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Juan Pablo Medina Claudio Soto

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THE CHILEAN BUSINESS CYCLES THROUGH THE LENS OF A STOCHASTIC GENERAL EQUILIBRIUM MODEL

Juan Pablo Medina
Gerencia de Investigación Económica
Banco Central de Chile

Claudio Soto
Gerencia de Análisis Macroeconómico
Banco Central de Chile

Resumen

Este trabajo estima un modelo de equilibrio general dinámico y estocástico con rigideces nominales y reales para la economía chilena. Este modelo estimado es utilizado para analizar las fuentes de los ciclos económicos en Chile. Nuestros resultados muestran que *shocks* externos y *shocks* de oferta dan cuenta de una importante fracción de las fluctuaciones del producto en los últimos veinte años. La política monetaria ha sido, en promedio, relativamente contractiva, lo cual ha contribuido a contener las presiones inflacionarias que se ha derivado de otros shocks adversos, tal como la desaceleración en la productividad a mediados de los noventa. Factores externos están detrás también de los grandes vaivenes en el tipo de cambio real. Sin embargo, la contracción monetaria en 1998 explica también parte del ajuste rezagado del tipo de cambio en respuesta a los efectos de la crisis asiática. La política monetaria restrictiva de 1998 también contribuyó a la lenta recuperación del empleo posterior.

Abstract

This paper uses an estimated dynamic stochastic general equilibrium model with nominal and real rigidities, to describe the sources of business cycle fluctuations in Chile. Our results show that foreign shocks and domestic supply shock account for a large share of output fluctuations over the last 20 years. Relatively tight domestic monetary conditions have contributed to contain inflationary pressures arising from other shocks, namely a slowdown in productivity by mid 90s. Foreign factors are also behind the large swings exhibited by the real exchange rate, although a monetary contraction in 1998 explains part of the delayed adjustment of the exchange rate in response to effects of the Asian crisis. The tight monetary policy around 1998 also contributes to the slow recovery of the employment afterwards.

In the development of the model we acknowledge comments and suggestions by Jaromir Benes, Rodrigo Caputo, Aaron Drew, Pablo García, Igal Magendzo, Anella Munro, Klaus Schmidt-Hebbel, Camilo Tovar, Rodrigo Valdés, and seminar participants at Reserve Bank of New Zealand, the Reserve Bank of South Africa, and the Central Bank of Chile. We also thank Raphael Bergoeing and Rodrigo Cerda for their valuable comments in the Seminar on "Unobservables Variables in Macroeconomics" organized by the Central Bank of Chile in June 2007. An anonymous referee makes useful corrections to an early draft. The usual disclaimers apply. E-mail: jmedina@bcentral.cl, csoto@bcentral.cl.

1 Introduction

Explaining business cycles has been at the core of the research in macroeconomics. During the 50s and the 60s, framed in the Keynesian tradition, large macro models where build to understand fluctuations in aggregate variables, and to assess the role of policies. The sharp criticism to the theoretical foundations and the identification schemes of these macro models led to a renewed emphasis in the a-theoretical approach to account for the business cycle (Sims, 1980). However, this a-theoretical perspective, where shocks are weakly identified or non-identified at all, poses several limitations to the proper understanding of the business cycle. Recent developments on both theory and estimation techniques of micro-founded macro models have stimulated a new literature that explains business cycles from a structural perspective. In this paper we provide a framework to identify the shocks underlying the business cycle in Chile from this structural perspective. We develop and estimate a micro-founded dynamic stochastic general equilibrium (DSGE) model, tailored to the Chilean economy. Using data on output, inflation, employment, interest rate, the current account, the real exchange rate, and oil and copper prices we estimate some key structural parameters and identify the historical evolution of fourteen underlying shocks that explain business cycles fluctuations.

The use of DSGE model to explain business cycles gained popularity since the prominent work of Kydland and Prescott (1982). They studied the quantitative predictions of a simple DSGE model where cycles were explained by technological shocks. They found that the covariances and autocorrelation of the variables in the model were consistent with those in the U.S. data. Researchers have extended the basic Kydland and Prescott real business cycle model to investigate the propagation mechanisms of many different shocks.[1] Recently, Chari, Kehoe and McGrattan (2007) have proposed a new methodology, based on a standard business cycle model, to infer which shocks are relevant to shed light on the structural features needed to explain business cycles.

Our structural model is based on the New Keynesian DSGE framework developed by Christiano, Eichenbaum and Evans (CEE 2005), Smets and Wouters (SW 2003, 2007), Altig *et al.* (2003, 2004), and Woodford (2003). Its main characteristics are the following: prices and wages are sticky and partially indexed to past inflation, the exchange rate pass-through to import prices is incomplete in the short run, there are adjustment costs in investment, and there is habit persistence in consumption. The model differs from CEE and SW in that it includes two main productive sectors: A domestic intermediate tradable sector, and a commodity-exporting sector. We assume that the supply of the exported commodity good is completely exogenous, and its price is determined in the foreign market. This sector is meant to characterize to copper sector in the Chilean economy, which accounts for about 40% of exports. The model also features a particular fiscal policy rule –the so called structural surplus fiscal rule– that has been used by the Chilean government since 2001. In order for the fiscal policy to play a non-trivial role in the economy, we also assume that a share of households are non-Ricardian. Finally, we assume that

[1] Christiano and Eichembaum (1992) and McGrattan (1994) add demand shocks to a standard RBC model to better explain the dynamic of hours and labor productivity. Mendoza (1995) includes terms of trade shocks in an international RBC model. Greenwood *et al.* (2000) analyze the role played by investment-specific shocks. Bernanke *et al.* (1999) and Carlstrom and Fuerst (1997) add financial frictions in a prototype business cycle model. Yun (1996), Rotemberg and Woodford (1997), Chari *et al* (2000), and Christiano *et al* (2005) among many others include nominal rigidities in monetary business cycle models to analyze the effects of monetary policy shocks on output and inflation.

the technology available to domestics firms producing tradable goods requires using imported oil as a complementary input, together with capital and labor.

Key model parameters are estimated by using Bayesian techniques as in SW and Lubik and Schorfheide (2006). An advantage of this empirical approach –over full information maximum likelihood (FIML) methods, for example– is that it allow us to introduce prior information to identify structural parameters. To compute the posterior distribution we use the Kalman filter with quarterly data on nine observable variables from 1987 until 2005. Within the estimation procedure, we allow for a structural break in the policy rule characterizing the behavior of the Central Bank. This break is consistent with the major changes in the policy framework occurred at the end of the 90s, when a target zone for the exchange rate was abandoned and a full-fledged inflation targeting regime was adopted with a permanent target for inflation of 3 per cent.[2]

We use the estimated model to compute the historical decomposition of the observed variables. Our results show that foreign shocks (foreign financial condition and foreign output shocks), and domestic supply shock (productivity and investment shocks) account for a large share of output fluctuations over the last 20 years. Terms of trade shocks explain just a small fraction of GDP growth fluctuations during the sample period. These results are consistent with the finding by Lubik and Teo (2005) for Chile, where foreign interest shocks explain up to 50% of output fluctuations. In our case, foreign financial shocks and productivity shocks also explain a large share of inflation fluctuations, with domestic demand shocks playing a minor role. Our model does not include mark-up shocks to prices and wages, which are the more important shocks driving inflation in US according to SW (2007). Relatively tight domestic monetary conditions have contributed to contain inflationary pressures arising from other shocks, namely the slowdown in productivity by mid 90s. Foreign factors are also behind the large swings exhibited by the real exchange rate, although a monetary contraction in 1998 explains part of the delayed adjustment of the exchange rate in response to the Asian crisis. The tight monetary policy around 1998 also contributes to the slow recovery of employment afterwards.

The rest of the paper is organized as follows: Section 2 presents in detail the model economy. Section 3 discuses the estimation of parameters using Bayesian techniques. Section 4 analyzes the transmission mechanism of different shocks implied by the model. It also presents the variance and historical decompositions of key macro variables. Finally, section 5 concludes.

2 Model Economy

The model economy is closely related to models developed by Christiano *et al* (2005), Altig *et al.* (2003, 2004), and Smets and Wouters (2003, 2007). There are three types of firms in the economy. One type are firms producing differentiated varieties of intermediate tradable goods. These firms produce using labor, capital and oil as inputs. They have monopoly power over the varieties they produce and set prices in a staggered way. These firms sell their varieties to assemblers that sale a composite *home* good in the domestic and foreign markets. A second type of firms are importers that distribute domestically different varieties of foreign intermediate varieties. These firms also have monopoly power over the varieties they

[2]Previously, decreasing yearly targets for CPI inflation were announced by the Central Bank.

distribute, and set prices in a staggered fashion. There is a third single firm that produces a commodity good which is completely exported abroad. This firm has no market power. It takes the international price of the commodity good as given and produces utilizing only natural resources. The stock of natural resources is determined exogenously and it is owned by the government and by foreign investors. This commodity-exporting sector is mean to characterize the copper sector in Chile, which accounts for about 10 % of GDP and 40% of total exports.

Domestic and foreign intermediate varieties are used to assemble two final goods: *home* and *foreign* goods. These two final goods are combined together with oil into a bundle consumed by household, another bundle consumed by the government and a third bundle that corresponds to new capital goods that are accumulated to increase the capital stock. We consider two type of households: Ricardian households, that make inter-temporal consumption and savings decisions in a forward looking manner by maximizing their utility subject to their inter-temporal budget constraint, and non-Ricardian households which consume their disposable income. These households receive no profits from the firms and have no savings. We assume that a fraction λ of households are non-Ricardian households.

Monetary policy is conducted through a policy rule for the interest rate while fiscal authority behaves in a manner that resembles the current *structural balance* rule implemented by the Chilean Government. The model exhibits a balanced growth path. We assume that in steady-state labor productivity grows at rate g_y. However, we assume that productivity is subject to both transitory and permanent shocks. Permanent productivity shocks introduces a unit root in major aggregates. All quantities are expressed in per-capita terms.

2.1 Households

The domestic economy is inhabited by a continuum of households indexed by $j \in [0,1]$. The expected present value of the utility of household j at time t is given by:

$$U_t = E_t \left\{ \sum_{i=0}^{\infty} \beta^i \zeta_{C,t+i} \left[\log \left(C_{t+i}\left(j\right) - \tilde{h} C_{t+i-1} \right) - \zeta_{L,t} \frac{l_{t+i}\left(j\right)^{1+\sigma_L}}{1+\sigma_L} + \frac{\zeta_{\mathcal{M}}}{\mu} \left(\frac{\mathcal{M}_{t+i}(j)}{P_{C,t+i}} \right)^{\mu} \right] \right\} \qquad (1)$$

where $l_t\left(j\right)$ is labor effort, $C_t\left(j\right)$ is its total consumption, and $\mathcal{M}_t\left(j\right)$ corresponds to nominal balances held at the beginning of period t. Parameter σ_L is the inverse of the Frish elasticity of labor supply. The variable $\zeta_{C,t}$ is a consumption preference shock that follows an AR(1) process subject to i.i.d. innovations. $\zeta_{L,t}$ is labor supply shock that can be interpreted as a technology change in the home production technology;[3] $\zeta_{\mathcal{M}}$ determines the weights of leisure and nominal balances in the households preferences while μ defines the semi-elasticity of money demand to the nominal interest rate. Preferences display habit formation measured by parameter $\tilde{h}$; C_t is the aggregate per capita consumption in period t.[4] The aggregate consumption bundle is a composite of a *core* consumption bundle, C_Z, and oil consumption C_O:

$$C_t\left(j\right) = \left[\alpha_C^{1/\omega_C} \left(C_{Z,t}\left(j\right)\right)^{\frac{\omega_C - 1}{\omega_C}} + \left(1-\alpha_C\right)^{1/\omega_C} \left(C_{O,t}\left(j\right)\right)^{\frac{\omega_C - 1}{\omega_C}} \right]^{\frac{\omega_C}{\omega_C - 1}}$$

[3]See Chang *et al.* (2003).

[4]Since the economy grows in the steady state, we adjust the habit formation parameter to $\tilde{h} = h(1+g_y)$ where h corresponds to the habit formation parameter in an economy without steady-state growth.

Parameter ω_C determines the degree of substitution between the *core* consumption bundle and oil, and α_C defines their corresponding shares. The optimal composition of the consumption bundle determines the following demands:

$$C_{Z,t}(j) = \alpha_C \left(\frac{P_{Z,t}}{P_{C,t}}\right)^{-\omega_C} C_t(j), \qquad C_{O,t}(j) = (1-\alpha_C)\left(\frac{P_{O,t}}{P_{C,t}}\right)^{-\omega_C} C_t(j)$$

where $P_{Z,t}$ is the price index of the *core* consumption bundle and $P_{O,t}$ is the price of oil. The aggregate consumption price level is given by $P_{C,t} = \left(\alpha_C P_{Z,t}^{1-\omega_C} + (1-\alpha_C) P_{O,t}^{1-\omega_C}\right)^{\frac{1}{1-\omega_C}}$. The *core* consumption bundle is given by the following constant elasticity of substitution (CES) aggregator of *home* and *foreign* goods,

$$C_{Z,t}(j) = \left[\gamma_C^{1/\eta_C} \left(C_{H,t}(j)\right)^{\frac{\eta_C-1}{\eta_C}} + (1-\gamma_C)^{1/\eta_C} \left(C_{F,t}(j)\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}$$

where η_C is the elasticity of substitution between *home* and *foreign* goods in this bundle, and γ_C defines their respective weights. Minimizing the cost of this bundle determines the demands for *home* and *foreign* goods by the household j, $C_{H,t}(j)$ and $C_{F,t}(j)$ respectively, which are given by

$$C_{H,t}(j) = \gamma_C \left(\frac{P_{H,t}}{P_{Z,t}}\right)^{-\eta_C} C_{Z,t}(j), \qquad C_{F,t}(j) = (1-\gamma_C)\left(\frac{P_{F,t}}{P_{Z,t}}\right)^{-\eta_C} C_{Z,t}(j), \tag{2}$$

where $P_{H,t}$ and $P_{F,t}$ are the price indices of *home* and *foreign* goods, and $P_{Z,t}$ is the price index of the *core* consumption bundle, defined as: $P_{Z,t} = \left(\gamma_C P_{H,t}^{1-\eta_C} + (1-\gamma_C) P_{F,t}^{1-\eta_C}\right)^{\frac{1}{1-\eta_C}}$.

2.1.1 Consumption-savings decisions by Ricardian households

Ricardian households, that correspond to a share 1-λ of the households, have access to three types of assets: money $\mathcal{M}_t(j)$, one-period non-contingent foreign bonds (denominated in foreign currency) $B_t^*(j)$, and one-period domestic contingent bonds $\mathcal{D}_{t+1}(j)$ which pays out one unit of domestic currency in a particular state (state contingent securities). The budget constraint of household j is given by:

$$\begin{aligned} P_{C,t}C_t(j) + E_t\left\{d_{t,t+1}\mathcal{D}_{t+1}(j)\right\} + \frac{\mathcal{E}_t B_t^*(j)}{(1+i_t^*)\,\Theta(\mathcal{B}_t)} + \mathcal{M}_t(j) = \\ W_t(j)l_t(j) + \Pi_t(j) - \mathcal{T}_{p,t} + \mathcal{D}_t(j) + \mathcal{E}_t B_{t-1}^*(j) + \mathcal{M}_{t-1}(j), \end{aligned}$$

where $\Pi_t(j)$ are profits received from domestic firms, $W_t(j)$ is the nominal wage set by the household, $\mathcal{T}_{p,t}$ are per-capita lump-sum net taxes from the government, and $\mathcal{E}_t$ is the nominal exchange rate (expressed as units of domestic currency per one unit of foreign currency). Variable $d_{t,t+1}$ is the period t price of one-period domestic contingent bonds normalized by the probability of the occurrence of the state. Assuming the existence of a full set of contingent bonds ensures that consumption of all Ricardian households is the same, independently of the labor income they receive each period.

Variable i_t^* is the interest rate on foreign bond denominated in foreign currency, and the term $\Theta(.)$ is the premium that domestic households have to pay when they borrow from abroad. This premium is function of the net foreign asset positions relative to GDP, $\mathcal{B}_t^*$, which is given by

$$\mathcal{B}_t^* = \frac{\mathcal{E}_t B_t^*}{P_{Y,t}Y_t}$$

where $P_{Y,t}Y_t$ is nominal GDP and B_t^* is the aggregate net asset position of the economy.[5]

The fact that the premium depends on the aggregate net asset position –and not the individual position– implies that Ricardian households take it as an exogenous variable when optimizing.[6] In the steady state we assume that $\Theta(.) = \Theta$ and $\frac{\Theta'}{\Theta}\mathcal{B} = \varrho$. When the country is a net debtor, ϱ corresponds to the elasticity of the upward-slopping supply of international funds.

