Copper Price, Fiscal Policy and Business Cycle in Chile*

Juan Pablo Medina
Research Department
Central Bank of Chile

Claudio Soto
Research Department
Central Bank of Chile

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Abstract

This paper analyzes the impact of copper-price shocks on the Chilean business cycle using a DSGE model. We compare the effects of copper-price shocks under different fiscal rules and different assumptions regarding the asset structure in the economy. The results show that when the fiscal policy is highly expansive in response to a transitory shock, and if an important fraction of households are non-Ricardian, then and increase in the copper price of 10% implies an output expansion of about 0.7%. The real exchange rate appreciate a bit more than 0.2% and inflation rises by 0.03%. If the fiscal policy is conducted in a way such that the government saves most of the extra revenues from the higher copper price, then output would increase only 0.05% and there would be a slight decrease in inflation. This last effect occurs due to the real appreciation of the exchange of 0.09% that compensates the slight increase in domestic goods inflation. Our calibrated model is also coherent with the idea that the apparent reduction of the impact of copper price shocks on GDP after year 2000 is related to the adoption of the structural fiscal rule, rather than the adoption of a fully flexible exchange rate regime.

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1 Introduction

Over the last months we have seen how the price of copper has reached unprecedented levels, surpassing US$ 3.5 per pound. Historically business cycle in Chile have been associated to

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fluctuation in the price of this commodity, which represents approximately 40% of total exports and about 10% of public revenues.[1]

In this paper we analyze the effects copper price shocks on different macro variables from a general equilibrium perspective, with particular reference to the Chilean economy. There are several potential mechanisms through which a shock to the copper price may affect the business cycle and variables such as the real exchange rate and inflation. Given the important government share in the copper sector in the case of Chile, many of these channels depend on how fiscal policy is conducted.

To encompass different first and second round effects of this type of shocks we use a version of the MAS model, a new dynamic stochastic general equilibrium (DSGE) model for the Chilean economy.[2] We analyze the impulse response functions to a copper price shock comparing the results under different fiscal rules. In one case, we let the government to consume all the proceeding from the higher copper price. In a second case, we assume the government rebates the proceedings to the domestic private sector by reducing taxes. Finally, we consider the *structural balance fiscal rule* introduced in 2001. This fiscal rule, based on a structural surplus of one percent of GDP, is an attempt to structure and signal fiscal policies over a medium term horizon. The rule is supposed to allow automatic stabilizers in the budget to work uninhibited, while avoiding fine-tuning of fiscal policy to the phases of the cycle.

Regarding the asset structure available to households –which is crucial to analyze fiscal policy– we assume, in one case, that households have full access to the capital market so that they can smooth consumption intertemporally (Ricardian households). In the second case, we assume that a fraction of households do not have access to the capital market. These households consume their disposable income period by period (non-Ricardian households).[3]

The results show that when the fiscal policy is highly expansive in response to a transitory shock, and if an important fraction of households are non-Ricardian, then and increase in the copper price of 10% implies an output expansion of about 0.7%.[4] The real exchange rate appreciate a bit more than 0.2% and inflation rises by 0.03%. If the fiscal policy is conducted in a way such that the government saves most of the extra revenues from the higher copper price then output would increase only 0.05% and there would be a slight decrease

[1] See Spilimbergo (2002) and Caballero (2001), among others.

[2] See Medina and Soto (2006).

[3] Alternatively, we could think of different behavior rule for different households instead of assuming a differentiated access to the capital market. For example, we could just assume that a fraction of households do not optimize intertemporaly a just consume their disposable income. In other words, we could assume a "rule of thumb" behavior for these agents. Results would not change.

[4] Drexler, Engel and Valdés (2001) report that an increase in the copper price by 10% increases non-mineral GDP in about 0.5%.

in inflation. This last effect occurs due to the real appreciation of the exchange of 0.09% that compensates the slight increase in domestic goods inflation. Our calibrated model also show that the apparent reduction of the impact of copper price shocks on GDP after year 2000 is related to the adoption of the structural fiscal rule rather than the adoption of a fully flexible exchange rate regime.

Another recent paper that studies the effects of copper-price shocks on the Chilean business cycle is García and Restrepo (2006). They also use a DSGE with micro foundations to analyze the impulse-response function to a copper price-shock. However, they do not carefully analyze the structural balance fiscal rule as in this paper.

The paper is organized as follows: The next section describes the MAS model. Then, the third section discusses the solution and parametrization of the model. The fourth section presents and discusses the impulse-response function of a transitory shock to the copper price. The fifth section presents an historical decomposition of GDP under alternative fiscal rules. Finally, section six concludes.

2 The MAS Model

The version of the MAS model in this paper considers two domestic sectors. One sector produces differentiated goods that are consumed domestically and exported. A second sector produces a commodity good (copper) that is completely exported abroad. Production in this sector requires no input: there is just a stochastic endowment of copper.[5] A share of proceedings is owned by the government the rest is owned by foreign investors. Firms producing differentiated domestic goods use a constant return technology with two inputs, capital and labor. In steady-state the economy grows at a rate $g_y + n$, where n is the growth rate of the labor force. Consumption exhibits habit formation and there are adjustment cost for investment. Monetary policy is conducted through a policy rule for the interest rate. The model is parametrized using some standard values in the literature and other that are chosen in order to match some steady state ratios. In what follows we describe in more detail the building blocks of the model.

2.1 Households

The domestic economy is inhabited by a continuum of households indexed by $j \in [0, 1]$. The size of each household in period t is $\mathcal{N}_t$. The expected present value of the utility of

[5]Copper production is intensive in capital, but a large share of the value added corresponds to rents associated to natural resources.

household j is given by:

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

where $l_t(j)$ is labor effort, $C_t(j)$ is a consumption bundle and $\mathcal{M}_t(j)$ corresponds to nominal balances held at the beginning of period t by household j. Parameters σ_C and σ_L are the intertemporal elasticity of substitution for consumption and the inverse elasticity of labor supply with respect to real wages, respectively. Variable $\zeta_{C,t}$ is a preference shock that shifts the demand for consumption goods, and $\zeta_{L,t}$ is a shock to the labor supply.[6] Preferences display habit formation, which are measured by parameter h. The external habit is defined as $H_t = C_{t-1}$, where C_t is the aggregate per capita consumption in period t. All variables are expressed as average values over the members of the household or in per capita terms.

The consumption bundle is a CES aggregator that includes domestically produced goods (home goods) and imported goods (foreign goods):

$$C_t(j) = \left[\gamma_C^{\frac{1}{\eta_C}} C_{H,t}(j)^{\frac{\eta_C - 1}{\eta_C}} + (1-\gamma_C)^{\frac{1}{\eta_C}} C_{F,t}(j)^{\frac{\eta_C - 1}{\eta_C}} \right]^{\frac{\eta_C}{\eta_C - 1}}, \quad (2)$$

where $C_H(j)$ and $C_F(j)$ are the domestic and imported goods consumed by household j, respectively. Parameter γ_C defines the share of domestic goods in the consumption basket and η_C is the elasticity of substitution between domestic and foreign consumption goods. For any level of consumption, each household purchases a composite of domestic and imported goods in period t in order to minimize the total cost of its consumption basket. Hence, each household minimizes $P_{H_D,t}C_{H,t}(j) + P_{F,t}C_{F,t}(j)$, subject to (2), where $P_{H_D,t}$ and $P_{F,t}$ are the prices of domestic and imported goods sold domestically, respectively. Therefore, the demand for home and imported goods are given by:

$$C_{H,t}(j) = \gamma_C \left(\frac{P_{H_D,t}}{P_{C,t}} \right)^{-\eta_C} C_t, \qquad C_{F,t} = (1-\gamma_C) \left(\frac{P_{F,t}}{P_{C,t}} \right)^{-\eta_C} C_t, \quad (3)$$

where $P_{C,t}$ is the price of the consumption good which is defined as: $P_{C,t} = \left(\gamma_C P_{H,t}^{1-\eta_C} + (1-\gamma_C) P_{F,t}^{1-\eta_C}\right)^{\frac{1}{1-\eta_C}}$.

[6] To ensure that per capita hours are stationarity, we assume that in steady state $\zeta_{L,t}$ grows at a rate $(1+g_y)^{1-\frac{1}{\sigma_C}} - 1$.

2.1.1 Budget constraint and consumption-savings decisions

We assume there are two type of households: Ricardian and non-Ricardian households. Non-Ricardian households are index in the interval $[0, \lambda]$. In other words, λ corresponds to the share of non-Ricardian households in the economy. These households have no access to the capital market and, therefore, can not smooth consumption intertemporally.

Ricardian households These households have access to three different types of assets: money $\mathcal{M}_t(j)$, one-period non-contingent foreign bonds (denominated in foreign currency) $B^*_{P,t}(j)$, and one-period domestic contingent bonds $d_{t+1}(j)$ which pays out one unit of domestic currency in a particular state. There are no adjustment costs in the portfolio composition. However, each time a domestic household borrows from abroad it must pay a premium over the international price of external bonds. This premium is introduced in the model to obtain a well defined steady state for the economy.[7] Hence, the household budget constraint is given by:

$$P_{C,t}C_t(j) + E_t[q_{t,t+1}d_{t+1}(j)] + \frac{\mathcal{E}_t B^*_{P,t}(j)}{(1+i^*_t)\Theta\left(\frac{\mathcal{E}_t B^*_t}{P_{Y,t}Y_t}\right)} + \mathcal{M}_t(j) =$$
$$W_t(j)l_t(j) + \Pi_t(j) - T_{P,t}(j) + \frac{\mathcal{N}_{t-1}}{\mathcal{N}_t}\left(d_t(j) + \mathcal{E}_t B^*_{P,t-1}(j) + \mathcal{M}_{t-1}(j)\right), \quad (4)$$

where $\Pi_t(j)$ are profits received from domestic firms, $W_t(j)$ is the nominal wage set by household j, $T_{P,t}(j)$ are per capita net taxes, and $\mathcal{E}_t$ is the nominal exchange rate. The term $\Theta(.)$ corresponds to the premium domestic households have to pay each time they borrow from abroad which depends on the ratio of net foreign asset position of the country to GDP, where B^*_t is the aggregate net foreign asset position of the economy and $P_{Y,t}Y_t$ is the nominal GDP. Variable $q_{t,t+1}$ is the period t price of domestic contingent bonds normalized by the probability of the occurrence of a particular state.

