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COPPER PRICE, FISCAL POLICY AND BUSINESS CYCLE IN CHILE

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Resumen

Este artículo analiza los efectos de shocks al precio del cobre en el ciclo económico de Chile. Utilizando un modelo dinámico de equilibrio general estocástico (DSGE), calibrado para la economía Chilena, evaluamos el efecto de un cambio en el precio del cobre bajo distintos supuestos respecto del comportamiento del sector público. Nuestros resultados indican que si la política fiscal se conduce bajo la regla de superávit estructural, de manera que los mayores ingresos por un alza transitoria del precio del cobre se ahorran, entonces un aumento del 10% en este precio incrementaría el PIB en solo 0,05% y generaría una pequeña caída en la inflación. Esto último, debido a la apreciación cambiaria que acompaña al shock, y que alcanzaría a 0,09%. Por otro lado, si el fisco no sigue la regla de superávit estructural y gasta completamente los ingresos adicionales del cobre, el mismo shock produciría una expansión del PIB de hasta 0,7%, un aumento importante de la inflación y una apreciación real del orden de 0,2%. Nuestros resultados también indican que la flexibilidad cambiaria habría contribuido a aislar el PIB (y la inflación) de las fluctuaciones del cobre, aunque nuestra cuantificación del efecto de este cambio en la forma de hacer política es más bien modesta. De la misma manera, mostramos que si la regla de superávit fiscal no es totalmente creíble, entonces este shock al precio del cobre puede implicar un aumento significativo de la inflación.

Abstract

This paper analyzes the impact of copper-price shocks on the Chilean business cycle from a general equilibrium perspective. Using a DSGE model, we compare the effects of transitory copper-price shocks under different fiscal rules. The results show that if the fiscal policy is conducted using a structural balance fiscal rule, such that the government saves most of the extra revenues from the higher copper price, then a copper price shock of 10% would increase output only by 0.05% and there would be a slight decrease in inflation. This last effect occurs due to a real appreciation of the exchange that compensates a slight increase in domestic goods inflation. In contrast, when fiscal policy is highly expansive, the same copper price increase implies an output expansion of up to 0.7%, an increase in inflation, and a real exchange rate appreciate of 0.2%. We show that the adoption of a flexible exchange rate regime would have contributed to isolate output (and inflation) from copper price shocks, although our quantification of the effect of this change in policy is small. We also show that if the structural balance fiscal rule lacks credibility, then a copper price shock would lead to much higher inflation than under full credibility.

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1 Introduction

Terms of trade fluctuations are an important source of volatility in most emerging market economies. In the case of Chile, business cycle have been historically associated to fluctuation in the price of copper, a commodity that represents approximately 40% of total exports and about 10% of public revenues.[1] Given the importance of copper price movements on the volatility of fiscal revenues, and potentially on output fluctuations, the fiscal authority introduced in 2001 a new fiscal rule intended to isolate government expenditure from these movements.

In this paper we analyze the effects copper price shocks on different macro variables from a general equilibrium perspective, with particular emphasis on the role played by the fiscal rule currently in place in Chile. 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. To encompass different first and second round effects of this type of shocks we use a dynamic stochastic general equilibrium (DSGE) model tailored to the Chilean economy (Medina and Soto, 2006).[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 half percent of GDP, is an attempt to commit and signal the fiscal policy 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.

We consider two asset structures available to households. In one case, we assume that all households have full access to the capital market so that they can smooth consumption intertemporally. 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

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

[2] Another recent paper that studies the effects of copper-price shocks on the Chilean business cycle using a DSGE model is García and Restrepo (2007).

[3] Alternatively, we could think of different behavioral rules for different households. For example, we could just assume that a fraction of households do not intertemporally optimize and just consume their disposable income ("rule of thumb" behavior for these agents). Nonetheless, the results would be identical.

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 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. We also show that the adoption of a flexible exchange rate regime would have contributed to isolate output (and inflation) from copper price shocks, although our quantification of the effect of this change in policy is small. Therefore, our analysis gives support to the view that the apparent reduction of the impact of copper price shocks on GDP, after year 2000, could be more related to the adoption of the structural fiscal rule rather than to the adoption of a fully flexible exchange rate regime.

Our analysis also shows that imperfect credibility about the structural fiscal policy rule would tend to amplify the effects of the copper price shocks on inflation and the real exchange rate. However, the effects of these shocks on GDP under imperfect credibility depend crucially on the sensitivity of investment to the expected course of monetary policy in the future. When investment decisions depends more on the current monetary policy stance, the boom in investment in response to the shock is larger under imperfect credibility, amplifying the output response to it. In contrast, when investment is more inertial, and depends more on the expected path of the interest rate in the future, then investment increase by less in response to the shock under imperfect credibility. This is due to the tighter monetary policy stance expected in the future derived from higher expected inflation under imperfect credibility. As a consequence, output expands by less when the fiscal policy rule is not perfectly credible.

A simple counterfactual quantification of the role of fiscal policy in amplifying GDP fluctuations attributed to the observed copper price shocks shows that an expansive fiscal policy would had increased significantly GDP fluctuations in the 90s compared to the outcome that would have result would the current structural balance fiscal rule being in place during that period.

The paper is organized as follows: The next section describes the 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 under different regimes for fiscal and monetary policies. The fifth section presents an historical decomposition of GDP under alternative fiscal rules. Finally, section six concludes.

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

2 The Model

There are two domestic sectors. One sector produces differentiated goods that are consumed domestically and exported abroad. Another 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 the proceedings from copper production 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 the steady state the economy grows at a rate g_y. 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 chosen in order to match some steady state ratios.

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 is given by:

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

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.[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):

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

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

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

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:

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

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

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:

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

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

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

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:

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

where we have used the fact that in equilibrium $1 + i_t = 1/E_t[q_{t,t+1}]$. Combining (5) with the first order condition with respect to foreign bonds we obtain the following expression for the uncovered interest parity (UIP) condition:

$$\frac{1+i_t}{(1+i_t^*)\,\Theta(\mathcal{B}_t)} = E_t \left(\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \right) + a_t. \tag{6}$$

where $j \in (\lambda, 1]$. The term a_t captures covariance terms and i_t^* is the foreign interest rate.

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

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

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 $\Gamma_{W,t}^i = \prod_{j=1}^i (1+\pi_{C,t+j-1})^{\xi_L} (1+\overline{\pi})^{1-\xi_L} \left(1+g_y\right)$ 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:

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

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.

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

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 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:

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

subject to

$$K_{t+1} = (1-\delta) K_t + S\left(\frac{I_t}{I_{t-1}} \right) I_t.$$

where 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] 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 assemble the differentiated intermediate goods to sell them in the domestic and foreign markets. This last type of firms behave competitively.

[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)).

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 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 goods 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

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

where $l_t(z_H)$ is the per capita amount of labor used, $K_t(z_H)$ is the amount of physical capital rented. 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:

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

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

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

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:

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

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: $P_{F,t} = \left[\int_0^1 P_{F,t}(z_F)^{1-\epsilon_F} dz_F \right]^{\frac{1}{1-\epsilon_F}}$.

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

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

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 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 $\Gamma_{F,t,t+i} = \Gamma_{F,t,t+i-1}(1+\bar{\pi})^{1-\xi_F}(1+\pi_{F,t+i-1})^{\xi_F}$, 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

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

subject to the domestic demand for variety z_F (16) and the updating rule. Variable is the foreign price of a generic imported variety denominated in foreign currency, which coincides to the relevant foreign price level.

2.5 Commodity sector

We assume that the production of this sector requires no inputs: there is an exogenous endowment of the commodity good. This endowment 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 grows at g_y.

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,

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

We assumed that the log-deviation of the real price copper (price of copper deflated by the foreign price level) can be represented as an AR(1) process,

$$\widehat{pr}^*_{S,t} = \rho_{cu}\widehat{pr}^*_{S,t-1} + \varepsilon_{cu,t} \tag{18}$$

where $0 < \rho_{cu} < 1$ and $E_{t-1}\varepsilon_{cu,t} = 0$.

