θ and 1-θ, respectively) and also respond to current labor market conditions (with an elasticity ω with regard to employment). Anticipating the simulations, the nominal wage equation is written in discrete-time form:

$$(10) \quad W = \exp(tg)\, l^{v} \left(\frac{PC}{PC_{-1}}\right)^{q} \left(\frac{PC_{-1}}{PC_{-2}}\right)^{1-q} W_{-1}$$

where $\omega \geq 0$, $0 \leq \theta \leq 1$.

Using the relation between the nominal wage and the real (product) wage per effective labor unit, that we denote v, $W/P = exp\,(tg\,t)\,v$, we obtain, after some manipulations, the following real wage equation:

$$(10') \quad v = l^{w}\ [pc/pc_{-1}]^{q}\ [pc_{-1}/pc_{-2}]^{1-q}\ [(P_{-1}/P_{-2})/(P/P_{-1})]^{1-q}\ v_{-1}.$$

This wage rule encompasses several interesting cases. First, when ω tends to infinity, it collapses into the neoclassical full-employment condition (l = 1). Second, for finite ω and θ = 1, it represents the case of real wage resistance. In turn, with finite ω and θ < 1, wages display nominal inertia.

Finally, ex-post inflation can be defined from the relation between real and nominal balances per effective labor unit:[8]

$$\frac{P}{P_{-1}} = \frac{hb_{-1}}{hb}\frac{(1+nmg_{-1})}{(1+g)}$$

2.3 Firms

Technology is summarized by a Cobb-Douglas production function for gross output with Harrod-neutral technical progress and quadratic adjustment costs for investment. The investment technology combines domestic and imported final goods according to a Cobb-Douglas specification, which allows for two-stage budgeting.[9]

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[8] Notice that, from (8), i-r is a measure of anticipated one-period ahead inflation. Because of the rational expectations assumption, it will equal actual (one-period ahead) inflation except at times of ‘news’ about the current and/or future paths of the exogenous variables.

[9] Wildasin (1984) provides exact conditions under which the investment technology gives rise to a two-stage

There are two groups of firms. The first group is not subject to liquidity constraints and determines its investment according to the maximization of market value -- i.e., the present value of future dividends -- subject to convex adjustment costs. Investment is financed by equity sold to domestic and foreign agents and through the public investment subsidy, which takes the form of a lump-sum transfer of capital goods to private firms. However, as long as the subsidy is infra-marginal, it has no effect on investment levels of unconstrained firms.

The second group of firms is restricted in its access to financial markets and gears its current investment to current profits <u>inclusive</u> of the public investment subsidy. Thus, for these constrained firms changes in the subsidy will affect fixed investment levels.

The production technology for gross output is described by a Cobb-Douglas production function, which allows for substitution between value added (capital and labor) and intermediate imports:

(11) $$y = a_o \, ld^{a_1} k^{a_2} mr^{(1-a_1-a_2)}$$

where $a_0 \geq 0, 0 \leq a_1, a_2 \leq 1$.

Investment adjustment costs are defined by:

(12) $$iac = \mu \left[\frac{(inv - (g+d)k)^2}{k} \right]$$

where $\mu > 0$. Adjustment costs vanish in steady-state equilibrium -- i.e., when gross investment per unit of effective labor is just sufficient to maintain the capital/effective labor ratio. The evolution of the latter is described by:

(13) $$\dot{k} = inv - (g + d)k$$

Market value maximization for unconstrained firms, as well as current profit maximization for constrained firms, yields the standard marginal productivity conditions for variable inputs (labor and imported materials):[10]

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investment decision. See also Hayashi and Inoue (1991) for a recent generalization with empirical applications. The specification in the text is a particular case of that used in Serven (1995, 1999).

[10] The derivation of these conditions, as well as of the unconstrained component of investment in equation (16) below, follows the standard maximization of the value of the firm, subject to equations (11) - (13). The details are not presented here for brevity.

(14) $ld = a_1 v^{-1} y$

(15) $mr = (1 - a_1 - a_2)(e\, pmr)^{-1} y$

Investment demand is, as described above, a combination of the market-value maximizing investment rule of unconstrained firms and the profit-constrained investment of restricted firms:[11]

(16) $$inv = b_1\left[\frac{k}{2m}\left[\frac{q}{pi} - \frac{pvig}{pi\, k} - 1\right] + (g+d)k\right] + (1-b_1)\left[b_2 \frac{op}{pi} + ig\right]$$

where b_1 is the share of unconstrained firms and b_2 is the marginal propensity of liquidity-constrained firms to invest out of operational profits; $0 \leq b_1,\ b_2 \leq 1$.

The present value of the public investment subsidy is implicitly defined by the dynamic equation:

(17) $\dot{pvig} = (r-g)\, pvig - pi\ ig$

Aggregate operational profits, which determine investment by liquidity-constrained firms, are:

(18) $op = y - v\, l - e\, pmr\, mr$

and dividends are the sum of operational profits, net of investment expenditure, the investment subsidy, and the proceeds of new issues of equity:

(19) $d = op - pi\ inv - pi\ iac + pi\ ig + q(\dot{k} + g\,\mathrm{k})$

After determining aggregate investment according to equation (16), the second-stage investment decision involves allocating investment expenditure between domestic goods and imports, according to a Cobb-Douglas aggregation that renders constant expenditure shares:

[11] Unconstrained investment (the content of the first large right-hand side parenthesis in eq. 16 above) is geared to Tobin's marginal q, i.e., average q minus the present value of the public investment subsidy per unit of capital (see Hayashi (1982) for general reasons causing marginal and average q to diverge). This reflects the fact that optimal investment is determined by the addition to future dividends of the marginal unit of capital, which excludes the subsidy due to its lump-sum nature. In contrast, the average value of existing capital, i.e., the present value of the dividends associated with an installed unit of capital, must include the subsidy. In turn, investment by constrained firms (the last term on the right side of (16)) rises one-for-one with the investment subsidy.

$$(20) \qquad in = g\,pi\,inv$$

$$(21) \qquad im = (1-g)\left[\frac{pi}{e\;pim}\right]inv$$

where g is the share of national-goods investment in aggregate investment expenditure, satisfying $0 \le g \le 1$. Therefore the aggregate investment deflator is a Cobb-Douglas average of national-goods investment prices and imported investment-goods prices:

$$(22) \qquad pi = (e\;pim)^{(1-g)}$$

2.4 Consumers

Consumer preferences also allow two-stage budgeting, distinguishing between intertemporal aggregate consumption decisions and intratemporal consumption composition choices. Intertemporal preferences reflect unit intertemporal elasticity of substitution (i.e., logarithmic intertemporal utility); intratemporal preferences also display unit elasticity of substitution between domestic and imported goods.

Private sector non-human wealth includes four assets: base money, domestic public bonds, foreign assets, and equity claims on the domestic capital stock. Forward-looking consumers fully discount from their wealth the costs of holding money balances:

$$(23) \qquad a = hb + bg + e\,fbp + q(k-fe) - pvihb$$

where the present value of money holding costs *pvihb* is just the discounted sum of interest payments foregone on money balances, and is implicitly defined by the dynamic equation:

$$(24) \qquad \dot{pvihb} = (r-g)\,pvihb - i\,hb$$

Human wealth is the present value of future labor income, net of taxes, and inclusive of current external transfers.[12] Under the assumption that individuals can freely borrow against their future labor income at the going real interest rate, the path of human wealth is characterized by:

$$(25) \qquad \dot{hu} = (r-g)\;hu + [\,td - v1 - e\,ftrp\,]$$

[12] For expositional convenience, all taxes and transfers have been lumped together in the human capital flow equation. Since both accrue in lump-sum fashion, this is of no consequence for the model's properties.

Consumption of non-liquidity constrained consumers is derived from standard maximization of intertemporal utility over an infinite horizon, subject to the intertemporal budget constraint equivalent of the private sector flow constraint in equation (3) -- which is exactly consistent with wealth definitions in equations (23) - (25).[13] Unconstrained consumers are of course Ricardian, internalizing the government's intertemporal budget constraint by anticipating the entire stream of current and future tax payments. Because these consumers face the same discount rate as the government,[14] and inflation taxation is non-distortionary, they are indifferent among tax, debt, or money financing. Thus government debt, although included in equation (23), ultimately "is not wealth" (Barro, 1974).

Total private consumption demand is an aggregate of consumption by unconstrained and constrained consumers. The latter hold no assets and consume their current net labor income:[15]

$$(26) \qquad cp = l_1 \left(l_2 - g \right) \frac{a + hu}{pc} + \left(1 - l_1 \right) \left[\frac{hd}{pc} + \left(l_2 - g \right) \frac{a}{pc} \right]$$

where $0 \leq l_1 \leq 1$ is the share of unconstrained consumers, and l_2 is the subjective discount rate. Note that consumption by constrained consumers is the sum of their disposable income plus their permanent income derived from their non-human wealth.