Each Ricardian household chooses a consumption path and the composition of its portfolio by maximizing (1) subject to its budget constraint. The first order conditions on different contingent claims over all possible states define the following Euler equation for consumption:

$$\beta E_t \left\{ (1+i_t) \frac{P_{C,t}}{P_{C,t+1}} \frac{\zeta_{C,t+1}}{\zeta_{C,t}} \left(\frac{C_{t+1}(j) - \tilde{h}C_t}{C_t(j) - \tilde{h}C_{t-1}} \right) \right\} = 1, \quad \text{for all } j \in (\lambda, 1] \tag{3}$$

where we have used the fact that in equilibrium $1/E_t[d_{t,t+1}] = 1 + i_t$, where i_t is the domestic risk-free interest rate. From this expression and the first order condition with respect to foreign bonds denominated in foreign currency we obtain the following expression for the uncovered interest parity (UIP) condition:

$$\frac{1+i_t}{(1+i_t^*)\Theta(\mathcal{B}_t)} = \frac{E_t\left\{ \frac{P_t}{P_{t+1}} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \frac{\zeta_{C,t+1}}{\zeta_{C,t}} \left(\frac{C_{t+1}(j) - \tilde{h}C_t}{C_t(j) - \tilde{h}C_{t-1}} \right) \right\}}{E_t\left\{ \frac{P_t}{P_{t+1}} \frac{\zeta_{C,t+1}}{\zeta_{C,t}} \left(\frac{C_{t+1}(j) - \tilde{h}C_t}{C_t(j) - \tilde{h}C_{t-1}} \right) \right\}} \quad \text{for all } j \in (\lambda, 1]. \tag{4}$$

The foreign interest rate is assumed to follow an AR(1) process subject to i.i.d shocks. These shocks to i_t^* (which we also call shocks to foreign financial conditions or UIP shocks) capture the relevant foreign financial factors faced by the domestic agents, including price, risk premia and any other factors associated with the exchange rate arbitrage.

2.1.2 Labor supply and wage setting by Ricardian households

Each household j is a monopolistic supplier of a differentiated labor service. There is a set of perfectly competitive labor service assemblers that hire labor from each household and combine it into an aggregate labor service unit,

$$l_t = \left(\int_0^1 l_t(j)^{\frac{\epsilon_L - 1}{\epsilon_L}} dj \right)^{\frac{\epsilon_L}{\epsilon_L - 1}} \tag{5}$$

This labor unit is then used as an input in production of domestic intermediate varieties. Parameter ϵ_L corresponds to the elasticity of substitution among different labor services. Cost minimization by labor unit assemblers give rise to demands for each type of labor services, which are function of the corresponding relative wages.

Following Erceg *et al.* (2000) we assume that wage setting is subject to a nominal rigidity à la Calvo (1983). In each period, each type of household faces a probability $1 - \phi_L$ of being able to re-optimize its nominal wage. In this set-up, parameter ϕ_L is a measure of the degree of nominal wage rigidity. The larger is this parameter the less frequently wages are adjusted (i.e. the more sticky they are). We assume that all those households that cannot re-optimize their wages follow an updating rule considering a geometric weighted average of past CPI inflation, and the inflation target set by the authority, $\overline{\pi}_t$. Once a household

[5] In our notation, $B_t^* = \int_\lambda^1 B_t^*(j)dj$.

[6] This premium is introduced mainly as a technical device to ensure stationarity (see Schmitt-Grohé and Uribe, 2003).

has set its wage, it must supply any quantity of labor service demanded at that wage. A particular household j that is able to re-optimize its wage at t must solve the following problem:

$$\max_{W_t(j)} = E_t \left\{ \sum_{i=0}^{\infty} \phi_L^i \Lambda_{t,t+i} \left[\frac{\Gamma_{W,t}^i W_t(j)}{P_{C,t+i}} l_{t+i}(j) - \zeta_{L,t} \frac{l_{t+i}(j)^{1+\sigma_L}}{1+\sigma_L} \left(C_{t+i} - \tilde{h} C_{t+i-1} \right) \right] \right\}$$

subject to labor demand and the updating rule for the nominal wage of agents who do not optimize defined by function $\Gamma_{W,t}^i$.[7] Variable $\Lambda_{t,t+i}$ is the relevant discount factor between periods t and $t+i$.[8]

2.1.3 Non-Ricardian households

Non-Ricardian households have no access to assets and own no shares in domestic firms. They consume all of their disposable after-tax disposable income:

$$C_t(j) = \frac{W_t}{P_{C,t}} l_t(j) - \frac{\mathcal{T}_{p,t}}{P_{C,t}}, \text{ for } j \in [0, \lambda] \tag{6}$$

where $\mathcal{T}_{p,t}$ are per-capita lump-sum taxes. For simplicity we assume that non-Ricardian households set wages equal to the average wage set by Ricardian households. Given the labor demand for each type of labor, this assumption implies that labor effort of non-Ricardian households coincides with the average labor effort of Ricardian households.

2.2 Investment and capital goods

There is a representative firm that rents capital goods to firms producing intermediate varieties. This firm decides how much capital to accumulate each period. New capital goods are assembled using a CES technology that combines *home* and *foreign* goods as follows:

$$I_t = \left[\gamma_I^{1/\eta_I} I_{H,t}^{1-\frac{1}{\eta_I}} + (1-\gamma_I)^{1/\eta_I} I_{F,t}^{1-\frac{1}{\eta_I}} \right]^{\frac{\eta_I}{\eta_I - 1}} \tag{7}$$

where η_I is the elasticity of substitution between *home* and *foreign* goods, and where parameter γ_I is the share of home goods in investment. The demands for home and foreign goods by the firm are given by

$$I_{H,t} = \gamma_I \left(\frac{P_{H,t}}{P_{I,t}} \right)^{-\eta_I} I_t, \qquad I_{F,t} = (1-\gamma_I) \left(\frac{P_{F,t}}{P_{I,t}} \right)^{-\eta_I} I_t, \tag{8}$$

where $P_{I,t}$ is the investment price index, given by $P_{I,t} = \left[\gamma_I P_{H,t}^{1-\eta_I} + (1-\gamma_I) P_{F,t}^{1-\eta_I} \right]^{\frac{1}{1-\eta_I}}$, and where I_t is total investment.

The firm may adjust investment each period, but changing investment is costly. This assumption is introduced as a way to obtain more inertia in the demand for investment (see Christiano *et al.* (2005)). It represents a short-cut to more cumbersome approaches to model investment inertia, such as time-to-build.

[7] All those that cannot re-optimize during i periods between t and $t+i$, set their wages at time $t+i$ to $W_{t+i}(j) = \Gamma_{W,t}^i W_t(j)$, where $\Gamma_{W,t}^i = (T_{t+i}/T_{t+i-1}) (1+\pi_{C,t+i-1})^{\chi_L} (1+\overline{\pi}_{t+i})^{1-\chi_L} \Gamma_{W,t}^{i-1}$ and $\Gamma_{W,t}^0 = 1$. T_t is a stochastic trend in labor productivity. This term in the updating rule prevents an increasing dispersion in the real wages across households along the steady-state balanced growth path.

[8] Since utility exhibits habit formation in consumption the relevant discount factor is given by $\Lambda_{t,t+i} = \beta^i \left(\frac{C_t(j) - \tilde{h} C_{t-1}}{C_{t+i}(j) - \tilde{h} C_{t+i-1}} \right)$, $j \in (\lambda, 1]$.

Let Z_t be the rental price of capital. The representative firm must solve the following problem:

$$\max_{K_{t+i},I_{t+i}} E_t \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \frac{Z_{t+i}K_{t+i} - P_{I,t+i}I_{t+i}}{P_{C,t+i}} \right\},$$

subject to the law of motion of the capital stock,

$$K_{t+1} = (1-\delta) K_t + \zeta_{I,t} S\left(\frac{I_t}{I_{t-1}}\right) I_t, \tag{9}$$

where δ is its depreciation rate. Function $S(.)$ characterizes the adjustment cost for investment. This adjustment cost satisfies: $S(1+g_y) = 1$, $S'(1+g_y) = 0$, $S''(1+g_y) = -\mu_S < 0$. The variable $\zeta_{I,t}$ is a stochastic shock that alters the rate at which investment is transformed into productive capital. A rise in $\zeta_{I,t}$ implies the same amount of investment generates more productive capital.[9] We consider this shock to be a domestic supply shock since it defines the "technology" to accumulate capital. Other papers (i.e. SW 2007) consider this shock to be a demand shock as it captures movements in investment not explained by fundamentals.[10]

The optimality conditions for the problem above are the following:

$$\begin{aligned} \frac{P_{I,t}}{P_{C,t}} &= \frac{Q_t}{P_{C,t}} \left[S\left(\frac{I_t}{I_{t-1}}\right) + S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} \right] \zeta_{I,t} - \\ & E_t \left\{ \Lambda_{t,t+1} \frac{Q_{t+1}}{P_{C,t+1}} \left[S'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2 \right] \zeta_{I,t+1} \right\}, \end{aligned} \tag{10}$$

$$\frac{Q_t}{P_{C,t}} = E_t \left\{ \Lambda_{t,t+1} \left(\frac{Z_{t+1}}{P_{C,t+1}} + \frac{Q_{t+1}}{P_{C,t+1}} (1-\delta) \right) \right\}. \tag{11}$$

These two equations simultaneously determine the evolution of the shadow price of capital, Q_t, and real investment expenditure.

2.3 Domestic production

There is a large set of firms that use a CES technology to assemble *home* goods using domestic intermediate varieties. These firms sell *home* goods in the domestic market and abroad. Let $Y_{H,t}$ be quantity of *home* goods sold domestically, and $Y^*_{H,t}$ the quantity sold abroad. The demands for a particular intermediate variety z_H by these assemblers are given by:

$$Y_{H,t}(z_H) = \left(\frac{P_{H,t}(z_H)}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t}, \qquad Y^*_{H,t}(z_H) = \left(\frac{P^*_{H,t}(z_H)}{P^*_{H,t}}\right)^{-\epsilon_H} Y^*_{H,t}, \tag{12}$$

where $P_H(z_H)$ is the price of the variety z_H when used to assemble *home* goods sold in the domestic market, and $P^*_{H,t}(z_H)$ is the foreign-currency price of this variety when used to assemble *home* goods sold abroad. Variables $P_{H,t}$ and $P^*_{H,t}$ are the corresponding aggregate price indices.

[9] Greenwood *et al.* (2000) argue that this type of investment-specific shocks are relevant to explain business cycle fluctuations in US.

[10] This distinction is less clear if the investment-specific shocks are capturing omitted features such as financial constraints in the investment decisions.

Intermediate varieties are produced by firms that have monopoly power. These firms maximize profits by choosing the prices of their differentiated good subject to the corresponding demands, and the available technology. Let $\mathbf{Y}_{H,t}(z_H)$ be the total quantity produced of a particular variety z_H. The available technology is given by

$$\mathbf{Y}_{H,t}(z_H) = A_{H,t}\left[(\alpha_H)^{1/\omega_H} V_{H,t}(z_H)^{1-1/\omega_H} + (1-\alpha_H)^{1/\omega_H} O_{H,t}(z_H)^{1-1/\omega_H}\right]^{\frac{\omega_H}{\omega_H-1}}, \tag{13}$$

where $V_{H,t}(z_H)$ is a composite of labor and capital used in production –value added– and $O_{H,t}(z_H)$ is the amount of oil used as intermediate input. α_H defines the weight of the composite of capital and labor in production and ω_H determines the degree substitution between oil and the other factors of production. Variable $A_{H,t}$ represents a stationary productivity shock common to all firms. The composite of labor and capital is given by a Cobb-Douglas technology:

$$\mathbf{V}_{H,t}(z_H) = [T_t l_t(z_H)]^{\eta_H}[K_t(z_H)]^{1-\eta_H}, \tag{14}$$

where $l_t(z_H)$ is the amount of labor utilized, and $K_t(z_H)$ is the amount of physical capital rented. Parameter η_H defines their corresponding shares in production. The variable T_t is a stochastic trend in labor productivity, evolving according to the following expression

$$\frac{T_t}{T_{t-1}} = \zeta_{T,t}. \tag{15}$$

The exogenous shocks to both types of technology process are given by

$$A_{H,t} = A_{H,t-1}^{\rho_{a_H}} \exp \varepsilon_{a_H,t} \qquad\qquad \zeta_{T,t} = (1+g_y)^{1-\rho_T}\zeta_{T,t-1}^{\rho_T}\exp\varepsilon_{T,t}$$

where $\varepsilon_{a_H,t} \sim N\left(0,\sigma_{a_H}^2\right)$ and $\varepsilon_{T,t} \sim N\left(0,\sigma_T^2\right)$ are i.i.d innovations

In every period, the probability that a firm receives a signal for adjusting its price for the domestic market is $1-\phi_{H_D}$, and the probability of adjusting its price for the foreign market is $1-\phi_{H_F}$. These probabilities are the same for all firms, independently of their history. If a firm does not receive a signal, it updates its price following a simple rule that weights past inflation and the inflation target set by the central bank. Thus, when a firm receives a signal to adjust its price for the domestic market it solves:

$$\max_{P_{H,t}(z_H)} E_t\left\{\sum_{i=0}^{\infty}\Lambda_{t,t+i}\phi_{H_D}^i\frac{\Gamma_{H_D,t}^i P_{H,t}(z_H) - MC_{H,t+i}}{P_{C,t+i}}Y_{H,t+i}(z_H)\right\},$$

subject to (12) and the updating rule for prices, $\Gamma_{H_D,t}^i$. Analogously, if the firm receives a signal to adjust optimally its price for the foreign market, then it solves:

$$\max_{P_{H,t}^*(z_H)} E_t\left\{\sum_{i=0}^{\infty}\Lambda_{t,t+i}\phi_{H_F}^i\frac{\mathcal{E}_{t+i}\Gamma_{H_F,t}^i P_{H,t}^*(z_H) - MC_{H,t+i}}{P_{C,t+i}}Y_{H,t+i}^*(z_H)\right\},$$

subject to (12) and the updating rule for firms that do not optimize prices defined by $\Gamma_{H_F,t}^i$.[11] Given this pricing structure, the optimal path for inflation is given by a New Keynesian Philips curve with indexation.

[11] If the firm does not adjust its price for the domestic market between t and $t+i$, then the price it charges at $t+i$ will be $P_{H,t+i}(z_H) = \Gamma_{H_D,t}^i P_{H,t}(z_H)$, where $\Gamma_{H_D,t}^i = \Gamma_{H_D,t}^{i-1}(1+\bar{\pi}_{t+i})^{1-\chi_{H_D}}(P_{H,t+i}/P_{H,t+i-1})^{\chi_{H_D}}$ and $\Gamma_{H_D,t}^0 = 1$. If the firm does not adjust its price for the foreign market, then the price charged at $t+i$ will be $P_{H,t+i}^*(z_H) = \Gamma_{H_F,t}^i P_{H,t}^*(z_H)$, where $\Gamma_{H_F,t}^i = \Gamma_{H_F,t}^{i-1}\left(P_{F,t}^*/P_{F,t-1}^*\right)^{1-\chi_{H_F}}\left(P_{H,t+i}^*/P_{H,t+i-1}^*\right)^{\chi_{H_F}}$ and $\Gamma_{H_F,t}^0 = 1$.

In its log-linear form, inflation depends on both last period's inflation, expected inflation next period and marginal cost.

The variable $MC_{H,t}$ corresponds to marginal costs of producing variety z_H, which are given by,

$$MC_{H,t} = \frac{W_t l_t\left(z_H\right) + Z_t K_t\left(z_H\right) + P_{O,t} O_{H,t}\left(z_H\right)}{\mathbf{Y}_{H,t}\left(z_H\right)}. \tag{16}$$

Given the constant return to scale technology available to firms, and the fact that there are no adjustment costs for inputs which are hired from competitive markets, marginal cost is independent of the scale of production.

2.4 Import goods retailers

We introduce local-currency price stickiness in order to allow for incomplete exchange rate pass-through into import prices in the short-run. This feature of the model is important in order to mitigate the expenditure switching effect of exchange rate movements.

There is a set of competitive assemblers that use a CES technology to combine a continuum of differentiated imported varieties to produce a final *foreign* good Y_F. This good is consumed by households and used for assembling new capital goods. The optimal mix of imported varieties in the final *foreign* good defines the demands for each of them. In particular, the demand for variety z_F is given by:

$$Y_{F,t}(z_F) = \left(\frac{P_{F,t}(z_F)}{P_{F,t}}\right)^{-\epsilon_F} Y_{F,t}, \tag{17}$$

where ϵ_F is the elasticity of substitution among imported varieties, $P_{F,t}(z_F)$ is the domestic-currency price of imported variety z_F in the domestic market, and $P_{F,t}$ is the aggregate price of import goods in this market.

Importing firms buy varieties abroad and re-sales them domestically to the assemblers. Each importing firm has monopoly power in the domestic retailing of a particular variety. They adjust the domestic price of their varieties infrequently, only when receiving a signal. The signal arrives with probability $1 - \phi_F$ each period. As in the case of domestically produced varieties, if a firm does not receive a signal it updates its price following a "passive" rule.[12] Therefore, when a generic importing firm z_F receives a signal, it chooses a new price by maximizing the present value of expected profits:

$$\max_{P_{F,t}(z_F)} E_t \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \phi_F^i \frac{\Gamma_{F,t}^i P_{F,t}(z_F) - \mathcal{E}_{t+i} P_{F,t+i}^*(z_F)}{P_{C,t+i}} Y_{F,t+i}(z_F) \right\},$$

subject to the domestic demand for variety z_F (17) and the updating rule for prices. For simplicity, we assume that $P_{F,t}^*(z_F) = P_{F,t}^*$ for all z_F.