The real exchange rate is defined as the relative price of a foreign price level and the price of a consumption basket in the domestic economy:

$$RER_t = \frac{\mathcal{E}_t P_t^*}{P_{C,t}}. \tag{19}$$

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

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

where ζ^* corresponds 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:

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

where φ_i defines the interest rate smoothing, φ_π and φ_y are the weights of inflation and GDP deviations in the monetary policy rule.

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

Fiscal net revenues come from two sources: net tax income from the private sector, which is a function of GDP, $T_{P,t} = \tau_t P_{Y,t} Y_t + seig$, 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.[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 constraint. Net taxes and the net position of the government are kept constant in response to a shock:

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

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

[12] Seignorage from the Central Bank is rebated to the private sector as a lump-sum transfer

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 a procyclicality in 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,

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

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

According to the structural balanced budget rule, the objective of the fiscal policy is to keep the structural balance at 0.5% of current GDP.[14] We assume that the net average

[13] The description of the structural balanced fiscal rule is an adaptation of the description of the rule in Marcel et., al. (2001).

[14] Originally the target for the structural surplus was 1% of GDP. This target was reduced in May 2007 to 0.5%. The logic for having a structural surplus rests on the fact that the state has some contingent liabilities not well accounted for in the public balance (e.g. pensions).

income tax (τ_t) is kept constant at τ. This assumption implies that our interpretation of the structural balance rule may result in a more expansive policy rule than the actual one. In practice, an important share of the increase in public expenditure when the copper reference price rises corresponds to transfers to the private sector. In our model this is equivalent to reducing τ.[15] Combining (24), (25) and (26) we obtain an expression for public expenditure, as a share of GDP, that is consistent with the rule,

$$\begin{aligned}\frac{P_{G,t}G_t}{P_{Y,t}Y_t} &= \left(1-\frac{1}{\left(1+i_{t-1}^*\right)\Theta_{t-1}}\right)\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\frac{\mathcal{E}_{t-1}B_{t-1}^*}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t}+ \\ & \tau\left(\frac{\overline{Y}_t}{Y_t}\right)+\mathcal{E}_t\overline{P}_{S,t}^{ref}\chi\frac{Y_{S,t}}{P_{Y,t}Y_t}-\frac{B_{S,t}}{P_{Y,t}Y_t} \qquad (27)\end{aligned}$$

where $\frac{B_{S,t}}{P_{Y,t}Y_t}=0.5\%$ is the target structural surplus.

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.

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 a copper price shock under this rule would be the same as under rule B when all households 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 $G_{H,t}$ corresponds to public expenditure devoted to home goods. 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).

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

[15] However, transfers to the private sector are 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 from a higher copper reference price to low income households would probably generate a very similar results.

government, the budget constraint of households, and the equilibrium condition in the goods and labor markets we obtain:

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

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:

$$P_{X,t} X_t = \mathcal{E}_t P_{H_F,t} Y_{H_F,t} + P_{S,t} Y_{S,t}, \tag{28}$$

$$P_{M,t} M_t = \mathcal{E}_t P_{F,t}^* Y_{F,t}. \tag{29}$$

$$P_{Y,t} Y_t = P_{C,t} C_t + P_{H_D,t} G_t + P_{I,t} I_t + P_{X,t} X_t - P_{M,t} M_t. \tag{30}$$

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.[16] 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.[17] This value implies a current account to GDP ratio of -1.8%. Government spending is calibrated to 12% of the GDP and is completely biased towards domestically produced goods ($\gamma_G = 1$).

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

[16]In Medina and Soto (2006) we present an estimated version of this model.

[17]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.

use a unitary labor supply elasticity, which is lower than traditional value used in U.S. real business cycle model. However, this value is more in line with microeconomics estimates for Chile.[18] 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 1.0. 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.

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 (Cobb-Douglas production function), and that the share of labor 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 for 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.

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%.[19]

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:

[18] See Mizala and Romaguera (1999).

[19] 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%.

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 case of rule A, 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 by a small amount given the nominal wage 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 in a quarterly basis. 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 70%.[20] 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 than in the case of only Ricardian households. 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 almost 0.7%. 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 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

[20]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.

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 wage 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 in the future. 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%, which is larger than under the rule B (0.25%).

4.2 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 previous copper price booms. 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, 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 tight 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 rate, 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 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. 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. It is worth noting that the looser monetary policy under the real exchange rate stabilization reduces significantly the real appreciation induced by the shock, and more than doubles the inflation response.

4.3 Imperfect credibility about the fiscal rule

As discussed before, the structural balance fiscal rule (rule C), by reducing the procyclicality of the fiscal policy, isolates the economy from transitory shocks. Moreover, the fact that the rule is known to the public helps signalizing the future behavior of the government. This affects current behavior of forward looking private agents. In this context, it is interesting analyzing in which way different degrees of credibility on this policy rule –i.e. different beliefs about the course of the fiscal policy in the future– affect the transmission mechanism of copper price shocks.

For this purpose, we consider the case where the reference price of copper is endogenously adjusted in response to copper price shocks. [21] Using (18) the log-deviation of the reference

[21] The reference price of copper is meant to be consistent with the expected average copper price over the future. When the structural fiscal rule was announced for the first time in 2000, the reference price of copper was decided by the government. In year 2002, and as a way of gaining credibility, the government nominated an independent commission of experts to determine this price. This commission meets once a

price of copper, $\widehat{\overline{pr}}^{ref}_{S,t}$ calculated as the average expected price over a $n-$periods horizon, is given by

$$\widehat{\overline{pr}}^{ref}_{S,t} = \widetilde{\rho}\,(n)\,\widehat{pr}^{*}_{S,t} + \varepsilon_{ref,t} \tag{31}$$

where $\widetilde{\rho}\,(n) = \frac{1}{n}\left(1 + \rho_{cu} + ...\rho_{cu}^{n-1}\right) < 1$, and $\varepsilon_{ref,t}$ is an *i.i.d.* (policy) shock to the reference price of copper that is normally distributed with variance σ^2_{ref}. Notice that the larger is n the less sensitive is the reference price to innovation to the real copper price. We utilize this expression for the reference price in the log-linearized version of (27).

Suppose that there are two types of governments. Government type a which has an horizon n_a, and government type b with an horizon n_b. We assume that $n_a > n_b$, which implies that $\widetilde{\rho}\,(n_a) < \widetilde{\rho}\,(n_b)$. Thus, government a tries to smooth out expenditure more in presence of transitory copper price shocks. We assume that under imperfect credibility, the public observes the price of copper, $\widehat{pr}^{*}_{S,t}$, and the reference price, $\widehat{\overline{pr}}^{*}_{S,t}$, which is publicly announced, but is not able to determine the type of government (i.e. it does not know parameter n) because of the stochastic term, $\varepsilon_{ref,t}$, in (31). In this setup, the reference price provides a noisy signal about the type of government. Therefore, in order to infer the future curse of the fiscal policy after a copper price shock the public needs to solve a signal extraction problem. To that end, they use a Bayesian updating through the Kalman filter.

We consider the effects of a copper price shock with a government type a –i.e. a more stabilizing government– under perfect and imperfect credibility. When the government has imperfect credibility –i.e. when the reference price is noisy– the public assigns some probability that it is of type b, and learn slowly over time its true type. Figures 7 and 8 present the corresponding impulse-responses to this shock.

A copper price shock leads to a much higher increase in inflation under imperfect credibility compared to the case of full credibility. Also the real appreciation that follows the shock is stronger under imperfect credibility. Interesting, the response of output is more muted when the public is uncertain about the future evolution of the reference price in the policy rule. In other words, imperfect credibility about the fiscal rule does not necessarily amplify the effects of copper price shocks on GDP.