Disposable income is defined by:

$$(27) \qquad yd = v\, l + e\, ftrp - td$$

After determining aggregate private consumption levels according to equation (26), the second-stage private consumption decision allocates it between domestic goods and imports, according to Cobb-Douglas intratemporal preferences:

$$(28) \qquad cnp = h\ pc\ cp$$

$$(29) \qquad cmp = \left(1 - h \right) \left[\frac{pc}{e\ pcmp} \right] cp$$

[13] As before, the analytical derivations are standard and can be omitted. Solving the maximization problem yields the standard result that private consumption of unconstrained households is equal to the subjective discount rate (net of effective labor growth) times total (human and non-human) wealth.

[14] The assumption of equal discount rates is crucial for Ricardian equivalence to hold. Higher private sector discount rates, whether due to finite lifetimes (reflected by a given probability of death, as in Blanchard, 1985) or to a risk premium on consumers' debt relative to the borrowing cost of the government (e.g., McKibbin and Sachs, 1989) would cause Ricardian equivalence to break down.

[15] For discussion and empirical analyses of the implications of liquidity constraints for consumer behavior -- as well as for Ricardian equivalence -- see, for example, Hayashi (1985), Hubbard and Judd (1986), Bernheim (1987),Seater (1993), and Lopez, Schmidt-Hebbel and Serven (2000)

where $0 \leq h \leq 1$ is the share of national goods in aggregate private consumption expenditure. Therefore the aggregate private consumption deflator is a Cobb-Douglas index of national-goods prices and imported consumption goods prices:

$$(30) \qquad pc = (e\ pcmp)^{(1\text{-}h)}$$

2.5 Government

The public sector determines policy exogenously, thus public consumption and investment expenditures are given. To finance its activity, the public sector can choose among taxes, money, domestic debt, or external borrowing (or any combination of them).

The accumulation of per capita real balances can be characterized as:

$$(31) \qquad \dot{hb} = \left[nmg - \left(\dot{P}/P \right) - g \right] hb$$

where it is worth noting that the rate of nominal money growth *nmg* will be endogenous under money finance of the deficit and exogenous otherwise.

2.6 Foreigners

The demand by foreigners for the domestically produced good is given by a conventional export function, which embodies imperfect substitution between the national and the foreign final good and a normal relation to foreign income:

$$(32) \qquad x = r_1 \ (e\ px)^{r_2}\ yf^{\,r_3} x_{-1}^{r_4}$$

where $r_1, r_2, r_3, r_4 \geq 0$.

Foreigners can also hold domestic equity. Rather than going into the details of their portfolio allocation problem, we assume that at every instant foreign investors use *dfi* units of foreign currency (in real per capita terms) to purchase domestic shares, whose price in terms of domestic output is *q*. Hence foreign investors' per-capita holdings of equity evolve according to the equation:

$$(33) \qquad \dot{fe} = \frac{e\ dfi}{q} - g\ fe$$

In turn, profit repatriation equals the total volume of dividends earned by foreign investors, which is given by the product of the share of foreign-held equity and total dividends:

$$(34) \qquad prem = \frac{fe}{k}\ d$$

3. THE STEADY STATE, DYNAMICS, AND MODEL SOLUTION

3.1 The 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[16], 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 can be 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.

In turn, real wealth accumulation can cease only when 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.[17] 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. In other words, we are left only with the goods market equilibrium condition to determine both long-run wealth and the real exchange rate -- an obviously impossible task.

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 therefore all other variables related to them) depend not only on the long-run values of the

[16] 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.

[17] Recall that, because of perfect asset substitutability, the per-capita real return on wealth is just equal to the real interest rate (net of effective labor force growth) times the wealth stock. In turn, steady-state consumption equals the rate of time preference (also net of effective labor force growth) times the wealth stock.

exogenous variables, but also on the particular trajectory followed by the economy. In other words, the model exhibits hysteresis. As noted by Giavazzi and Wyplosz (1984), this follows from 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.

An important implication of the model's hysteresis property is that transitory disturbances have long-run effects. For the case of fiscal policy, this has been highlighted by Turnovsky and Sen (1991).[18] In our framework even transitory monetary disturbances can have permanent real effects: if some consumers are liquidity constrained (or myopic), a transitory increase in inflationary taxation matched by a reduction in direct taxes raises disposable income and consumption, leading to reduced wealth accumulation and eventually causing a fall in long-run wealth and a permanent real depreciation.[19]

The fact that production requires the use of imported inputs (intermediates and capital goods) has important consequences for the economy's long-run properties: across steady states real output (and also the capital stock and the real wage) is inversely related to the real exchange rate. The reason is that a real depreciation raises the real cost of imported inputs and therefore reduces the profitability of production.

3.2 Dynamics, Stability, and Model Solution

The model's dynamics combine predetermined variables (i.e., asset stocks) subject to initial conditions, and 'jumping' variables (i.e., Tobin's q, the real exchange rate, real money balances, human wealth, the present value of the investment subsidy, and the present value of the cost of holding money). 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. The necessary and sufficient conditions for the existence and uniqueness of such initial values are known for the case of linear models,[20] but not for nonlinear systems such as the one at hand.[21] While a

[18] Turnovsky and Sen (1991) use a non-monetary model with intertemporally optimizing consumers in which transitory fiscal disturbances have long-run effects. Their result depends critically on the endogeneity of labor supply in their framework, 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 the constancy of full employment across steady states. This issue is investigated analytically in Serven (1995).

[19] Without liquidity constraints 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 Serven (1994c).

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

[21] 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.

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. Two leading examples are the "multiple shooting" method proposed by Lipton et al. (1982), and the "extended path" algorithm of Fair and Taylor (1983). For the simulations below, 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,[22] at which time the process stops. In practice, the length of the simulation horizon required for this procedure to converge 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 adjustment costs associated with investment.

Finally, to close the model it is necessary to specify how the public and private sectors finance their activity -- i.e., which two endogenous variables are determined residually by their budget constraints. For the simulations discussed below, the adjusting variable for the public sector is total taxes, and for the private sector the residual budgetary variable is foreign asset holdings.[23]

[22] 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. This typically required a horizon between 80 and 480 periods (quarters) for convergence. For the actual simulations, the model was made discrete.

[23] Recall that Walras' Law ensures that one of the three sectoral budget constraints (for the public, private, or foreign sector) holds identically when markets clear. Hence we do not need to specify a third residual variable.

4. Model Parameterization for Chile and Initial Steady State Solution

Parameterization involves a choice of values for the model's behavioral parameters and a calibration of the equations and budget identities to a certain base period. The parameters of the model's behavioral equations were estimated econometrically using Chilean quarterly data covering 1986-1997. These equations and the three budget constraints were calibrated to a recent historical quarter 1997.2. For this year steady-state equilibrium conditions were imposed, i.e., per capita state variables and relative prices were assumed to be constant.[24] Hence the first period of our counter-factual simulations could be interpreted as 1997.3, if 1997.2 had been a stationary equilibrium year. Tables 4.1 to 4.3 show structural coefficients, and base-year steady-state values of exogenous and endogenous variables that result from the econometric estimations and the calibration of budget identities. In the Appendix we provide a detailed explanation of the parameterization process, including data sources, the complete set of econometric estimations, parameter values, calibrated base-year budget identities, and base-year steady-state values of exogenous and endogenous variables.

As discussed above, the speed of convergence to a new steady state and the particular adjustment path taken by the endogenous variables depend critically on the values of certain key parameters, summarized briefly next. The elasticity of nominal wages with respect to employment is 2.8 (under instantaneous labor market clearing it would be infinity). Nominal wages are indexed to current and lagged consumer price inflation with weights 66% and 34%, respectively. The quadratic adjustment cost coefficient for investment is 35, a large figure that implies a very slow investment response. The shares of unconstrained consumers and firms in the total are 74 % and 38%, respectively, substantially below the 100% share of the unconstrained neoclassical benchmark.[25] The import content of investment (29%) is

[24] 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

[25] Several studies have estimated, using various techniques, the share of constrained consumers (λ_1) in Chile and in other developed and developing countries. In the case of Chile, Corbo and Schmidt-Hebbel (1991) estimated λ_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; and Bandiera et al. (1999) 0.55 for the 1970-1995 period. More recently 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.

almost six times the import content of consumption (5%); this agrees well with the cross-country data reported in Servén (1999). Finally, the intertemporal elasticity of substitution in consumption is restricted to one, a value consistent with previous econometric estimations for Chile (Schmidt-Hebbel 1987, Arrau 1989).