In this setup, changes in the nominal exchange rate will not immediately be passed through into prices of imported good sold domestically. Therefore, exchange rate pass-through will be incomplete in the short-run. In the long-run firms freely adjust their prices, so the weak form of law of one price holds and accumulated changes in the exchange rate are transmitted completely to imported prices in

[12] This "passive" rule is defined by $\Gamma_{F,t}^i = \Gamma_{F,t}^{i-1}(1 + \bar{\pi}_{t+i})^{1-\chi_F}(P_{F,t+i}/P_{F,t+i-1})^{\chi_F}$ and $\Gamma_{F,t}^0 = 1$.

domestic currency. The presence of a incomplete exchange rate pass-through in the short run mitigates the expenditure-switching effect of exchange rate movements and allows to match the observed degree of sensitivity of net exports to the real exchange rate in the short run, without relying in an extremely low elasticity of substitution between domestic and foreign goods.

2.5 Commodity sector

We assume that a single firm produces a homogenous commodity good that is completely exported abroad. Production evolves with the same stochastic trend as other aggregate variables and requires no inputs:

$$Y_{S,t} = \left[\frac{T_t}{T_{t-1}} Y_{S,t-1}\right]^{\rho_{y_S}} \left[T_t Y_{S,0}\right]^{1-\rho_{y_S}} \exp(\varepsilon_{y_S,t}),$$

where $\varepsilon_{y_S,t} \sim N(0, \sigma^2_{y_S})$ is a stochastic shock and ρ_{y_S} captures the persistence of the shock to the production process.[13] This sector is particularly relevant for the two economies, as it captures the developments in the copper sector.

An increase in the production of the commodity good implies directly an increase in domestic GDP. Because there are no inputs, this increase in production comes as a windfall gain. As with any expansion of the technological frontier biased towards tradable goods, a boom in this sector would induce an exchange rate appreciation. It may also increase exports, if no counteracting effect on home goods exports dominates. The magnitude of the appreciation would depend on the structural parameters governing the degree of intra-temporal and inter-temporal substitution in aggregate demand and production.

2.6 Government

The government is composed by the fiscal and monetary authorities. The government budget corresponds to the consolidated budget of both of them. The only asset own by the government is its share in the commodity exporting firm. Government liabilities are public bonds held by the private sector, and money.

2.6.1 Fiscal Policy

Let $B^*_{G,t}$ and $B_{G,t}$ be the net asset position of government in foreign and domestic currency, respectively. The evolution of the total the net position of the government is given by:

$$\frac{\mathcal{E}_t B^*_{G,t}}{(1+i^*_t)\,\Theta\left(\frac{\mathcal{E}_t B^*_t}{P_{Y,t} Y_t}\right)} + \frac{B_{G,t}}{(1+i_t)} = \mathcal{E}_t B^*_{G,t-1} + B_{G,t} + \mathcal{T}_t - P_{G,t} G_t,$$

where $(1+i^*_t)\,\Theta\,(.)$ is the relevant gross interest rate for public asset denominated in foreign currency, while $(1+i_t)$ is the one for public asset denominated in domestic currency. Variable G_t is government expenditure and $\mathcal{T}_t$ are total net fiscal nominal revenues (income tax revenues plus seignorage minus transfers to the private sector). We assume that the basket consumed by the government includes both home and foreign goods:

$$G_t = \left[\gamma_G^{\frac{1}{\eta_G}} G_{H,t}^{\frac{\eta_G-1}{\eta_G}} + (1-\gamma_G)^{\frac{1}{\eta_G}} G_{F,t}^{\frac{\eta_G-1}{\eta_G}}\right]^{\frac{\eta_G}{\eta_G-1}}$$

[13] Production in this sector could be interpreted as the exogenous evolution of an endowment of natural resources.

The government decides the composition of its consumption basket by minimizing its cost. The demands for the two types of goods from the government is given by

$$G_{H,t} = \gamma_G \left(\frac{P_{H,t}}{P_{G,t}}\right)^{-\eta_G} G_t, \qquad G_{F,t} = (1-\gamma_G)\left(\frac{P_{F,t}}{P_{G,t}}\right)^{-\eta_G} G_t,$$

where the deflator of government expenditure (which is defined as the minimum expenditure required to buy one unit of G_t) is given by: $P_{G,t} = \left[\gamma_G P_{H,t}^{1-\eta_G} + (1-\gamma_G) P_{F,t}^{1-\eta_G}\right]^{\frac{1}{1-\eta_G}}$.

Fiscal policy is defined by the four variables $B^*_{G,t}$, $B_{G,t}$ $\mathcal{T}_{,t}$ and G_t. Therefore, given the budget constraint of the government, it is necessary to define a behavioral rule for three of these four variables in order to completely characterize the fiscal policy.

When agents are Ricardian, defining a trajectory for the primary deficit is irrelevant for households decisions, as long as the budget constraint of the government is satisfied. On the contrary, when a fraction of the agents are non-Ricardian then the trajectory of the public debt and the primary deficit are relevant. In addition, the path of public expenditure may be relevant on its own as long as its composition differs from the composition of private consumption.

We assume that the fraction of non-Ricardian households is positive. Hence, the timing of the fiscal variables is relevant for the private sector decisions. We also assume that public asset position is completely denominated in foreign currency ($B_{G,t} = 0$). Fiscal revenues come from two sources: tax income from the private sector, which is a function of GDP, $\mathcal{T}_{p,t} = (\tau_t P_{Y,t} Y_t)$, and revenues from copper which are given by $P_{S,t}\chi Y_{S,t}$, where $\chi Y_{S,t}$ are copper sales from the state company. The parameter χ defines the public share of ownership in total copper production. The variable τ_t corresponds to the average income tax.

Finally, we assume that the Chilean government follows a structural balance fiscal rule according to which government expenditure, as a share of GDP, evolves as follows:

$$\begin{aligned}\frac{P_{G,t}G_t}{P_{Y,t}Y_t} &= \left\{\left(1 - \frac{1}{\left(1+i^*_{t-1}\right)\Theta_{t-1}}\right)\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\frac{\mathcal{E}_{t-1}B^*_{G,t-1}}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t} + \right. \\ &\quad \left. \tau\left(\frac{\overline{Y}_t}{Y_t}\right) + \mathcal{E}_t \overline{P}^*_{S,t}\chi\frac{Y_{S,t}}{P_{Y,t}Y_t} - \frac{B_{S,t}}{P_{Y,t}Y_t}\right\}\exp\left(\zeta_{G,t}\right) \qquad (18)\end{aligned}$$

where $\overline{P}^*_{S,t}$ is the long-run ("reference") price of copper, that we treat as a constant in the model, and where $\zeta_{G,t}$ is a shock that captures deviation of government expenditure from this fiscal rule. This shock follows an AR(1) process with i.i.d. innovations.[14]

This rule was officially set in place by the government during 2001 and it is meant to avoid excessive fluctuations in government expenditure coming from transitory movements in fiscal revenues (see Medina and Soto, 2007). For example, in the case of a transitory rise of fiscal revenues originated by a copper price increase, the rule implies that the additional fiscal income should be mainly saved.[15] Notice that this rule does not necessarily characterizes the behavior of the fiscal authority before 2001. Therefore, we would expect that innovations to $\zeta_{G,t}$ would be larger before that year. In this version of the paper, we assume that the standard deviation of this shock is the same for the whole sample.

[14] In practice, the reference price of copper is defined once a year by an independent panel of experts.

[15] The level of public expenditure that is consistent with the rule includes interest payments. Therefore, if the net position of the government improves, current expenditure may increase.

2.6.2 Monetary policy rule

Monetary policy is characterized as a simple feedback rule for the interest rate. Under the baseline specification of the model, we assume that the central bank responds to deviations of *core* CPI inflation from target and to deviations of output growth from its trend.

The Central Bank of Chile (CBC), after a decade of partial implementation of an Inflation Targeting regime, made an upgrade in its policy framework at the end of 1999. From that period onwards, the inflation target was set permanently in 3 percent. Previously, from 1991 until 1999, targets for the end of the year CPI inflation were pre-announced once a year. Those targets were declining over time. Together with this modification, an explicit target zone for the nominal exchange rate was eliminated. Moreover, until July 2001 the CBC utilized an index interest rate as its policy instrument.[16] Since then on the policy instrument has been an overnight nominal interest rate. In order to capture some of these policy modifications, we allow for a discrete change in the specification of the monetary policy rule.

We define, for the period 1987-99, a rule that uses as the policy instrument the real interest rate . We also allow the central bank to react to deviations of the real exchange from a long-run level. This is meant to capture the fact that the CBC had a target for the exchange rate over that period. From year 2000 onwards we specify a rule that utilizes as the policy instrument the nominal interest rate and we eliminate any direct policy reaction to real exchange rate fluctuations. In summary, we have the following two rules to characterize the monetary policy:

- *Period 1987-1999*:

$$\frac{1+r_t}{1+r} = \left(\frac{1+r_{t-1}}{1+r}\right)^{\psi_{i,1}} \left(\frac{Y_t}{\overline{Y}_t}\frac{\overline{Y}_{t-1}}{Y_{t-1}}\right)^{(1-\psi_{i,1})\psi_{y,1}} \left(\frac{1+\pi_{Z,t}}{1+\overline{\pi}_t}\right)^{(1-\psi_{i,1})(\psi_{\pi,1}-1)} \left(\frac{RER_t}{\overline{RER}}\right)^{(1-\psi_{i,1})\psi_{rer,1}} \exp\zeta_{m,t}$$

- *Period 2000-2005*:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\psi_{i,2}} \left(\frac{Y_t}{\overline{Y}_t}\frac{\overline{Y}_{t-1}}{Y_{t-1}}\right)^{(1-\psi_{i,2})\psi_{y,2}} \left(\frac{1+\pi_{Z,t}}{1+\overline{\pi}_t}\right)^{(1-\psi_{i,2})\psi_{\pi,2}} \exp\zeta_{m,t}$$

where $\pi_{Z,t} = P_{Z,t}/P_{Z,t-1} - 1$ is the *core* consumption price inflation and $\overline{\pi}_t$ is the inflation target set for period t, and $r_t = (1+i_t)/(P_{C,t}/P_{C,t-1}) - 1$ is the net (ex-post) real interest rate; $(RER_t/\overline{RER})$ is the deviation of real exchange rate deviations from its long-run level. Variable $\zeta_{m,t}$ is an i.i.d. monetary policy shock. In the estimation we also allow for shifts in the smoothing parameter, ψ_i.[17]

2.7 Foreign sector

Foreign agents demand the commodity good and the *home* good. The demand for the commodity good is completely elastic at the international price $P^*_{S,t}$. The law of one price holds for this good. Therefore, its domestic-currency price is given by,

$$P_{S,t} = \mathcal{E}_t P^*_{S,t}, \tag{19}$$

[16] This indexed interest rate corresponds roughly to an ex-post real interest rate (Fuentes *et al.*, 2003).

[17] This change in policy coefficients is assumed to be permanent and unanticipated. This means that when agents make decisions, they expect that these parameters will remain constant for ever.

The supply of oil faced by domestic agents is completely elastic at any given price. For this good, we also assume that the law of one price holds. Hence, the oil price in domestic currency is given by

$$P_{O,t} = \mathcal{E}_t P^*_{O,t}, \tag{20}$$

where $P^*_{O,t}$ is the international price of oil. The real exchange rate is defined as the relative price of a foreign price index, P^*_t, and the price of the consumption bundle in the domestic economy:

$$RER_t = \frac{\mathcal{E}_t P^*_t}{P_{C,t}}. \tag{21}$$

We assume that the foreign price index P^*_t co-integrates with $P^*_{F,t}$, the CIF price of imported goods. In other words we have that:

$$P^*_{F,t} = P^*_t \zeta^*_{F,t}, \tag{22}$$

where $\zeta^*_{F,t}$ is a stationary transitory shock to the relative price of import goods abroad. This shock captures, amongst other things, changes in the relative productivity across sector in the foreign economy.

Foreign demand for the *home* good depends on its relative price abroad and the total foreign aggregate demand, Y^*_t

$$Y^*_{H,t} = \zeta^* \left(\frac{P^*_{H,t}}{P^*_t} \right)^{-\eta^*} Y^*_t, \tag{23}$$

where ζ^* corresponds to the share of domestic intermediate goods in the consumption basket of foreign agents, and η^* is the price elasticity of the demand. This demand can be obtained from a CES utility function with an elasticity of substitution across varieties equal to that parameter.

2.8 Aggregate equilibrium

Once firms producing domestic varieties set their prices, they must supply any quantity demanded at those given prices. Therefore, the market clearing condition for each variety implies that:

$$\mathbf{Y}_{H,t}(z_H) = \left(\frac{P_{H,t}(z_H)}{P_{H,t}} \right)^{-\epsilon_H} Y_{H,t} + \left(\frac{P^*_{H,t}(z_H)}{P^*_{H,t}} \right)^{-\epsilon_H} Y^*_{H,t}$$

where $Y_{H,t} = C_{H,t} + I_{H,t} + G_{H,t}$, and where $Y^*_{H,t}$ is defined in (23). The equilibrium implies that total labor demand by intermediate varieties producers must be equal to labor supply: $\int_0^1 l_t(z_H) dz_H = l_t$, where l_t is defined by (5).

Since the economy is open and there is no reserves accumulation by the central bank, the current account is equal to the capital account. Using the equilibrium conditions in the goods and labor markets, and the budget constraint of households and the government we obtain the following expression for the evolution of the net foreign asset position:

$$\frac{\mathcal{E}_t B^*_t / P_{Y,t} Y_t}{(1+i^*_t)\Theta\left(\frac{\mathcal{E}_t B^*_t}{P_{Y,t} Y_t}\right)} = \frac{\mathcal{E}_{t-1} B^*_{t-1}}{P_{Y,t} Y_t} - (1-\chi)\frac{P_{S,t} Y_{S,t}}{P_{Y,t} Y_t} + \frac{P_{X,t} X_t}{P_{Y,t} Y_t} - \frac{P_{M,t} M_t}{P_{Y,t} Y_t},$$

where B^*_t is the aggregate net (*liquid*) asset position of the economy vis-a-vis the rest of the world, χ is the share of the government in the revenues from the commodity sector ($1-\chi$ is the share of foreign investors) and $P_{Y,t}Y_t = P_{C,t}C_t + P_{H,t}G_t + P_{I,t}I_t + P_{X,t}X_t - P_{M,t}M_t$ is the nominal GDP –measured from demand side. Nominal imports and exports are given by $P_{M,t}M_t = \mathcal{E}_t \left(P^*_{F,t}Y_{F,t} + P^*_{O,t} \left(C_{O,t} + O_{H,t} \right) \right)$ and $P_{X,t}X_t = \mathcal{E}_t \left(P^*_{H,t}Y^*_{H,t} + P^*_{S,t}Y_{S,t} \right)$, respectively. The amount of foreign goods imported is $Y_{F,t} = C_{F,t} + I_{F,t} + G_{F,t}$.

3 Model Estimation: A Bayesian Approach

The model is estimated by using a Bayesian approach (see DeJong, Ingram, and Whiteman (2000), Fernández-Villaverde and Rubio-Ramírez (2004), and Lubik and Schorfheide (2006)).[18] The Bayesian methodology is a full information approach to jointly estimate the parameters of a DSGE model. The estimation is based on the likelihood function generated by the solution of the log-linear version of the model. Prior distributions for the parameters of interest are used to incorporate additional information into the estimation.[19]

Appendix A presents the log-linearized version of the model developed in the previous section. The whole set of linearized equations forms a linear rational expectation system that can be written in canonical form as follows,

$$\Gamma_0 \left(\vartheta \right) \mathbf{z}_t = \Gamma_1 \left(\vartheta \right) \mathbf{z}_{t-1} + \Gamma_2 \left(\vartheta \right) \varepsilon_t + \Gamma_3 \left(\vartheta \right) \xi_t$$

where $\mathbf{z}_t$ is a vector containing the model's variables expressed as log-deviation from their steady-state values. Vector ε_t contains white noise innovations to the exogenous shocks of the model, and ξ_t is a vector containing rational expectation forecast errors. Matrices Γ_i are non-linear functions of the structural parameters contained in vector ϑ. Vector $\mathbf{z}_t$ collects the endogenous variables of the model and the fourteen exogenous shocks: preference shock ($\zeta_{C,t}$), labor supply shock ($\zeta_{L,t}$), foreign interest rate shock (i^*_t), foreign inflation shock (π^*_t), transitory and permanent productivity shocks ($a_{H,t}$) and ($\zeta_{T,t}$), investment adjustment cost shock ($\zeta_{I,t}$), commodity production shock ($y_{S,t}$), foreign commodity price shock ($P^*_{S,t}$), oil price shock ($P^*_{O,t}$), government expenditure shock ($\zeta_{G,t}$), monetary policy shock ($\zeta_{m,t}$), price of imports shock ($\zeta^*_{F,t}$), and foreign output shock (Y^*_t). In the log-linear form, these shocks are assumed to follow orthogonal autoregressive processes of order one.