To shed light on this last result, that may appear counterintuitive, we lift one by one some of the real rigidities of the model, comparing the responses to a copper price shock under perfect and imperfect credibility. Figures 13 and 14 present the responses assuming that all households are Ricardian (forward looking). In this case we observe that the response of output to the copper price shock is still more muted under imperfect credibility. Figures 9 and 10 present the case of no habit persistence in consumption. In this case, we

year to define the reference price of copper that determines the budget of the next year..

observe again that under imperfect credibility output is less responsive to the copper price shock.

Finally, in figures 11 and 12 we consider a case where there are no adjustment cost for investment. In this case, the response of output to the shock, under imperfect credibility, is larger than under perfect credibility. Recall that in the basel1ine case, when investment plans take time to materialize –i.e if investment is very inertial– the response of output lower was lower under imperfect credibility (figure 7. To understand this, notice that when the government lacks credibility, forward looking firms will adjust their prices by more than under full credibility, because they expect a more expansive fiscal policy in the future. That leads to higher inflation under imperfect credibility. On the other hand, the expectation of a more expansive fiscal policy stimulates current investment. However, the increase in inflation implies that the monetary policy will be more contractive in the future. Therefore, the effects of a copper price shock on investment are, in principle, ambiguos. When investment is inertial, it depends not only on the current interest rate but also on the future evolution of this variable. Therefore, expected future increases in the monetary policy rate reduce the incentives to invest. This latter effect dominates and investment falls in response to a copper price shock. In contrast, if the investment is more forward looking, expected future increases in the monetary policy rate exert a small effects on current investment decisions. As a consequence, investment rises in response to the copper price shock. Since output is demand determined, the increase in investment leads to an output expansion which is exacerbated under imperfect credibility.

5 A historical decomposition of the effects of copper price

In this section we evaluate how much of the volatility exhibited by output, inflation and other variables over the last years could be attributed to copper price fluctuations and the role played by the fiscal policy. In order to perform such an exercise, we use our calibrated model to construct the historical decomposition of several macro series. As we discussed above, the response of most of the macro series to a copper price shock depends crucially on the way the fiscal policy is conducted. Since the structural balance fiscal rule was established only in 2001, we need to make an assumption regarding the behavior of the government in previous years. As a methodological assumption we consider the historical decomposition under policy rule A, which give us an upper bound of for the effect o copper price shocks on output. Then, we compare this with the outcome of a scenario that would have occurred if government had followed rule C instead. The comparison gives us a quantification of the propagating role exerted by a expansive fiscal policy feeding the observed fluctuations during the 90s.

Figure 15 presents the historical evolution of some macro variables over the 90s (variables have been HP detrended) and the fraction 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.[22] As we can see, copper price fluctuation would contributed to a large fraction of GDP movements under a expansive fiscal policy (serie `yRA` in the figure). 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, we have identified copper price shocks through a univariate AR process that is orthogonal to other exogenous shocks affecting the Chilean economy. However, in practice there may be some correlation between our estimated copper price shock and other international 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 figure 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. For example, the external premium can be affected each time the copper price rise. Also, the interaction of the availability of foreign currency in the domestic financial market attributed to copper exports with the willingness of banks in providing loans might be important.

6 Conclusion

In this paper we use a dynamic stochastic general equilibrium (DSGE) model for the Chilean economy to analyze the effect of copper price shocks. We compare the results of copper price-shocks under different fiscal rules and different assumptions regarding the households' behavior. The results show that when the fiscal policy is highly expansive in response to a transitory copper price 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 quarterly 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

[22] 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 15 under rule A would over estimate the effects of copper price shocks.

goods inflation.

Using the model we analyze the implications of imperfect credibility about the structural budget fiscal, currently in place in Chile. Our analysis shows that imperfect credibility about this fiscal rule tends to amplify the effects of the copper price shocks on inflation and the real exchange rate. However, the effects of this type of shocks on GDP, under imperfect credibility, depend crucially on the sensitivity of investment to the expected course of the monetary policy in the future. When investment decisions depend more on the current monetary policy stance, a copper price shock generates a boom in investment, that is larger under imperfect credibility. Therefore, the output response to such shock is amplified when the fiscal policy rule is not fully credible. In contrast, when investment is more inertial, the output response to a copper price shock is reduced when the fiscal rule lacks credibility.

Finally, a simple counterfactual quantification of the role played by the fiscal policy in amplifying GDP fluctuations in response to copper price shocks shows that is the structural balance fiscal rule would have been in place during the 90s, GDP fluctuations would have been significantly lower.

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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
λ	0.0/0.7	fraction of Non Ricardian Households
Consumption, Gov't Expenditure 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
γ_G	1.0	share of domestic goods in gov't expenditure
η_G	1.0	elasticity of substitution in gov't expenditure between domestic and imported goods
Capital Accumulation		
μ_S	2.0	investment adjustment cost coefficient
δ	6.0% (annual)	depreciation rate
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 to 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 ratio
χ	40%	share of property of commodity sector holds for the government
τ	9.2%	average net tax rate
B_S/Y	0.5%	structural balance

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

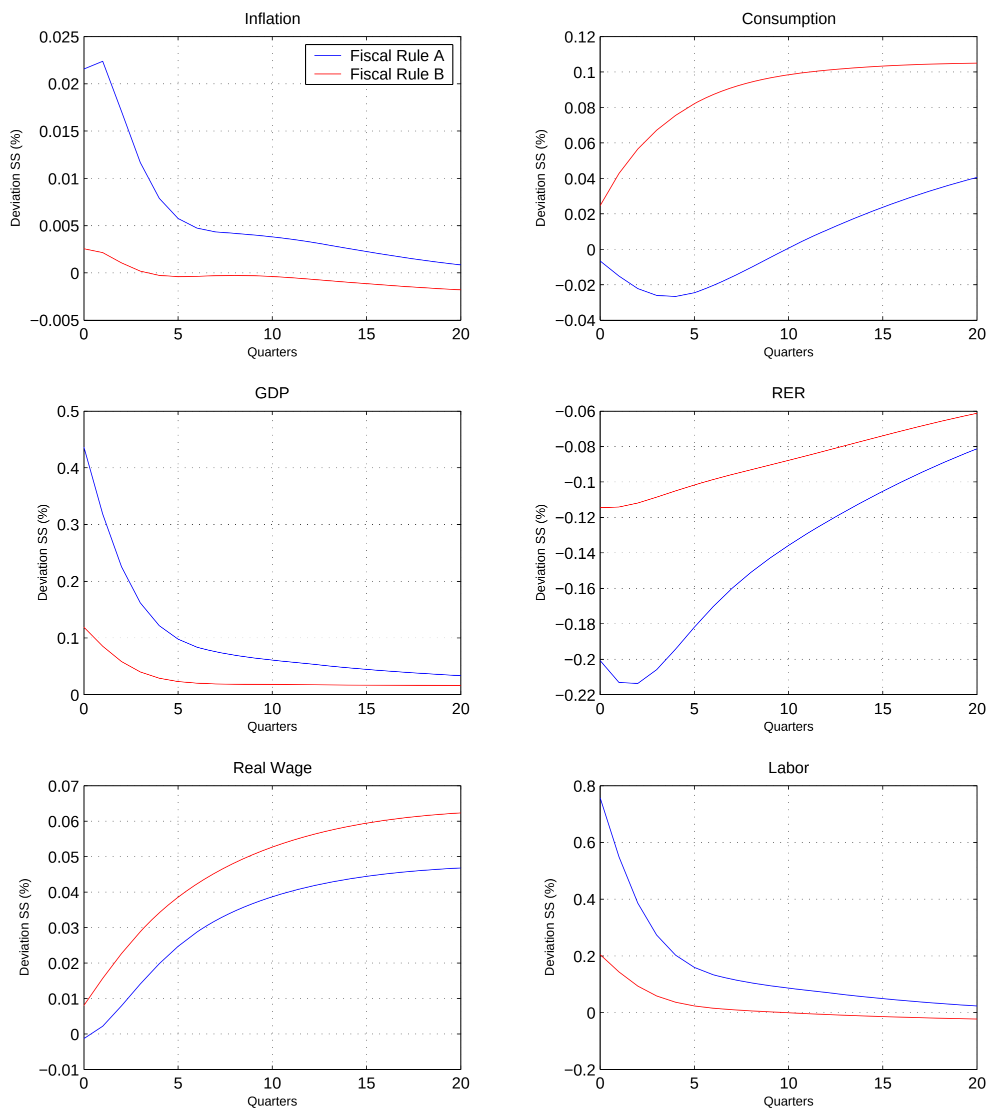


Figure 2: Impulse-Response to a Copper Price Shock. Only Ricardian households (cont.).