Ricardian households choose consumption and the composition of their portfolios by maximizing (1) subject to (4). Since we are assuming the existence of a complete set of contingent claims, consumption is equalized across Ricardian households. By aggregating the first order conditions on different contingent claims over all possible states we obtain the following Euler equation:

$$\frac{1}{1+n}\beta E_t\left[(1+i_t)\frac{P_{C,t}}{P_{C,t+1}}\frac{\zeta_{C,t+1}}{\zeta_{C,t}}\left(\frac{C_{t+1}(j)-(1+g_y)hC_t}{C_t(j)-(1+g_y)hC_{t-1}}\right)^{-\frac{1}{\sigma_C}}\right] = 1, \quad (5)$$

[7] See Schmitt-Grohé and Uribe (2003) for different ways to get steady state independent of initial conditions for small open economy models.

where we have used the fact that in equilibrium $1+i_t = 1/E_t[q_{t,t+1}]$. Analogously, the first order condition with respect to foreign bonds implies:

$$\frac{1}{1+n}\beta E_t\left[(1+i_t^*)\,\Theta\left(.\right)\frac{P_{C,t}}{P_{C,t+1}}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\frac{\zeta_{C,t+1}}{\zeta_{C,t}}\left(\frac{C_{t+1}\left(j\right)-(1+g_y)hC_t}{C_t\left(j\right)-(1+g_y)hC_{t-1}}\right)^{-\frac{1}{\sigma_C}}\right]=1. \tag{6}$$

where $j\in(\lambda,1]$.

These two equations imply that non-arbitrage opportunities must hold. In other words, the *uncovered interest parity* condition must be satisfied.

Non-Ricardian households As we said, these households have no access asset and own no share in domestic firms. Therefore, they must consume completely their disposable labor income, period by period:

$$P_{C,t}C_t\left(j\right)=W_t(j)l_t\left(j\right)-T_{P,t}\left(j\right). \tag{7}$$

where $j\in[0,\lambda]$.

2.1.2 Labor supply and wage setting

Each household j is a monopolistic supplier of a differentiated labor service. There is a set of perfect competitive labor service assemblers that hire labor from each household and combine it into an aggregate labor service unit, l_t, that is then used by the intermediate goods producer. The labor service unit is defined as:

$$l_t=\left(\int_0^1 l_t(j)^{\frac{\epsilon_L-1}{\epsilon_L}}dj\right)^{\frac{\epsilon_L}{\epsilon_L-1}}. \tag{8}$$

The optimal composition of this labor service unit is obtained by minimizing its cost, given the different wages set by different households. In particular, the demand for the labor service provided by household j is:

$$l_t(j)=\left(\frac{W_t\left(j\right)}{W_t}\right)^{-\epsilon_L}l_t, \tag{9}$$

where $W_t\left(j\right)$ is the wage rate set by household j and W_t is an aggregate wage index defined as $W_t=\left(\int_0^1 W_t(j)^{1-\epsilon_L}dj\right)^{\frac{1}{1-\epsilon_L}}$.

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 constant probability $(1-\phi_L)$ of being able to re-optimize its nominal wage. We assume there is an updating rule for all those households that cannot re-optimize their wages. In particular, if a household cannot re-optimize during i periods between t and $t+i$, then its wage at time $t+i$ is given by

$$W_{t+i}(j) = \Gamma_{W,t}^{i} W_t(j), \tag{10}$$

where $\Gamma_{W,t}^{i} = \prod_{j=1}^{i}(1+\pi_{C,t+j-1})^{\xi_L}(1+\overline{\pi}_{t+j})^{1-\xi_L}(1+g_y)$ defines the updating rule.

This "passive" adjustment rule implies that workers who do not optimally reset their wages update them by considering a geometric weighted average of past CPI inflation and the inflation target set by the authority, $\overline{\pi}_t$, where ξ_L is the weight to past inflation. The presence of $(1+g_y)$ in the expression above is included in order to avoid large real wage dispersion along the steady state growth path. Once a household has decided a wage, it must supply any quantity of labor service that is demanded at that wage.

A particular household j that is able to re-optimize its wages at t solves the following problem:

$$\begin{aligned} \max_{W_t(j)} \quad = \quad & E_t \left\{ \sum_{i=0}^{\infty} \phi_L^i \left[\Lambda_{t,t+i} \left(\frac{W_t(j)\Gamma_{W,t}^{i} l_{t+i}(j)}{P_{C,t+i}} \right) - \right.\right. \\ & \left.\left. \zeta_{L,t+i} \frac{1}{1+\sigma_L} \left(l_{t+i}(j)\right)^{1+\sigma_L} \left(C_{t+i} - h(1+g_y)C_{t+i-1}\right)^{1/\sigma_C} \right] \right\} \end{aligned}$$

subject to the labor demand (9) and the updating rule for the nominal wage (10). The variable $\Lambda_{t,t+i}$ is the relevant discount factor between periods t and $t+i$.[8]

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 by Ricardian households.

2.2 Investment and capital goods

Investment goods consist of a CES aggregator of home $(I_{H,t})$ and foreign goods $(I_{F,t})$:

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

where η_I is the elasticity of substitution between home and foreign investment goods, and γ_I defines the share of domestic goods in investment. Maximizing the expression above subject

[8]Since utility exhibits habit formation in consumption and population growth at a rate n, the relevant discount factor is given by $\Lambda_{t,t+i} = \left(\frac{\beta}{1+n}\right)^i \left(\frac{C_t(j)-(1+g_y)hC_{t-1}}{C_{t+i}(j)-(1+g_y)hC_{t+i-1}}\right)^{1/\sigma_C}$.

to the budget constraint $P_{I,t}I_t = P_{H_D,t}I_{H,t} + P_{F,t}I_{F,t}$ we obtain the following investment demand functions:

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

where the investment price index (which is defined as the minimum expenditure required to buy one unit of I_t) is given by: $P_{I,t} = \left[\gamma_I P_{H_D,t}^{1-\eta_I} + (1-\gamma_I) P_{F,t}^{1-\eta_I} \right]^{\frac{1}{1-\eta_I}}$.

To obtain more inertia in the demand for investment goods, we assume that adjusting investment is costly. A representative firm chooses a path for investment that maximizes the present value of its profits:

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

subject to

$$(1+n)K_{t+1} = (1-\delta(u_t))\, K_t + \zeta_t^I S \left(\frac{I_t}{I_{t-1}} \right) I_t.$$

where u_t is the rate of utilization of capital at period t, K_t is the amount of physical capital available at the begin of period t, and Z_t is the rental rate per unit of effective capital. Function $S(.)$ characterizes the adjustment cost for investment.[9] Variable ζ_t^I is a stochastic shock. We assume that an increase in the rate of utilization of capital implies a faster depreciation of the physical capital: $\delta'(.) > 0$.

2.3 Domestic production

This sector consists of two types of firms. One type of firms are producers of differentiated intermediate goods. Each of these firms has monopoly power and face a nominal rigidity that prevents them to adjust optimally prices every period. A second type of firms assembly the differentiated intermediate goods to sell them in the domestic and foreign markets. These firms behave competitively.

2.3.1 Assembly of intermediate goods

Assemblers of intermediate goods sell different final goods in the domestic and the foreign market. In order to produce $Y_{H_D,t}$ units of home goods to be sold in the domestic

[9] The adjustment cost of investment satisfies: $S((1+g_y)) = 1$, $S'((1+g_y)) = 0$, $S''((1+g_y)) = -\mu_S < 0$ (see Altig et al. (2005)).

market, they combine domestically produced intermediate varieties by using the following aggregator:

$$Y_{H_D,t} = \left[\int_0^1 Y_{H_D,t}(z_H)^{\frac{\epsilon_{H_D}-1}{\epsilon_{H_D}}} dz_H \right]^{\frac{\epsilon_{H_D}}{\epsilon_{H_D}-1}}, \tag{11}$$

where $Y_{H_D}(z_H)$ is the quantity of intermediate variety z_H used for final good sold in the domestic market. The demand for a variety z_H for the domestic market is, therefore, given by:

$$Y_{H_D,t}(z_H) = \left(\frac{P_{H_D,t}(z_H)}{P_{H_D,t}} \right)^{-\epsilon_{H_D}} Y_{H_D,t}, \tag{12}$$

where $P_{H_D}(z_H)$ is the price of variety z_H in the domestic market and P_{H_D} is the price index of one unit of Y_{H_D} (which is obtained as the minimum expenditure required to produce one unit of Y_{H_D}): $P_{H_D,t} = \left[\int_0^1 P_{H_D,t}(z_H)^{1-\epsilon_{H_D}} dz_H \right]^{\frac{1}{\epsilon_{H_D}-1}}$.

Analogously, in order to export $Y_{H_F,t}$ units of the home good assemblers combine intermediate varieties using the following technology:

$$Y_{H_F,t} = \left[\int_0^1 Y_{H_F,t}(z_H)^{\frac{\epsilon_{H_F}-1}{\epsilon_{H_F}}} dz_H \right]^{\frac{\epsilon_{H_F}}{\epsilon_{H_F}-1}}, \tag{13}$$

where $Y_{H_F,t}(z_H)$ is the amount of variety z_H used to export $Y_{H_F,t}$ unit of the final home good. The demand by exporting assemblers for each variety is given:

$$Y_{H_F,t}(z_H) = \left(\frac{P^*_{H_F,t}(z_H)}{P^*_{H_F,t}} \right)^{-\epsilon_{H_F}} Y_{H_F,t}, \tag{14}$$

where $P^*_{H_F,t}(z_H)$ is the price of variety z_H expressed in foreign currency, and $P^*_{H_F,t}$ is the price of the final home good that is exported (in foreign currency) given by $P^*_{H_F,t} = \left[\int_0^1 P^*_{H_F,t}(z_H)^{1-\epsilon_{H_F}} dz_H \right]^{\frac{1}{\epsilon_{H_F}-1}}$.

