Non-Ricardian Aspects of Fiscal Policy in Chile

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In this paper, we examine the effects of government spending shocks in the Chilean economy. The study of the effects of such shocks in an emerging market economy is of special interest because of the potential presence of non-Ricardian households, that is, households that do not own any assets or have any liabilities and just consume their current labor income.[1] The existence of non-Ricardian households has been suggested as a key ingredient in the transmission mechanism of government spending shocks in some developed economies. Several factors may explain non-Ricardian behavior, including myopia and lack of access to capital markets. Such behavior is likely to be especially important in less developed economies.

The Chilean fiscal rule ties total government spending to structural revenues. Structural revenues correspond to the sum of cycle-adjusted tax revenues and copper-related fiscal revenues evaluated at what could be considered a long-term copper price.

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1. See, for example, Campbell and Mankiw (1991); Mankiw (2000); Galí, López-Salido, and Vallés (2007).

Fiscal Policy and Macroeconomic Performance, edited by Luis Felipe Céspedes and Jordi Galí, Santiago, Chile.

Under this fiscal rule, government spending plus a structural fiscal surplus target must be equal to permanent (structural) revenues. Shocks to GDP (deviations from potential output) and to copper prices that transitorily affect fiscal revenues do not alter the path of government spending (which is only affected by changes in potential output and the long-term copper price). For example, the rule implies that if effective copper prices are transitorily above the estimated long-term copper price, the government saves the amount of copper-related fiscal revenues associated with this transitory copper price shock.[2] When officially implemented in 2001, the government announced a structural fiscal surplus target equivalent to one percent of GDP (that is, structural revenues minus government expenditure equals one percent of GDP). We show that the specification of a fiscal policy rule that approximates the Chilean rule leads to consumption and output fiscal multipliers that are positive in the short run, in a way consistent with the evidence.[3]

The structure of the paper is as follows. Section 1 presents VAR evidence on non-Ricardian effects of fiscal policy for the Chilean case. Section 2 introduces a dynamic stochastic general equilibrium model for Chile.[4] The model is calibrated and estimated, and results are reported in Section 3. Numerical simulations of the estimated model are presented in Section 4. Therein we examine impulse response functions and dynamic fiscal multipliers. Finally, Section 5 concludes.

1. Some Evidence on the Effects of Government Spending in Chile

This section provides some evidence on the macroeconomic effects of government spending shocks, using Chilean data for the past two decades. Following much of the literature, we rely on

2. Potential output and the long-term copper price are determined by two committees of experts that are independent of the government. See Frankel (in this volume) for a description of the Chilean fiscal rule.

3. The exercise of implementing a zero deficit rule provides a good benchmark; however, results are not reported. Briefly, a zero-deficit fiscal rule instrumented by transfers leaving public expenditure exogenous (as in Forni, Monteforte, and Sessa, 2009) yields positive fiscal multipliers (of consumption and GDP). If the shock is on government expenditures, we find a negative fiscal multiplier for consumption but a positive one for GDP.

4. An appendix with full derivations is available in the working paper version of this article (Céspedes, Fornero, and Galí, 2012).

estimated VARs. While the literature largely focuses on the effects of government purchases (often restricted to military spending), we also examine the impact of changes in transfers, since the latter constitute an important stabilization tool in Chile and have historically been subject to large changes. In both cases, we report impulse response functions, as well as estimates of the size of the output and consumption multipliers.

1.1 The Effects of Government Purchases

We first consider a small VAR specification including four variables: government purchases (government consumption plus public investment), GDP (excluding copper and other natural resources), private consumption (of durables and nondurables), and government deficit (excluding copper-related revenues).[5] The first three variables are expressed in logs and normalized by the size of the population. The deficit is normalized by lagged GDP. Data availability restricts the sample to the period 1990:1 to 2010:1. Our VAR includes four lags of all the variables, a constant term, and a second-order polynomial in time.