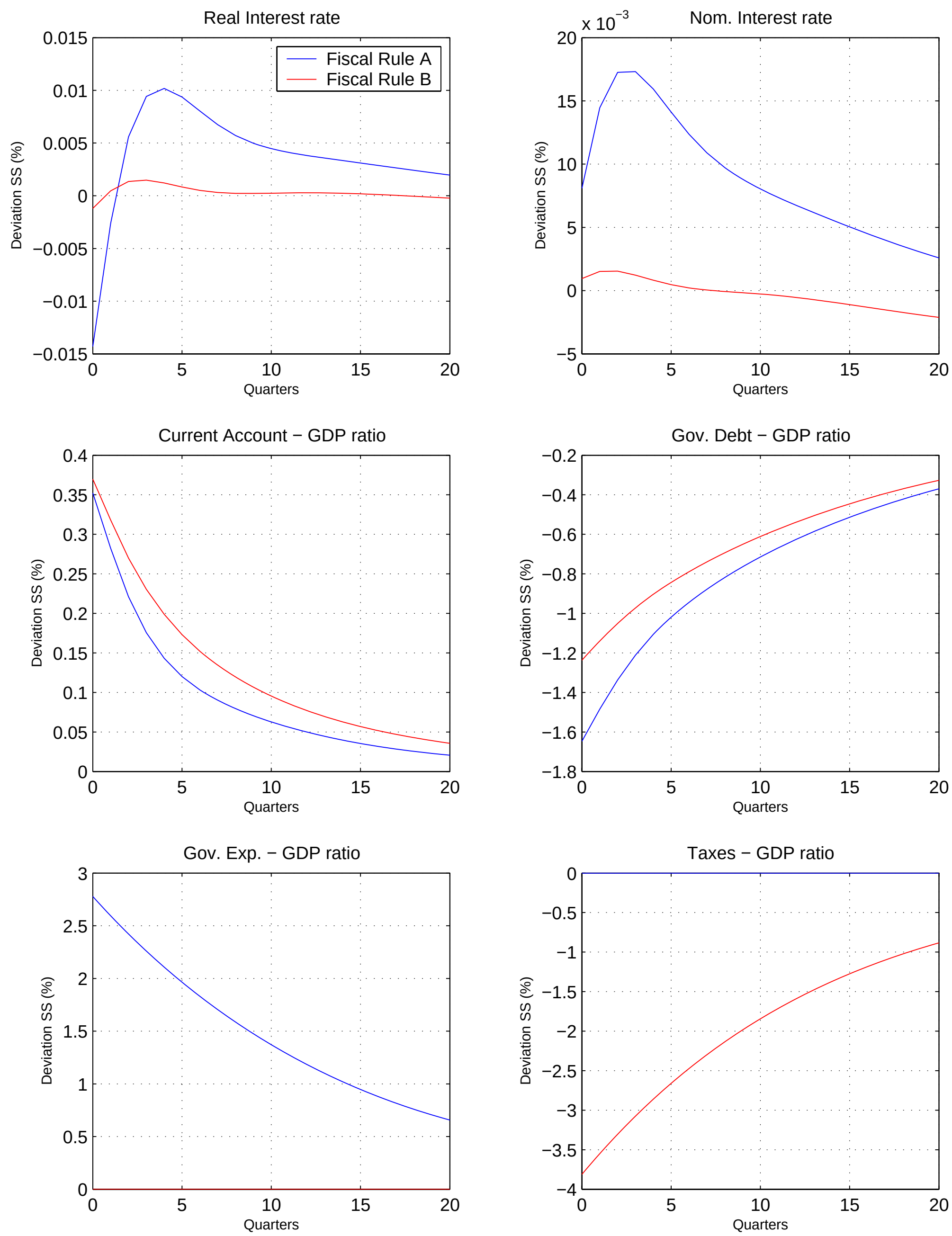


Figure 3: Impulse-Response to a Copper Price Shock. Ricardian and non-Ricardian households.

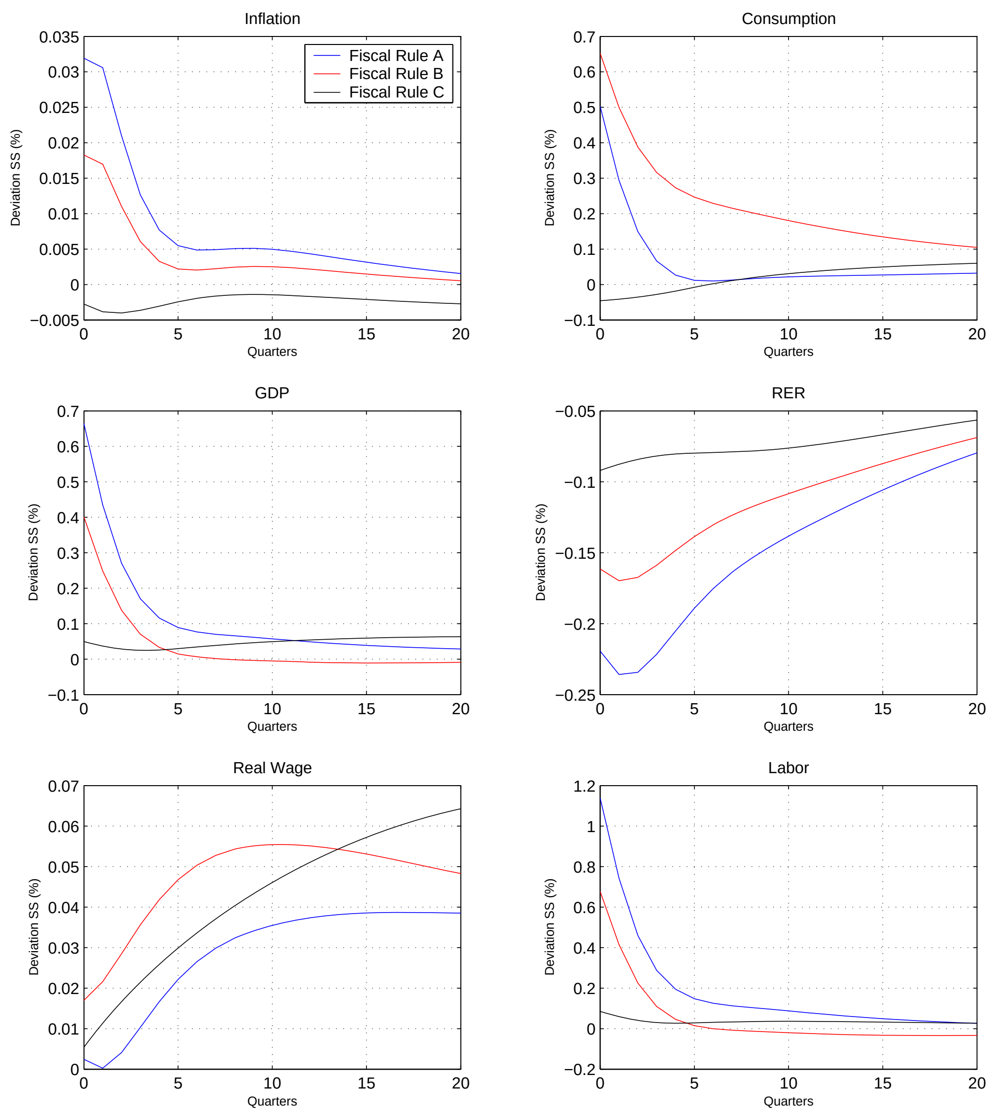


Figure 4: Impulse-Response to a Copper Price Shock. Ricardian and non-Ricardian households (cont.).