2.3.2 Producers of intermediate goods

The production of intermediate good is characterized by firms that act as a monopoly in the production of a single variety. These firms differentiate their production to be used by exporting assemblers and domestic market assemblers. Each firm maximizes profits by choosing the price of its variety subject to the corresponding demand and the available technology. Let $Y_{H,t}(z_H) = Y_{H_D,t}(z_H) + Y_{H_F,t}(z_H)$ be the total quantity produced of a particular variety z_H, where $Y_{H_D,t}(z_H)$ corresponds to the quantity produced for the domestic market and $Y_{H_F,t}(z_H)$ the quantity produced for the foreign (exports) market. The technology available is given by

$$Y_{H,t}(z_H) = A_{H,t}\left[\eta_H{}^{\frac{1}{\theta_H}}\left((1+g_y)^t l_t(z_H)\right)^{\frac{\theta_H-1}{\theta_H}} + (1-\eta_H)^{\frac{1}{\theta_H}}\left(u_t K_t(z_H)\right)^{\frac{\theta_H-1}{\theta_H}}\right]^{\frac{\theta_H}{\theta_H-1}},$$

where $l_t(z_H)$ is the per capita amount of labor used, $K_t(z_H)$ is the amount of physical capital rented with a rate of utilization u_t. Variable $A_{H,t}$ represents a productivity shock common to all firms in this sector. Parameter θ_H is the elasticity of substitution between labor and capital services and η_H control the share of labor services in production.

Demand for inputs and marginal cost Firms determine the optimal mix of inputs by minimizing total cost of production, subject to the constraint imposed by the technology. From the first-order condition we obtain the following relationship:

$$\left(\frac{\eta_H K_t(z_H)}{(1-\eta_H)\mathcal{N}_t(1+g_y)^t l_t(z_H)}\right)^{1/\theta_H} = \frac{W_t}{Z_t}.$$

Using this last expression and the production function we also obtain an expression for the marginal cost of firm producing variety z_H:

$$MC_{H,t} = \frac{W_t l_t(z_H) + Z_t u_t K_t(z_H)}{Y_{H,t}(z_H)}.$$

Notice that the marginal cost depends only on factor prices and the technology level, which is common for all firms. Hence, the marginal cost is independent of the scale of production of a particular variety producer.

Price setting Following Calvo (1983) we assume that firms adjust their prices infrequently. In particular, they do so when receiving a signal. In every period the probability of receiving a signal and adjusting their prices in the domestic market is $1-\phi_{H_D}$ for all firms, independently of their history. Similarly, each firm has a probability receiving a signal to be able to re-optimize its exporting price equal to $1-\phi_{H_F}$. The chance of receiving this other signal is equal for all firms, and independent of their history and from the event of adjusting optimally prices in the domestic market. We assume that a firm that does not receive any type of signal will update its prices following simple "passive" rules. In particular, if the firm does not adjust its domestic price between t and $t+i$, then the price it charges in $t+i$ is given by $\Gamma_{H_D,t,t+i}P_{H_D,t}(z_H)$, where $\Gamma_{H_D,t,t+i}$ is a function that defines the updating rule for the domestic price. Analogously, if a firm does not receive a signal to adjust its exporting price, then it follows a simple updating rule for its exporting price, which is given by $\Gamma_{H_F,t,t+i}$.

Therefore, if a firm z_H receives a signal in period t to adjust optimally its domestic price, then it will adjust the price of its variety, $P_{H_D,t}(z_H)$, so as to maximize the following expression:[10]

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

subject to (12). In contrast if the firm receives a signal in period t to adjust optimally its exporting prices (in foreign currency), then it will choose the price of its variety, $P^*_{H_F,t}(z_H)$, in order to maximize:

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

subject to (14).

2.4 Import goods retailers

The import sector consists of a continuum of firms that buy a homogenous good in the foreign market. These firms turns the importer good into a differentiated import.[11] Competitive assemblers combine this continuum of differentiated imports in a final import good Y_F. The technology of importing assemblers is given by:

$$Y_{F,t} = \left[\int_0^1 Y_{F,t}(z_F)^{\frac{\epsilon_F - 1}{\epsilon_F}} dz_F \right]^{\frac{\epsilon_F}{\epsilon_F - 1}}, \tag{15}$$

where $Y_{F,t}(z_F)$ is the quantity of a differentiated import z_F used by the assemblers. The optimal mix of the differentiated import is given by the following demand:

$$Y_{F,t}(z_F) = \left(\frac{P_{F,t}(z_F)}{P_{F,t}} \right)^{-\epsilon_F} Y_{F,t}, \tag{16}$$

where $P_{F,t}(z_F)$ is the price of the import brand z_F charged in the domestic market, and $P_{F,t}$ is the aggregate price of import goods in the domestic market, which is given by: $P_{F,t} = \left[\int_0^1 P_{F,t}(z_F)^{1-\epsilon_F} dz_F \right]^{\frac{1}{1-\epsilon_F}}$.

The different importing firms buy the homogenous foreign good at price $P^*_{F,t}$ abroad in foreign currency. Each different importing firm posses monopoly power over domestic

[10] The updating rules are given by: $\Gamma_{H_D,t,t+i} = \Gamma_{H_D,t,t+i-1} \left(1 + \bar{\pi}_{t+i}\right)^{1-\chi_{H_D}} \left(1 + \pi_{H_D,t+i-1}\right)^{\chi_{H_D}}$, and $\Gamma_{H_F,t,t+i} = \Gamma_{H_F,t,t+i-1} \left(1 + \bar{\pi}^*_{F,t+i}\right)^{1-\chi_{H_F}} \left(1 + \pi_{H_F,t+i-1}\right)^{\chi_{H_F}}$, where $1 + \pi_{H_D,t} = (P_{H_D,t}/P_{H_D,t-1} - 1)$, $1 + \pi_{H_F,t} = (P_{H_F,t}/P_{H_F,t-1} - 1)$, $1 + \pi^*_{F,t} = (P^*_{F,t}/P^*_{F,t-1} - 1)$, and $\bar{\pi}_t$ is the inflation target set by the central bank for period t.

[11] This differentiating technology can be interpreted as brand naming.

retailing of that variety. We assume local currency price stickiness in order to allow for incomplete exchange rate pass-through to the import prices. A different importing firm adjust the domestic price of its variety infrequently, when receiving a signal. The signal arrives with probability $1 - \phi_F$ each period. As in the case of domestically produced goods, if a firm does not receive a signal, it updates its price following a "passive" rule. This "passive" rule is defined through $\Gamma_{F,t,t+i}$. This updating rule is defined as $\Gamma_{F,t,t+i} = \Gamma_{F,t,t+i-1}(1+\bar{\pi}_{t+i})^{1-\xi_F}(1+\pi_{F,t+i-1})^{\xi_F}$, where $1+\pi_{F,t} = P_{F,t}/P_{F,t-1}$.

Hence, when a generic importing firm z_F receives a signal, it chooses a new price by maximizing the following expression

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

subject to the domestic demand for variety z_F (16) and the updating rule.

2.5 Commodity sector

We assume that the production of this sector evolves stochastically and requires no inputs: there is an exogenous endowment of the commodity good. This endowment of commodity is completely exported; it can be interpreted as the value added by natural resources to the commodity gross production. The endowment of the commodity good (in per capita terms) evolves as follows:

$$Y_{S,t} = \left[(1+g_y)Y_{S,t-1}\right]^{\rho_S} \left[(1+g_y)^t Y_S\right]^{1-\rho_S} \exp(\varepsilon_{S,t}),$$

where $\varepsilon_{S,t}$ is a shock to the endowment and ρ_S captures the persistence in this shock.

2.6 Foreign sector

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

$$P_{S,t} = \mathcal{E}_t P^*_{S,t}, \tag{17}$$

The real exchange rate is defined as the relative price of a foreign price index, P^*_t, and the price of a consumption basket in the domestic economy:

$$RER_t = \frac{\mathcal{E}_t P^*_t}{P_{C,t}}. \tag{18}$$

We assume that the foreign price index P_t^* is not necessarily equal to $P_{F,t}^*$, the CIF price of imported goods. However, we assume that both prices co-integrate, such that:

$$P_{F,t}^* = P_t^* \zeta_{F,t}^*, \tag{19}$$

where $\zeta_{F,t}^*$ is transitory shock to the relative price of imports to the foreign price level.

Foreign demand for domestically produced goods depends on the relative price of this type of goods and the total foreign aggregate demand,

$$Y_{H_F,t} = \zeta_t^* \left(\frac{P_{H_F,t}^*}{P_t^*} \right)^{-\eta^*} C_t^*, \tag{20}$$

where ζ_t^* corresponds to a shock to the share of domestic intermediate goods in the consumption basket of foreign agents, and where 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.

2.7 Monetary Policy

Monetary policy is defined through a rule for the interest rate on public bonds. The rule implies interest rate adjustment in response to deviations of consumption goods inflation from the inflation target and GDP deviations from its trend, $\overline{Y}_t$. We also allow for interest rate smoothing:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i} \right)^{\varphi_i} \left(\frac{P_{C,t}}{P_{C,t-1}} \frac{1}{1+\overline{\pi}_{C,t}} \right)^{(1-\varphi_i)\varphi_\pi} \left(\frac{Y_t}{\overline{Y}_t} \right)^{(1-\varphi_i)\varphi_y} \exp \zeta_{m,t}, \tag{21}$$

where φ_i controls the interest rate smoothing, φ_π and φ_y are the weights of inflation and GDP deviations on the monetary policy rule, and $\zeta_{m,t}$ is a monetary policy shock.

2.8 Fiscal policy

Lets consider the budget constraint of the government. The net position of the government measured in foreign currency, $B_{G,t}^*$, evolves according to:

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

where $(1+i_t^*)\,\Theta\,(.)$ is the relevant gross interest rate for public debt, G_t is government expenditure and T_t are total net fiscal nominal revenues (income tax revenues minus transferes to the private sector). We assume that the basket consumed by the government includes is given by

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

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

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

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

Fiscal net revenues come from two sources: net tax income from the private sector, which is a function of GDP, $T_{P,t} = (\tau_t P_{Y,t} Y_t)^{\epsilon}$, and revenues from copper which are given by $P_{S,t} \chi Y_{S,t}$, where $\chi Y_{S,t}$ are copper sells from the state company (parameter χ defines the share of the public company in total copper production). Variable τ_t corresponds to the average net income tax. Parameter ϵ is the income elasticity of public revenues. This parameter may be larger than one due to expansions in the tax base as a consequence of GDP growth.[12]

The fiscal policy is defined by the three variables $B_{G,t}$, τ_t and G_t. Therefore, given the budget constraint of the government, it is necessary to define behavior rule for two of these three variables.