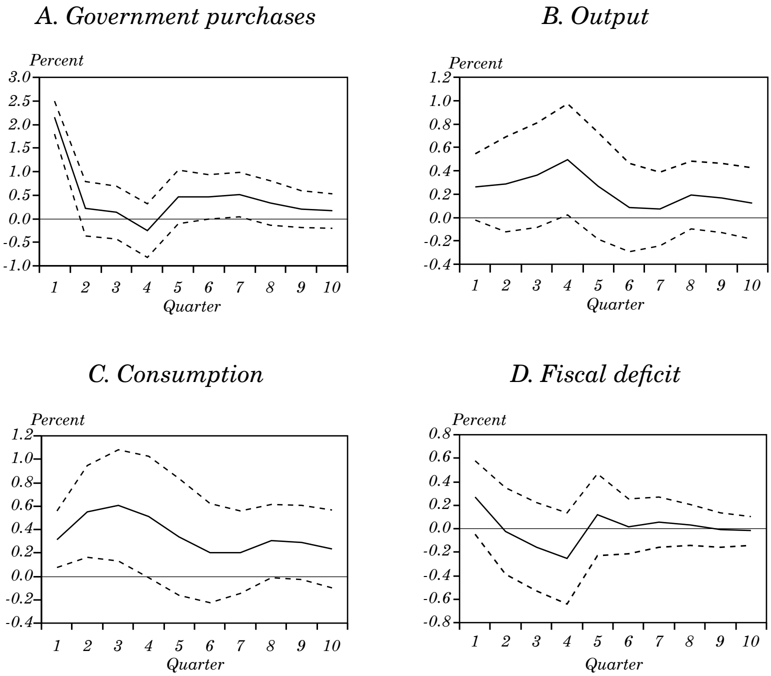
Following much of the literature, identification relies on the assumption that government purchases are predetermined relative to the other variables included in the VAR.[6] In other words, we interpret reduced-form innovations to government purchases as exogenous shocks to that variable. This is equivalent to ordering government purchases first in a Cholesky factorization of the VAR.

Figure 1 reports the impulse responses to a one-standard-deviation shock to government purchases, together with the corresponding 95 percent confidence intervals. Government purchases increase by nearly close to two percent on impact. Both GDP and consumption rise in response to that fiscal expansion. These two variables display a pattern that is roughly similar over time, with the peak occuring four quarters after the shock in the case of output and three quarters in the case of consumption. Not surprisingly, the deficit increases on impact.

5. We exclude copper and other natural resources from GDP because they are mainly affected by supply conditions. This strategy is consistent with the way in which we model GDP in our theoretical model.

6. See, for example, Blanchard and Perotti (2002); Fatás and Mihov (2001); Galí, López-Salido, and Vallés (2007); Perotti (2008).

Figure 1. Impulse Response to Government Purchases Shock: Small VAR



Source: Authors' computations.

Table 1. Effects of Goverment Purchases: Small VAR

	Basic		*Cumulative*	
Time / multipliers	*dC / dG*	*dY / dG*	*dC / dG*	*dY / dG*
$t = 1$	0.59	0.67	0.56	0.67
$t = 2$	1.03	0.73	1.47	1.27
$t = 4$	0.94	1.27	3.53	3.46
$t = 6$	0.37	0.22	3.17	3.06
$t = 8$	0.56	0.5	3.01	2.79

Source: Authors' computations.

Table 1 reports the corresponding multipliers for both GDP and consumption at different horizons. The basic multiplier measures dX_{t+k} / dG_t for $k = \{1, 2, 4, 6, 8\}$, where dG_t is the corresponding response in the level of GDP (when $X = Y$) or consumption (when $X = C$), k periods after the shock.[7] The GDP multiplier is above one-half (0.7) on impact, and it peaks close to 1.3 at a four-quarter horizon, before it declines. These values are similar to those obtained with U.S. data by a variety of authors (see Hall, 2009, for a survey of existing results). A look at the consumption multiplier points to the importance of that variable in generating the large GDP multiplier, suggesting the presence of non-Ricardian effects.

In addition to the basic multiplier, we also report estimates of the cumulative multiplier at different horizons, defined as