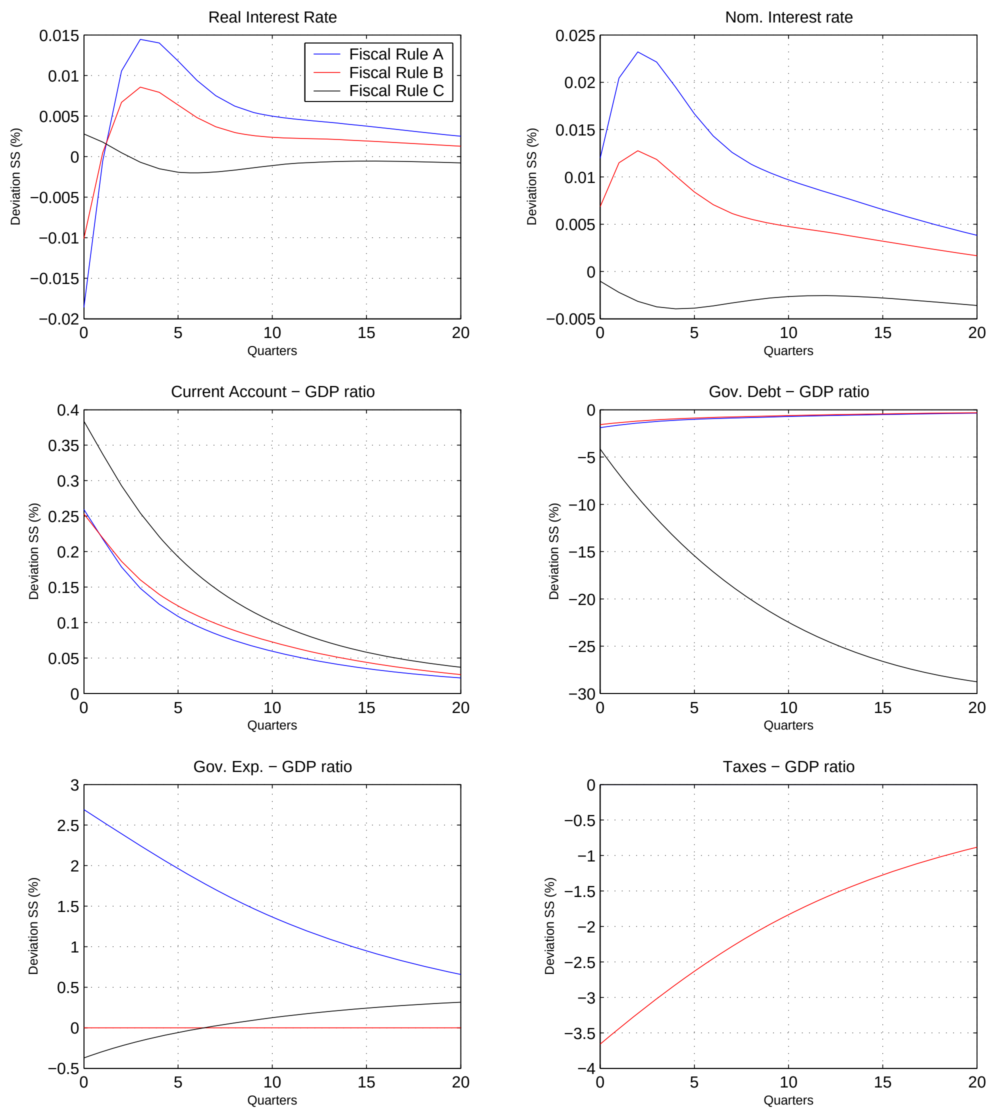


Figure 5: Impulse-Response to a Copper Price Shock. Fiscal Rule A and alternative monetary policy rules.

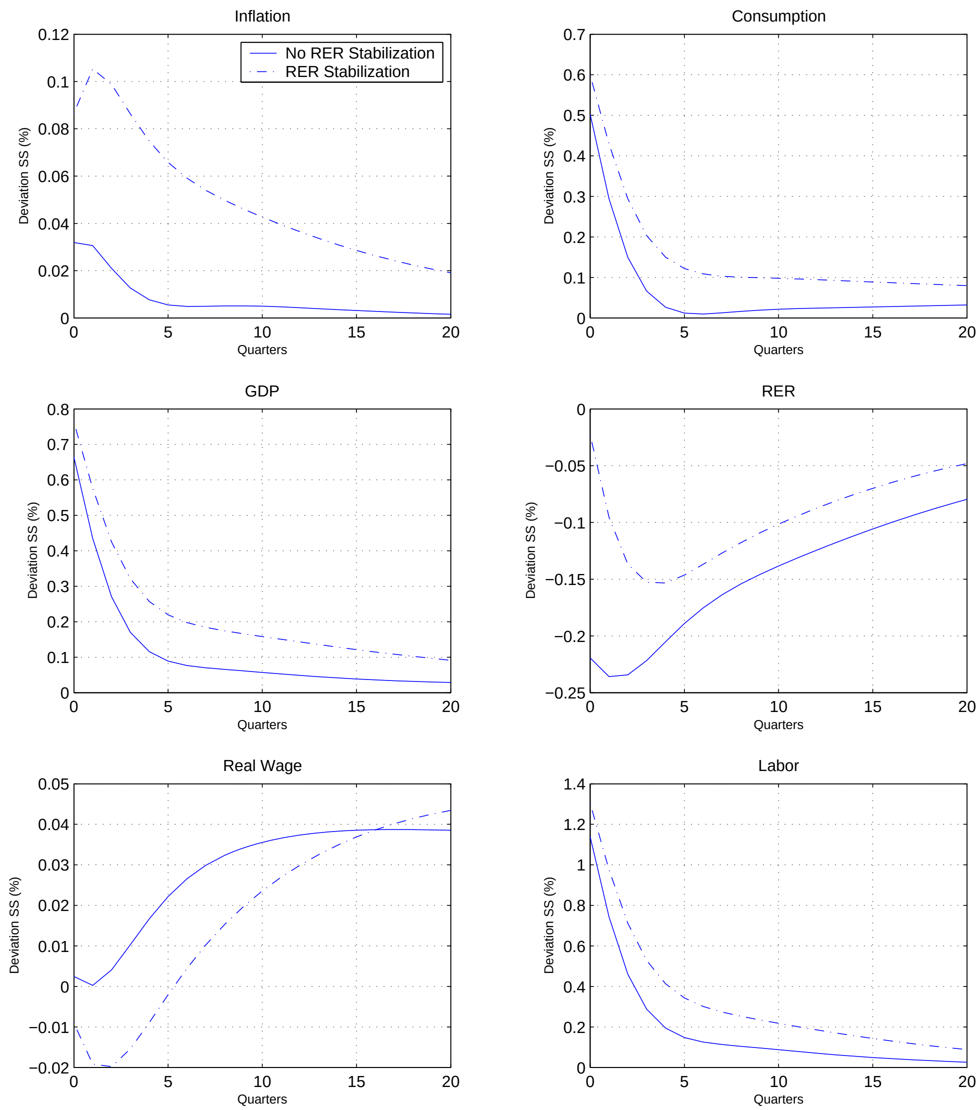


Figure 6: Impulse-Response to a Copper Price Shock. Fiscal Rule A and alternative monetary policy rules (cont.).