When agents are Ricardian, defining a trajectory for the primary deficit is irrelevant for the 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 precise trajectory of the public debt and the primary deficit would be relevant. Additionally, the path of the public expenditure may be relevant on its own as long as its composition differs from the composition of private consumption.

We consider the following rules for the fiscal policy:

Rule A: Government expenditure adjustment Under this rule we assume that public expenditure adjusts in order to satisfy budget constraintnet. Net taxes and the net position of the government are kept constant in response to a shock. :

$$B_{G,t} = const; \qquad \tau_t = const \tag{22}$$

[12] This typically occurs when the tax system is progressive, i.e. the marginal tax rate is increasing in income.

Under this rule, an increase in the price of copper induces automatically an expansion of the public expenditure.

Rule B: Tax and transfers adjustment Under this rule, net taxes (taxes and or transfers) are adjusted in order to satisfy the budget constraint. Public expenditure (as a share of GDP, in nominal terms) and the net position of the government are kept constant. :

$$B_{G,t} = const; \qquad \frac{P_{G,t}G_t}{P_{Y,t}Y_t} = const \tag{23}$$

Under this rule an increase in the copper price induces a reduction in taxes in order to satisfy the budget constraint

Rule C: *Structural balance* fiscal rule. The *structural balance* fiscal rule is a rule for the fiscal policy that has been in place in Chile since 2001.[13] The explicit objective for this rule is to smooth the path of public expenditure in order to avoid the pro-cyclicity of the fiscal policy. As it will be clear, this rule allows for a change in the net asset position of the government together with an endogenous adjustment in public expenditure and/or net taxes.

Consider the balance of the government,

$$BA_t = T_t - P_{G,t}G_t + \left(1 - \frac{1}{\left(1 + i^*_{t-1}\right)\Theta_{t-1}}\right)\mathcal{E}_t B^*_{G,t-1}, \tag{24}$$

Equation (24) implies that the balance of the government includes interest payments (the last term on the RHS). The structural balance, $B_{S,t}$, is defined as the effective balance minus cyclical revenues:

$$B_{S,t} \equiv BA_t - \widetilde{T}_t = T_t - \widetilde{T}_t - P_{G,t}G_t + \left(1 - \frac{1}{\left(1 + i^*_{t-1}\right)\Theta_{t-1}}\right)\mathcal{E}_t B^*_{G,t-1} \tag{25}$$

where $\widetilde{T}_t = \widetilde{T}_{P,t} + \widetilde{T}_{cu,t}$ corresponds to cyclical revenues, which are given by,

$$\widetilde{T}_{P,t} = T_{P,t}\left[1 - \left(\frac{\tau_t P_{Y,t}\overline{Y}_t}{\tau_t P_{Y,t} Y_t}\right)^{\epsilon}\right] \qquad \widetilde{T}_{cu,t} = P_{S,t}\chi Y_{S,t} - \mathcal{E}_t \overline{P}^*_{S,t}\chi Y_{S,t} \tag{26}$$

where $\overline{P}^*_{S,t}$ is a long run price of copper which is called the *reference price*, and $\overline{Y}_t$ is potential output.

[13] The description of the structural balanced fiscal rule is an adaptation of the description of the rule in Marcel et., al. (2001). This rue was put partially in place by 2000.

According to the structural balanced budget rule, the structural balance should correspond to 1% of current GDP and it is assumed that the net average income tax (τ_t) is kept constant at τ. This assumption implies that our interpretation of the structural balance rule may be more expansive than the actual rule. Part of the adjustment of the fiscal balance in order to satisfy the rule in our model may be obtained by reducing net taxes. In fact, in practice an important share of the increase in public expenditure when copper price rises are transfers to the private sector. In our model this is equivalent to reducing τ.[14] Combining (24), (25) and (26) we obtain an expression for public expenditure, as a share of GDP, that is consistent with the rule,

$$\frac{P_{G,t}G_t}{P_{Y,t}Y_t} = \left(1 - \frac{1}{\left(1+i^*_{t-1}\right)\Theta_{t-1}}\right)\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\frac{\mathcal{E}_{t-1}B^*_{t-1}}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t} + \tag{27}$$

$$\tau\left(\frac{\overline{Y}_t}{Y_t}\right) + \mathcal{E}_t\overline{P}^*_{S,t}\chi\frac{Y_{S,t}}{P_{Y,t}Y_t} - \frac{B_{S,t}}{P_{Y,t}Y_t} \tag{28}$$

where $\frac{B_{S,t}}{P_{Y,t}Y_t} = 1\%$, and where we have assumed for simplicity that $\epsilon = 1$.

Notice that the public expenditure that is consistent with the rule includes interest payments. Therefore, if the net position of the government improves, current expenditure may increase. We consider an alternative version for this rule where we allow for endogenous adjustments in the reference price.

It is important to recall that rule C is different than rule B because we allow for an accumulation or de-accumulation of net assets by the government. However, the effects of the shock under this rule would be the same as under rule B when agent are Ricardian.

2.9 Aggregate equilibrium

The market clearing condition for domestically produced goods are given by,

$$Y_{H_D,t} = C_{H,t} + I_{H,t} + G_{H,t}, \qquad Y_{H_F,t} = \zeta^*_t\left(\frac{P^*_{H_F,t}}{P^*_t}\right)^{-\eta^*} C^*_t.$$

where G_t corresponds to public expenditure. The equilibrium in the labor market implies that:

$$l_t = \int_0^1 l_t(z_H)dz_H.$$

where l_t is defined in (8).

[14] However, probably transferes to the private sector would be focused on low income households which tend to have a larger marginal propensity to consume (they are "less" Ricardian). Therefore, whether the government increase their consumption or whether they transfer the extra income to low income hopuseholds would probably generate a very similar effect on the results.

Since the economy is open and there is no reserves accumulation by the central bank, the current account is equal to the capital account. Utilizing the budget constraint of the government, the budget constraint of households, and the equilibrium condition in the goods and labor markets we obtain:

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

where $B_t^* = B_{G,t}^* + B_{P,t}^*$ is the aggregate per capita net (*liquid*) asset position of the economy vis-a-vis the rest of the world.

The second term in the right hand side is the income investment of foreign investor in the commodity sector. The last term is the net exports. Exports, imports and GDP (from the demand side) are defined as follows:

$$P_{X,t}X_t = \mathcal{E}_t P_{H_F,t}Y_{H_F,t} + P_{S,t}Y_{S,t}, \tag{29}$$

$$P_{M,t}M_t = \mathcal{E}_t P_{F,t}^* Y_{F,t}. \tag{30}$$

$$P_{Y,t}Y_t = P_{C,t}C_t + P_{H_D,t}G_t + P_{I,t}I_t + P_{X,t}X_t - P_{M,t}M_t. \tag{31}$$

where $Y_{F,t} = C_{F,t} + I_{F,t} + G_{F,t}$.

3 Parametrization and solution

To solve the model we first solve for the non-stochastic steady-state by using numerical methods. Then we solve the log-linearize decision rules from the behavioral equations of the model. We use the QZ factorization described in Uhlig (1997). Table 1 presents the value chosen for the structural parameters of the model.[15] Many of these parameters were taken directly from the literature. Some other parameters were chosen so as to match long-run features of the Chilean economy.

We calibrate the share of the commodity export sector over total GDP to 10%, which resembles the share of cooper exports in total production for the Chilean economy. Net exports to GDP ratio is calibrated to 2%. The foreign debt as percentage of GDP is calibrated to about 30%, which is also consistent with Chilean data.[16] This value implies a current account to GDP ratio of -1.8%. Government spending is calibrated to 12% of the GDP.

[15] We are currently working on a estimated version of the model.

[16] The total external debt of the Chilean economy is currently 50% of the annual GDP. However, the central bank holds reserves of about 20% of GDP. Therefore, the net position of the country is about 30% of annual GDP.

The parameters of household's preferences are the elasticities of substitution among the different types of goods, and the share of them in the consumption basket. The intertemporal elasticity of substitution is fixed in 1.0 as estimated by Duncan (2003) for Chile. We use a unitary labor supply elasticity, which is lower than traditional value used in U.S. real business cycle model. However, this value is in line with microeconomics estimates for Chile.[17] The discount factor is set such that the annual real interest rate is about 4% (annual basis). The elasticity of substitution between domestic and imported consumption goods is also set to 5.0. Preliminary attempts to estimate the model by Bayesian methods point to a somehow large value for this parameter. The share of domestic produced goods in consumption is 65%. To calibrate the parameters that define government consumption, we assume that government expenditure is completely biased toward domestically goods. Investment goods presents a lower degree of substitution

In the commodity export sector, we assume that the participation of the copper sector in exports is about 40%. For the production function of the capital good we assume that the elasticity of substitution between domestic and imported good is fixed at 0.5 and the share of domestic produced goods in investment is 50%. The annual depreciation rate of this type of capital is 2.2%. Producers of domestic intermediate goods have access to a constant return technology. We assume that the elasticity of substitution between capital and labor is 1, and that the share of labor 0.66 in production. The demand elasticity for several varieties is set to a value consistent with steady-state markups of 10%. Finally, the foreign demand or domestic traded goods has an elasticity of 4. This value can be considered higher than standard short run estimated real exchange rate elasticity of foreign demand for non-commodities exports. However, the presence of price rigidity of non-commodity export generates a lower elasticity in the short run. This value is also in line with the estimates provided in Obstfeld and Rogoff (2000).

4 Effects of a transitory shock to the price of copper

In this section we analyze the effects of a copper price shock on several macro variables. We assume that the logarithm of the real US$ price of copper follows an AR(1) process with an autoregressive coefficient of 0.93 –this figure is consistent the data. The shock in period 0 is 10%.[18]

[17] See Mizala and Romaguera (1999).

[18] Using quarterly data for the period 1990 to 2005, the estimated standard deviation of the innovation of an AR(1) for the copper price is 8.8%.