$$\frac{\sum_{j=1}^{k} dX_{t+j}}{\sum_{j=1}^{k} dG_{t+j}}.$$

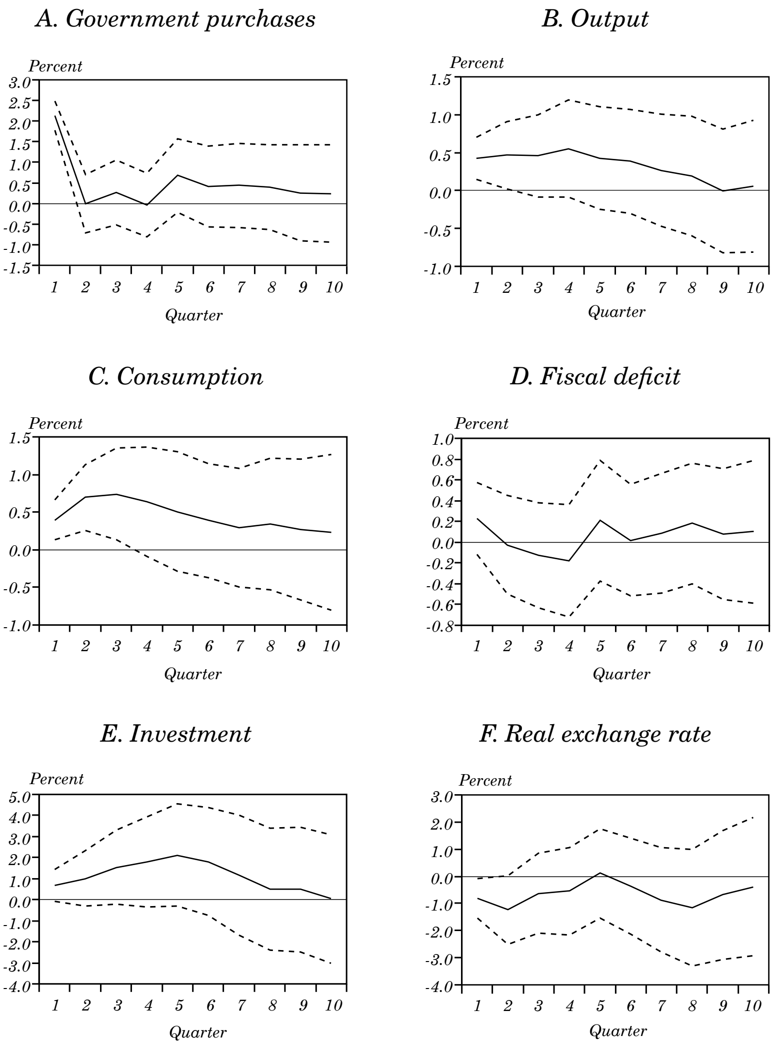
The latter takes into account not only the size of the initial increase in government purchases, but also its subsequent pattern of adjustment. As shown in table 1, both the GDP and consumption cumulative multipliers increase in the first year, reflecting the persistence of the GDP and consumption responses in that horizon, beyond that of government purchases.

We explore the robustness of these findings to the use of a larger VAR, which includes the real copper price, total private investment, and the real exchange rate in addition to the four variables listed above. Given the fiscal rule in place, whereby the government is allowed to spend only the fraction of the increase in copper revenues considered to be permanent, it is natural to order that price before government purchases, which now appears in second place in the VAR.[8] Figure 2 displays the estimated impulse response functions to a government purchases shock using the larger VAR. The corresponding multipliers are shown in table 2. The picture that emerges is qualitatively and

7. Using the impulse response functions for the logs, we compute the multiplier as $(dX_{t+k}/dG_t) = (d\log X_{t+k}/d\log G_t)\,(X_{t+k}/G_t)$.

8. The fiscal policy rule in place in Chile establishes that government spending is linked to structural revenues (that is, the permanent component of effective revenues). One component of those structural revenues corresponds to copper-related revenues. Structural copper revenues correspond to the revenues that the government would collect if the price of copper was equal to its long-run or permanent price.

Figure 2. Impulse Response to Government Purchases Shock: Large VAR



Source: Authors' computations.

quantitatively very similar to that obtained using the small VAR. In this case, investment also rises in response to the increase in government purchases, suggesting that it could play a complementary role to consumption in generating the large GDP multiplier. That amplification effect is likely to be partially offset by the real exchange rate appreciation, which should dampen the growth of aggregate demand. The pattern of the deficit response estimated using the large VAR is also very similar, with a deficit increase on impact.