The solution to this system can be expressed as follows

$$\mathbf{z}_t = \Omega_z \left(\vartheta \right) \mathbf{z}_{t-1} + \Omega_\varepsilon \left(\vartheta \right) \varepsilon_t, \tag{24}$$

where Ω_z and Ω_ε are function of the structural parameters. Let $\mathbf{y}_t$ be a vector of observable variables. This vector is related to the variables in the model through a measurement equation:

$$\mathbf{y}_t = H\mathbf{z}_t \tag{25}$$

where H is a matrix that selects elements from $\mathbf{z}_t$.

Equations (24) and (25) correspond to the state-space form representation of $\mathbf{y}_t$. If we assume that the white noise innovations ε_t are normally distributed we can compute the conditional likelihood function for

[18] Fernández-Villaverde and Rubio-Ramírez (2004) and Lubik and Schorfheide (2006) discuss in deep the advantages of this approach to estimate DSGE models.

[19] One of the advantages of the Bayesian approach is that it can cope with potential model mis-specification and possible lack of identification of the parameters of interest (Lubik and Schorfheide, 2006).

the structural parameters using the Kalman filter. Let $\mathbf{p}(\vartheta)$ a prior density on the structural parameters and $L(\vartheta \mid \mathcal{Y}^T)$ the conditional likelihood function, where $\mathcal{Y}^T = \{\mathbf{y}_1, ..., \mathbf{y}_T\}$ collects observable variables. The joint posterior density of the parameters is computed using the Bayes theorem

$$\mathbf{p}\left(\vartheta \mid \mathcal{Y}^T\right) = \frac{L(\vartheta \mid \mathcal{Y}^T)\mathbf{p}(\vartheta)}{\int L(\vartheta \mid \mathcal{Y}^T)\mathbf{p}(\vartheta)\, d\vartheta} \tag{26}$$

Since the conditional likelihood function has no analytical expression, we approximate it using numerical methods based on the Metropolis-Hastings algorithm. The parameter vector to be estimated is $\vartheta = \{\sigma_L,\, h,\, \phi_L,\, \chi_L,\, \eta_C,\, \omega_C,\, \eta_I,\, \mu_S,\, \phi_{H_D},\, \chi_{H_D},\, \phi_{H_F},\, \chi_{H_F},\, \omega_H,\, \phi_F,\, \chi_F,\, \psi_{i,1},\, \psi_{\pi,1},\, \psi_{y,1},\, \psi_{rer,1},\, \psi_{i,2},\, \psi_{\pi,2},$ $\psi_{y,2},\, \eta^*,\, \varrho,\, \rho_{a_H},\, \rho_{\zeta_T},\, \rho_{y_S},\, \rho_{y^*},\, \rho_{i^*},\, \rho_{\pi^*},\, \rho_{\zeta_L},\, \rho_{\zeta_C},\, \rho_{\zeta_G},\, \rho_{\zeta_I},\, \rho_{\zeta_F^*},\, \sigma_{a_H},\, \sigma_{\zeta_T},\, \sigma_{y_S},\, \sigma_{y^*},\, \sigma_{i^*},\, \sigma_{\pi^*},\, \sigma_m,\, \sigma_{\zeta_L},\, \sigma_{\zeta_C},$ $\sigma_{\zeta_G},\, \sigma_{\zeta_I},\, \sigma_{\zeta_F^*}\}$. Parameter ρ_m is assumed to be zero, i.e. we assume monetary policy shock to be very short lived.

Calibrated parameters

Parameters that are not estimated, were chosen so as to match the steady-state of the model with some long-run trend data in the Chilean economy. The complete list of calibrated parameters are presented in table 5. We assume an annual long run labor productivity growth, g_y, of 3.5%.[20] The long-run annual inflation rate is set to 3%, which is consistent with the midpoint target value for CPI inflation defined by the CBC since 1999. The subjective discount factor, β, is set to 0.999 (annual basis) in order to get an annual nominal interest rate around 6.5 % in the steady state. The share of oil in the consumption basket is assumed to be 1.5% ($\alpha_C = 0.985$). The share of domestic goods in the *core* consumption and investment basket, γ_C and γ_I, are set to 65% and 50%, respectively. For simplicity we assume that the government only consumes domestic goods (i.e. $\gamma_G = 1$). We calibrate the relative size of Non-Ricardian households to 50% ($\lambda = 0.5$).

The share of the value added in the commodity-exporting sector in total GDP is set to 10%.[21] The net exports to GDP ratio, $\frac{X-M}{Y}$, in steady state is equal to 2% which is consistent with its average value in the sample period. The government share in commodity production is set to 40%, which is consistent with the average fraction of CODELCO (the state owned company) in the total production of copper in Chile. Consistently with the fact that Chile is a net debtor in the international financial markets, we calibrate the steady-state current account GDP ratio in -1.8%. The depreciation rate of capital is set to 5.8% in annual basis. For the production function of domestic producers we assume that the labor share is about two thirds ($\eta_H = 0.66$) of the value added. Oil, as intermediate input, represents 1% of the gross value of good H production ($\alpha_H = 0.99$). We do not have information on prices and wages markups. Therefore, we use values consistent with those utilized by other studies. In particular, we set $\epsilon_L = \epsilon_{H_D} = \epsilon_{H_F} = \epsilon_F = 11$.[22] Finally, we use OLS estimates for the parameters governing the AR(1) processes of the international copper and oil prices. The point estimates are $\rho_{p_S^*} = 0.95$ and $\rho_{p_O^*} = 0.97$

[20] This is consistent with 5% long run GDP growth and 1.5% of labor force growth.

[21] The value added in the mining sector in Chile accounts for approximately 10% of total GDP.

[22] Christiano *et al* (2005) use $\epsilon_L = 21$ and $\epsilon_H = 6$ for a closed economy model calibrated for US. Adolfson *et al* (2005) use the same values for an open economy model calibrated for Euro area. Brubakk *et al* (2005) use $\epsilon_L = 5.5$ and $\epsilon_H = 6$ for a calibrated model of the Norwegian economy. Jacquinot *et al* (2005) calibrate $\epsilon_L = 2.65$ and $\epsilon_H = 11$ for a model of the Euro Area.

with standard deviation equal to 9% and 12% for copper and oil prices, respectively.

Data

We use Chilean quarterly data for the period 1987:Q1 to 2005:Q4. We choose the following observable variables: real GDP, Y_t; natural resources based value added as a proxy of commodity production, $Y_{S,t}$; the short-run interest rate –the real rate for the first part of the sample, r_t, and a nominal interest rate for the second part, i_t; a measure of *core* inflation computed by the Central Bank ("IPCX1") as a proxy for *core* inflation; the real exchange rate, RER_t;; the current account to GDP ratio, $\frac{CA_t}{P_{Y,t}Y_t}$; and labor input l_t. We also include as observable variable the international price of copper and the international price of oil (in dollars, deflated by a proxy of the foreign price index). In total, we have nine observable variables. Inflation rate is expressed as deviation from its target. In the case of real output, we use the logarithm of its first difference, demeaned. Labor input is measured as the ratio of formal employment to working age population. The current account to GDP ratio, labor, and copper and oil real prices are demeaned using the their average sample values for the period 1987-2005. Our set of observable variables is the following:

$$\mathbf{y}_t = \left\{ \Delta \ln Y_t, \widehat{R}_t, \widehat{\pi}_{Z,t}, \widehat{rer}_t, \frac{CA_t}{P_{Y,t}Y_t}, \widehat{l}_t, \widehat{pr}^*_{S,t}, \widehat{pr}^*_{O,t}, \right\}$$

where $\widehat{R}_t$ is the real ex-post interest rate $(\widehat{i}_t - \widehat{\pi}_{C,t})$ for the period 1987:1-1999:4 and is the nominal interest rate for the period 2000:1-2005:4 $(\widehat{i}_t)$.

Prior distributions

Prior distributions for the parameters are presented in table 2. For the elasticities of substitution between domestic and foreign goods (η_C, η_I, η^*) we set prior distributions that are concentrated around one –i.e unitary elasticities. In the case of parameters governing the degree of substitution for oil in the consumption basket and in production technology (ω_C and ω_H) we consider prior distribution with mass around a low value (0.3). Prior distribution for parameters determining the degree of nominal rigidities (ϕ_L, ϕ_{H_D}, ϕ_{H_F}, ϕ_F) imply that prices and wages are re-optimized around every four quarters on average. Also, the weights of the inflation target in the automatic nominal readjustment functions (χ_L, χ_{H_D}, χ_{H_F}, χ_F) have prior distributions with more probability in a range around 0.5.

For the monetary policy rule, prior distributions for the relevant parameters take into account values that have been reported in other empirical studies.[23] In particular, the policy inertia parameter, ψ_i, has a distribution with mass around 0.70. The combined parameter defining the policy response to inflation –when the policy instrument is the nominal interest rate–, φ_π, has a gamma distribution with mode 1.50 and standard deviation equal to 0.15 These values are coherent with parameter φ_π lying between 1.26 and 1.75 with 90% of probability. The parameter defining the policy response to output growth, φ_y, also follows a gamma distribution with mean 0.5 and a standard deviation of 0.15. Our prior for the coefficient that captures the interest rate response to real exchange rate for the period 1987-99, ψ_{rer} is a gamma distribution with mean 0.2 and standard deviation of 0.1. Finally, we impose relatively flat priors on the distribution of the parameters governing the stochastic process of exogenous shocks.

[23] See Schmidt-Hebbel and Tapia (2004), Caputo (2005) and Céspedes and Soto (2007).

Posterior estimation

Table 2 also presents the mode of the posterior distributions of the parameters and the inverse of the Hessian evaluated at the mode. This last statistic measures the degree of concavity of the posterior distribution at the mode; it can be interpreted as a (local) approximation of the standard deviation of the posterior mode for each parameter.

The mode of the Frish labor supply elasticity, σ_L^{-1} is estimated to be around 1.2. The habit formation parameter has a posterior mode of 0.65. This coefficient reflects a large degree of consumption inertia in Chile and it is in line with the one estimated for the Euro area by Adolfson *et al* (2005). The intra-temporal elasticities of substitution between *home* and *foreign* goods in different bundles are estimated to have modes close to one. The data seems not to be informative regarding the degree of substitution of oil in the consumption basket and in the production technology: the posterior mode of the corresponding parameters resembles quite closely our prior. The mode of the posterior distributions of different parameters defining the degree of nominal rigidity in the economy are consistent with nominal wages being re-optimized every five quarter and prices every two to four quarters approximately. Regarding the parameters of the monetary policy reaction function, our results indicate a significant degree of policy inertia (autoregressive coefficient of about 0.73). The parameter that captures the policy response to inflation has a posterior mode between 1.6 and 1.7 depending on the period considered. The policy response to output growth is lower than the response to inflation, with a range from 0.3 to 0.4.

Although we allow for both transitory and permanent productivity shocks, the estimated persistence of the transitory shock turns out to be quite large: its mode is 0.89. However, the persistence of the permanent productivity shock seems not to be well identified in the data. The posterior mode of this parameter is very close to our prior, and the inverse Hessian is relatively large. Transitory productivity shocks are more volatile than permanent shocks, with a standard deviation almost four times larger. Preference shocks and labor supply shocks are also very persistent. Their modes are close to 0.9, well above the modes of our prior distributions. On the contrary, investment shocks are less persistent than our prior but more volatile.

4 What accounts for the Business Cycle in Chile?

The estimated model allows us to tell a "story" about the evolution of the main aggregate variables of the economy. In order to gain some insights on the transmission mechanisms implied by the model, we first discuss some of the impulse-response functions. Then, we present the variance decomposition of the different variables, which gives us a recount of the relative importance of different shocks. Lastly, we use our identified shocks to decompose the evolution of each endogenous observable variable according to the contribution of each type of shock over the sample period.

4.1 Impulse-response Functions

Figure 1 presents the impulse-response of the endogenous variables to the fourteen shocks hitting the economy, under the two monetary policy rules –the one characterizing the period 1987-1999 and the one characterizing the period 2000-2005. The two productivity shocks have a positive impact on output growth.

Both of them imply an immediate fall in inflation, as they reduce marginal costs. However, in response to the permanent productivity shock inflation rises above its steady state after some periods. Initially the Central Bank loosens its monetary policy in response to the fall in inflation. For both shocks, employment initially falls because the increase of aggregate demand associated with the monetary expansion is not strong enough as to rise labor demand. Both shock increase labor productivity, allowing firms to keep their production levels with less employment. When the productivity shock is permanent, investment rises over time, increasing the marginal productivity of labor. This last effect eventually leads to an increase in labor demand, with the consequent rise in wages and the subsequent rise in inflation. The transitory technology shock tends to depreciate the real exchange rate, as it induces a fall in domestic prices. On the contrary, the permanent shock leads to a real appreciation of the currency, explained by the monetary policy tightening that follows some periods after the shock to curb inflation. In response to both shocks, the current account –as a fraction of GDP– deteriorates.

Consumption and investment shocks rise temporarily output growth and inflation. The investment shock leads to a depreciation of the real exchange rate, as investment goods are relatively more import-intensive than other final goods. The consumption shock, on the contrary, results in a real appreciation of the currency. The policy response to both of these shocks leads to an interest rate increase. The copper-price shock generates an output expansion, an increase in employment, and a fall in inflation. This last effect is explained by the currency appreciation, which reduces imported-goods inflation and makes capital goods cheaper –which counteracts the pressures on marginal cost derived from the expansion of employment and the increase of real wages. The oil price shock has a direct impact on marginal cost. therefore, inflation rises whereas output and employment both fall. The rise in inflation generates a real appreciation of the currency.[24]

A foreign interest rate shock affects negatively investment decisions, it contracts consumption and leads to a fall in output and in employment. This shock also generates both a nominal and a real depreciation of the currency. In spite of the recession induced by this shock, the exchange rate depreciation leads to an increase in inflation. A shock that is not straight forward to interpret is the shock to the relative price of imported goods. This shock corresponds to an increase in the price of the goods imported by the domestic economy, while keeping the prices of other goods consumed by foreign agents constant. It is, therefore, equivalent to a relative fall in the productivity of the traded sector abroad. Consistently with the Balassa-Samuelson hypothesis, this shock leads to an increase in the price of the imported goods relative to goods that foreign agents consume. The increase of the price of imported goods leads to an increase in domestic inflation, a tightening of monetary policy, and a fall in output and employment.

The change in the monetary policy rule, at the end of the 90s, did not significantly modified the propagation mechanisms of the various shocks affecting the economy. Perhaps, the most important implication of the change in the policy rule is that oil price shock have now less effects on inflation than under the rule prevailing before 2000. As we mentioned, an oil price shock tends to appreciate the real exchange rate. The first policy rule would tend to exacerbate the reduction in GDP growth and rise in inflation with the purpose of stabilizing the real exchange rate. However, the reaction of the real interest rate under the

[24]An alternative interpretation for the currency appreciation generated by the oil-price shocks is the following: Oil is an input in production. An increase in its price is equivalent to a negative technology shock in the non-commodity sector. The commodity export sector becomes relatively more competitive, leading to a currency real appreciation.

second period rule is weaker to inflation changes and the currency appreciates more on impact under the first period rule.[25] Despite of this, monetary policy of the second period achieves a lower increase in the inflation due to the fact that the stabilization of inflation does not compete with the stabilization of the real exchange rate. Nevertheless, it should be noted that without confidence intervals, we are not sure whether the change in monetary policy imply difference responses in a statistical sense.

4.2 Variance Decomposition

To make a formal assessment of the contribution of each structural shock to the fluctuations of the endogenous observable variables at different horizons, in Table 3 we present their variance decompositions. We focus here on a 1 to 4 years horizon. We classify the identified shocks in four groups. The first contains domestic supply shocks: transitory, and permanent productivity shocks, commodity production shocks, investment adjustment cost shocks, and labor supply shocks.[26] The second group includes the domestic demand side shocks of the economy: preference shocks, and government expenditure shock. Then, we consider monetary policy shocks alone. Finally, the four group includes shocks that are associated with external factors: copper price shocks, oil price shocks, foreign demand shocks, foreign interest rate shocks, foreign inflation shocks, and imported goods price shocks. We report the variance decompositions under the two monetary policy rules, the one for the period 1987-1999 and the one for the period 2000-2007.

Domestic supply shocks explain between 40 to 50% of the fluctuations in GDP growth. The change in the monetary policy rule in 1999 seems to have marginally reduced the impact of these shocks on output volatility. This result is in line with those of Smets and Wouters (2003). Domestic demand shocks explain between 10 to 30% of output volatility, with a relatively larger importance over a medium term horizon. Monetary policy shocks account for about 2 to 3% percent of output fluctuations in an horizon of one year. The larger contribution of these shocks to output fluctuations occurs two years after the shocks, accounting for about 9 to 10% of its volatility. External shocks explain about 45% of the output variance in the short run. Over a medium run horizon these shocks explain a lower share of the variance of the forecast error of output growth. However, on a long-run horizon, as domestic demand and monetary shocks reduce their influence on activity, external shocks account again for about half the variance of the forecast error of output.