4.1 Comparing different fiscal rules

As we said before, the first effect of the shock is to increase government income revenues. What the government does with the proceedings from copper depends on the fiscal policy rule followed. In turn, the macro effects of the shock under these different policies depends on the households type:

Only Ricardian households In this case, the precise path of the public debt does not have an impact on the consumption and savings decisions of households. Results are depicted in figures 1 and 2.

Under rule A, where the government consumes all additional revenues obtained from copper, the increase in the public expenditure directly implies an expansion in aggregate demand. Under rule B, where all extra income from copper are transferred to households by means of a tax reduction, there is a rise in permanent private disposable income and private consumption increases up to 0.1% some quarters after the shock. Notice that since all households are Ricardian, this result of the tax reduction on consumption would be exactly the same if fiscal policy lowered fiscal debt which is closer to the followed by rule C.

Under both rules there is an expansion in the demand for domestically produced goods. However, in the first case the expansion is much larger because the government spends all extra revenues, while Ricardian households save a share of the windfall as they try to smooth consumption over time. The effect under rule A is also larger because of the composition of the public expenditure which is tilted towards domestic goods.

The expansion in demand for domestic goods translates into an increase in the demand for labor. Employment and output rise. Real wages also increase, but only but a small amount given the nominal rigidities in the economy.

Under rule A private consumption initially falls. But after some quarters, it rises above its steady-state value. This is explained by the slight increase in permanent income associated to the increase in employment and to a lesser extent to rise in real wages. The initial fall in consumption is explained by the contraction in the monetary stance that follow the shock under this fiscal rule.

Although real wages increase by a small amount, unitary labor cost rise by a larger amount due to a decrease in labor productivity. This, in turn, is the consequence of the slow responses of investment and the capital stock to the shock. The increase in labor costs rises domestic goods inflation under both fiscal rules. However, there is a real appreciation of the exchange rate (of about 0.2% under rule A and of about 0.11% under rule B) that reduces imported goods inflation. Total inflation, that includes both domestic and imported goods inflation, increase slightly under rule A reaching 0.02% approximately. Under rule B, where the expansion in demand for domestic goods is much more muted, there is a slight decrease in total inflation few quarters after the shock. Consistent with this result, the interest rate falls in response to the shock. The smaller response of the real exchange rate under this rule is explained by the fact that households consume both domestic and imported goods while the government consumes only domestic goods. Therefore, the movement of the real exchange rate needed to induce an expenditure switching towards imported goods —which is needed in order to balance the external account— a smaller under fiscal rule B.

Ricardian and non-Ricardian households We consider now the responses of the variables to the same shock assuming that a fraction of households are non-Ricardian. These households do have access to the capital market to smooth consumption and, therefore, consume all their disposable income. We assume that the fraction of these types of households is 60%.[19] Figures 3 and 4 present the results.

As we discussed before, rule A is the more expansive of the fiscal rules considered as it implies a direct expansion in the aggregate demand. Now, when a fraction of households are non-Ricardian the impacts of the shock on output and employment are even larger. As the governments expends directly the proceedings from copper, the expansion in aggregate demand stimulates domestic production which generates a large increase in employment. GDP increases by Although real wages do not increase by much, this large increase in employment results in a increase in disposable income to the private sector. As a consequence, non-Ricardian households expand their consumption which leads to an increase in total private consumption. This effect is the standard Keynesian multiplier effect in textbooks. The expansion in employment leads to an increase in the marginal product of capital and, therefore, in the demand for this factor. Investment, however, responds slowly to the increase in the demand for capital. For this reason the price of capital rises on impact after the shock. This conveys an increment in the marginal cost marginal and domestic goods inflation rises. The real exchange rate appreciates more than 0.2% on impact. In turn, total inflation rises something more than 0.03% after the shock.

As we discussed previously, when a fraction of households are non-Ricardian the path followed by public debt and taxes is relevant to determine private consumption. Under rule

[19] Several studies have estimated, using various techniques, the share of non-Ricardian consumers in Chile and in other developed and developing countries. In the case of Chile, Corbo and Schmidt-Hebbel (1991) estimated λ equal to 0.60 for the period 1968-88; Schmidt-Hebbel and Servén (1996) 0.45 for the period 1963-1991; and Bandiera et al. (1999) 0.55 for the 1970-1995 period. More recently López et al. (2000), using a panel of developed and developing countries, found a share of constrained consumers of 0.61 for developing countries.

B the net position of the government vis-a-vis the private sector remains constant as all proceedings are transferred to the private sector through a tax reduction. Private consumption increases as disposable income rises. However, since now there is a fraction of households that are non-Ricardian the expansion in consumption is much larger than without this type of households. Ricardian households also increase their consumption but to a lesser extent as they smooth consumption intertemporally. Overall, private consumption rises about 0.6%. The real appreciation of the exchange rate modifies the composition of expending increasing private consumption of imported goods by more than of domestic goods. GDP rises by a bit more than a half the increase in consumption, about 0.4% on impact after the shock. This expansion in output leads to an increase in employment. As before, real wages increase only slightly due to the nominal rigidities in the economy, but marginal cost rise enough to produce an increase in domestic goods inflation and total inflation. The increase in total inflation is only 0.02% while the real exchange rate appreciates about 0.16% approximately.

Let consider now the effects under rule C, where public expenditure as a share of GDP is determined by the structural balance rule. Consumption by Ricardian households increase immediately after the shock because they know that all asset accumulation by the government will eventually give rise to a reduction in taxes. Non-Ricardian households increase their consumption slowly as their disposable income increase through the rise in employment and real wages. The path of private consumption, therefore, is increasing over time reaching 0.07% thee years after the shock. Consistent with the previous result there is an expansion in aggregate demand. Despite the fact that foreign demand for domestic goods fall as the real exchange appreciates, demand for domestic goods rises. Output and employment increase, as well as real wages and marginal costs. Domestic goods inflation rises. However, total inflation falls slightly due to the appreciation of the exchange rate. The maximum expansion of GDP under this rule is less than 0.1% about three years after the shock. The current account, as a share of GDP, improves by 0.4%.

4.2 Effects with endogenous adjustment of the reference price of copper

Lets consider now the effects under the assumption that the reference price of copper is endogenously adjusted. We have assumed that the log-deviation of the real price copper (price of copper deflated by the foreign price level) can be represented as,

$$\widehat{pr}^*_{S,t} = \rho_{cu}\widehat{pr}^*_{S,t-1} + \varepsilon_{cu,t}$$

where $E_{t-1}\varepsilon_{cu,t} = 0$. If the reference price is calculated as the average expected price over a n-period horizon, we have that

$$\widehat{\widetilde{pr}}^*_{S,t} = \widetilde{\rho}\widehat{pr}^*_{S,t} + \varepsilon_{ref,t}$$

where $\widetilde{\rho} = \frac{1}{n}\left(1 + \rho_{cu} + ...\rho_{cu}^{n-1}\right) < 1$, and where $\widehat{\widetilde{pr}}^*_{S,t}$ is the log deviation of the reference real price of copper and $\varepsilon_{ref,t}$ is a (policy) shock to the reference price of copper. We utilize this expression for the reference price in the log-linearized version of (28).

[TO BE COMPLETED]

4.3 Interaction between fiscal and monetary policy

One of the puzzles in the current business cycle in Chile is that despite the large increase in the copper price, GDP is not growing as fast as in the previous copper price booms.[20] De Gregorio (2006) argues that in Chile the current fiscal and monetary policies have achieved a better stabilization of the copper price cycles than in the past. In particular, a direct explanation for this phenomena is the successful implementation of the structural balance fiscal rule that, as we saw in the previous subsection, implies a much muted response of public expenditure and GDP to a copper price shock.

However, as it is emphasized by De Gregorio (2006), there is an alternative explanation that is related to the way monetary policy reacted previously to such shocks. As it was clear from the previous exercises, one of the effects of a copper price shock was to appreciate the real exchange rate. Over the 90s, as the Chilean economy became more integrated to the world capital market and as rapid productivity growth attracted large capital inflows, there was a permanent tension between the needs for a contractive monetary policy and concerns of an over appreciated exchange rate. Precisely, the restriction imposed by target zone for the exchange rate limited the scope for an effective countercyclical monetary policy in response to shocks such as the copper price shock we are analyzing.

To evaluate whether monetary policy constraints, derived from an implicit target for the real exchange, may have amplified business cycle response to copper price shocks, we compute impulse-responses assuming an alternative monetary policy that includes a response of the interest rate to real exchange rate deviation from trend. A rule like the one proposed is an approximated representation of the behavior of the Central Bank of Chile over the 90s (see Caputo, 2005 and Schmidt-Hebbel and Tapia, 2002). Figures 5 and 6 presents impulse-response functions to a 10% increase in the price of copper under fiscal

[20] GDP grew at 6% in 2005 and it is expected to grow between 5 and 6% in 2006. Hence, GDP seems not being accelerating after the boom in copper price since the second part of 2005. During the nineties, each boom in the cooper price coincides with a more dynamic economic activity.

rule A (assuming a 70% of non-Ricardian households). From the figures is clear that when the central bank tries to stabilize the real exchange rate in response to the shock, there is a larger response of output, consumption and employment. The increase in inflation is also larger. Notice that when the central bank follows this policy, there is a decrease of real wages on impact. This is explained by the nominal wage rigidities and the larger increase of inflation under this monetary policy rule. Despite the fact that the response of output is in fact larger in this case, the magnitude of the effect produced by the attempt of the monetary authority in stabilizing the real exchange rate is rather small. It would imply only a 0.1% extra expansion in GDP.

4.4 Credibility

Now we analyze credibility problems associated with the structural balance rule. Suppose that the public does not know n, the number of periods considered to compute the reference price. Instead, private agents think that there are two types of government. Government type a whith an horizon n_a and government type b whith an horizon n_b. We assume that $n_a > n_b$. The public observes the price of copper and the reference price, but is not able to determine parameter $\widetilde{\rho}$ bacause of the shock to the reference price [TO BE COMPLETED].