Table 2. Effects of Goverment Purchases: Large VAR

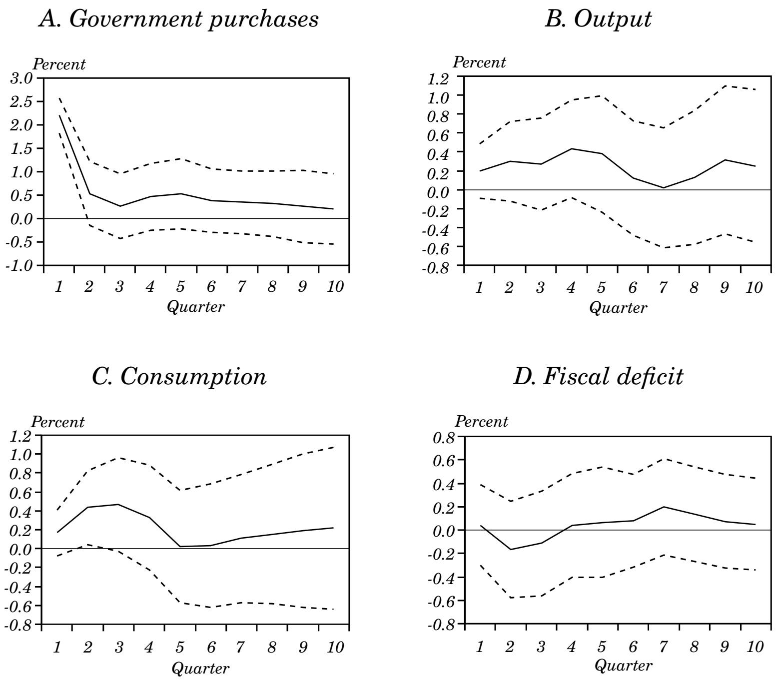
	Basic		*Cumulative*	
Time/multipliers	*dC/dG*	*dY/dG*	*dC/dG*	*dY/dG*
$t = 1$	0.74	1.10	0.74	1.10
$t = 2$	1.30	1.20	2.05	2.31
$t = 4$	1.19	1.43	4.18	4.45
$t = 6$	0.72	1.00	3.89	4.34
$t = 8$	0.64	0.50	3.72	4.08

Source: Authors' computations.

1.2 The Effects of Government Transfers

Next we report estimates of the dynamic effects of government transfers, using an approach analogous to the one in the previous subsection, with total government transfers substituting for government purchases in the two VARs. Figure 3 reports the impulse responses to a transfer shock. As shown in the first panel, the increase in transfers appears to have a similar persistence to the increase in government purchases studied above. The resulting responses of output, consumption, and the deficit show a pattern not too different from that obtained for government purchases. Also, the sign of the response of the deficit is less clear-cut in the case of a shock to transfers. The estimated multipliers shown in table 3 point to similar orders of magnitude for both GDP and consumption. The evidence based on the large VAR, reported in figure 4 and table 4, provides a similar picture, although the real exchange depreciates in response to an increase in transfers.

Figure 3. Impulse Response to Government Transfers Shock: Small VAR



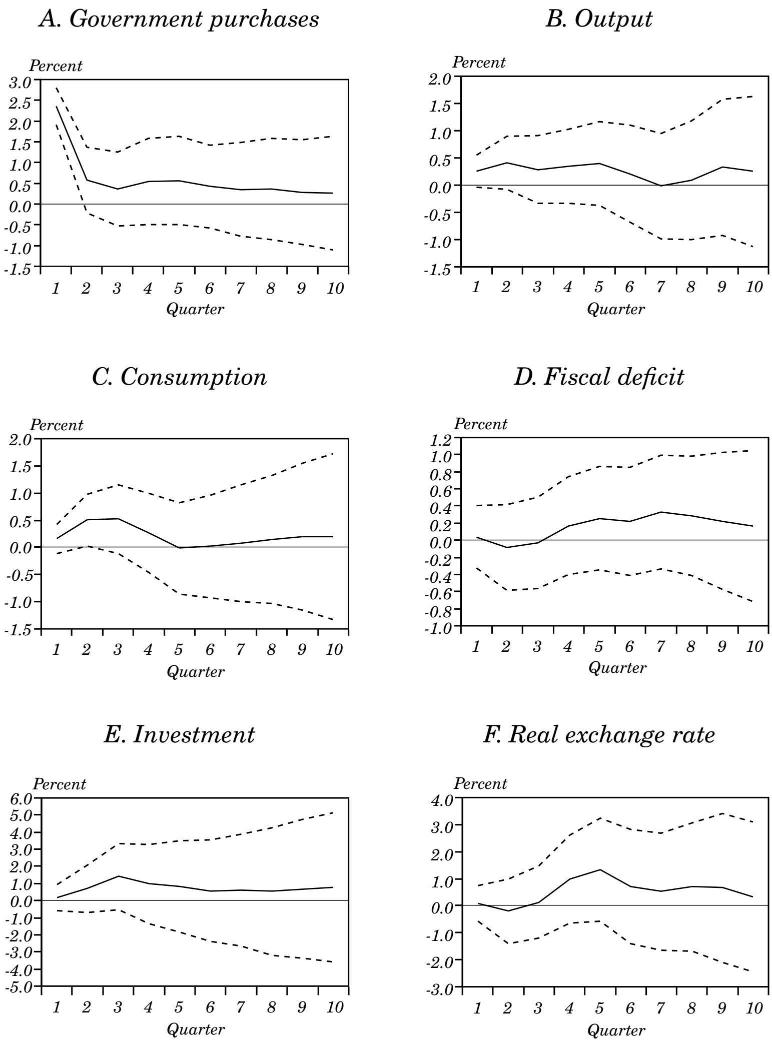
Source: Authors' computations.