Table 4.1
Structural Coefficients

Money Demand

Constant (ϕ_1)	0.3434
Income Elasticity (ϕ_2)	1
Interest rate Semi-elasticity (ϕ_3)	-3.3216

Wage Equation

Constant (ϕ_1)	
Employment elasticity (ω)	2.8163
Indexation to current inflation (θ)	0.6575

Production Function

Constant (α_0)	0.4676
Labor share (α_1)	0.5218
Capital share (α_2)	0.3969
Intermediate imports (α_3)	0.0814

Private Investment Demand

Share of unconstrained firms (β_1)	0.3809
Marginal Propensity to Invest of constrained firms (β_2)	0.50
Adjustment Costs to Investment (μ)	35
Rate of depreciation of physical capital (δ)	0.0108

Share of national goods in investment (γ)	0.7141

Private Consumption Demand

Share of unconstrained consumers (λ_1)	0.7490

Share of national goods in consumption (η)	0.9523

Export Demand

Constant (ρ_1)	0.2006
Real exchange rate elasticity (ρ_2)	0.1320
Foreign income elasticity (ρ_3)	0.6830
Lagged exports (ρ_4)	0

Table 4.2
Predetermined Variables

Income, Transfers, and Capital Flows	
Foreign Transfers to the Public Sector (ftrg)	0.0001
Foreign Transfers to the Private Sector (ftrp)	0.0043
Foreign Income (yf)	1.0000
Direct Foreign Investment (dfi)	0.0200

Rates[26]	
Real interest rate on foreign assets/liabilities (rf)	0.05
Rate of growth of the nominal money stock (nmg)	0.07
Harrod neutral technical progress (tg)	0.024
Population growth (pg)	0.016

Stocks	
Domestic debt of the public sector (bg)	1.3138
Foreign assets held by the public sector (fbg)	0.0640

External Prices	
Intermediate imports (pmr)	1.0000
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
Public investment subsidy (ig)	0.0296

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

Table 4.3
Initial steady-state values of endogenous variables

Income, Transfers, and Capital Flows	
Operational Profits (op)	0.3968
Dividends (d)	0.1330
Taxes (td)	0.1317
Private disposable income (yd)	0.3975
Profit remittances abroad (prem)	0.0436
Stocks	
Private sector total wealth (a+hu)	192.6646
Non-human wealth of the private sector (a)	28.3126
Stock of domestic equity held by foreigners (fe)	1.1368
Domestic base money (hb)	0.3217
Human wealth of the private sector (hu)	164.3520
Physical Capital (k)	12.7454
Present value of government investment subsidy (pvig)	12.2468
Present value of cost of holding money (pvihb)	2.6182
Foreign assets held by the private sector (fbp)	-1.9938
Goods Flows	
Private aggregate consumption (cp)	0.5067
Private imported-goods consumption (cmp)	0.0242
Private national-goods consumption (cnp)	0.4825
Gross domestic investment (inv)	0.2635
Private national-goods investment (in)	0.1882
Private imported-goods investment (im)	0.0753
Investment adjustment costs (iac)	0
Exports (x)	0.2160
Intermediate imports (mr)	0.0465
Total imports (m)	0.1446
Trade Balance	0.0714
Current Account Surplus	-0.0103

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	3.1247
Real wage per effective labor unit (rw)	0.5218

5 SIMULATION RESULTS

In this section we use the model calibrated for the Chilean economy to run counterfactual simulations. We report results for two policy changes (an expansionary fiscal policy and a contractionary monetary policy) and two changes in Chile's external environment (a favorable oil price shock and an increase in the foreign interest rate). In all cases the shocks are unanticipated at period zero, but at that time their future time path becomes perfectly known. Both permanent and temporary shocks are considered. Temporary shocks are assumed to last 16 quarters (in the case of the first three shocks) or 4 quarters (in the case of the last shock).

We organize the discussion around a series of graphs depicting the trajectories of key endogenous variables. To avoid repetition, we only provide a full graphic presentation of the dynamics (covering a total of 12 variables) for the first simulation (fiscal expansion). In subsequent simulations we show only the dynamic response of output, inflation, the real exchange rate, and the current account.

5.1 Fiscal Expansion

We simulate the effects of a fiscal expansion that raises public consumption by 3 pp, from 11% to 14% of GDP.[27] [28] Three variants are considered: two balanced-budget (tax-financed) fiscal expansions (one permanent and the second temporary) and a temporary foreign-debt financed expansion.

We begin by considering the balanced-budget fiscal expansions. Higher taxes shift wealth from the private sector to the government, reducing private consumption. Since public consumption falls only on domestic goods (while 5% of private consumption falls on imported goods), the transfer raises aggregate demand for national goods. This expenditure-switching effect is the main direct consequence of the balanced-budget fiscal expansion, other than temporary effects on the behavior of borrowing-constrained agents.

In the long term, the expenditure switch causes a real exchange rate appreciation, an increase in investment (because imported investment goods are cheaper), higher output, and higher real wages. The impact effects differ from the steady-state effects: on impact there is an increase in aggregate demand, followed by a gradual rise in aggregate supply as the capital stock expands slowly due to investment adjustment costs.

[27] In previous papers we 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. In Schmidt-Hebbel and Servén (1994a) we analyze fiscal policy under alternative means of financing and in Schmidt-Hebbel and Servén (1994b, 1995a) we assess the impact of external shocks in a representative open economy. In Schmidt-Hebbel and Servén (1994c) we 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 in Schmidt-Hebbel and Servén (1995b) we 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.

[28] Percentage points of GDP are denoted by pp here and below. Perecentage point changes in variables that are themselves expressed as a percentage (e.g., interest rates) are noted as %.

Consider first the permanent tax-financed fiscal policy shift. Tax revenue as a share of GDP rises by 3 pp of GDP in quarter 1 and thereafter (see Figure 5.1). Higher public consumption reduces wealth of borrowing-unconstrained consumers who internalize the government's budget constraint and also decreases disposable income (net of taxes) of borrowing-constrained consumers. As a result of the behavior of both groups of consumers, the share of private consumption in output falls on impact by 3.1 pp, close to the steady-state effect on private consumption.

The investment/output ratio increases by 0.2 pp in period 1, since the real appreciation reduces the price of imported capital goods. In the long term, the investment ratio rises by another 0.1 pp. More capital and more intermediate imports expand domestic production – hence output rises by 0.2% in quarter 1 and by 0.6% in the long term.[29]

The increase in aggregate demand for national goods immediately raises their relative price in quarter 1. This is reflected by a 2.1% real exchange rate appreciation on impact, which exceeds the long-term equilibrium real appreciation. This overshooting is due to the fact that starting in period 2 aggregate supply expands in tandem with the gradual addition of new capital, causing a gradual, slight depreciation until the new steady state is attained. At that point the real exchange rate is still 1.6% more appreciated than at the initial equilibrium.

The real exchange rate depreciation from period 2 onwards is fully reflected in the higher ex-ante domestic real interest rate, as dictated by uncovered real interest parity. The interest rate returns towards its original value of 5% on its path to the new steady-state equilibrium. Another relevant asset price is Tobin's q, that rises on impact in response to the higher demand for capital, prompting the investment increase discussed above. However the new steady-state level of q is lower than at the initial equilibrium, reflecting the parallel decline in the relative price of new capital goods resulting from the equilibrium real appreciation.

The change in the real exchange rate also affects exports. Given a long-term real-exchange-rate elasticity of export demand of 0.13, exports decline by 0.2% in response to the long-term appreciation.

With unchanged monetary growth, the output increase in period 1 raises money demand, causing inflation to decrease by 0.2% on impact. Inflation subsequently converges back to its stationary level of 3%.

In the long term, the behavior of the real wage reflects the change in labor productivity. Due to the higher capital stock, labor productivity and the real wage increase by 0.6% in the new steady state. However during the transition wages are also affected by

[29] Note that this increase in gross national output (gross of intermediate imports) is model-specific and reflects the negative relation between output and the relative price of imported goods in units of national goods. In a more general model with a disaggregated production structure (say between tradable and non-tradable goods), the relation between aggregate output and the real exchange rate is ambiguous. In addition this model assumes lump-sum taxation. In a more general model taxes are distortionary for production (and hence reduce output) and/or consumption (and hence reduce consumer welfare).

contemporaneous and backward indexation to inflation. Sluggish wage adjustment during the transition 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. Lagged upward wage adjustment in period 1 and subsequent periods leads to overemployment. The rate of employment rises by 0.1% on impact, converging gradually back to full employment in subsequent periods.

Recall that the experiment under consideration is a balanced-budget fiscal expansion, without changes in public saving – as opposed to an expansion in government consumption that would result in lower public saving and, hence, a higher first-round current-account deficit. Thus, all temporary current-account effects stem from the public/private wealth transfer and the investment expansion. Under these conditions, the current account could deteriorate or improve in the short run, depending on the size of the intertemporal elasticity of substitution in consumption relative to the coefficient of investment adjustment costs.[30] In our case of unit intertemporal elasticity and high investment adjustment costs, the foreign-currency current account ratio to GDP deteriorates by 0.1 pp in period 1. However the domestic-currency current account ratio deteriorates by only 0.02 pp because it also reflects the real exchange rate appreciation.[31]

Now consider the transitory fiscal expansion that hits the economy from quarters 1 to 16. For the effects of temporary shocks, the role of borrowing-constrained consumers and investors is crucial. If all consumers were unconstrained and forward-looking, a temporary expansion in government consumption and taxation would lead only to a modest private consumption decrease and hence would cause a stronger temporary output expansion and real exchange rate appreciation than under a permanent policy change. However 25% of consumers are borrowing-constrained and hence respond to the temporary tax hike by cutting down on consumption in proportion to the tax increase. Therefore aggregate private consumption is lowered for 16 periods – by less than under the permanent policy change but by more than what would be observed in the absence of borrowing-constrained consumers. Reflecting the higher aggregate demand, the real exchange rate appreciates by more and output rises by more on impact and in the subsequent 15 periods than under the permanent fiscal expansion.