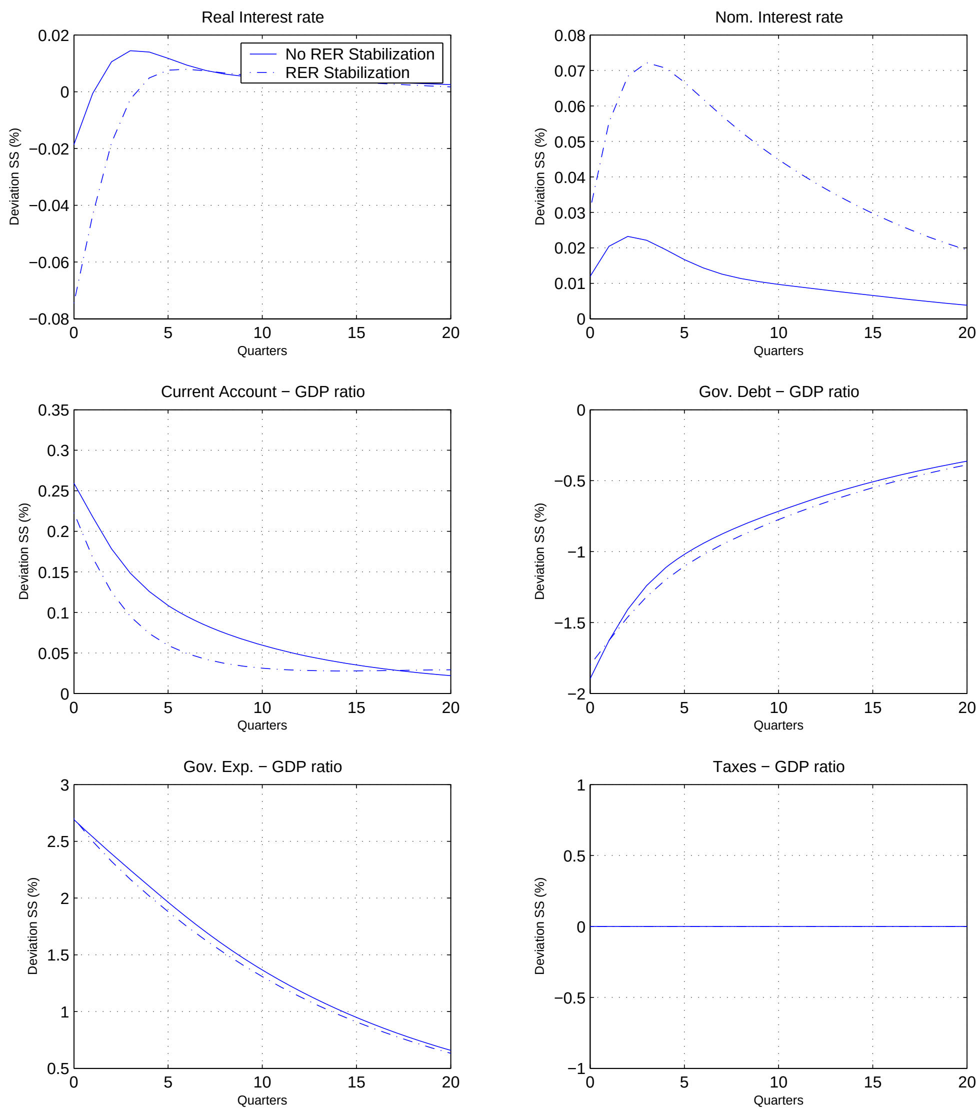


Figure 7: Impulse-response to a copper price shock: Imperfect credibility.

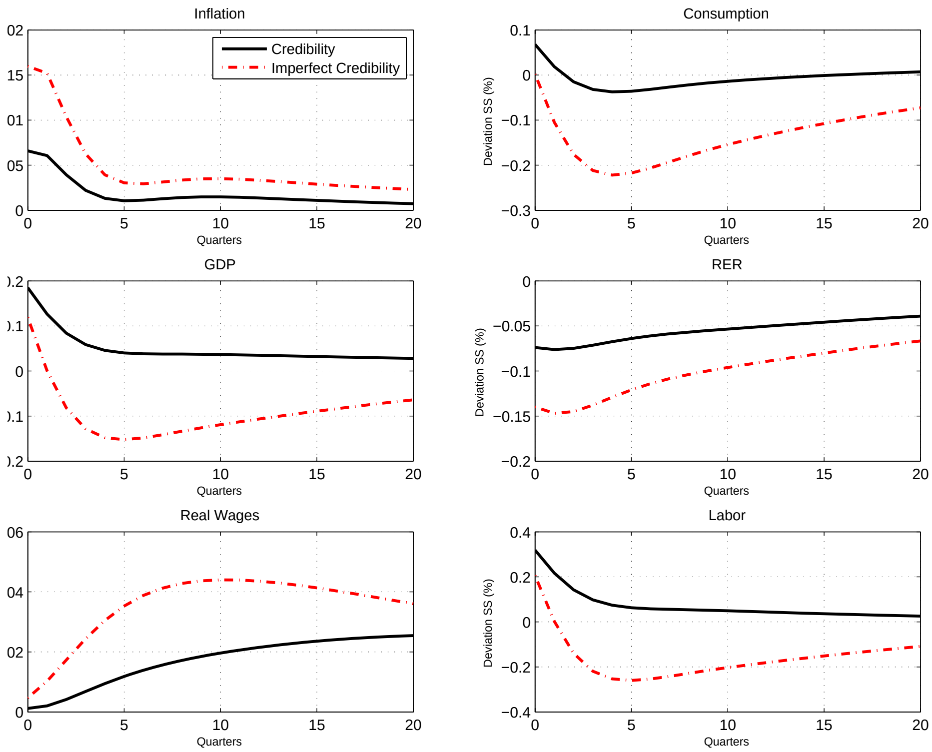


Figure 8: Impulse-response to a copper price shock: Imperfect credibility (cont.).

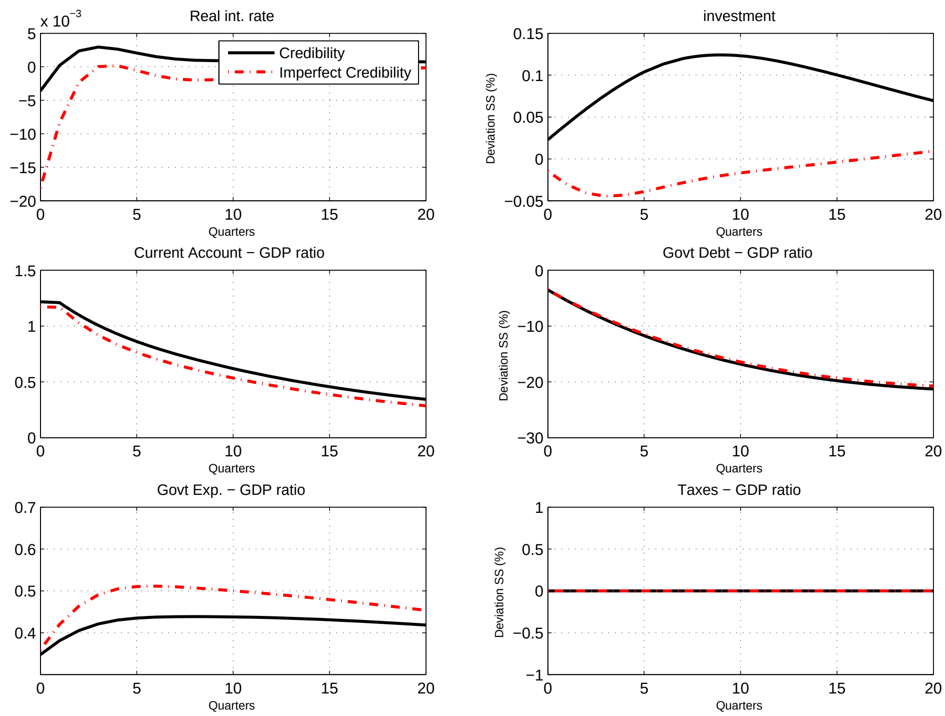


Figure 9: Impulse-response to a copper price shock: Imperfect credibility without habit in consumption.