Table 3. Effects of Government Transfers: Small VAR

	Basic		Cumulative	
Time / multipliers	*dC / dG*	*dY / dG*	*dC / dG*	*dY / dG*
$t = 1$	0.45	0.72	0.45	0.72
$t = 2$	1.17	1.11	1.30	1.47
$t = 4$	0.87	1.61	2.38	2.82
$t = 6$	0.09	0.45	1.96	3.16
$t = 8$	0.41	0.49	2.00	2.98

Source: Authors' computations.

Figure 4. Impulse Response to Government Transfers Shock: Large VAR



Source: Authors' computations.

Table 4. Effects of Government Transfers: Large VAR

	Basic		*Cumulative*	
Time / multipliers	*dC / dG*	*dY / dG*	*dC / dG*	*dY / dG*
$t = 1$	0.40	0.88	0.40	0.88
$t = 2$	1.27	1.42	1.34	1.85
$t = 4$	0.68	1.21	2.25	2.76
$t = 6$	0.04	0.72	1.79	3.22
$t = 8$	0.36	0.31	1.78	2.92

Source: Authors' computations.

1.3 Discussion

The evidence presented on the effects of shocks to government purchases and government transfers points to the existence of positive multiplier effects on GDP. The sign and size of the estimated response of consumption is suggestive of strong non-Ricardian effects, which would account for the size of both the GDP and consumption multipliers. In the next section, we develop an open economy New Keynesian model that tries to account for these regularities.

2. A Small Open Economy Model for Chile

This section presents the structure of a dynamic stochastic general equilibrium (DSGE) model along the lines of Altig and others (2005), Adjemian, Darracq-Pariès, and Smets (2008), and Adolfson and others (2007), which we have extended to incorporate a role for fiscal policy. We build on the work by Galí, López-Salido, and Vallés (2007) and Coenen, McAdam, and Straub (2008), who develop versions of a New Keynesian model allowing for a fraction of non-Ricardian households, but modified to capture particular features of the Chilean economy. The relevant features include copper income as a nonnegligible share of government income, a fiscal rule that seeks to keep government spending closely linked to structural (permanent) fiscal revenues, and an inflation-targeting monetary policy regime. A complementary appendix with the main model's derivations is available on request.

2.1 Consumers

There are two types of consumers: Ricardian (with weight $\lambda - 1$) and non-Ricardian (with weight λ), denoted with superscript $j = \{R,N\}$. Ricardian consumers are assumed to have access to financial markets to smooth consumption over time, whereas non-Ricardian consumers do not. Implicitly, though, we make an exception to the latter assumption to simplify the analysis: we assume full insurance of the risk generated by Calvo wage setting among consumers of a given type (as in Coenen, McAdam, and Straub, 2008).