5 Historical Decomposition

In this section we evaluate how much of the volatility exhibited by output, inflation and other variables over the last years may be attributed to copper price fluctuations. In order to perform such an exercise, we use our calibrated model to construct an historical decomposition of several macro series. As we saw in the previous section, the response of most of the macro series to a copper price shock depends crucially in the form the fiscal policy reacts to such shock. Since the structural balance fiscal rule was established only in 2001, we have to make an assumption regarding the behavior of the government in previous years. As a methodological assumption we consider in turn either the historical decomposition under policy rule A and compare the outcome to the counterfactual scenario that would have occurred had the government followed rule C.

Figure 7 presents the historical evolution of some macro variables over the 90s (variables have been HP detrended) and the portion of their behavior that could be attributed to copper price movements assuming that the government followed either rule A or rule C over this period.[21] As we can see, copper price fluctuation did contributed to a large fraction of

[21] Some empirical studies show that over the 90s the Chilean government followed a rather countercyclical fiscal policy (García, García and Piedrabuena 2005). Therefore, our preliminary results in figure 7 would

GDP movements (serie `yRA` in the figure). However, the effects of copper price fluctuations seem to precede actual movement in output (serie `y`). In contrast, if the government had followed the structural balance fiscal rule –rule C– copper price fluctuation would almost had no effects on output (serie `yRC` in the figure).

There are some caveats that are important to remark. First, our copper price shock is an identified shock,and all exogenous shocks in the model are orthogonal. However, in practice there may be some correlation between some of those variables. In particular, it is clear that the copper price is highly correlated to the international business cycle (foreign consumption in our model). The historical decomposition in the figures does not take into consideration such correlation as it is build isolating completely the pure efects of the copper price. Second, our model omits other financial channels that affect more significative the external premium each type the copper price rise and the interaction of the availability of foreign currency in the financial market with the willingness of lending of banks.

6 Conclusion

In this paper we use a version of the MAS model, a new dynamic stochastic general equilibrium (DSGE) model for the Chilean economy, to analyze the impact of copper price shocks on the business cycle. We compare the results of copper price-shocks under different fiscal rules and different assumptions regarding the asset structure in the economy. The results show that when the fiscal policy is highly expansive in response to a transitory shock, and if an important fraction of households are non-Ricardian, then and increase in the copper price of 10% implies an output expansion of about 0.7%. The real exchange rate appreciate a bit more than 0.2% and inflation rises by 0.03%. If the fiscal policy is conducted in a way such that the government saves most of the extra revenues from the higher copper price then output would increase only 0.05% and there would be a slight decrease in inflation. This last effect occurs due to the real appreciation of the exchange of 0.09% that compensates the slight increase in domestic goods inflation. Our calibrated model also show that the apparent reduction of the impact of copper price shocks on GDP after year 2000 is related to the adoption of the structural fiscal rule rather than the adoption of a fully flexible exchange rate regime. Still much work is needed in this front. In particular, we should better characterize the actual behavior of the government over the 90s. Also, many of the results depend crucially on the parametrization of the model. We are currently working on an estimated version of the model that would shed light on the most likely value of some of those parameters.

over estimate the effects of copper price shocks.

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Table 1: **Baseline Parametrization**

Parameter	Value	Description
Household Preferences		
β	0.9975	Subjective discount factor
μ	0.2	money demand elasticity to $i/(1+i)$
σ_C	1.0	elasticity of intertemporal substitution in consumption
σ_L	1.0	inverse of the labor supply elasticity
h	0.75	habit formation coefficient
g_y	3% (annual)	productivity growth rate
n	1% (annual)	population growth rate
λ	0.0/0.7	fraction of Non Ricardian Households
Consumption and Investment Baskets		
γ_C	0.65	share of domestic goods in consumption
η_C	1.0	elasticity of substitution in consumption between domestic and imported goods
γ_I	0.5	share of domestic goods in investment
η_I	0.5	elasticity of substitution in investment between domestic and imported goods
Capital Accumulation		
μ_S	2.0	investment adjustment cost coefficient
$\delta(1)$	2.2% (annual)	depreciation rate
$\delta''(1)/\delta'(1)$	10^6	
Nominal Rigidities		
ϕ_L	0.75	prob. adjusting wages
ξ_L	0.5	wage indexation
ϕ_{H_D}	0.75	prob adjusting P_{H_D}
ξ_{H_D}	0.5	domestic goods indexation (home)
ϕ_{H_F}	0.75	prob adjusting P_{H_F}
ξ_{H_F}	0.5	domestic goods indexation (abroad)
ϕ_F	0.75	prob adjusting P_F
ξ_F	0.5	imported goods indexation
Domestic Production Technology		
η_H	0.66	labor share in domestic production
θ_H	1.0	elasticity of substitution between labor and capital

Table 1 (cont.)

Parameter	Value	Description
Foreign Sector		
NX/Y	2%	net exports GDP ratio
η^*	4.0	price elasticity of foreign demand for domestically produced goods
ϱ	0.001	elasticity of the external supply of debt
CA/GDP	-1.8%	current account to GDP ratio
Y_S/Y	10%	copper share in total GDP
Monetary Policy		
φ_i	0.75	interest rate smoothing
φ_π	1.5	reaction to inflation
φ_y	0.0	reaction to output
φ_{rer} (alternative monetary rule)	0.0/0.3	reaction to RER
Fiscal Sector		
G/Y	12%	government expenditure to GDP
χ	40%	share of property of commodity sector holds for the government
τ	9.2%	average net tax rate
B_S/Y	1%	structural balance

Figure 1: Impulse-Response to a Copper Price Shock. Only Ricardian households.

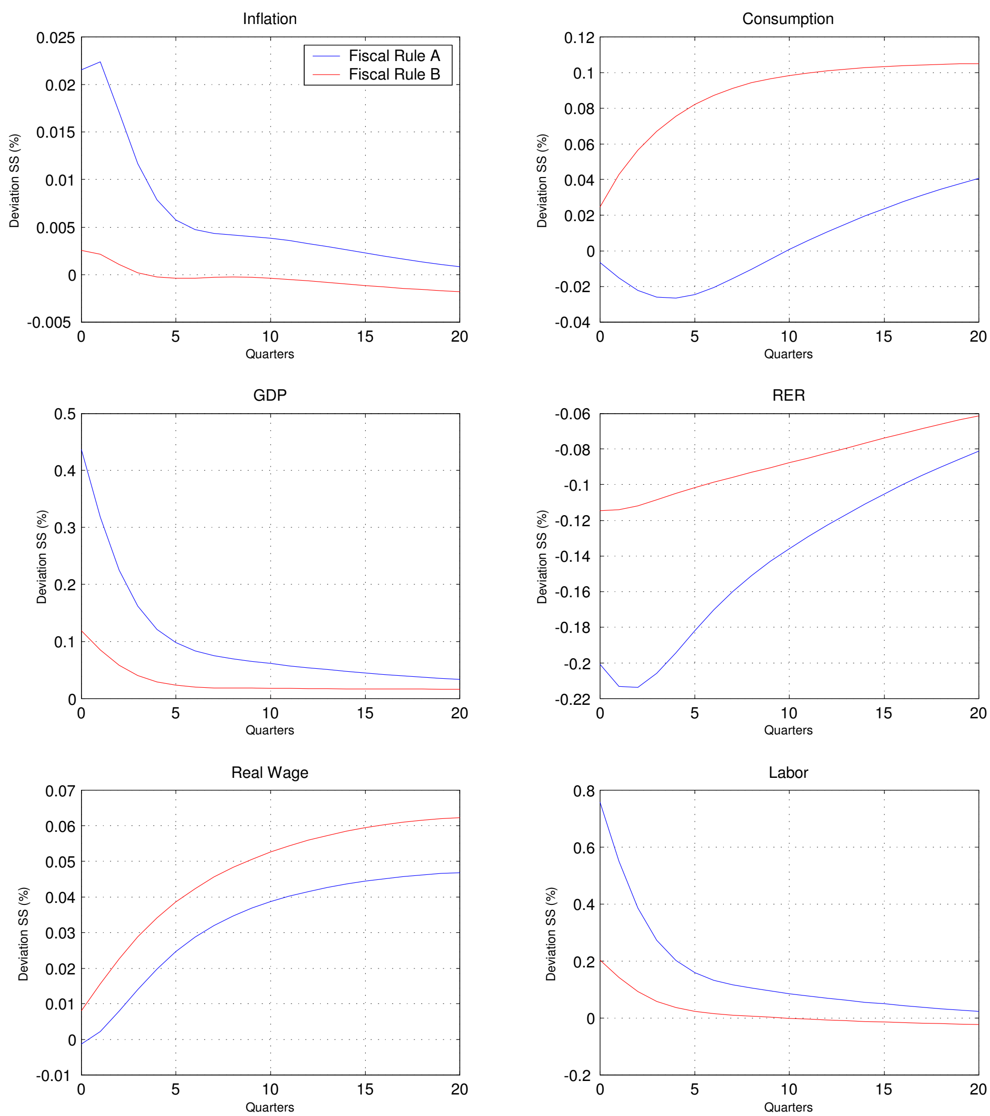

Figure 2: Impulse-Response to a Copper Price Shock. Only Ricardian households.