External shocks account for most of the fluctuation of inflation in the short run. Domestic supply shocks explain only 20% of the variance of the forecast error of inflation in an horizon of one year. However, these shocks account for up to 60% of this variance on a medium-run horizon. In spite of the fact that domestic demand shocks account for less than 10% of inflation volatility in the short run, these shocks explain between 20 to 30% of fluctuation in this variable over longer horizons. Monetary policy shock account for 15 to 20% of fluctuations in inflation in a one year horizon, but they have a relatively small

[25] The change in the monetary policy instrument has a first order effect in the reaction of monetary policy. The second period monetary policy written in terms of the real interest rate can be expressed as $\widehat{r}_t = \psi_{i,2}\widehat{r}_{t-1} + (1-\psi_{i,2})(\psi_{\pi,2}-1)\widehat{\pi}_{Z,t} + (1-\psi_{i,2})\psi_{y,2}\Delta\widehat{y}_t - \psi_{i,2}\Delta\widehat{\pi}_{Z,t} + \psi_{i,2}(1-\alpha_C)(\widehat{\pi}_{o,t}-\widehat{\pi}_{Z,t}) + \zeta_{m,t}$

[26] We classify investment shocks as supply shocks because their correspond to changes in the technology used to transform new capital goods into installed capital. Alternatively, we could have classified these shocks as demand shocks since they capture movement in the incentive to investment not captured by the monetary policy rate and the marginal productivity of capital.

importance there after.

Approximately two thirds of the real exchange rate fluctuations are accounted for by external shocks. Domestic supply shocks are able to explain between 20 to 30% of real exchange rate movements. Monetary policy shocks explain only 7% of the variance of the forecast error of the real exchange rate in the short run. Their contribution to the volatility of this variable is even smaller over longer horizons. Domestic demand factors seem not to be relevant to explain short-run fluctuations of the real exchange rate. However their relative contribution to the volatility of this variable after the first year increases up to 11%.

Most of the variance of the forecast error of labor is also accounted for by external shocks. On a one year horizon, these shocks explain between 40 to 45% of the volatility of this variable. From the second year onwards, these shocks account for up to 80% of the variance. Domestic demand factors explain one fourth of the volatility of labor in the short run, but their contribution at longer horizons is less relevant. Domestic supply factors also have a more important role in explaining short-run variations of labor accounting for about 20% of its volatility. As expected, most of the current account variations are explained by external factors. In the short run, domestic demand shocks account for up to 40% of variance of the forecast error of this variable. Monetary policy shocks and domestic supply shocks jointly account for less than 10% of the volatility of the current account over a short-run horizon. Domestic supply shocks are relatively more important in explaining movements in this variable over longer horizons.

4.3 Historical Decomposition

Table 4 summarizes the historical decomposition of five of the endogenous observable variables of the model. As in the previous section, we classify shocks into domestic supply shocks, domestic demand shocks, monetary policy shocks and external shocks. We present sub-sample averages for the periods 1990-1993, 1994-1997, 1998-2001, and 2002-2005. The complete historical decomposition is depicted in figures 3 to 7. In this figures, for each variable, we graph the cyclical variation attributed to each one of the fourteen identified shocks. The historical evolution of these shocks is depicted in figure 2.[27]

Output growth presents two clear phases. Between 1990 and 1997 it grew above its sample average, whereas from 1998 onwards it grew below average. Domestic supply shocks were important between 1990 and 1993 while the fast growth of GDP in the period 1994-97 is explained mostly by foreign shocks. According to the model, the post 1998 recession is explained mostly by domestic factors: a slow-down in productivity and a contraction in demand. Monetary policy seems to have been relatively tight over the whole sample period, except for the last four years with a positive contribution to growth. When looking at the contribution of each specific shock over the whole sample period, we observe that an important part of the dynamic of output is explained by both persistent and transitory productivity shocks (Figure 3). Positive permanent productivity shocks led to increases in output growth over the 90s. However, after the Asian crisis, negative innovations to permanent productivity account for a non negligible size of the reduction in growth. In turn, transitory productivity shocks also explain the fast GDP growth by the end of the 80s and beginning of the 90s, but they contributed in a negative way to output growth in mid 90s. Investment shock explain an important share of output growth fluctuations over the sample, although

[27]The approach of inferring shocks and their relative contribution to the observed fluctuations through an estimated DSGE model has been used among others by Adolfson *et al* (2005), Chang *et al* (2003), Chari *et al* (2007).

these type of shocks do not have a distinctive behavior over the sample. However, they contributed in an important way to the recession of 1998-99. Tight monetary conditions also played a sizable role in explaining the fall in GDP growth after the Asian crisis. Among the external factors, positive foreign financial shocks were behind the high growth rates of the 90s, while detrimental foreign financial conditions explain in part the slowdown after the Asian and Argentinean crises. The model identifies a negative shock to the relative price of imported goods –a fall in this relative price– by the end of the 90s. The reduction in foreign import prices associated to this shock would have helped the output recovery after the recession of 1998-99.

Core inflation has been, on average, below target except for the period 1990-1993. This is mostly explained by monetary shocks, that have push inflation down. Also, positive supply shocks contributed to keep inflation below target during the 90s. However, the supply factors that explain part of the recession during 1998-01 generated inflationary pressures. The fall of inflation from its constant target from 2000 until 2005 is attributed by the model to external shocks and favorable supply shocks. If we look at individual shocks, we observe that transitory productivity shocks pushed inflation below target for several periods at the beginning of the 90s (4). The effect of these transitory productivity shocks were counterbalanced by still relatively tight foreign financial conditions, which kept the real exchange rate above average. In the second part of the 90s, a fall in productivity generated important inflationary pressures, which were offset by tight domestic monetary conditions. These tight monetary condition exerted their more intense deflationary effects around 1999. More recently, the monetary policy has pushed up inflation back to its target.

The evolution of real exchange rate presents three clear phases. At the beginning of the 90s it was 10% above its sample mean. During the period 1994-2001 it was around 7-8% below its mean. Over the last years it has been again above its sample mean (about 6% on average). These large swings in the real exchange rate are mostly explained by external factors. In particular, the important currency appreciation during the mid 90s is, to a larger extent, explained by these shocks. The monetary contraction of the end of the 90s also explains an important size of the real appreciation by those years and the beginning of the 2000s. Also, the real depreciation post 2000 is attributed mostly to external factors. In particular, half of the dynamics of the real exchange rate is explained by shocks to the foreign financial conditions (Figure 5).

The employment rate –employment as a share of working-age population– was well below its trend at the end of the 80s. This is explained mainly by negative external conditions. During mid 90s, as in the case of output, favorable external conditions was an important factor pushing employment above trend. Relatively tight monetary conditions during the 90s avoided employment from rising by more. Also, the monetary contraction at the end of the 90s explains the weakness in employment over the last years. Supply shocks exerted a positive contribution to employment until 2001. Figure 6 shows that foreign demand and foreign financial conditions have been the main external factors behind employment swings. The reduction in the relative price of imported goods helped attenuating the negative impact of detrimental foreign demand and foreign financial conditions on employment.

The current account is characterized by deficits during most of the 90s and by surpluses from 2002 until 2005.[28] At the beginning of the 90s, supply shocks were the main responsible for current account deficits, partially offset by less favorable external conditions. On the contrary, current account deficits in the second part of the 90s were explained by favorable external conditions. Since 2000 current account surpluses are attributed mainly to supply shocks. Although with a smaller effects, tight monetary policy stances contributed to keep low the current account deficits during the 90s. From figure 7 we observe that the inferred behavior of foreign financial conditions played key role in the evolution of the current account during most part of the sample period. More recently, the inferred increase in foreign demand and the copper price boom has gained importance to explains the current account surplus. Among domestic factors, productivity shocks and investment adjustment cost shocks also explains a significant part of the swings in the current account.

5 Conclusions

In this paper we identify shocks underlying the business cycle in Chile from a structural perspective. We develop and estimate a dynamic stochastic general equilibrium (DSGE) model, tailored to the Chilean economy. Using data on output, inflation, employment, interest rate, the current account, the real exchange rate, and oil and copper prices we identify the historical evolution of fourteen shocks that explain business cycles fluctuations.

We use the estimated model to decompose the fluctuations of the observed variables into the latent exogenous shocks that drives them. Our results show that foreign shocks and domestic supply shock account for a large share of output and employment fluctuations over the last 20 years. Relatively tight domestic monetary conditions have contributed to contain inflationary pressures arising from other shocks, namely the slowdown in productivity by mid 90s. Since in our estimated model monetary policy affects strongly and persistent on employment, the tight monetary policy conditions at the end of the 90s helps to explain part of the slow recovery of the employment after 2000. Foreign factors are also behind the large swings exhibited by the real exchange rate and current account, although a monetary contraction in 1998 explains part of the delayed adjustment of the exchange rate in response to the Asian crisis. The tight monetary policy around 1998 also contributes to the slow recovery of the employment afterwards.

[28] In a related work, Medina, Munro, and Soto (2006) provide a historical decomposition exclusively for the current account dynamics in Chile and New Zealand through estimated DSGE models for both countries. Although the quantitative results here are not identical to that work due to a different set of observable variables, the main qualitative results remains.

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Appendix A: Log-linearized model

In this appendix we present the full log-linearized model.

- Consumption of *Ricardian* households

$$\widehat{c}_t^R = -\frac{1-h}{1+h}E_t\left[\widehat{i}_t - \widehat{\pi}_{C,t+1}\right] + \frac{1}{1+h}E_t\left[\widehat{c}_{t+1}^R\right] + \frac{h}{1+h}\widehat{c}_{t-1}^R + \frac{1-h}{1+h}\left[\widehat{\zeta}_{C,t} - E_t[\widehat{\zeta}_{C,t+1}]\right] - \frac{1}{1+h}\left[h\widehat{\zeta}_{T,t} - E_t[\widehat{\zeta}_{T,t+1}]\right] \tag{1}$$

- Consumption of *Non-Ricardian* households

$$\widehat{c}_t^{NR} = \frac{W}{P_C C}\left(\widehat{wr}_t + \widehat{l}_t\right) - \frac{\mathcal{T}_p}{P_C C}\widehat{\tau}_{p,t} \tag{2}$$

- Aggregate Consumption:

$$\widehat{c}_t = (1-\lambda)\widehat{c}_t^R + \lambda\widehat{c}_t^{NR} \tag{3}$$

- Uncovered interest parity condition

$$\widehat{i}_t = \widehat{i}_t^* + \varrho\widehat{\mathbf{b}}_t^* + E_t[\Delta\widehat{e}_{t+1}] \tag{4}$$

- Labor supply:

$$[\kappa_L + (1+\beta)]\,\widehat{wr}_t = \kappa_L\left(\sigma_L\widehat{l}_t + \frac{1}{1-h}\widehat{c}_t - \frac{h}{1-h}\widehat{c}_{t-1} + \widehat{\zeta}_{L,t}\right) + \widehat{wr}_{t-1} + \beta E_t[\widehat{wr}_{t+1}] - (1+\beta\chi_L)\,\widehat{\pi}_{C,t} + \chi_L\widehat{\pi}_{C,t-1} + \beta E_t[\widehat{\pi}_{C,t+1}]$$

where $\kappa_L = \frac{(1-\beta\phi_L)(1-\phi_L)}{\phi_L(1+\sigma_L\epsilon_L)}$

- Consumption goods bundle:

$$\widehat{c}_{Z,t} = \widehat{c}_t - \omega_C\widehat{pr}_{Z,t} \tag{5}$$

$$\widehat{c}_{O,t} = \widehat{c}_t - \omega_C\widehat{pr}_{O,t} \tag{6}$$

$$0 = \alpha_C\widehat{pr}_{Z,t} + (1-\alpha_C)\widehat{pr}_{O,t} \tag{7}$$

$$\widehat{c}_{H,t} = \widehat{c}_{Z,t} - \eta_C\widehat{pr}_{H_D,t} \tag{8}$$

$$\widehat{c}_{F,t} = \widehat{c}_{Z,t} - \eta_C\widehat{pr}_{F,t} \tag{9}$$

$$\widehat{pr}_{Z,t} = \gamma_C\widehat{pr}_{H_D,t} + (1-\gamma_C)\widehat{pr}_{F,t} \tag{10}$$

- Capital accumulation:

$$\widehat{k}_{t+1} = \frac{1-\delta}{(1+n)(1+g_y)}\widehat{k}_t + \left(1 - \frac{1-\delta}{(1+n)(1+g_y)}\right)\left(\widehat{inv}_t + \widehat{\zeta}_{I,t}\right) \tag{11}$$

- Investment goods bundle:

$$\widehat{inv}_{H,t} = \widehat{inv}_t - \theta_I\left(\widehat{pr}_{H_D,t} - \widehat{pr}_{I,t}\right) \tag{12}$$

$$\widehat{inv}_{F,t} = \widehat{inv}_t - \theta_I\left(\widehat{pr}_{F,t} - \widehat{pr}_{I,t}\right) \tag{13}$$

$$\widehat{pr}_{I,t} = \gamma_I\widehat{pr}_{H_D,t} + (1-\gamma_I)\widehat{pr}_{F,t} \tag{14}$$

- De-trending and log-linearizing the equations above we will have the following supply and demand for investment goods:

$$\begin{aligned}\widehat{pr}_{I,t} &= \frac{Qr}{Pr_I}\left(\widehat{qr}_t+\varepsilon_{I,t}\right)-\frac{Qr}{Pr_I}\left(1+\frac{1}{1+r}\right)\mu_S(1+g_y)^2\widehat{inv}_t+\\ &\quad \frac{Qr}{Pr_I}\mu_S(1+g_y)^2\widehat{inv}_{t-1}+\frac{Qr}{Pr_I}\mu_S(1+g_y)^2\frac{1}{1+r}E_t[\widehat{inv}_{t+1}]\end{aligned}$$

$$\widehat{qr}_t=E_t[\pi_{C,t+1}-i_t]+\frac{1}{1+r}\frac{Zr}{Qr}E_t[\widehat{zr}_{t+1}]+\frac{1}{1+r}(1-\delta)E_t[\widehat{qr}_{t+1}]$$

- First order conditions for cost minimization and marginal cost:

$$\left(\widehat{k}_t-\widehat{\zeta}_{T,t}-\widehat{l}_t\right)=\widehat{wr}_t-\widehat{zr}_t \tag{15}$$

$$\frac{1}{\omega_H}\widehat{o}_{H,t}-\left(\left(\frac{1}{\omega_H}+\frac{1}{\theta_H}\right)\eta_H-\frac{1}{\theta_H}\right)\widehat{l}_t-\left(\frac{1}{\omega_H}+\frac{1}{\theta_H}\right)(1-\eta_H)\left(\widehat{k}_{t-1}-\widehat{\zeta}_{T,t}\right)+\widehat{pr}_{O,t}-\widehat{wr}_t=0 \tag{16}$$

$$\widehat{mcr}_{H,t}=\frac{Zrk}{MCr_HY_H}(\widehat{zr}_t+\widehat{k}_t)+\frac{Wrl}{MCr_HY_H}(\widehat{wr}_t+\widehat{l}_t)+\frac{P_OO_H}{MCr_HY_H}(\widehat{pr}_{O,t}+\widehat{o}_{H,t})-\widehat{y}_{H,t} \tag{17}$$

- De-trending and log-linearizing we have, we get the following Phillips curve for the domestic goods consumed at home:

$$\widehat{\pi}_{H_D,t}=\frac{\beta}{1+\beta\chi_{H_D}}E_t\left[\widehat{\pi}_{H_D,t+1}\right]+\frac{\chi_{H_D}}{1+\beta\chi_{H_D}}\pi_{H_D,t-1}+\frac{\kappa_{H_D}}{1+\beta\chi_{H_D}}\left[\widehat{mcr}_{H,t}-\widehat{pr}_{H_D,t}\right] \tag{18}$$

- Similarly, we can write an expression for the inflation of the exported goods in this sector:

$$\widehat{\pi}_{H_F,t}=\frac{\beta}{1+\beta\chi_{H_F}}E_t\left[\widehat{\pi}_{H_F,t+1}\right]+\frac{\chi_{H_F}}{1+\beta\chi_{H_F}}\pi_{H_F,t-1}+\frac{\kappa_{H_F}}{1+\beta\chi_{H_F}}\left[\widehat{mcr}_{H,t}-\widehat{rer}_t-\widehat{pr}_{H_F,t}\right] \tag{19}$$

- Phillips curve for the imported goods:

$$\widehat{\pi}_{F,t}=\frac{\beta}{1+\beta\chi_F}E_t\left[\widehat{\pi}_{F,t+1}\right]+\frac{\chi_F}{1+\beta\chi_F}\pi_{F,t-1}+\frac{\kappa_F}{1+\beta\chi_F}\left[\widehat{rer}_t+\widehat{\zeta}^*_{F,t}-\widehat{pr}_{F,t}\right] \tag{20}$$

where $\kappa_{H_D}=\frac{(1-\beta\phi_{H_D})(1-\phi_{H_D})}{\phi_{H_D}}$, $\kappa_{H_F}=\frac{(1-\beta\phi_{H_F})(1-\phi_{H_F})}{\phi_{H_F}}$ and $\kappa_F=\frac{(1-\beta\phi_F)(1-\phi_F)}{\phi_F}$