[30] Servén (1995) shows analytically the opposing influence on the saving-investment balance of intertemporal substitutability in consumption and investment. On the one hand, the fiscal expansion raises investment (as noted in the text), more so the smaller adjustment costs are. On the other hand, private consumption falls relative to output, and more so the higher the elasticity of intertemporal substitution in consumption, due to the anticipation of real depreciation along the adjustment path, which encourages substitution against present consumption. Thus, both saving and investment rise, and the net effect on the current account is in principle ambiguous.

[31] Note that the ratio of the current account balance to output in Figure 5.1 shows the value of the current account balance in units of domestic goods (i.e., the product of the foreign-currency current account and the exchange rate) divided by domestic output. Hence this ratio reflects real exchange rate changes too. Although the initial and final steady-state values of the current account must be the same in foreign currency units, the final steady-state level of the domestic-currency current account ratio is smaller in magnitude than the initial level due to the accompanying real exchange rate appreciation.

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 16-17. Note that tax revenue starts to increase substantially as a fraction of GDP in period 14 and attains a spike at period 16 when it is 3.34 pp larger than under the permanent case. This endogenous response in tax revenue is required to finance the rising interest payments on public debt caused by the increasing domestic interest rate.

Higher tax payments reduce further consumption spending of the 25% of borrowing-constrained consumers. Aggregate private consumption declines gradually and reaches a trough in period 16. When the fiscal expansion is reverted in period 17, private consumption raises back to a level close to its initial steady-state level and a large real exchange rate depreciation takes place.

Hence the real exchange rate depreciates at increasing rates during periods 14-16, in tandem with declining private consumption. At period 17 the temporary balanced budget expansion is reverted and, because of the expenditure-switch back to imported goods, a depreciation of 2.56 % takes place. The build-up of increasing rates of depreciation is anticipated and hence fully reflected by the domestic real interest rate.

The interest rate rise in periods 13-17 – with a peak at quarter 16 – has important implications for the dynamics of inflation, real wages, employment, and output. Inflation, given an unchanged flow supply of money, is positively affected by the real interest rate and negatively by output. Well before quarter 16, inflation starts to rise gradually with declining output and increasing real interest rates, peaking at 4.8% in quarter 14. Subsequently inflation falls and in period 17, when the temporary fiscal expansion is reversed, it attains a through at –4.8%. Thereafter, inflation returns towards its unchanged long-run level of 3 percent..

Negative inflation in quarter 17 – and somewhat lower inflation in periods 16 and 18 than the stationary 3% level – raises real wages beyond levels consistent with full employment. Hence employment falls by 0.3% at quarter 17, deepening the recession induced by the decline in aggregate demand for national goods that takes place at quarter 17. The cyclical downturn of employment and output during quarters 15-17 is offset by overemployment and high output in quarters 18-19 – a reflection of the lagged effect of inflation on real wages.

The current account to output ratio shows a strong cycle, reflecting the pattern of consumption and investment, output, and the real exchange rate. As discussed above, the intertemporal consumption path of unconstrained consumers leads to dissaving during the 16 quarters of temporary fiscal expansion, contributing to a higher current account deficit. During the same period, however, output is high and the real exchange rate is appreciated. Therefore the domestic-currency value of the current account ratio to output is lowered during the first 16 quarters, jumping subsequently toward its steady-state level.

It is important to note that the steady-state effects are significant when fiscal adjustment is permanent but almost negligible when it is temporary. The reason is that the permanent policy shift causes a permanent change in expenditure from domestic to imported goods, giving rise to a permanent real exchange rate appreciation, an output expansion (and thus a real wage higher than its initial value), and lower consumption ratios. Under a transitory expansion, however, the changes in the public-private composition of aggregate spending are transitory too. 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.

Finally, let us consider a temporary fiscal expansion financed by issuing government debt. The public debt stock rises monotonically from 131.38 % of GDP at quarter 1 to 177.33% at quarter 16, with a further jump to 191.80 % at quarter 17 (due to the high quarter-16 interest rate) and stays at that level thereafter.

Now private consumption and output decline by less than under the temporary tax-financed fiscal expansion. This is because borrowing-constrained consumers do not adjust to the fiscal expansion – only unconstrained consumers do, and only by an amount consistent with the wealth loss caused by the temporary fiscal expansion. This implies that variable changes are much more intense and concentrated in quarters 16 or 17. The real exchange rate depreciates by more on impact and stays approximately flat during the 16 quarters of fiscal expansion – a reflection of a largely unchanged private consumption level during this period. Therefore the real exchange rate depreciation that takes place between periods 16 and 17 is substantial, amounting to 5.42%. The ex-ante real interest rate has a one-period spike in period 16, at 29.36 % (at annual rate). Because of the intensity of the real interest rate rise at quarter 16, the drop in inflation, employment, and output are more intense than under a tax-financed expansion, and so are the levels of overemployment and production in periods 18 and 19.

5.2 Monetary Contraction

Next we simulate the effects of a monetary contraction consistent with a long-term reduction in inflation from 3% to 1.5% per annum. The reduction in seigniorage collection – specifically its inflation tax component – is matched by a tax hike. The rate of money growth falls from 7.0% to 5.5%. Two alternative scenarios are considered: a permanent and a temporary monetary contraction, the latter lasting 16 quarters.

A permanent reduction in inflation by 1.5% raises the stock demand for base money relative to annual output from 22.17% to 22.54%. In spite of the rise in real money demand, the decline in nominal money growth leads to a decline in seigniorage from 0.5% to 0.4% of annual output, which is matched by a rise in conventional tax revenue from 13.2% to 13.3% of output. Unconstrained consumers are indifferent between paying conventional taxes or the unconventional inflation tax – hence there is no first-round effect of a contractionary monetary policy on long-term consumption by unconstrained agents. However borrowing-constrained consumers look only at conventional taxes (not inflation taxation) when deciding their spending levels. Therefore their consumption – as well as aggregate private consumption and aggregate demand – declines in response to the shift towards tax financing of government expenditure.

Consider first the permanent monetary contraction. Inflation follows a revealing pattern (Figure 5.2). The rise in money demand consistent with lower inflation is accommodated by a massive drop in inflation, from 3% in the preceding steady state equilibrium to –1.73% in quarter 1. Inflation converges subsequently to the new stationary level of 1.5%. The sum of the latter figure plus stationary output growth of 4% equals the new rate of annual money growth at 5.5%.

On impact private consumption of both unconstrained and constrained consumers is reduced. The former 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 latter do it because taxes are exceptionally high in that period as a result of the government's need to finance higher interest payments on its debt. The interest rate spike in quarter 1 also depresses slightly private investment. Regarding aggregate supply, the 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 slump dominates the demand contraction, hence the relative price of national goods rises, as reflected by a real exchange rate appreciation on impact.

In the next period all variables reverse their previous pattern. An exceptionally low real interest rate prompts a strong aggregate demand response, and higher inflation reduces real wages, causing overemployment. Subsequently all variables converge monotonically toward their new steady-state levels. Most real variables attain new stationary levels that are very close to their initial steady-state values – the small deviations are again a reflection of the model's path dependence.

It is revealing to turn now to the results of a temporary 4-year monetary contraction financed by higher temporary conventional taxes. The role of forward-looking behavior in determining the model's dynamics is clearly illustrated by the behavior of inflation. The consolidated government's reversion from tax to monetary financing in quarter 16 is anticipated early on, leading to a gradual rise in inflation from 1.5% in quarter 5 to 3% in quarter 18 and thereafter.

As before, the temporary tax rise reduces consumption of constrained agents during quarters 1 through 16. Now, however, forward-looking consumers anticipate a return to lower taxes in the future, which will eventually prompt a recovery of aggregate demand (by constrained consumers) and hence a real appreciation. The result is that on impact the aggregate demand reduction now – as opposed to the permanent policy change – dominates the aggregate supply contraction, leading to a slight real exchange rate depreciation. During most of the transitory 4-year period during which the financing shift occurs, real variables display a qualitatively similar pattern to that shown under the permanent change. However the dynamics now reflect the anticipation of the policy reversal in quarter 17 – consistent with forward-looking behavior in goods and assets markets. The gradual real exchange rate appreciation resulting from the upcoming tax cut is anticipated, leading to a temporary slump in interest rates, lower taxes, higher consumption and investment, and overemployment. Part of the real cycle observed in periods 1-5 is replicated, with opposite sign, during periods 15-19. Afterwards the economy converges to its new steady state that is almost identical to the initial stationary equilibrium.

5.3 Oil Price Increase

Now consider the macroeconomic response to an increase in oil prices by 50% – say from US$ 14 per barrel of oil to US$ 21 per barrel. This translates into a 10% rise in the average price of intermediate imports used in the production of output, reflecting a 20% share of Chile's imported oil in aggregate intermediate imports. Two alternative scenarios are considered: a permanent and a temporary oil shock, the latter lasting 16 quarters.

A higher oil price has two first-round effects: a decline in income proportional to the loss in terms of trade (that leads to a reduction in private consumption) and a reduction in the demand for intermediate imports (causing a supply contraction). The dominance of the supply shock over the demand contraction leads to a real exchange rate appreciation.