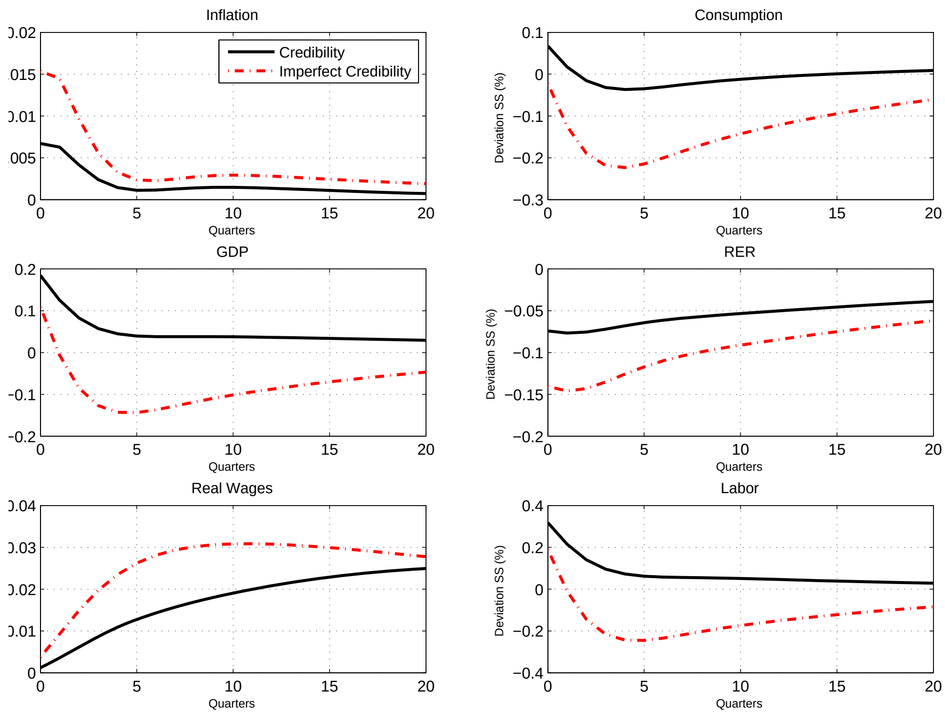


Figure 10: Impulse-response to a copper price shock: Imperfect credibility without habit in consumption (cont.).

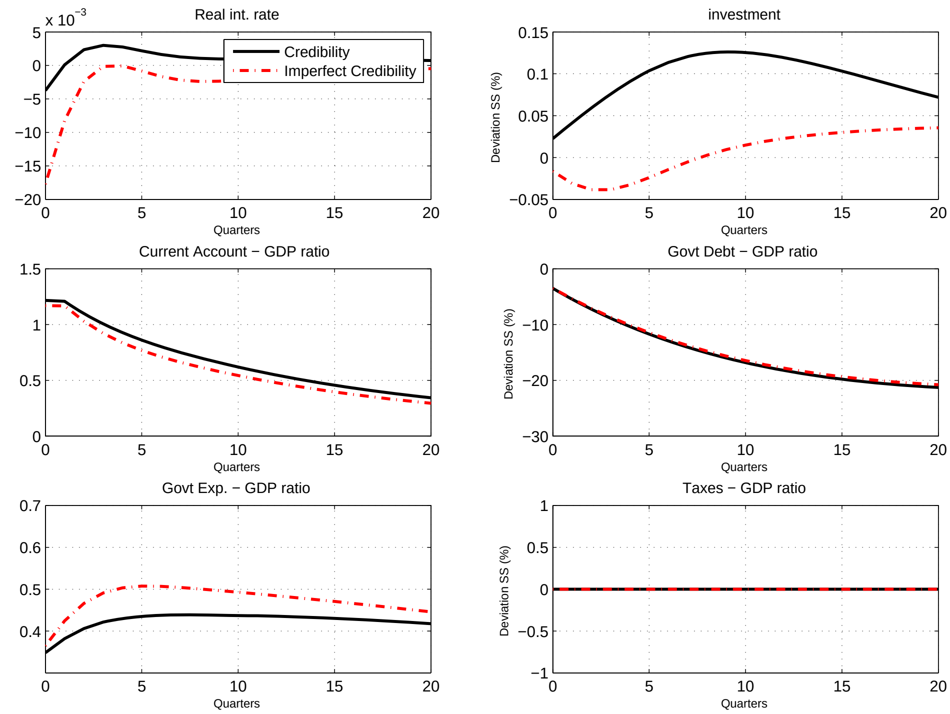


Figure 11: Impulse-response to a copper price shock: Imperfect credibility without investment inertia.

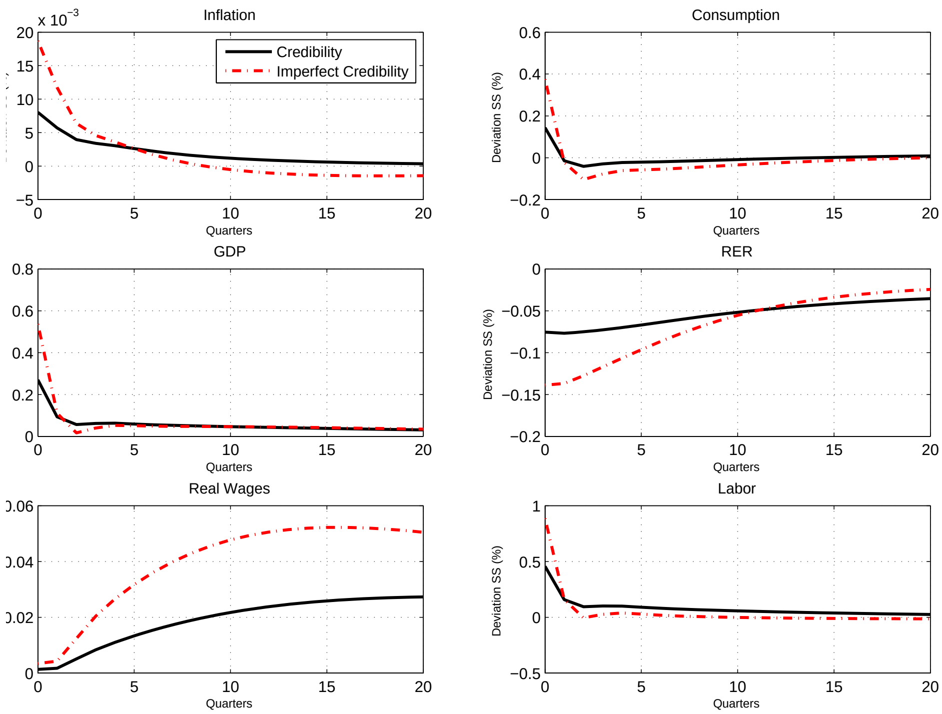


Figure 12: Impulse-response to a copper price shock: Imperfect credibility without investment inertia (cont.).

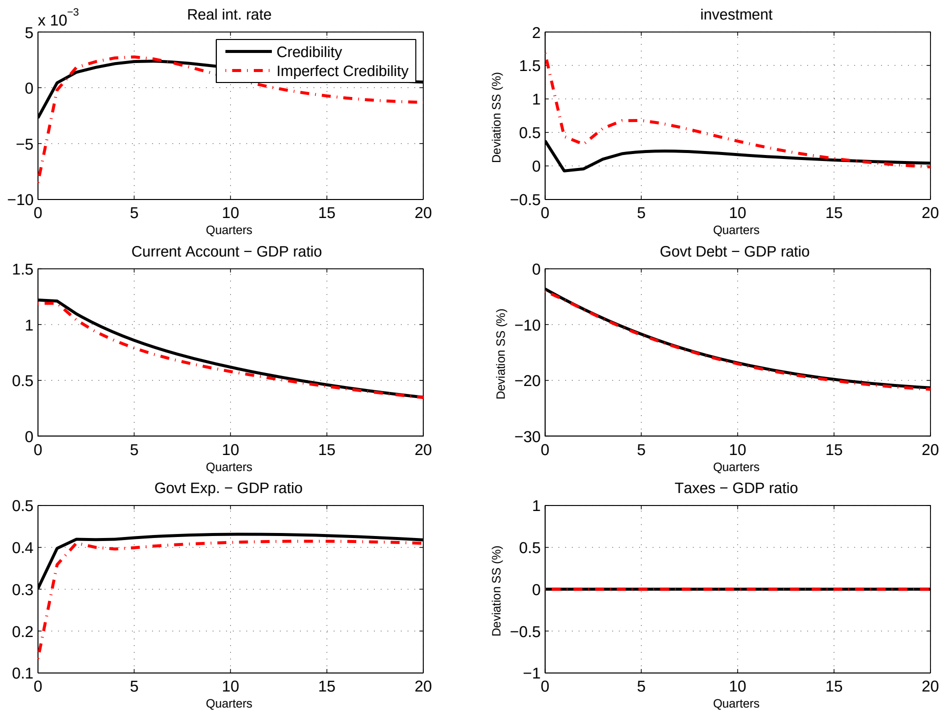


Figure 13: Impulse-response to a copper price shock: Imperfect credibility with only Ricardian households.