- *Structural Balance Rule* for government consumption:

$$\begin{aligned}\tfrac{P_GG}{P_YY}\widehat{g}_t &= \tfrac{\mathcal{T}_p}{P_YY}\left(\widehat{\tau}_{p,t}-\widehat{y}_t\right)+\chi\tfrac{P_SY_S}{P_YY}\left(\widehat{\widehat{pr}}_{S,t}+\widehat{y}_{S,t}-\widehat{pr}_{y,t}-\widehat{y}_t\right)\\ &\quad+\left(1-\tfrac{1}{\Theta(1+i^*)}\right)\tfrac{B_G}{P_YY}\tfrac{1}{(1+\pi^*)(1+g_y)(1+n)}\left(\Delta\widehat{e}_t-\widehat{\pi}_{C,t}+\widehat{b}_{G,t-1}-\Delta\widehat{pr}_{Y,t}-\Delta\widehat{y}_t-\widehat{\zeta}_{T,t}\right)\\ &\quad+\tfrac{1}{\Theta(1+i^*)}\tfrac{B_G}{P_YY}\tfrac{1}{(1+n)(1+g_y)(1+n)}\widehat{i}^*_{d,t-1}+\tfrac{P_GG}{P_YY}\left(\widehat{\zeta}_{G,t}+\widehat{pr}_{H_D,t}-\widehat{pr}_{Y,t}-\widehat{y}_t\right)\end{aligned} \tag{21}$$

- Choice of fiscal policy instrument: fiscal authority keeps real government expenditure constant as percentage of the trend real GDP

$$\widehat{g}_t-\widehat{pr}_{H_D,t}+\widehat{pr}_{Y,t}+\widehat{y}_t=0 \tag{22}$$

- Evolution of the fiscal net asset position

$$\frac{\mathcal{E}B_G^*}{P_Y Y}\frac{1}{\Theta(1+i^*)}\widehat{b}_{G,t} = \frac{1}{(1+\pi^*)(1+g_y)(1+n)}\frac{\mathcal{E}B_G^*}{P_Y Y}\left(\Delta\widehat{e}_t - \widehat{\pi}_{C,t} + \widehat{b}_{G,t-1} - \Delta\widehat{pr}_{Y,t} - \Delta\widehat{y}_t - \widehat{\zeta}_{T,t}\right) + \frac{\mathcal{T}_p}{P_Y Y}\widehat{\tau}_{p,t} + \chi\frac{P_S Y_S}{P_Y Y}\left(\widehat{pr}_{S,t} + \widehat{y}_{S,t} - \widehat{pr}_{Y,t} - \widehat{y}_t\right) - \frac{P_G G}{P_Y Y}\widehat{g}_t + \frac{B_G}{P_Y Y}\frac{1}{\Theta(1+i^*)}\widehat{i}^*_{d,t-1} \quad (23)$$

where

$$\widehat{i}^*_{d,t} = \widehat{i}^*_t + \varrho\widehat{\mathbf{b}}^*_t$$

- The monetary policy:

$$\text{90-99:}\quad \widehat{r}_t = \psi_{i,1}\widehat{r}_{t-1} + (1-\psi_{i,1})(\psi_{\pi,1}-1)\widehat{\pi}_{Z,t} + (1-\psi_{i,1})\psi_{y,1}\Delta\widehat{y}_t + (1-\psi_{i,1})\psi_{rer,1}\widehat{rer}_t + \zeta_{m,t}$$
$$\text{00-05:}\quad \widehat{i}_t = \psi_{i,2}\widehat{i}_{t-1} + (1-\psi_{i,2})\psi_{\pi,2}\widehat{\pi}_{Z,t} + (1-\psi_{i,2})\psi_{y,2}\Delta\widehat{y}_t + \zeta_{m,t} \quad (24)$$

- The foreign demand for domestically produced goods is:

$$\widehat{y}^*_{H,t} = \widehat{y}^*_t - \eta^*\widehat{pr}_{H_F,t} \quad (25)$$

- The law of one price for the commodity goods implies:

$$\widehat{pr}_{S,t} = \widehat{rer}_t + \widehat{pr}^*_{S,t} \quad (26)$$

$$\widehat{pr}_{O,t} = \widehat{rer}_t + \widehat{pr}^*_{O,t} \quad (27)$$

- Law of motion for relative prices:

$$\widehat{\pi}_{Z,t} = \widehat{pr}_{Z,t} - \widehat{pr}_{Z,t-1} + \widehat{\pi}_{C,t} \quad (28)$$

$$\widehat{\pi}_{H_D,t} = \widehat{pr}_{H_D,t} - \widehat{pr}_{H_D,t-1} + \widehat{\pi}_{C,t} \quad (29)$$

$$\widehat{\pi}_{H_F,t} = \widehat{pr}_{H_F,t} - \widehat{pr}_{H_F,t-1} + \widehat{\pi}^*_t \quad (30)$$

$$\widehat{\pi}_{F,t} = \widehat{pr}_{F,t} - \widehat{pr}_{F,t-1} + \widehat{\pi}_{C,t} \quad (31)$$

$$\Delta\widehat{e}_t = \widehat{rer}_t - \widehat{rer}_{t-1} + \widehat{\pi}_{C,t} - \widehat{\pi}^*_t \quad (32)$$

- Real interest rate (*ex-post*)

$$\widehat{r}_t = \widehat{i}_t - \widehat{\pi}_t \quad (33)$$

- The total demand for domestically produced goods is:

$$\frac{P_H Y_H}{P_Y Y}\widehat{y}_{H,t} = \gamma_C\frac{P_C C}{P_Y Y}\widehat{c}_{H,t} + \frac{P_G G}{P_Y Y}\left(\widehat{g}_t - \widehat{pr}_{H_D,t} + \widehat{pr}_{Y,t} + \widehat{y}_t\right) + \gamma_I\frac{P_I I}{P_Y Y}\widehat{inv}_{H,t} + \frac{P_H Y^*_H}{P_Y Y}\widehat{y}^*_{H,t} \quad (34)$$

- The total supply of domestically produced goods is:

$$\widehat{y}_{H,t} = \widehat{a}_{H,t} + \gamma_H^{1/\omega_H}(A_H\frac{O_H}{Y_H})^{\frac{\omega_H-1}{\omega_H}}\widehat{o}_{H,t} + (1-\gamma_H)^{1/\omega_H}(A_H\frac{V_H}{Y_H})^{(\omega_H-1)/\omega_H}\eta_H\widehat{l}_t + (1-\gamma_H)^{1/\omega_H}(A_H\frac{V_H}{Y_H})^{(\omega_H-1)/\omega_H}(1-\eta_H)\left(\widehat{k}_{t-1} - \widehat{\zeta}_{T,t}\right)$$

- Real GDP:

$$\widehat{y}_t = \frac{P_C C}{P_Y Y}\widehat{c}_t + \frac{P_G G}{P_Y Y}\left(\widehat{g}_t - \widehat{pr}_{H_D,t} + \widehat{pr}_{Y,t} + \widehat{y}_t\right) + \frac{P_I I}{P_Y Y}\widehat{inv}_t + \frac{P_X X}{P_Y Y}\widehat{x}_t - \frac{P_M M}{P_Y Y}\widehat{m}_t \tag{35}$$

- Balance of payments:

$$\begin{aligned}\frac{(1-\varrho)\,\mathbf{B}^*}{(1+i^*)\Theta\left(\mathbf{B}^*\right)}\widehat{\mathbf{b}}_t^* \quad = \quad & \frac{\mathbf{B}^*}{(1+i^*)\Theta\left(\mathbf{B}^*\right)}\widehat{i}_t^* \\ & -(1-\chi)\frac{\mathcal{E}P_S^* Y_S}{P_Y Y}\left(\widehat{pr}_{S,t} + \widehat{y}_{S,t} - \widehat{pr}_{Y,t} - \widehat{y}_t\right) \\ & +\frac{\mathbf{B}^*}{(1+\pi^*)(1+n)(1+g_y)}\left(\Delta\widehat{e}_t - \widehat{\pi}_{C,t} - \Delta\widehat{pr}_{Y,t} - \Delta\widehat{y}_t + \widehat{\mathbf{b}}_{t-1}^* - \widehat{\zeta}_{T,t}\right) \\ & \frac{P_X X}{P_Y Y}\left(\widehat{pr}_{X,t} + \widehat{x}_t - \widehat{pr}_{Y,t} - \widehat{y}_t\right) - \frac{P_M M}{P_Y Y}\left(\widehat{pr}_{M,t} + \widehat{m}_t - \widehat{pr}_{Y,t} - \widehat{y}_t\right)\end{aligned} \tag{36}$$

where $\mathbf{B}^* = \mathcal{E}B^*/P_Y Y$

- Real exports, imports and the corresponding price deflators:

$$\widehat{x}_t = \frac{\mathcal{E}P_S^* Y_S}{P_X X}\widehat{y}_{S,t} + \left(1 - \frac{\mathcal{E}P_S^* Y_S}{P_X X}\right)\widehat{c}_{H,t}^* \tag{37}$$

$$\widehat{pr}_{X,t} = \frac{\mathcal{E}P_S^* Y_S}{P_X X}\widehat{pr}_{S,t} + \left(1 - \frac{\mathcal{E}P_S^* Y_S}{P_X X}\right)\left(\widehat{pr}_{H_F,t} + \widehat{rer}_t\right) \tag{38}$$

$$\widehat{m}_t = (1-\gamma_C)\frac{P_C C}{P_M M}\widehat{c}_{F,t} + (1-\gamma_I)\frac{P_I I}{P_M M}\widehat{inv}_{F,t} + \frac{P_O\left(C_O + O_H\right)}{P_M M}\left(\frac{C_O}{C_O + O_H}\widehat{c}_{O,t} + \frac{O_H}{C_O + O_H}\widehat{o}_{H,t}\right) \tag{39}$$

$$\widehat{pr}_{M,t} = \widehat{rer}_t + \left(1 - \frac{P_O\left(C_O + O_H\right)}{P_M M}\right)\widehat{\zeta}_{F,t}^* + \frac{P_O\left(C_O + O_H\right)}{P_M M}\widehat{pr}_{O,t}^* \tag{40}$$

- Exogenous shocks:

$$\widehat{\xi}_t = \rho_\xi \widehat{\xi}_t + \varepsilon_{\xi,t},\ \varepsilon_{\xi,t} \sim N(0, \sigma_\xi^2)$$

with $\xi = a_H$, ζ_T, y_S, y^*, i^*, π^*, ζ_m, ζ_L, ζ_C, ζ_G, ζ_I, ζ_F^*, p_O^* and p_S^*.

Table 1: Calibrated Parameters

Name	Description	Value
g_y	Steady state GDP growth	3.5% [annual basis]
$\overline{\pi}$	Steady state Inflation target	3% [annual basis]
NX/Y	Steady Net export/GDP ratio	2%
CA/Y	Current Account/GDP ratio	-1.8%
β	discount factor	0.999 [quarter basis]
α_C	share of core consumption	98.5%
γ_C	share of home goods in *core* cons.	65%
γ_I	share of home goods in investment	50%
γ_G	share of home goods in Gov't cons.	100%
Y_S/Y	share of comm production in GDP	10%
χ	Gov't share in comm production	40.0%
δ	Depreciation rate	5.8% [annual basis]
α_H	labor and capital share in gross production of home goods	99%
η_H	labor share in value added production of home goods	66%
ϵ_L	elasticity of substitution among labor varieties	11
ϵ_{H_D}	elasticity of substitution among home goods varieties	11
ϵ_{H_F}	elasticity of substitution among home goods varieties	11
ϵ_L	elasticity of substitution among import varieties	11
$\rho_{p_S^*}$	AR(1) coefficient of the international copper price	0.95
$\rho_{p_O^*}$	AR(1) coefficient of the international oil price	0.97
$\sigma_{p_S^*}$	AR(1) coefficient of the international copper price	9%
$\sigma_{p_O^*}$	AR(1) coefficient of the international oil price	12%

Table 2: Priors and Posterior statistics

Name	Description	mean/mode	stdv/df	shape	post mode	inv Hessian
σ_L	inverse of the elasticity of labor supply	1.00	1.00	Gamma	0.84	0.20
h	habit formation	0.50	0.25	Beta	0.65	0.23
ϕ_L	calvo probb in nominal wages	0.75	0.10	Beta	0.82	0.15
χ_L	indexation of nominal wages	0.50	0.25	Beta	0.44	0.57
η_C	intratemporal elasticity in consumption	1.00	5.00	Inv Gamma	1.12	0.14
η_I	intratemporal elasticity in investment	1.00	5.00	Inv Gamma	1.04	0.08
μ_I	investment inertia coeff	2.00	3.00	Inv Gamma	1.48	0.20
ϕ_{H_D}	calvo probb in dom price of home goods	0.75	0.10	Beta	0.74	0.16
χ_{H_D}	indexation of dom price of home goods	0.50	0.25	Beta	0.34	0.18
ϕ_{H_F}	calvo probb in foreign price of home goods	0.75	0.10	Beta	0.59	0.17
χ_{H_F}	indexation of foreign price of home goods	0.50	0.25	Beta	0.31	0.67
ϕ_F	calvo probb in price of imported goods	0.75	0.10	Beta	0.66	0.08
χ_F	indexation price of imported goods	0.50	0.25	Beta	0.28	0.34
ω_C	elasticity of subst of oil in the cons basket	0.30	5.00	Inv Gamma	0.30	0.03
ω_H	elasticity of subst of oil in the production	0.30	5.00	Inv Gamma	0.30	0.09
$\psi_{i,1}$	smoothing coef in period 90-99	0.75	0.15	Beta	0.73	0.09
$\psi_{\pi,1}$	reaction to inflation deviation in period 90-99	1.50	0.15	Gamma	1.61	0.09
$\psi_{y,1}$	reaction to GDP growth deviation in period 90-99	0.50	0.15	Gamma	0.28	0.13
$\psi_{rer,1}$	reaction to RER deviation in period 90-99	0.20	0.10	Gamma	0.02	0.16
$\psi_{i,2}$	smoothing coef in period 00-05	0.75	0.15	Beta	0.74	0.29
$\psi_{\pi,2}$	reaction to inflation deviation in period 00-05	1.50	0.15	Gamma	1.67	0.09
$\psi_{y,2}$	reaction to GDP growth deviation in period 00-05	0.50	0.15	Gamma	0.39	0.26

For Inverse gamma distributions, mode and degrees of freedom are presented

Table 2 (cont.)

Name	Description	mean/mode	stdv/df	shape	post mode	inv Hessian
η^*	intratemporal elasticity in foreign demand	1.00	4.00	Inv Gamma	0.79	0.14
ϱ	elasticity of endogenous external premium	0.01	4.00	Inv Gamma	0.01	0.13
ρ_{a_H}	persistence transitory productivity shock	0.70	0.20	Beta	0.89	0.50
ρ_{y_S}	persistence comm production shock	0.70	0.20	Beta	0.77	0.48
ρ_{y^*}	persistence foreign demand shock	0.70	0.20	Beta	0.67	0.53
ρ_{i^*}	persistence foreign interest rate shock	0.70	0.20	Beta	0.87	0.24
ρ_{π^*}	persistence foreign inflation shock	0.70	0.20	Beta	0.80	0.07
ρ_{ζ_L}	persistence labor supply shock	0.70	0.20	Beta	0.89	0.02
ρ_{ζ_C}	persistence preference shock	0.70	0.20	Beta	0.87	0.07
ρ_{ζ_G}	persistence gov't expenditure shock	0.70	0.20	Beta	0.65	0.27
ρ_{ζ_I}	persistence investment adj cost shock	0.70	0.20	Beta	0.34	0.39
$\rho_{\zeta_F^*}$	persistence of foreign imported price shock	0.70	0.20	Beta	0.90	0.27
ρ_{ζ_T}	persistence permanent productivity shock	0.70	0.20	Beta	0.73	0.44
σ_{a_H}	st dev transitory productivity shock innovation	1.00	3.00	Inv Gamma	1.43	0.09
σ_{Y_S}	st dev comm production shock innovation	1.00	3.00	Inv Gamma	4.51	0.08
σ_{y^*}	st dev foreign demand shock innovation	1.00	3.00	Inv Gamma	3.57	0.10
σ_{i^*}	st dev foreign interest rate shock innovation	0.50	3.00	Inv Gamma	0.37	0.16
σ_{π^*}	st dev foreign inflation shock innovation	0.25	3.00	Inv Gamma	0.28	0.22
σ_m	st dev monetary policy shock innovation	0.20	3.00	Inv Gamma	0.39	0.08
σ_{ζ_L}	st dev labor supply shock innovation	1.00	3.00	Inv Gamma	1.01	0.01
σ_{ζ_C}	st dev preference shock innovation	1.00	3.00	Inv Gamma	3.41	0.23
σ_{ζ_G}	st dev gov't expenditure shock innovation	1.00	3.00	Inv Gamma	1.01	0.01
σ_{ζ_I}	st dev investment adj cost shock innovation	1.00	3.00	Inv Gamma	5.99	0.24
$\sigma_{\zeta_F^*}$	st dev of foreign imported price shock innovation	1.00	3.00	Inv Gamma	4.16	0.09
σ_{ζ_T}	st dev permanent productivity shock innovation	0.20	3.00	Inv Gamma	0.40	0.39

For Inverse gamma distributions, mode and degrees of freedom are presented

Table 3: Variance Decomposition

(% contribution of each type of shock)