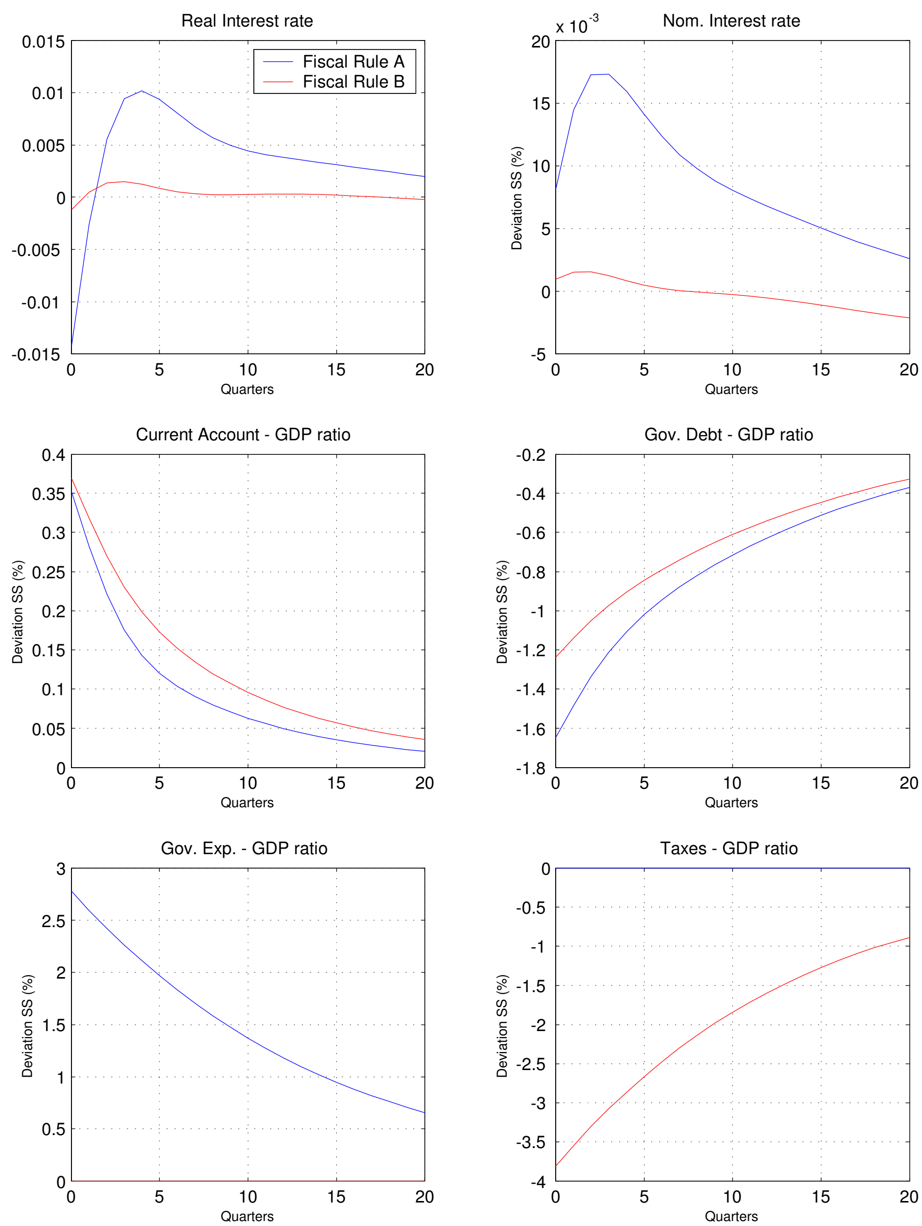

Figure 3: Impulse-Response to a Copper Price Shock. Ricardian and non-Ricardian households.

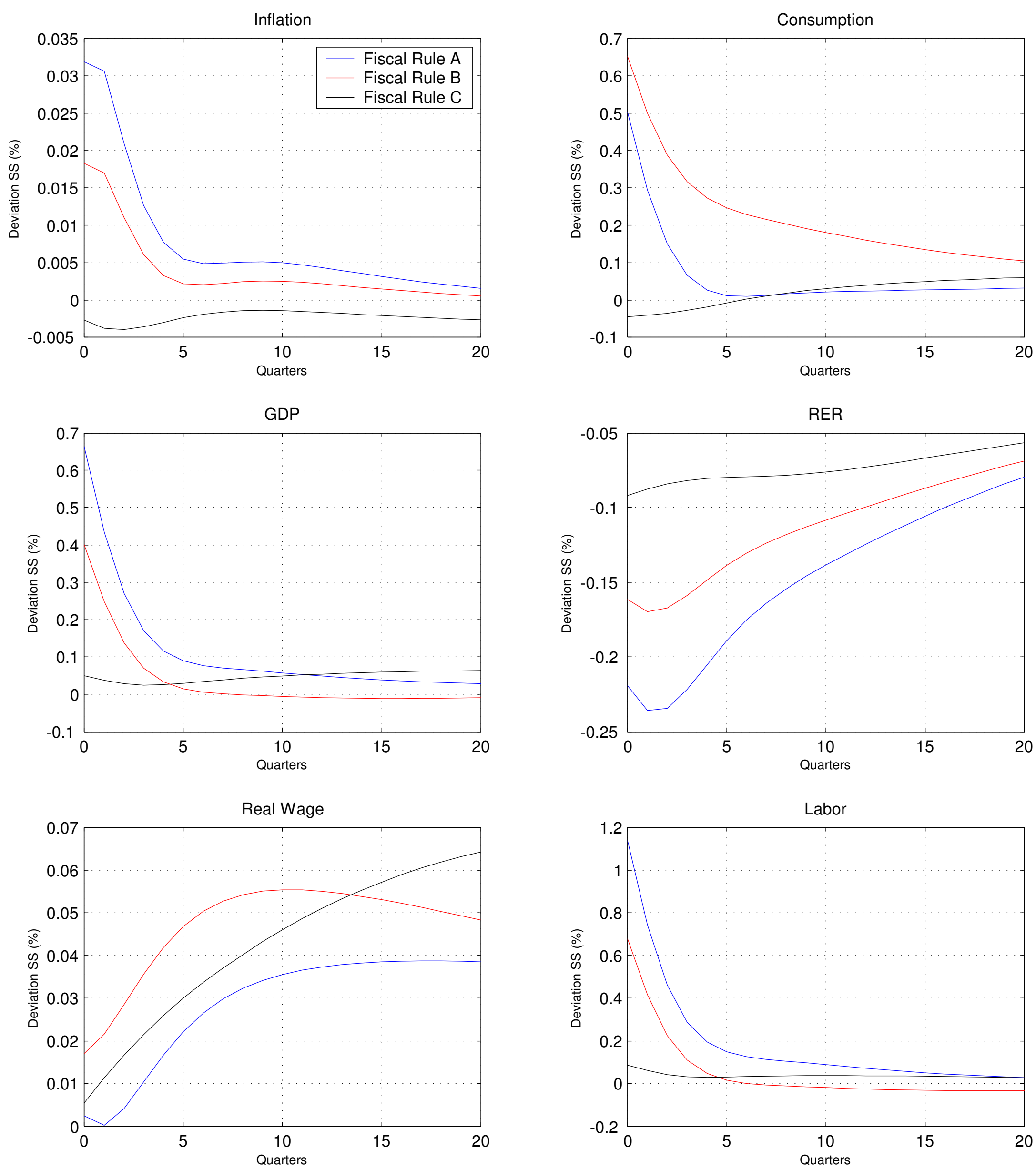

Figure 4: Impulse-Response to a Copper Price Shock. Ricardian and non-Ricardian households.