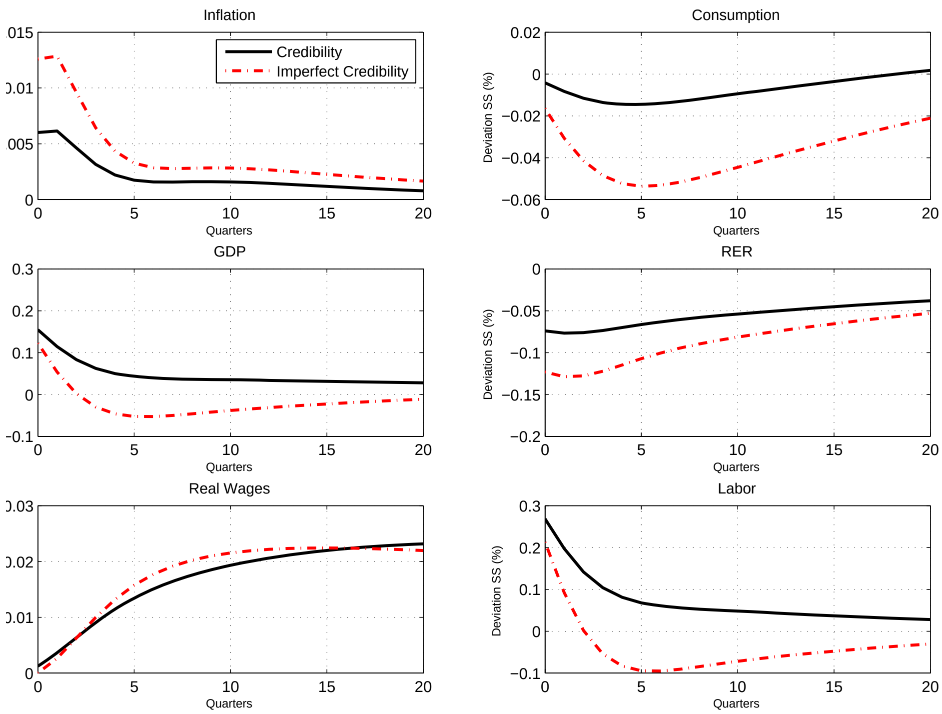


Figure 14: Impulse-response to a copper price shock: Imperfect credibility with only Ricardian households (cont.).

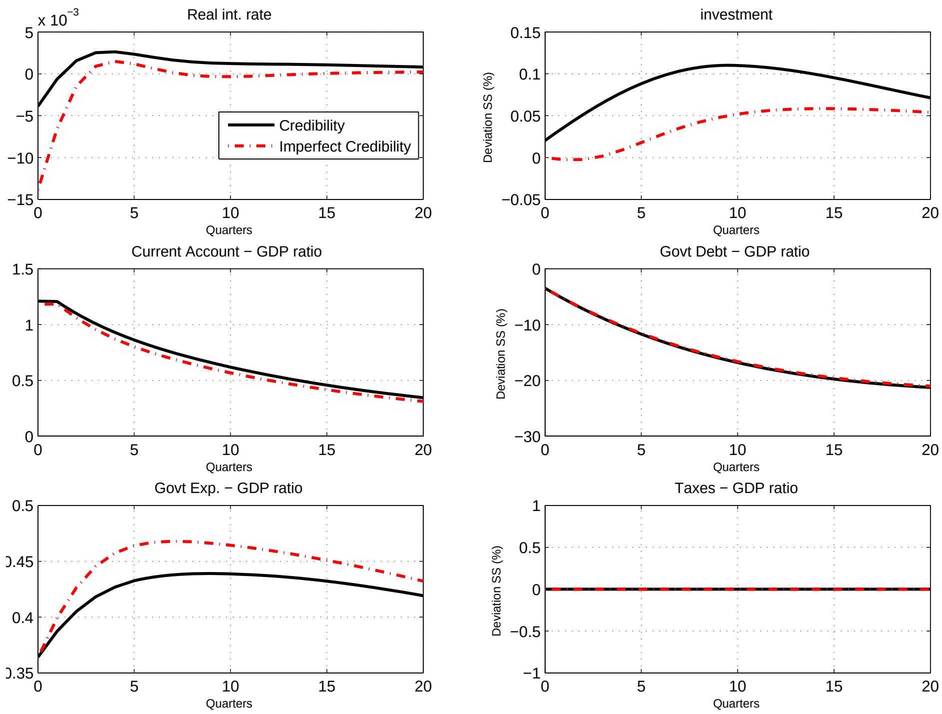
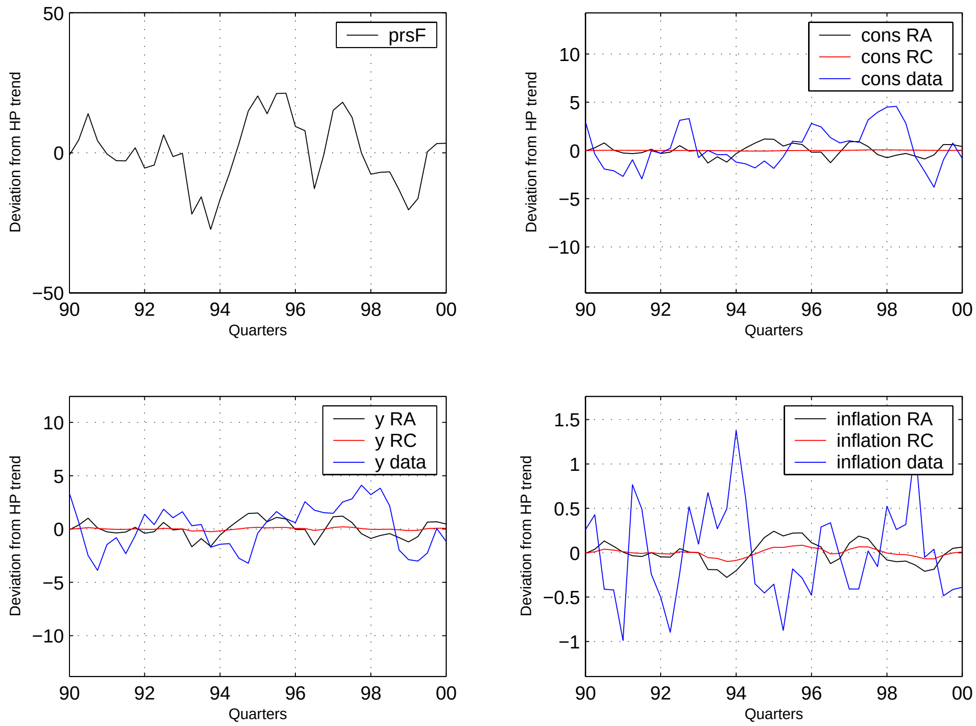


Figure 15: Historical decomposition Consumption, Output and Inflation (1990.1 - 2000.1)



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