	Domestic Shocks						External Shocks	
	Supply		Demand		Monet Pol			
	1987-1999	2000-2005	1987-1999	2000-2005	1987-1999	2000-2005	1987-1999	2000-2005
GDP growth								
year 1	42.3	39.8	11.6	11.4	2.4	3.0	43.7	45.8
year 2	50.9	45.9	27.7	28.5	8.9	10.4	12.5	15.2
year 3	57.4	54.0	18.8	14.0	7.0	3.8	16.9	28.1
year 4	45.8	45.3	9.7	5.4	4.2	1.7	40.3	47.6
***Core* Inflation**								
year 1	22.4	20.2	6.1	9.9	15.8	21.3	55.6	48.7
year 2	42.2	18.1	21.9	34.0	17.1	19.9	18.8	28.0
year 3	61.6	43.3	31.5	22.5	1.4	0.5	5.5	33.7
year 4	55.4	62.0	29.3	30.0	0.8	0.1	14.6	7.9
Real exchange rate								
year 1	21.4	21.3	2.1	1.5	7.1	7.0	69.4	70.1
year 2	29.4	30.9	8.0	5.6	3.4	1.7	59.3	61.7
year 3	26.9	28.5	11.4	8.5	3.2	1.7	58.4	61.3
year 4	20.5	22.4	10.0	7.7	2.8	1.6	66.7	68.3
Labor input								
year 1	20.4	20.1	24.6	22.3	13.9	12.2	41.1	45.4
year 2	2.3	5.0	13.0	7.0	17.4	7.9	67.2	80.1
year 3	4.1	8.6	3.0	0.7	13.6	4.5	79.3	86.1
year 4	12.3	10.4	0.7	1.3	13.0	5.2	74.0	83.1
Current Account to GDP ratio								
year 1	4.2	4.1	39.0	37.6	4.8	4.9	52.0	53.4
year 2	8.0	9.3	8.5	6.4	2.3	1.2	81.3	83.1
year 3	9.5	11.2	0.9	1.2	0.3	0.1	89.2	87.6
year 4	14.2	15.1	11.9	12.9	0.2	0.5	73.7	71.5

Table 4: Historical Decomposition

(Deviation from steady state levels)

Period	Domestic Shocks			External Shocks	Total
	Supply	Demand	Monet Pol		
GDP growth					
90-93	1.55	0.25	-0.10	-0.37	1.34
94-97	0.02	0.09	-0.39	2.08	1.81
98-01	-3.29	-0.38	-0.10	0.20	-3.56
02-05	-0.87	0.00	0.60	-0.27	-0.54
***core* inflation**					
90-93	-1.25	0.09	-0.45	1.90	0.29
94-97	-0.17	0.38	-1.27	0.39	-0.67
98-01	1.79	0.36	-2.40	-0.18	-0.42
02-05	-0.75	-0.18	0.43	-0.65	-1.15
Real exchange rate					
90-93	8.27	-0.43	-0.94	3.09	9.99
94-97	4.76	-0.69	-2.22	-9.34	-7.49
98-01	-2.76	-0.48	-5.28	0.06	-8.46
02-05	-2.34	0.40	-1.05	9.26	6.26
Labor input					
90-93	2.31	0.05	-0.93	-6.75	-5.32
94-97	0.87	0.24	-2.34	2.36	1.12
98-01	1.60	0.27	-5.69	4.40	0.59
02-05	-1.23	-0.39	-0.31	1.60	-0.33
Current Account to GDP ratio					
90-93	-3.50	-0.19	0.13	2.41	-1.15
94-97	-0.52	-0.22	0.44	-0.87	-1.18
98-01	2.43	-0.05	0.97	-3.60	-0.25
02-05	2.40	0.32	-0.57	0.05	2.20

Figure 1: Impulse-Response functions

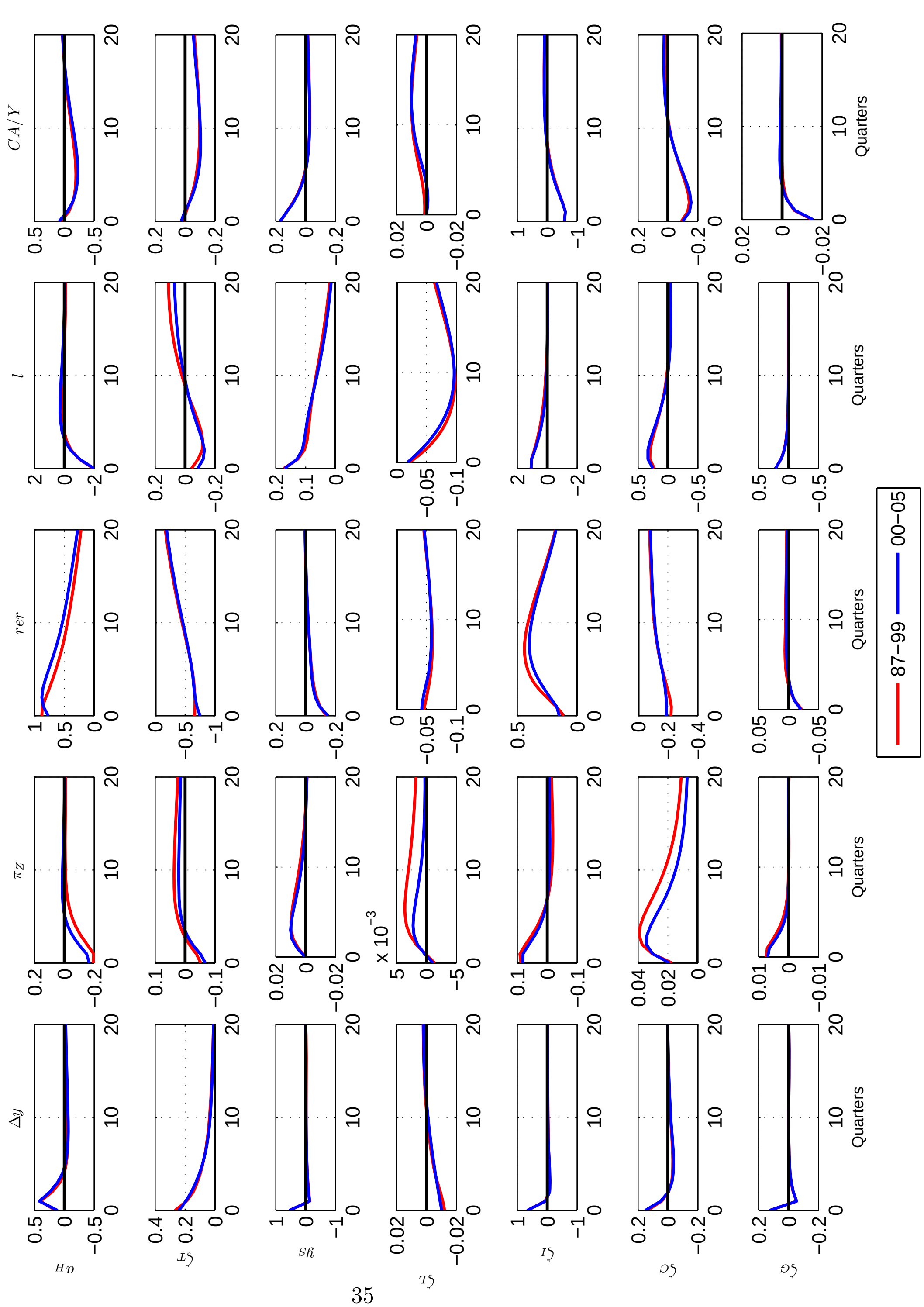


Figure 1 (cont.)