Let's start with the permanent oil price hike. The real exchange rate appreciates on impact by 6.8%. This figure is so large that its positive effect on private investment (through lower prices of imported capital goods) more than offsets the negative influence of a lower Tobin's q on private investment. Hence the rate of private investment increases slightly, giving rise to a gradual (and small) subsequent output expansion in quarters 2 and later. Therefore output – which had contracted by 1% in period 1 – recovers in part to attain a new stationary level that is only 0.5% lower than at the initial steady state. The gradual increase in aggregate supply in periods 2 and thereafter leads to a slight real exchange rate depreciation. However the real exchange rate is still 6.57% more appreciated at the final steady state than in the initial one.

The oil shock and its derived output slump cause a one-time inflation spike at 7.5% in period 1. However, wage sluggishness precludes real wages from declining on impact to the level consistent with full employment. Hence employment declines on impact by 1%, contributing marginally to a deeper output contraction. The labor market normalizes after 3 periods (and so does output), when the effects of the temporary inflation shock have faded away.

Now consider the temporary oil price shock reverted at quarter 17, that leads to a subsequent recovery of most variables to levels close to the initial ones. A significant real exchange rate depreciation takes place at and shortly before period 17 and a corresponding spike in the ex-ante real interest rate is observed, reflected in a 7.5% level in quarter 15 and a 12% level in quarter 16. Consumption by non-restricted agents drops accordingly on impact – by more than under a permanent oil shock. The rise in the real interest rate also depresses Tobin's q which, in conjunction with a less appreciated exchange rate, now leads to a decline in private investment. The larger aggregate demand slump is reflected by a larger temporary output drop and a smaller real exchange rate appreciation, in comparison to what is observed under a permanent oil price shock. Hence inflation also raises by more on impact – to 9.47 % – leading to deeper employment loss and reinforcing the output decline.

The current account deficit mimics the pattern of aggregate demand – a lower deficit in periods 1 through 16, followed by a slightly larger deficit in periods 17 onwards, and converging subsequently to a new stationary level that is almost equal to that of the old steady state.

During periods 15-19 most variables display a pattern opposite to the one observed during the first year. For instance, inflation starts to decline gradually from period 14 onwards and peaks at -3.41 % in period 17.

5.4 Higher Foreign Interest Rate

Finally we consider a temporary increase in the foreign rate of interest from 5% to 6% that lasts 4 quarters. The higher foreign rate involves a wealth loss for the domestic economy because of its net debtor position vis-a-vis the rest of the world. Unconstrained consumers reduce their consumption level accordingly, leading to permanently lower aggregate demand and output 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 5 and thereafter, their intertemporal spending pattern responds accordingly. With interest rates above their long run level (equal to the rate of time preference), consumption must drop on impact and then follow 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 jumps to 6.4 % on impact, falling to levels under 3% subsequently to converge close to 3% only in quarter 6 and thereafter. The inflationary shock raises real wages and lowers employment, and hence output even further during quarters 1 and 2. The opposite cycle of slight overemployment is observed at quarters 3 through 7.

High inflation at quarter 1 raises government revenue from seigniorage, so that tax revenue is not required to rise as much on impact – as would be necessary in the absence of seignorage financing – in order to finance the steep rise in the government's interest bill. In the following quarter, however, taxes have to rise even further because now the extraordinary inflation tax financing has ceased.

On impact the real exchange rate depreciates by 5.29 %,. Then it appreciates until quarter 5, and more gradually thereafter to attain a stationary level that is 4.19% more appreciated than at the start. The impact effect on output is a loss of 0.5%, most of which is reverted in quarters 2 through 5. However subsequent disinvestment leads to a gradual reduction in output, converging to a steady-state level that is 0.3% lower than the initial one.