Both consumer types are assumed to maximize an objective function of the form

$$\sum_{t=0}^{\infty} \beta^t U_t^j(h),$$

with period utility given by

$$U_t^j(h) = \ln\left[C_t^j(h) - bC_{t-1}^j(h)\right] - \bar{\zeta}\zeta_t \frac{L_t^j(h)^{1+\sigma_L}}{1+\sigma_L}, \tag{1}$$

Where $C_t^j(h)$ is a consumption index, $L_t^j(h)$ denotes hours of work, b measures the degree of internal habit formation, $\bar{\zeta}$ is a constant, σ_L is the inverse of the Frisch elasticity, and ζ_t is a shock to the disutility from work. The latter parameter is assumed to follow a first-order autoregressive, or AR(1), process with unconditional mean of one, persistence ρ_ζ, and constant variance σ_ζ^2.[9]

The consumption index takes the form

$$C_t^j(h) \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^j(h)^{1-\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^j(h)^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{2}$$

where

$$C_{H,t}^j(h) \equiv \left[\int_0^1 C_{H,t}^j(h,i)^{1-\frac{1}{\varepsilon_H}} di\right]^{\frac{\varepsilon_H}{\varepsilon_H-1}}$$

9. We abuse of notation declaring $C_t^j(h)$ for $j = \{R,N\}$, but the decisionmaker is the individual h.

and

$$C_{F,t}^{j}\left(h\right)\equiv\left[\int_{0}^{1}C_{F,t}^{j}\left(h,i\right)^{1-\frac{1}{\varepsilon_F}}di\right]^{\frac{\varepsilon_F}{\varepsilon_F-1}}.$$

are constant elasticity of substitution (CES) indexes for domestic and imported consumption goods, respectively, with parameter α determining the degree of openness and $\eta > 1$ being the CES between domestic and imported goods. Notice that ε_H and ε_F are (constant) elasticities of substitution among varieties and are greater than 1

2.1.1 Ricardian consumers

Ricardian consumers ($h = R$) maximize utility subject to two constraints. The first is a flow budget constraint of the form

$$\begin{aligned}
&B^{R}\left(s^{t},h\right)+S_{t}B^{R,*}\left(s^{t},h\right)+\left(1-\tau_{w,t}\right)\mathcal{S}_{WR}W_{t}^{R}\left(h\right)L_{t}^{R}\left(h\right)\\
&+R_{t}^{k}u_{t}^{R}\left(h\right)K_{t-1}^{R}\left(h\right)-P_{t}\Phi\left[u_{t}^{R}\left(h\right)\right]K_{t-1}^{R}\left(h\right)+P_{t}\left[Tr_{t}^{R}\left(h\right)-TX_{t}^{R}\left(h\right)\right]\\
&+\left(1-\tau_{\mathrm{Pr},t}\right)\mathrm{Pr}_{t}^{R}\left(h\right)\leq\sum_{s^{t+1}|s^{t}}Q\left(s^{t+1},s^{t}\right)B^{R}\left(s^{t+1},h\right)\\
&+S_{t}\mathrm{RP}_{t}\sum_{s^{t+1}|s^{t}}Q^{*}\left(s^{t+1},s^{t}\right)B^{R,*}\left(s^{t+1},h\right)\\
&+\int_{0}^{1}P_{H,t}\left(i\right)\left[C_{H,t}^{R}\left(h,i\right)+I_{H,t}^{R}\left(h,i\right)\right]di\\
&+\int_{0}^{1}P_{F,t}\left(i\right)\left[C_{F,t}^{R}\left(h,i\right)+I_{F,t}^{R}\left(h,i\right)\right]di.
\end{aligned}\tag{3}$$

The terms on the left-hand side represent consumer h's cash inflows, which include the following: maturing one-period nominal discount bonds (domestic and foreign); labor income (given by the wage after taxes and subsidies—S_{WR} is a subsidy to eliminate monopolistic distortions—times the number of hours worked); income from capital leased to firms net of utilization costs;[10] transfers, $Tr_t^R(h)$, net of

10. In our notation, $K_{t-1}^{j}(h)$, reflects agent h's end-of-period stock of physical capital ready to be used in the productive process in period t.

lump-sum taxes, $TX_t^R(h)$; and transfers and profits in the form of net of tax distributed dividends, $(1-\tau_{\text{Pr},t})\,\text{Pr}_t^R(h)$. The nominal exchange rate is denoted by S_t, which measures the number of Chilean pesos (Ch$) needed to buy one U.S. dollar (USD). The utilization rate of physical capital, $u_t^R(h)$, is a choice variable. Following Adolfson and others (2007), the utilization cost function $\Phi(\cdot)$ takes the form

$$\Phi\left[u_t^R(h)\right] \equiv \frac{\theta}{2}\left[u_t^R(h)-1+r^k\right]\left[u_t^R(h)-1\right], \tag{4}$$

where $\theta > 0$ is a parameter that directly influences the sensitivity of the cost function when $u_t^R(h)$ varies and r^k is the real steady-state capital rental rate. Capital income simplifies to $R_t^k K_{t-1}^R(h)$ when capital is fully utilized, at $u_t^R(h) = 1$, because $\Phi(1) = 0$.[11]