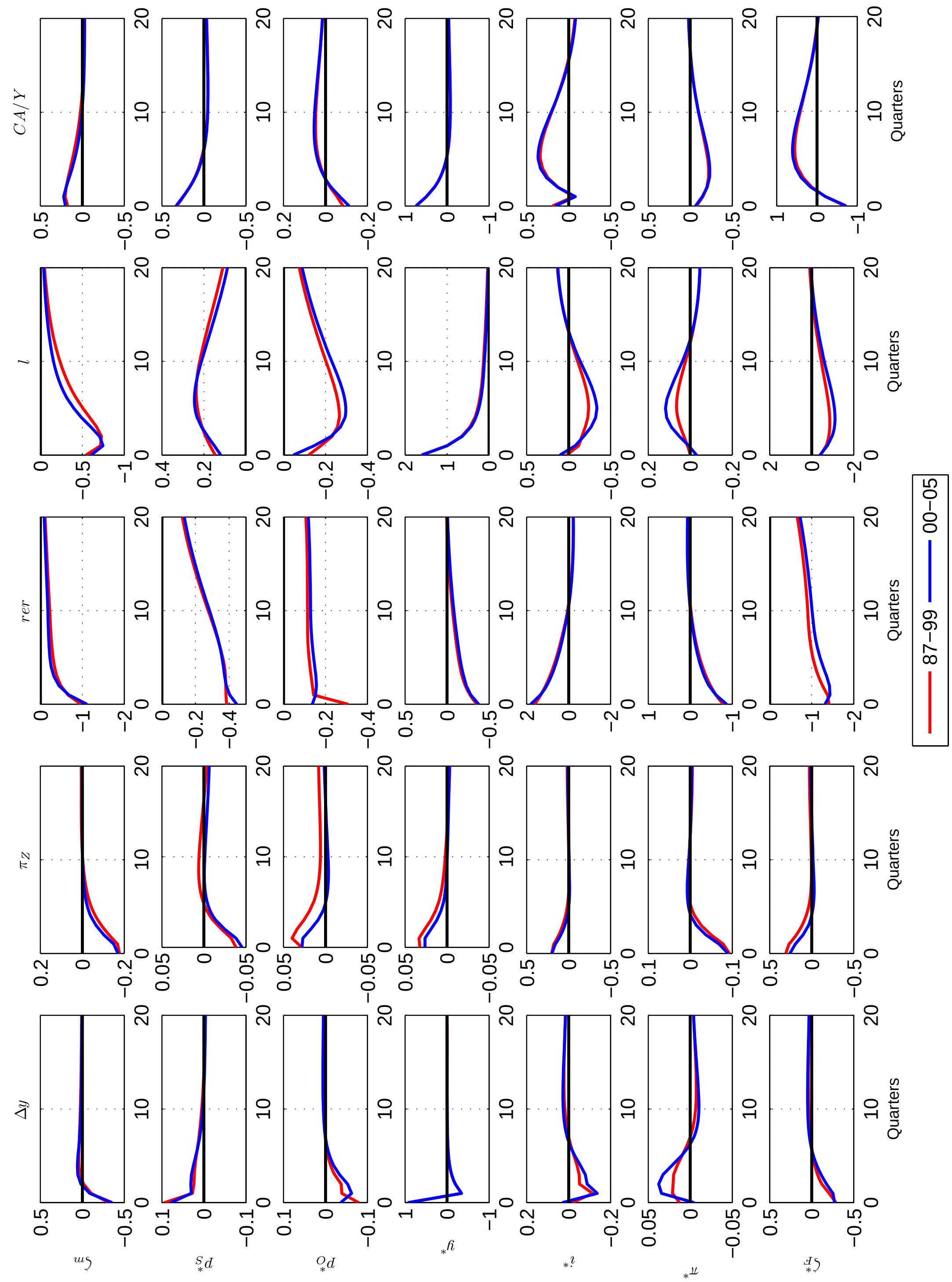


Figure 2: Historical decomposition of shocks

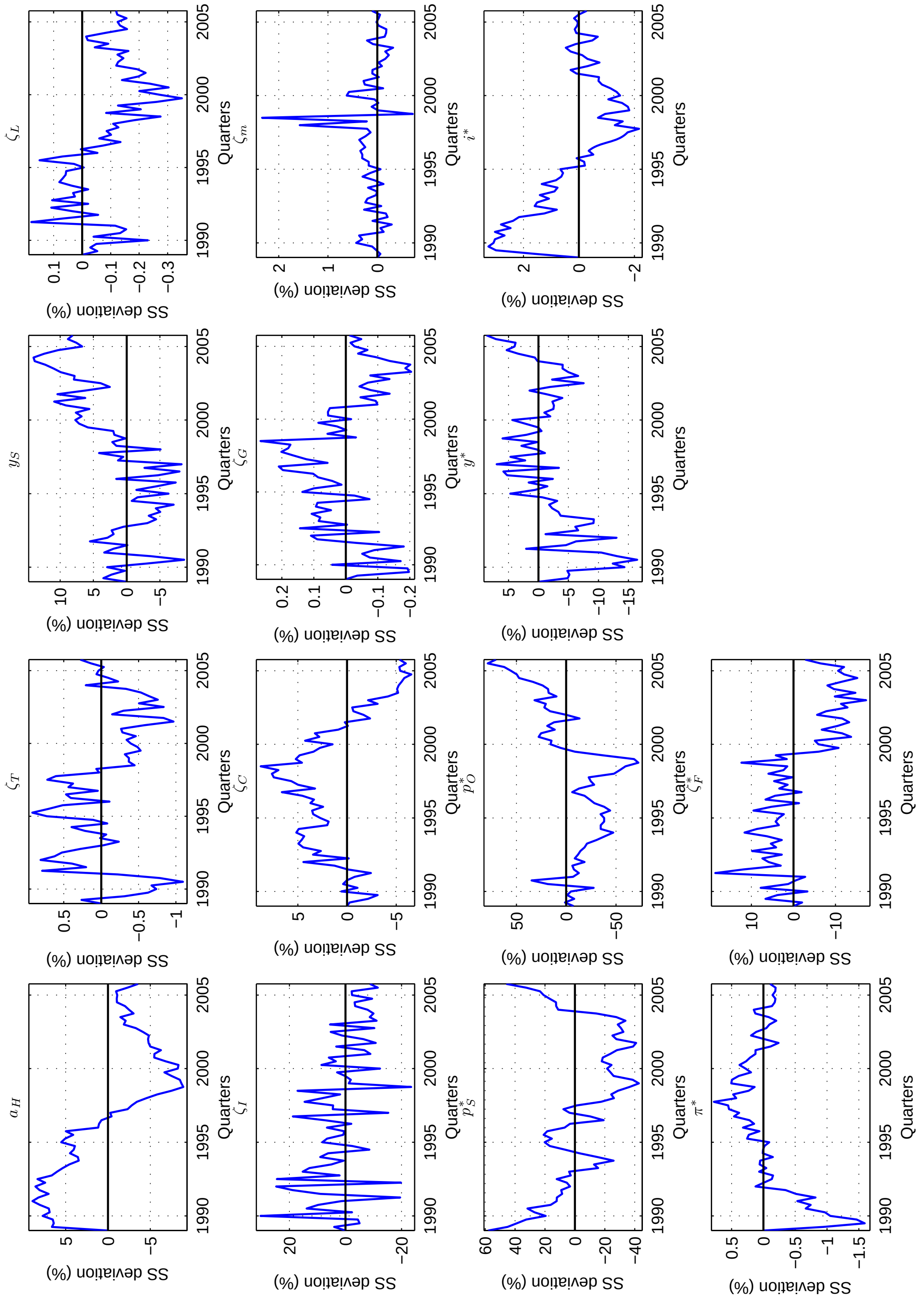


Figure 3: Historical decomposition of annual GDP growth

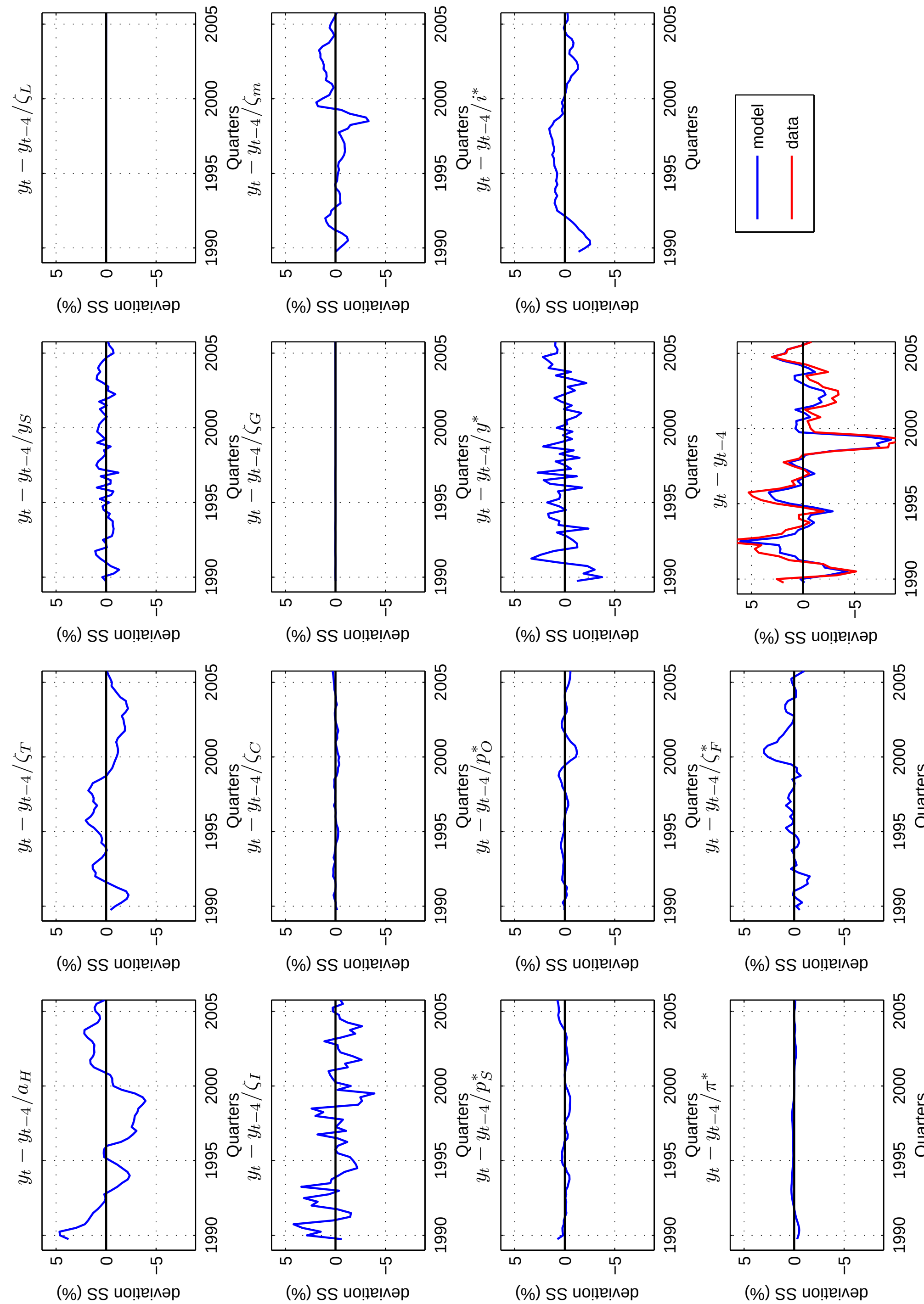


Figure 4: Historical decomposition of annual *core* inflation rate

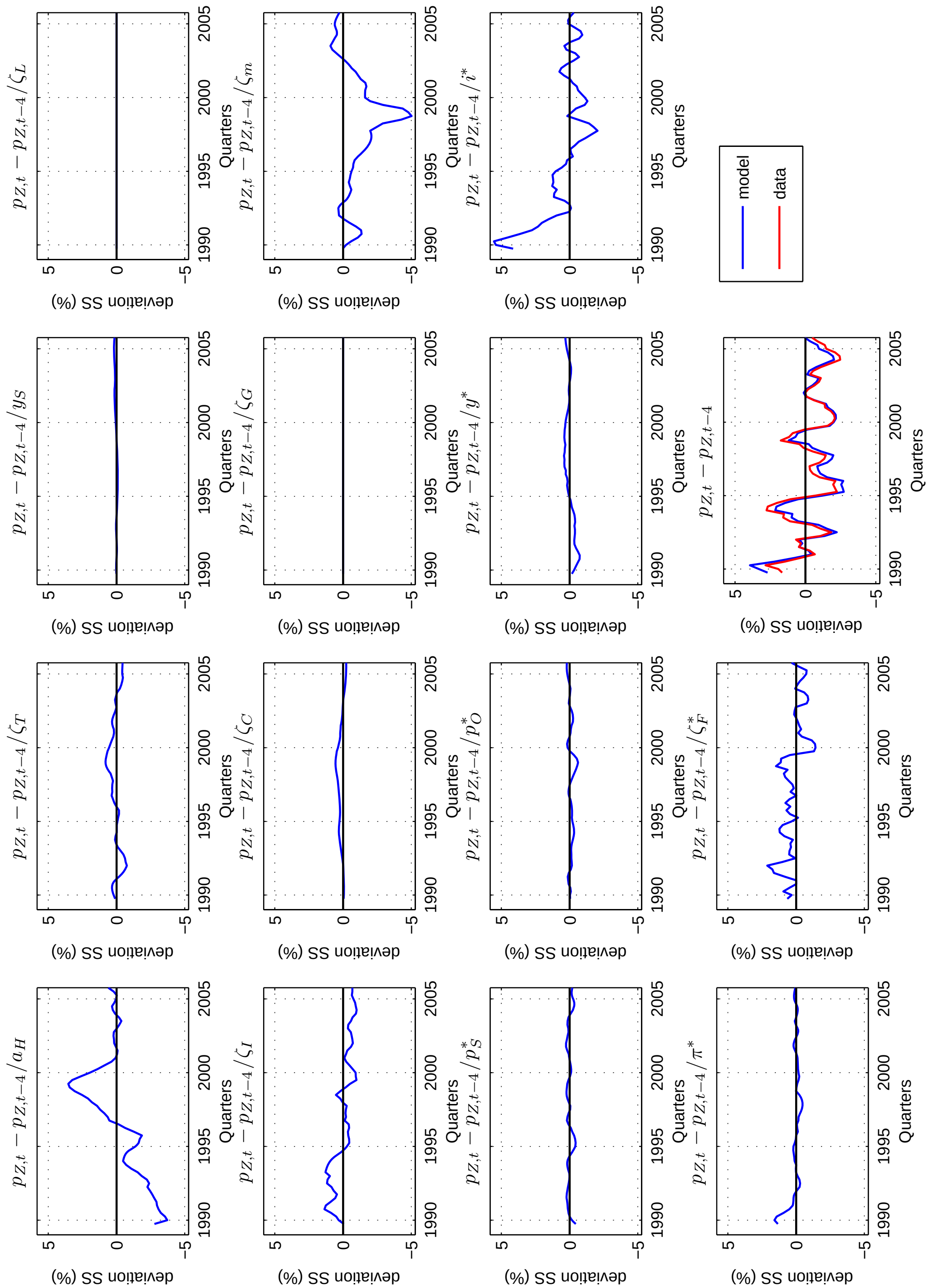


Figure 5: Historical decomposition of Real Exchange Rate (annual moving average)

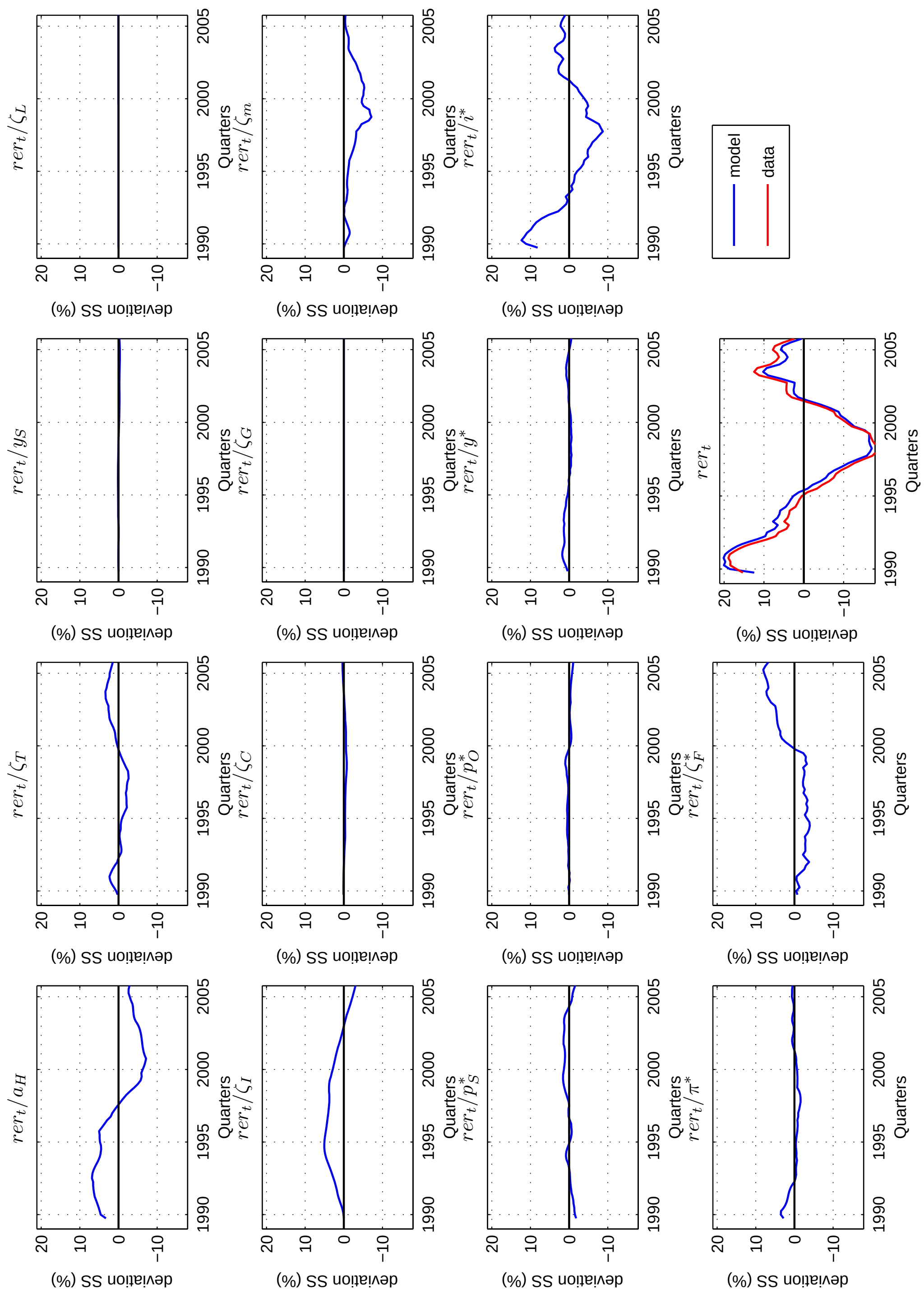


Figure 6: Historical decomposition of Labor (annual moving average)

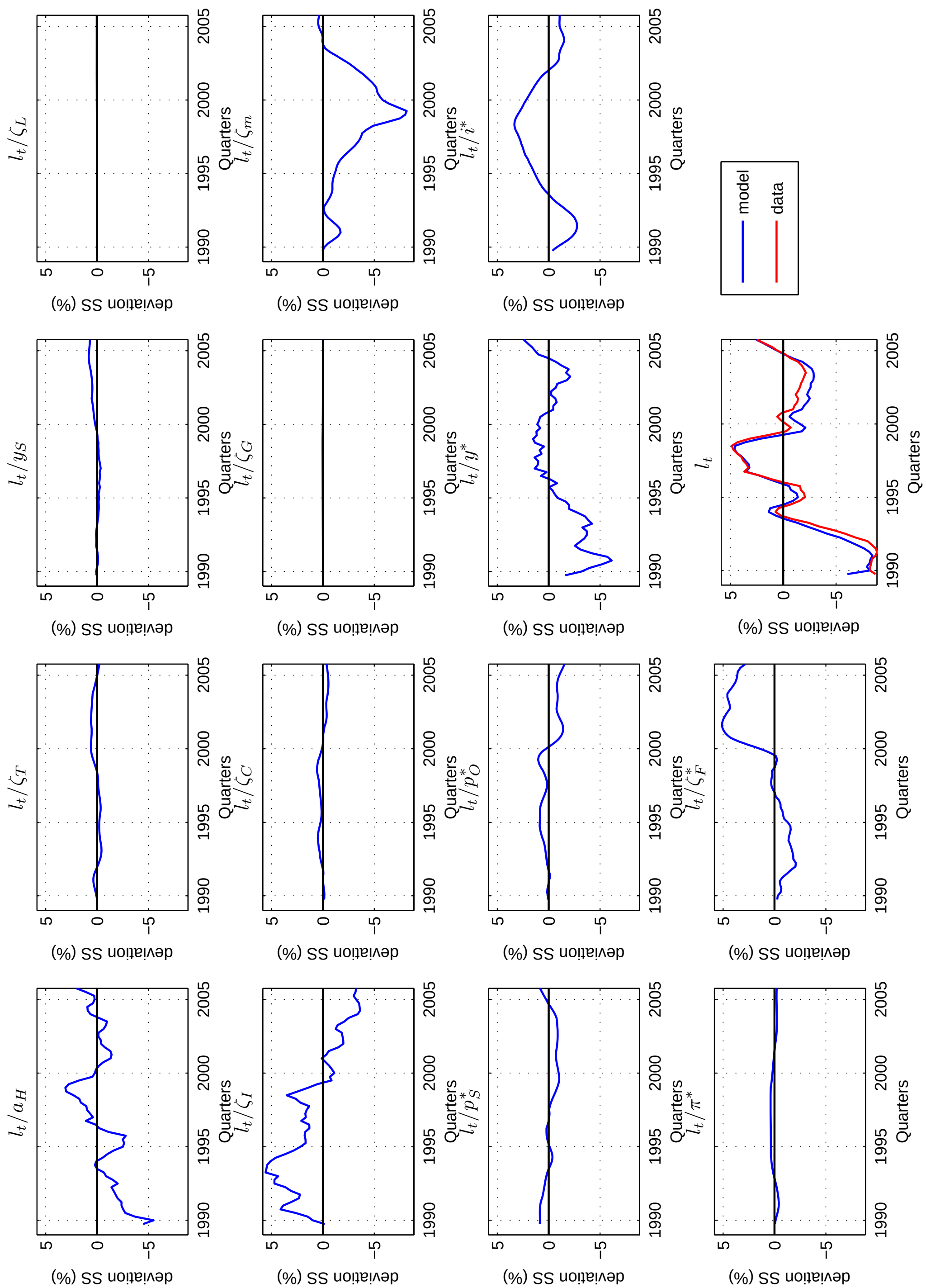
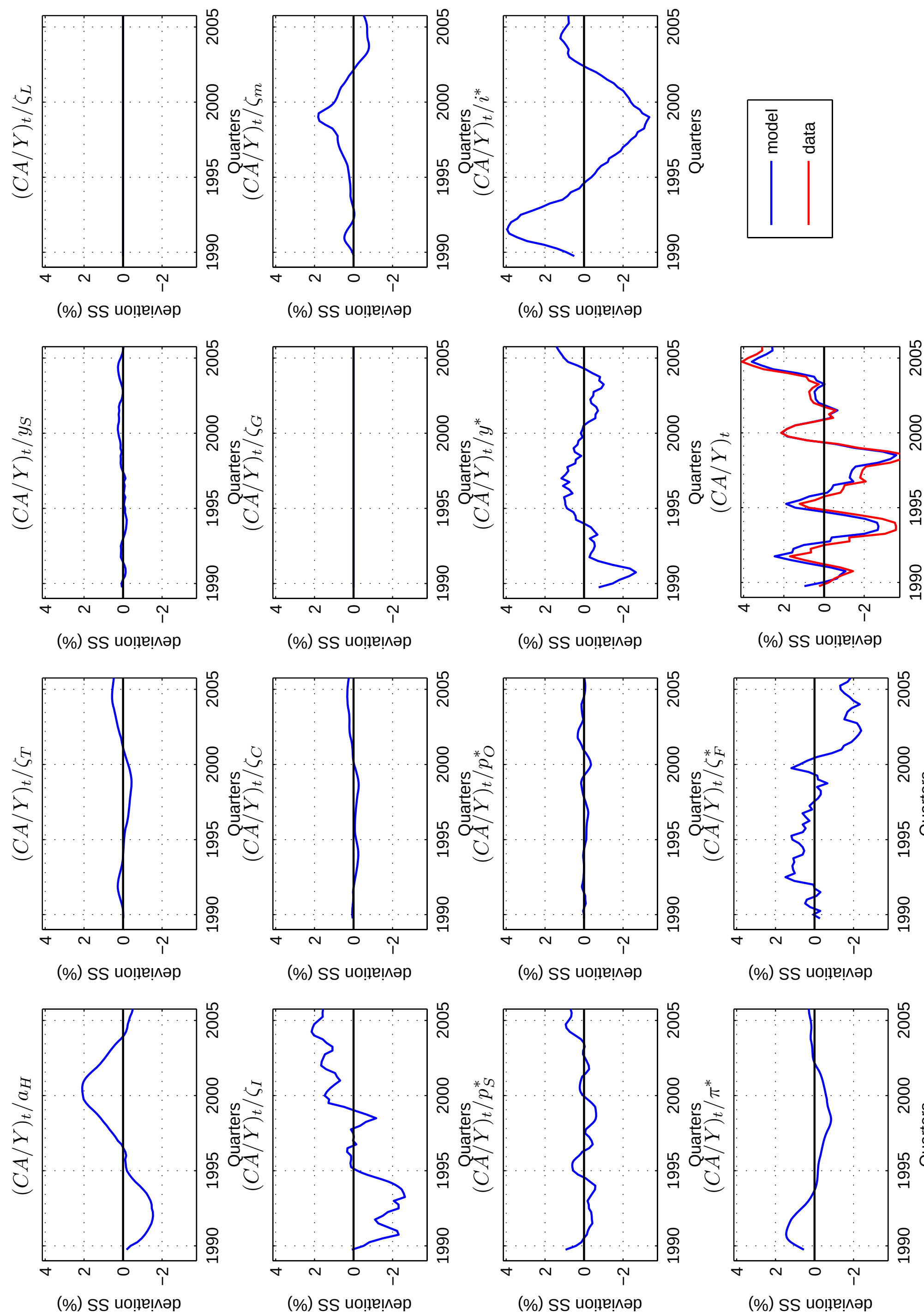


Figure 7: Historical decomposition of CA-GDP ratio (annual moving average)



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