Figure 5.1
Fiscal Expansion

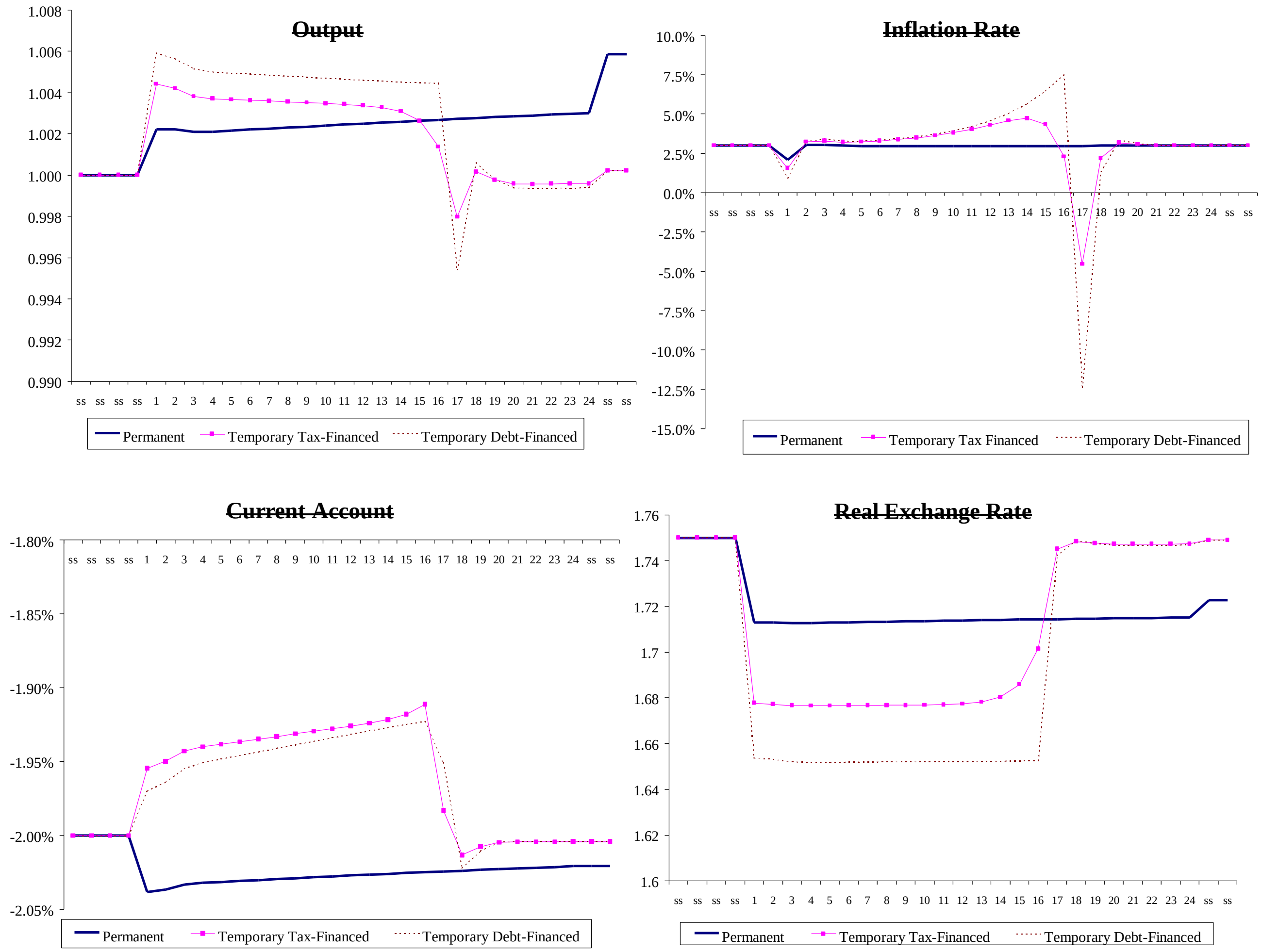


Figure 5.1 (Cont.)
Fiscal Expansion

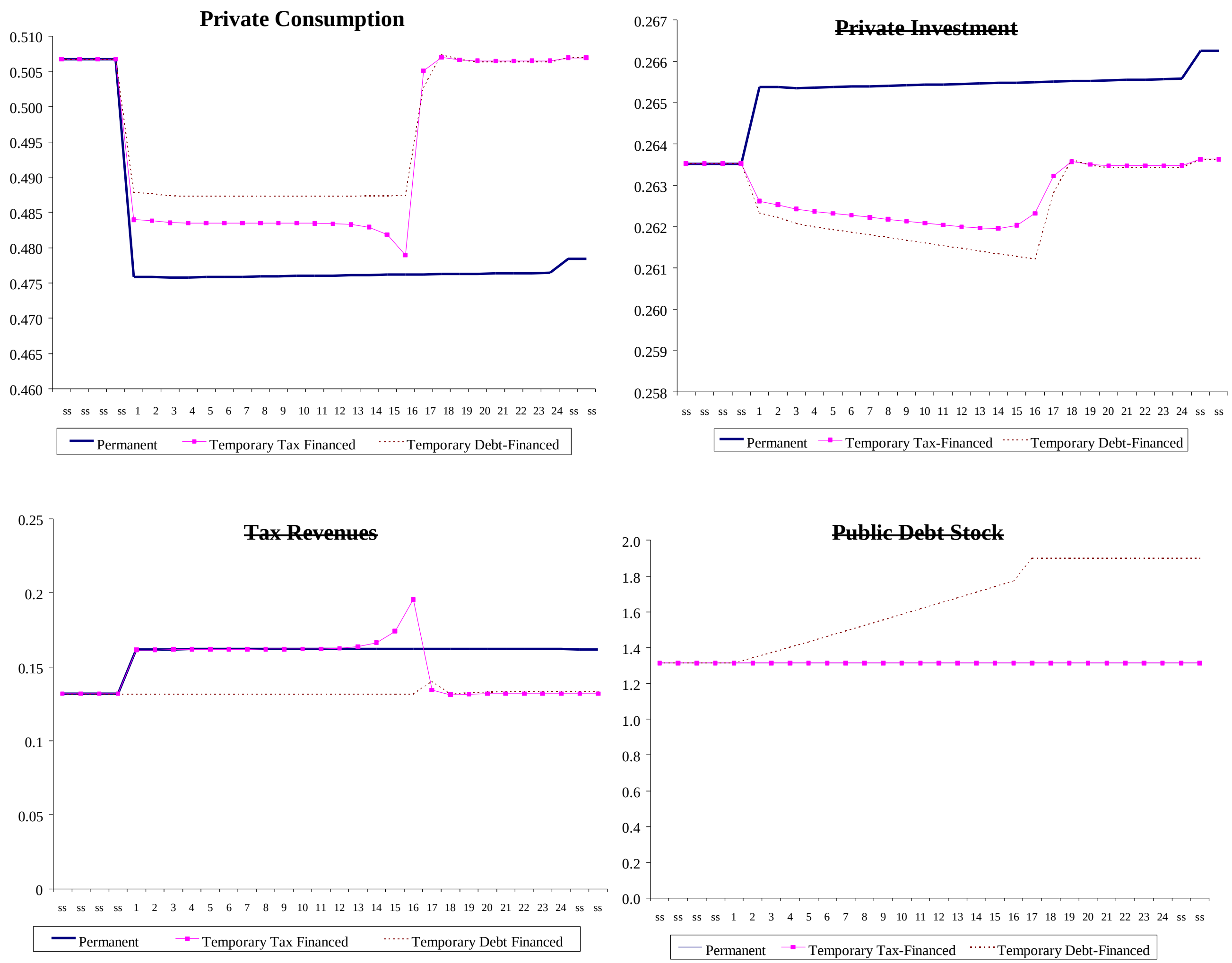


Figure 5.1 (Cont)
Fiscal Expansion

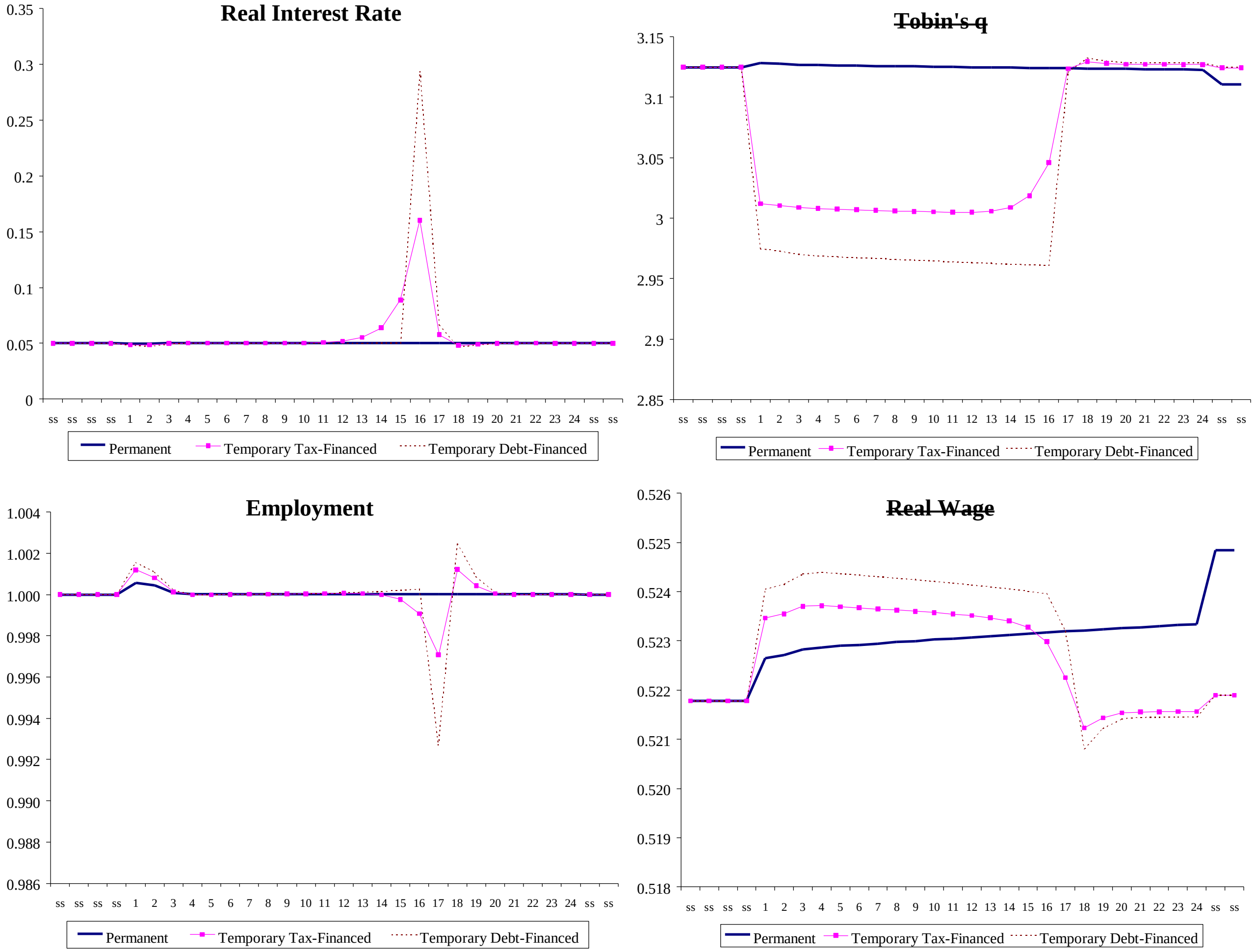


Figure 5.2
Monetary Contraction

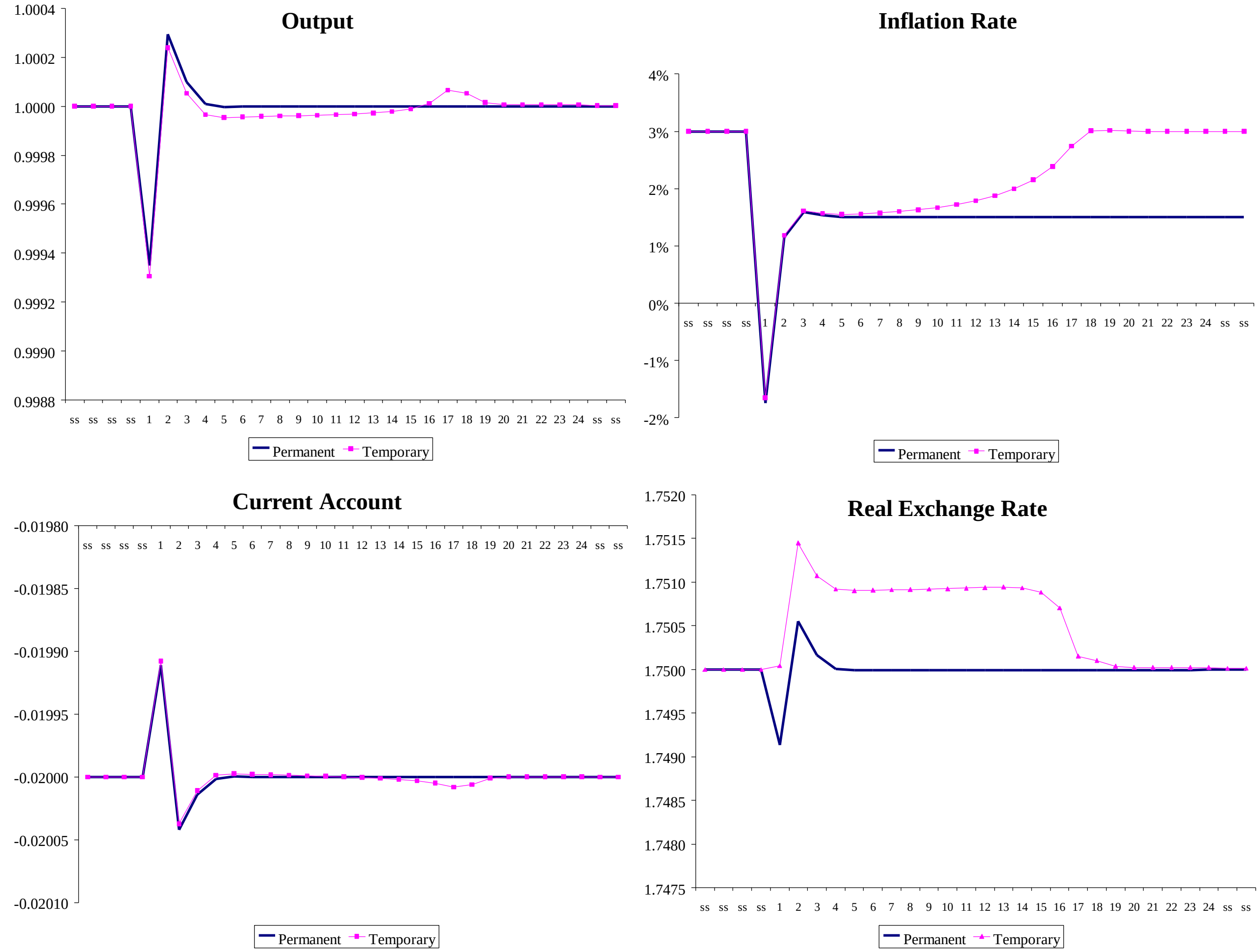


Figure 5.3
Oil Price Shock

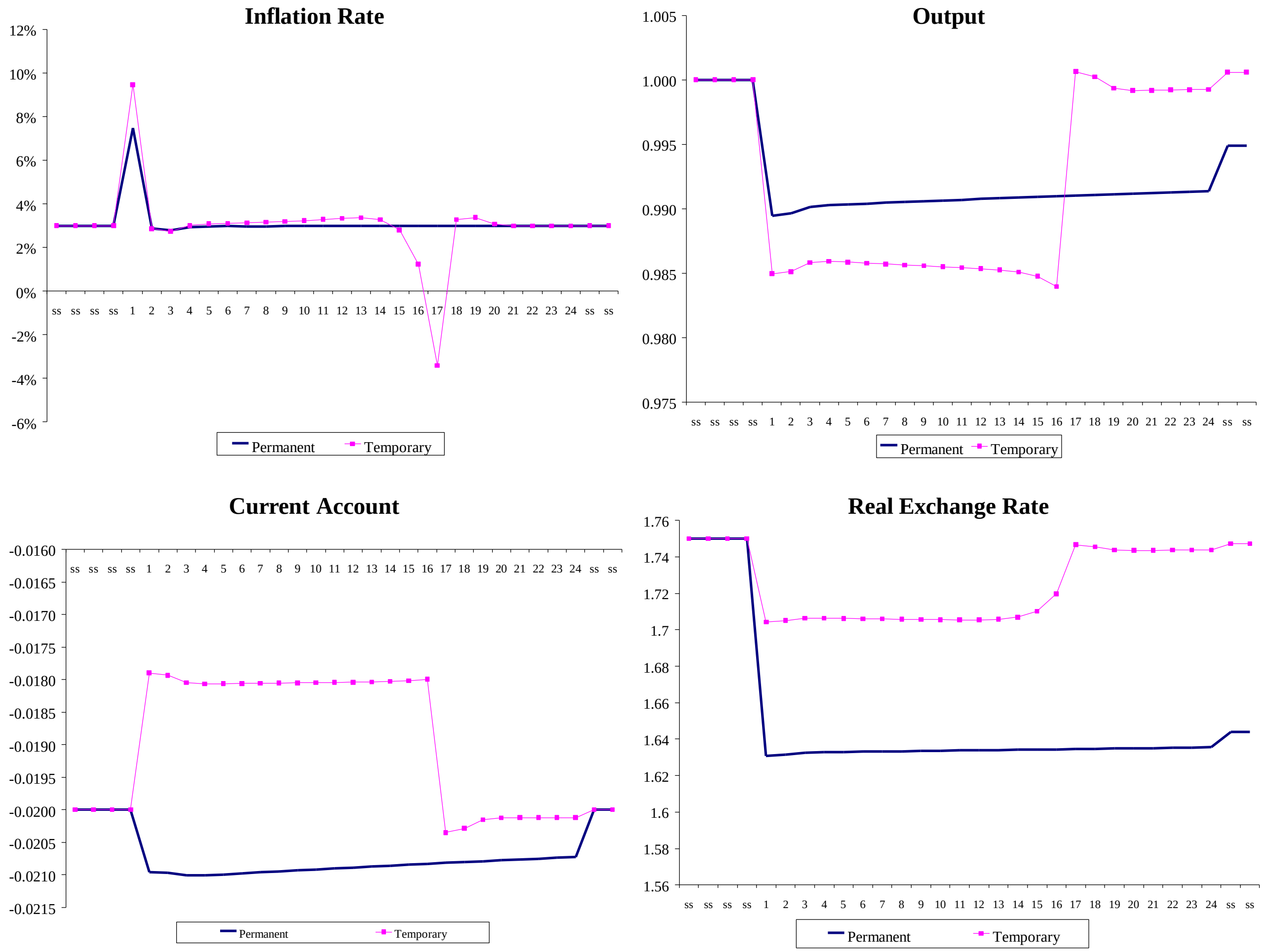
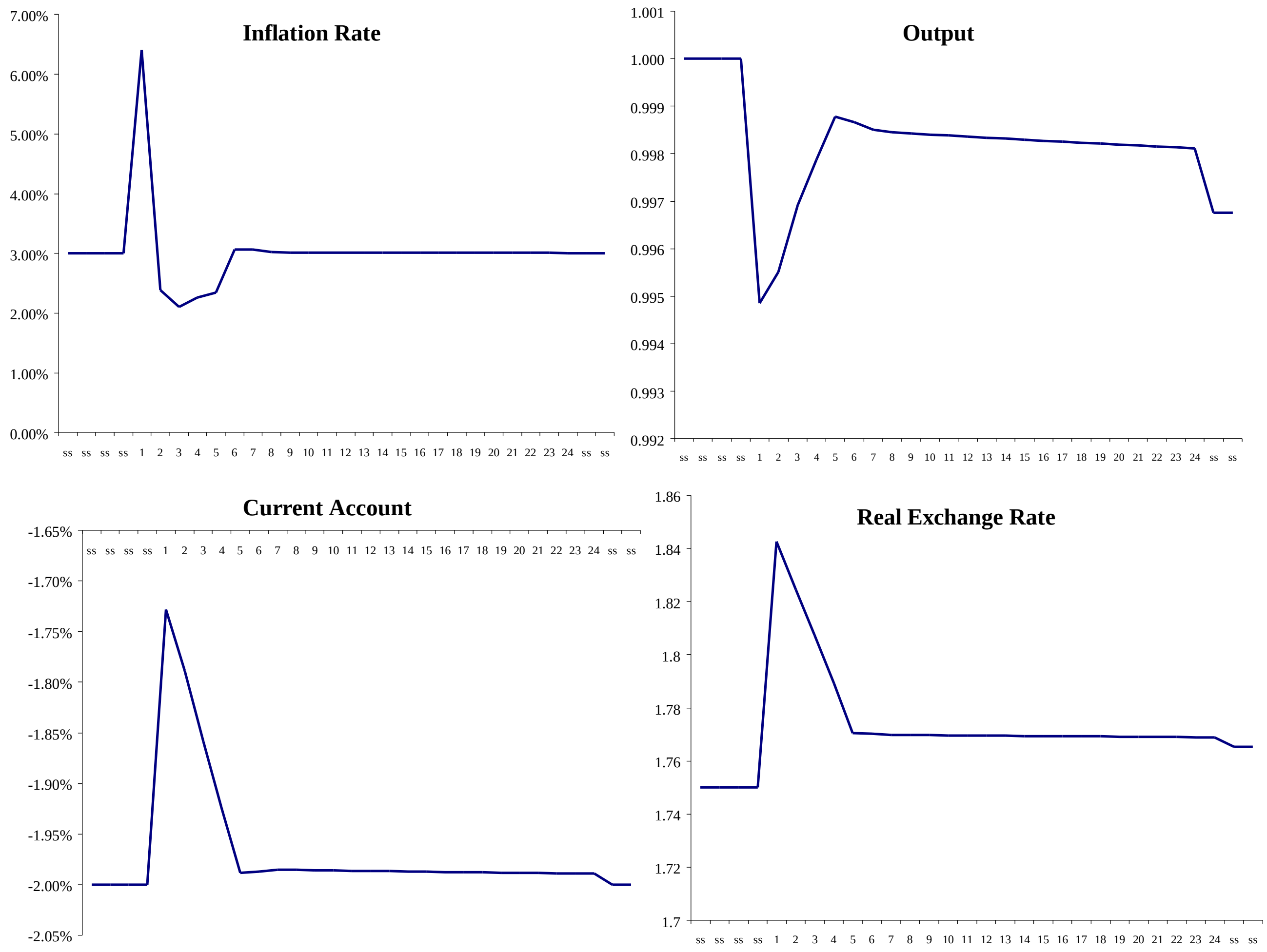


Figure 5.4
Foreign Interest RateIncrease



6 CONCLUSIONS AND FUTURE EXTENSIONS

This paper has developed a macroeconomic general-equilibrium model fully parameterized for the Chilean economy. The model's basic relations can be rigorously derived from intertemporal optimization by rational forward-looking agents. However, it also introduces critical real-world features – such as short-run wage rigidities and liquidity constraints – that generate deviations from the frictionless full-employment equilibrium of the unconstrained neoclassical paradigm. The model is numerically simulated to explore the effects of various permanent and temporary unanticipated policy shifts and foreign shocks. The experiments – a fiscal expansion, a monetary contraction, and adverse international oil price and interest rate shocks – reflect the policy changes and foreign shocks that Chile is likely to face at the turn of the millenium.