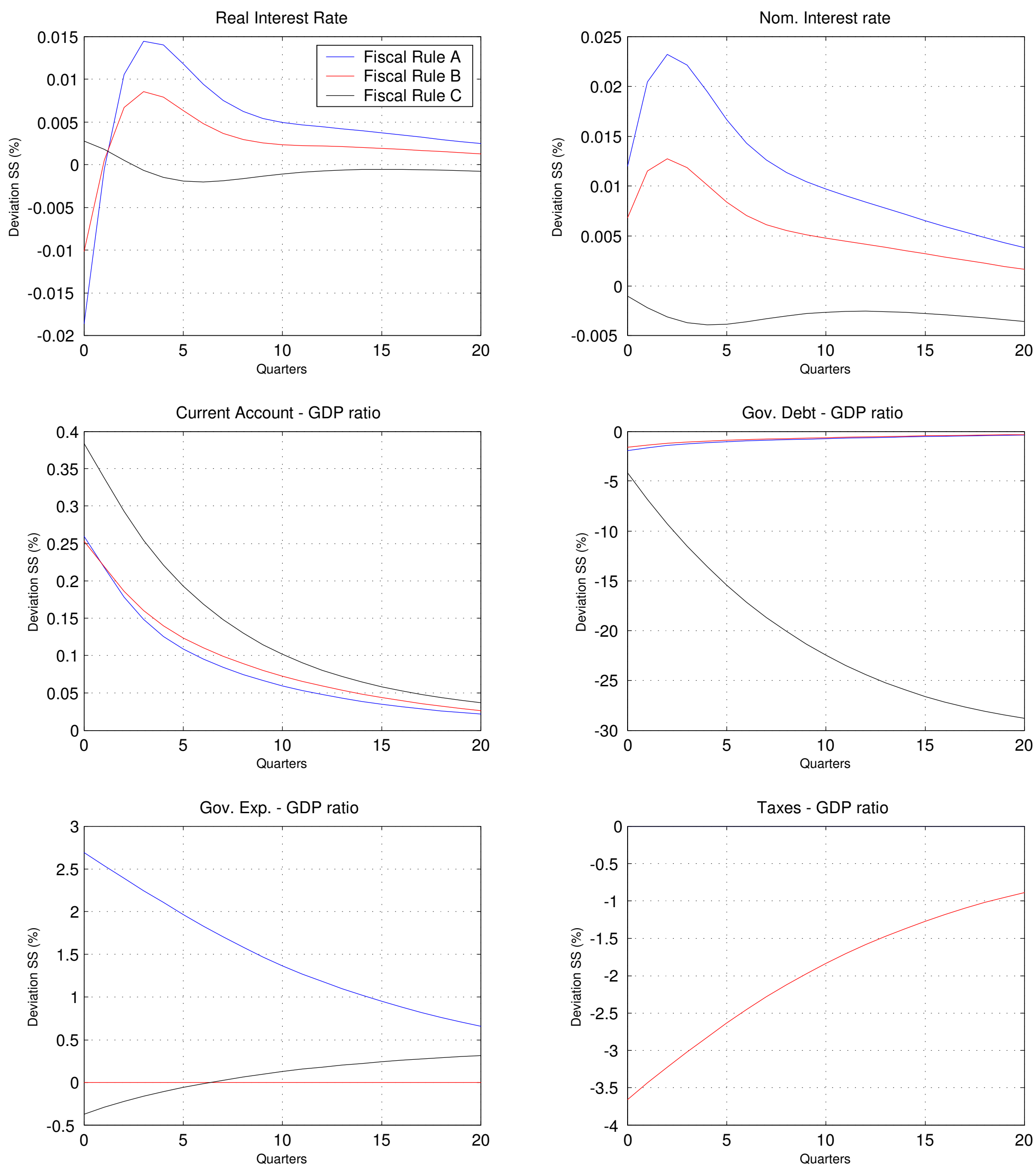

Figure 5: Impulse-response under Rule C with and with reference price adjustment

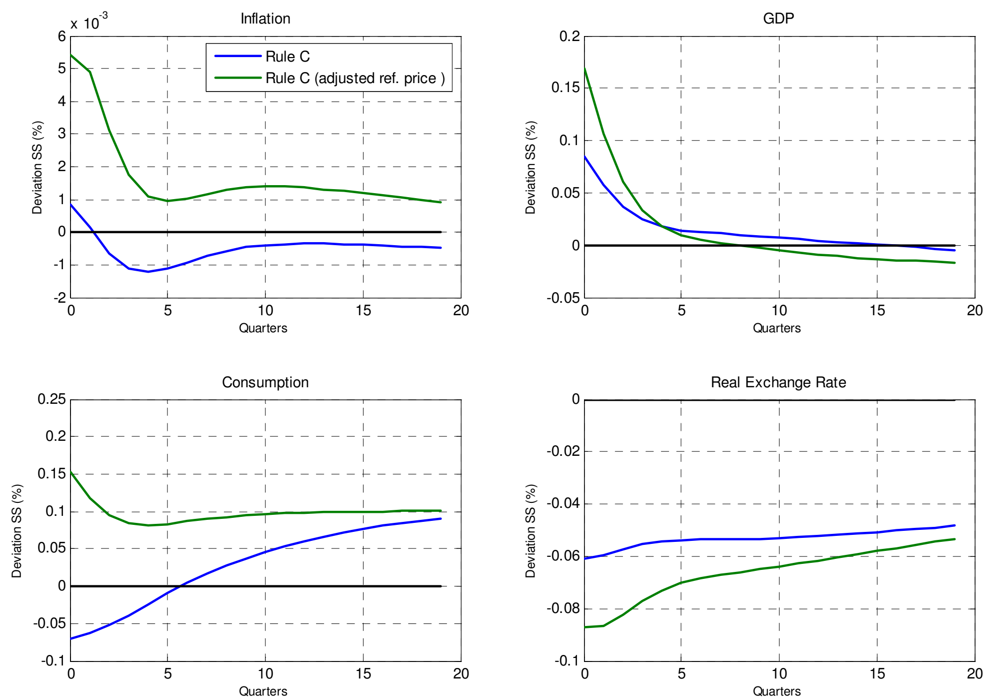

Figure 6: Impulse-Response to a Copper Price Shock. Fiscal Rule A and alternative monetary policy rules

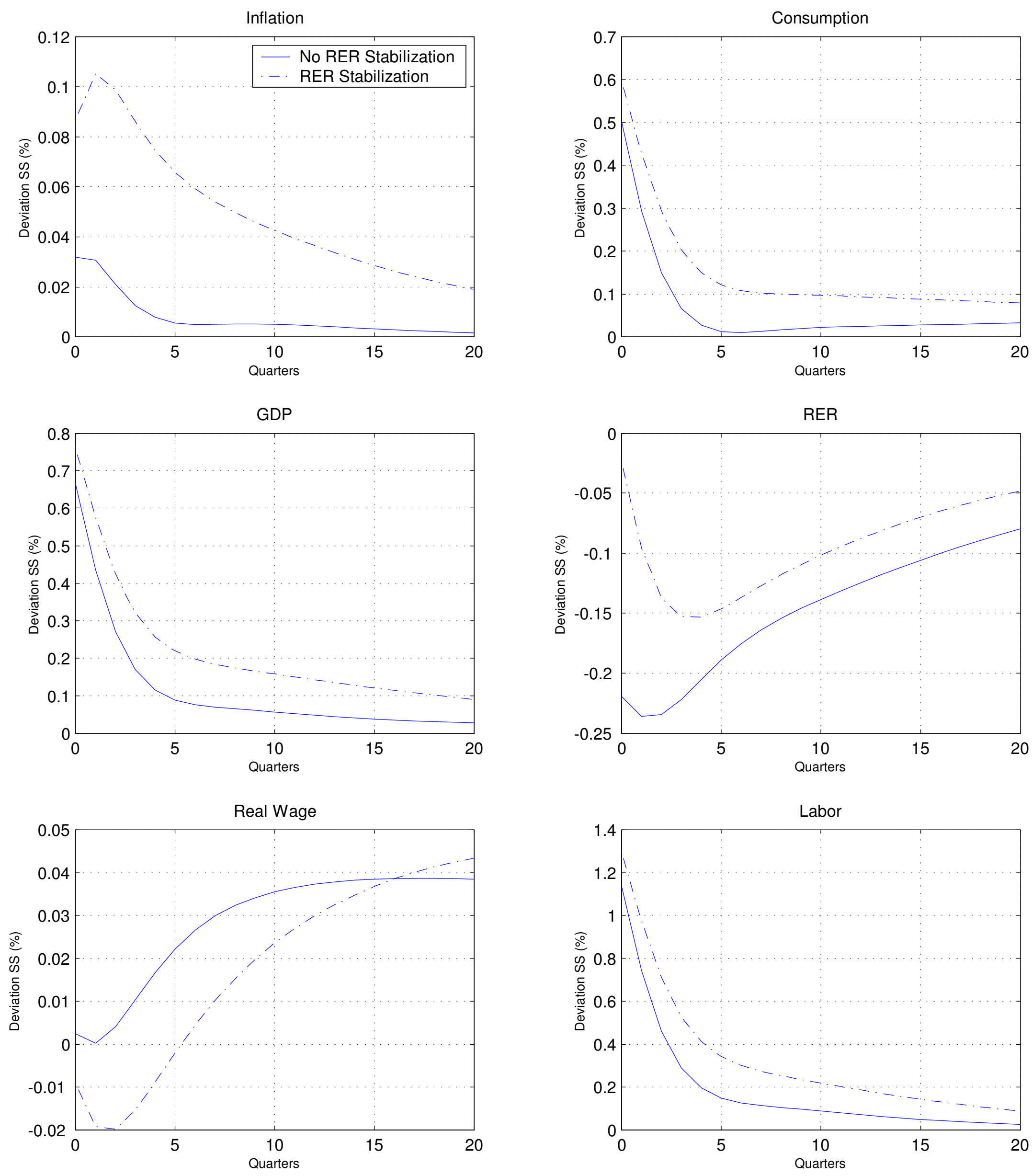

Figure 7: Impulse-Response to a Copper Price Shock. Fiscal Rule A and alternative monetary policy rules.

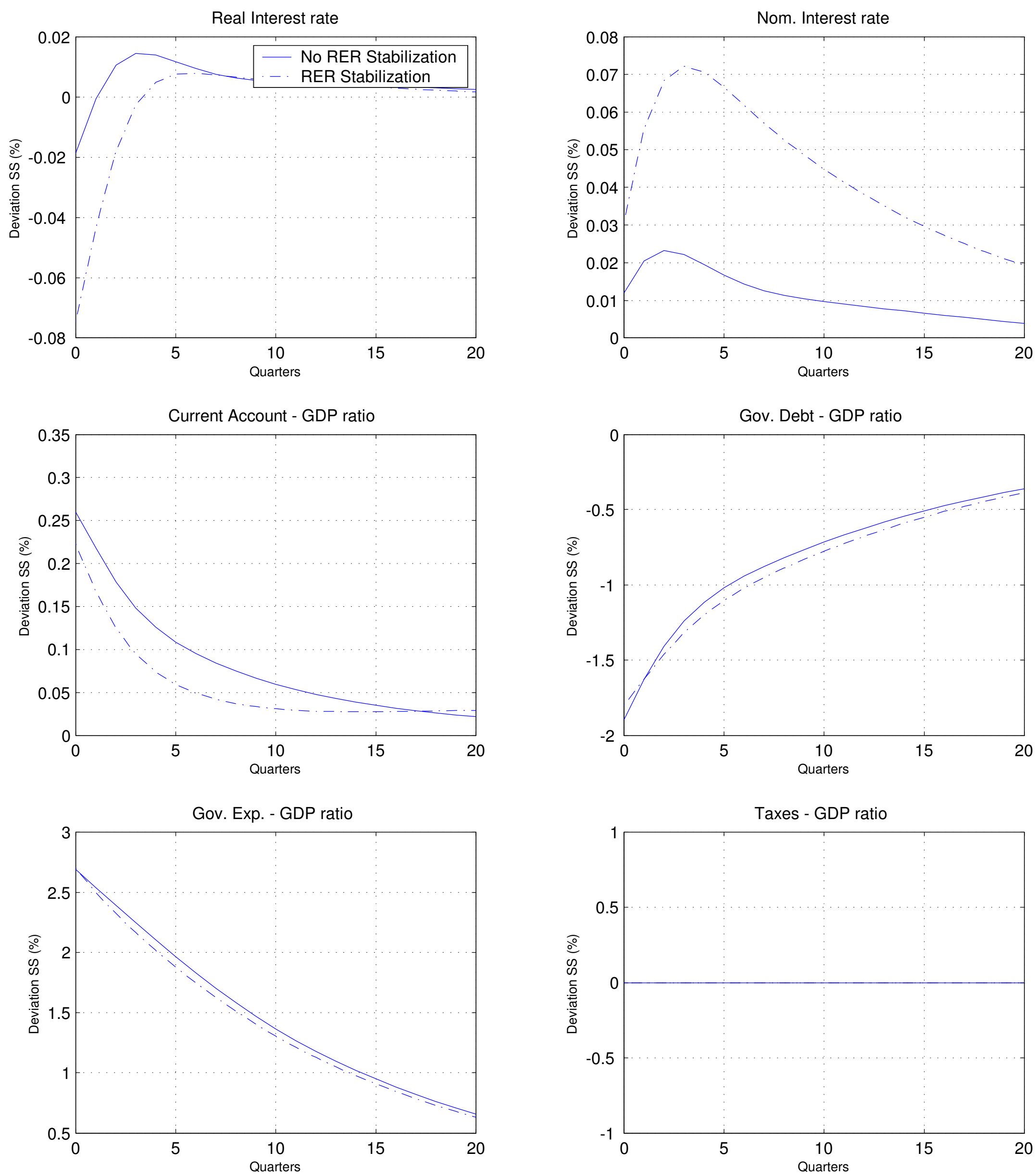

Figure 8: Historical Decomposition: 1990.1 - 2000.1