The right-hand side of equation (3) includes the various purchases incurred by the Ricardian consumer: consumption, investment, and purchases of (state-contingent) domestic and foreign assets. The risk premium factor,

$$\text{RP}_t \equiv \exp\left(-\phi_a\left(\frac{S_t B_{t+1}^*}{P_{t+1}}\right)-\phi_{\Delta S}\left(E_t\left[\frac{S_{t+1}}{S_t}\right]-1\right)+\phi_t\right),$$

adjusts the return at which domestic consumers can borrow from or lend to the rest of the world. It depends on the country's aggregate net foreign asset position, B_t^*, the expected rate of depreciation, $E_t[S_{t+1} / S_t]$, and an exogenous risk premium shock, ϕ_t.[12] The risk premium function can be viewed as a measure of international asset market incompleteness (such as asymmetric information, entry costs to build the portfolio, and so on). I_t^R is an investment index given by

11. It follows that $\Phi'(\cdot)=\theta\left[u_t^R(h)-1\right]+r^k$. At the steady state, $\Phi'(1) = r^k$ and $\Phi''(1) = \theta > 0$.

12. B_t^* is the sum of the net debt position maintained by Ricardian agents, $(1-\lambda)B_t^{R,*} \equiv \int_\lambda^1 B^{R,*}(s^t,h)\,dh$, and the government. Besides the usual mechanism stressed by Schmitt-Grohé and Uribe (2001) (that is, the mechanism involving deviations from the targeted net foreign position, which in this case we assume is zero for Chile), we follow Adjemian, Darracq-Pariès, and Smets (2008) and Adolfson and others (2009) by adding a second argument that captures the deviation of the expected exchange gross depreciation rate from one. Including this additional explanatory variable induces a negative correlation between the expected depreciation rate and the risk premium, which is a relevant empirical finding (Duarte and Stockman, 2005).

$$I_t^R \equiv \left[(1-\alpha)^{\frac{1}{\eta}} \left(I_{H,t}^R \right)^{1-\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} \left(I_{F,t}^R \right)^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{5}$$

where, in a way analogous to consumption,

$$I_{H,t}^R \equiv \left[\int_0^1 I_{H,t}^R (j)^{1-\frac{1}{\varepsilon_H}} dj \right]^{\frac{\varepsilon_H}{\varepsilon_H-1}},$$

$$I_{F,t}^R \equiv \left[\int_0^1 I_{F,t}^R (j)^{1-\frac{1}{\varepsilon_F}} dj \right]^{\frac{\varepsilon_F}{\varepsilon_F-1}}$$

represent indexes of domestic and imported investment goods.

The second constraint is given by the law of motion of physical capital:

$$K_t^R(h) = (1-\delta) K_{t-1}^R(h) + \varepsilon_{I,t} I_t^R(h) - \frac{1}{2}\Psi \left[\frac{\varepsilon_{I,t} I_t^R(h)}{K_{t-1}^R(h)} - \delta \right]^2 K_{t-1}^R(h) \tag{6}$$

where δ is the depreciation rate, $\varepsilon_{I,t}$ is an investment-specific technology shock, and $\Psi \geq 0$ is a parameter that scales the quadratic installation costs associated with any positive net investment. The first-order conditions are presented in the working paper version of this study.[13]

2.1.2 Non-Ricardian consumers

Non-Ricardian consumers ($j = N$) are assumed to have no access to financial markets, so they consume in the same period their wage income and the transfers they receive from the government.[14] Their consumption is thus given by

$$\int_0^1 P_{H,t}(i) C_{H,t}^N(h,i) di + \int_0^1 P_{F,t}(i) C_{F,t}^N(h,i) di$$
$$= (1-\tau_{w,t}) \mathcal{S}_{WN} W_t^N(h) L_t^N(h) + P_t \left[Tr_t^N(h) - TX_t^N(h) \right]. \tag{7}$$

13. See section 8.1 in the appendix to the working paper version (Céspedes, Fornero, and Galí, 2012).

14. As in Galí, López-Salido, and Vallés (2007), we rule out the possibility that non-Ricardian households can smooth consumption through money holdings, in contrast with Coenen, McAdam, and Straub (2008).