While the model is a useful device to portray the economy's dynamic path in response to various shocks, some of its structural features are admittedly unrealistic for a small open developing economy like Chile. Future extensions of this research should focus on the re-specification of certain model features to bring them closer to Chile's realities. First and foremost, the one-sector specification of aggregate supply should be lifted. By distinguishing between traded and non-traded goods, a clearer distinction between the terms of trade and the real exchange rate can be drawn, allowing also for price-taking behavior in the traded-goods sector. Second, the assumption of perfect substitutability between domestic and foreign assets should be revised, to allow for an endogenous country-risk premium that drives a wedge between domestic interest rates and depreciation-adjusted foreign rates. Third, the simplistic money demand adopted here should be replaced with a more satisfactory specification derived from first principles. Fourth, a more realistic treatment of taxation should replace the lump-sum taxes assumed in the present version of the model.

Such specification enhancements, however, would also increase the complexity of the model. Abstracting from model development, calibration, and programming costs, the biggest drawback may be the loss of transparency in the interpretation of model simulation results. In the end, the question is whether the benefits outweigh the costs. We strongly suspect they do.

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Appendix: Model Parameterization for Chile

The model parameterization for Chile involved six steps, which are below and summarized in Tables 4.1-4.3, and A.1-A.2.

1. Quarterly Database Construction

The main database was constructed using several publications (Central Bank of Chile: *Boletín Mensual*, various issues; Central Bank of Chile, 1998; Budget Office, *Estadísticas de las Finanzas Públicas*, various issues; and the Central Bank of Chile Database). Besides, to build quarterly data for several variables it was necessary to interpolate to higher frequency. The interpolation procedure was used in the case of capital stocks for the full period, investment and consumption prices and quarterly disposable private income up to 1990, among others. We use the values calculated in Braun and Braun (1999) as a pivot for 1995.4. In the case of non-human capital, we build the quarterly values using quarterly investment flows, and a quarterly depreciation rate of 1.1%. In the case of human capital we use the quarterly evolution of wages and labor force to construct quarterly observations. In the case of prices and private disposable income, we use a modified Chow-Lin procedure. The modification takes advantage of the availability of quarterly observations since 1991, and uses backward the seasonal pattern to complement the traditional Chow-Lin method.

Finally, to obtain usable data for the model, we divide the variables by the labor force in units of efficiency. The resulting database is available upon request.

2. Calibration of the coefficients and structural variables not-estimated coefficients

Three parameters were computed directly from the database: the domestic content of consumption and investment (taken from the National Accounts and Trade Statistics), and the Harrod neutral technological progress growth rate (quarterly average of each variable between 1986 and 1997). Additionally, three other coefficients were taken from the results of other studies. Namely, the subjective discount rate was assumed equal to the neutral interest rate relevant for Chile in 1997 as computed by Loayza and Gallego (1999).

The marginal propensity to invest of liquidity-constrained firms was fixed at 0.45 (Gallego and Loayza, 1999). These values were imposed in the econometric estimations.

A few other parameters that characterize the economy's steady state are selected arbitrarily (for a better characterization of the steady state): the labor force growth rate (equal to 1.6%); the money growth rate consistent with the steady-state inflation target of 3% and an annual steady state GDP grow of 4%.; and the flow of foreign investment relative to GDP, which is set at 2%. Finally, we take advantage of a recent paper by Adam (1999) to parameterize money demand.[32]

3. Econometric estimations

Table A.1 presents the estimation results for the model's structural equations. The samples and estimation techniques are presented at the bottom of the table. In the estimations, we fixed exogenously the values of the rate of depreciation, the steady-state growth rate, the marginal propensity to invest by unrestricted firms, and the subjective discount rate. In each equation, we make occasional use of dummies, in order to take care of adjust for special events or unexplained regression outliers.

4. Calibrated base-quarter

We chose the second quarter of 1997 to calibrate the model. This is done in two stages:

1. We add the regression residuals to the estimated intercepts, in order to exactly replicate the values observed in 1997.2.
2. We force the budget constrains to hold with equality in 1997.2 at constant asset stocks. This implies that real stocks grow at the economy's steady-state (exogenous) growth rate. This assumption requires the identification of two residual variables for two independent restrictions; by Walras' Law, it is not necessary to identify a third residual variable for the third budget constraint if the goods market equilibrium condition

[32] Adam (1999) uses a system cointegration method to estimate money demand in Chile for the 1986-1999 period. We estimated a money demand equation using a TSLS technique, and the results are presented in Table A.1. The main difference relative to Adam's results is the implied interest rate elasticity (Adam estimated a value of –0.1145, and we estimated a value of –0.1814). Since Adam's (1999) methodology is more robust to spurious correlation than ours, we took his estimated elasticity and computed the semi-elasticity consistent with the average nominal interest rate for the 1986.1-1997.1 period.

(equation 4) holds.[33] As mentioned before, the adjustment variables for the private and public sector budget constrains are total foreign assets held by private sector, and total taxes, respectively. Table A.2 shows the calibrated budget constraints for 1997.2. The adjusted values are 13.2% of GDP for total taxes (the actual value was 16.3% in 1997.2), and –1.9938% of GDP for the stock of foreign assets held by the private sector (the actual value was –1.8538% in 1997.2). In the table, stocks and flows are presented relative to initial steady-state GDP.

The predetermined variables were estimated using the model's calibration and the values effectively observed in 1997.2. Table 4.2 summarizes these values.

6. Initial steady state values of the endogenous variables

Finally, Table 4.3 summarizes the initial steady state values of the endogenous variables, that were obtained from the model's solution for the base quarter. They replicate the actual values but for the two exceptions just mentioned.

[33] To satisfy this condition it was necessary to make an additional adjustment: to add inventory variation (equal to 3.1% of GDP in 1997) into fixed investment.

Table A.1
Econometric Estimations for Chile[34]

1. Money Demand (equation 5)

$$\log(\frac{hb}{y}) = -0.985 - 6.405(\frac{i}{1+i})$$

(3.20) (1.93)

R^2A=0.87 S.E.=0.035 LM (4)=0.10 LM (8)=0.40

2. Real wage (equation 10)

$$\ln(v) - \ln(v_{-1}) - \ln(\frac{pc_{-1}}{pc_{-2}}) - \ln(\frac{p_{-1}/p_{-2}}{p/p_{-1}}) = 0.124 + 2.816\ln(l) + 0.658(\ln(\frac{pc}{pc_{-1}}) - \ln(\frac{pc_{-1}}{pc_{-2}}) - \ln(\frac{p_{-1}/p_{-2}}{p/p_{-1}})$$

(3.90) (8.03) (7.62)

R^2A=0.82 S.E.=0.033 LM (4)=0.40 LM (8)=0.02

3. Production Function (equation 11)

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

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

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

4. Aggregate Private Investment (equation 16)

$$inv = (1-0.669)\{0.381(\frac{k}{2\times 35}(\frac{q}{pi} - \frac{pvig}{pi\, k} - 1) + 0.0204k) + (1-0.381)(0.50\frac{op}{pi} + ig)\} + 0.669\, inv_{-1}$$

(6.24) (5.49) (5.49) (6.24)

R^2A=0.97 S.E.=2.818 LM (4)=0.72 LM (8)=0.66

5. Aggregate Private Consumption (equation 26)

$$dcp = (0.012-0.010)d(\frac{a+hu}{pc}) + (1-0.749)(d(\frac{yd}{op}) - (0.012-0.010)d(\frac{hu}{pc}))$$

(6.14)

R^2A=0.22 S.E.=3.130 LM (4)=0.39 LM (8)=0.37

6. Export Demand (equation 32)

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

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

R^2A=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 TSLS. 2. TSLS, dummy variables are 1990.2 and 1991-1992. 3. LS in first differences, dummy variables are 1987.2, 1990.2, and 1990.3. 4. LS with restricted adjustment cost parameter chosen to maximize adjusted R^2, dummy variables are 1990.1 and 1991-1992.[35] 5. TSLS, dummy variables are 1992.3, 1995, and 1996.4. 6. TSLS in first differences.

[34] At the bottom of each equation we report the adjusted R^2 (R^2A), 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.

[35] When adjustment costs are left unrestricted the estimation generates implausible values. To resolve this, we

Table A. 2

Public Sector Budget Constraint

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

Simulated Initial Steady-State

$$0.1317 + 1.75 * 0.004 - 0.1045 - 1.1 * 0.02962 - (0.0123 - 0.0099) * 1.3138 + (0.0099 + 0.0074) * 0.3217$$
$$+ 1.75 * (0.0123 - 0.0099) * 0.0640 = 0$$

External Sector Budget Constraint

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

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

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

Simulated Initial Steady-State

$$(1 - 1.1 * 0.2635 - 1.1 * 0 - 1.75 * 1 * 0.0465 + 1.75 * 0.0043 - 0.1317 + 1.1 * 0.0296 - 0.9 * 0.5067) - (0.0123 - 0.0099) * 03217$$
$$+ (0.0123 - 0.0099) * 0.3217 - 0.0436 + (0.0123 - 0.0099) * 1.75 * -1.9938 = 1.75 * -0.0200$$