2.1.3 Wage setting

Wage setting closely follows the formalism in Erceg and Levin (2003), with indexation as in Smets and Wouters (2007). Each consumer is specialized in a differentiated labor service, which is demanded by all firms. The wage elasticity of the demand for each type of labor is constant. Each period, a given consumer can optimally reset the nominal wage for his labor type with probability ϕ_L. Once the new wage is set, the consumer fully meets the demand for its labor type at the quoted wage. Between reoptimization periods, we allow the nominal wage to be adjusted mechanically according to the following indexation rule:

$$W_t^j(h) = (\Pi_{t-1})^{\xi_L} (\bar{\Pi})^{1-\xi_L} W_{t-1}^j(h),$$

which makes the rate of change of the individual wage a weighted geometric average of lagged price inflation, Π_{t-1}, and steady-state price inflation, $\bar{\Pi}$, with ξ_L representing the weight of the former. Presumably, non-Ricardian agents will react more to wages than Ricardian agents. Thus, in contrast to Medina and Soto (2007), we allow for each agent type to supply different number of hours.[15]

2.2 Firms

There are two types of firms operating in the economy: intermediate goods producers and importers. There are also foreign firms, but we do not model their behavior explicitly.

2.2.1 Domestic producers

We assume a continuum of monopolistically competitive firms, each of which produces a differentiated good. Firm *i*'s production function depends on an exogenous technology, capital, and labor:

$$Y_{H,t}(i) = A_{H,t} \left[u_t^R K_{t-1}(i) \right]^{\gamma} L_t(i)^{1-\gamma} - FC_H, \tag{8}$$

where FC_H is a nonnegative fixed cost, measured in terms of output.

15. See appendix for details.

The labor input bundle, $L_t(i)$, is given by the CES function

$$L_t(i) \equiv \left[\lambda^{\frac{1}{\eta_L}} L_t^N(i)^{1-\frac{1}{\eta_L}} + (1-\lambda)^{\frac{1}{\eta_L}} L_t^R(i)^{1-\frac{1}{\eta_L}} \right]^{\frac{\eta_L}{\eta_L - 1}}, \tag{9}$$

where η_L is the elasticity of substitution between Ricardian and non-Ricardian labor and where

$$L_t^R(i) \equiv \left[\left(\frac{1}{1-\lambda} \right)^{\frac{1}{\varepsilon_{LR}}} \int_\lambda^1 L_t^R(i,h)^{1-\frac{1}{\varepsilon_{LR}}} dh \right]^{\frac{\varepsilon_{LR}}{\varepsilon_{LR}-1}}$$

and

$$L_t^N(i) \equiv \left[\left(\frac{1}{\lambda} \right)^{\frac{1}{\varepsilon_{LN}}} \int_0^\lambda \left(L_t^N(i,h) \right)^{1-\frac{1}{\varepsilon_{LN}}} dh \right]^{\frac{\varepsilon_{LN}}{\varepsilon_{LN}-1}}.$$

Firms minimize costs subject to equation (8) and conditional on any given output level. The resulting real marginal cost function is as follows (where we drop the i index since firms have identical costs):

$$MC_{H,t} = \frac{1}{A_{H,t}} \frac{\left(r_t^k\right)^\gamma w_t^{1-\gamma}}{\gamma^\gamma (1-\gamma)^{1-\gamma}}. \tag{10}$$

Each period, each domestic firm decides how much of each type of labor to hire, given the wage $W_t^j(h)$, and how much capital services to rent, given the rental rate R_t^K. In addition, and with probability ϕ_H, any given firm can optimally readjust the price of its good, setting a price $\tilde{P}_{H,t}(i)$. In the absence of reoptimization, the firm's price is adjusted mechanically according to the indexation rule

$$P_{H,t}(i) = \left(\Pi_{t-1}\right)^{\xi_H} \left(\bar{\Pi}\right)^{1-\xi_H} P_{H,t-1}(i).$$

Given its price at any point in time, the firm produces a quantity that fully meets the demand for its good.

2.2.2 Importers

There is a continuum of firms that import a good produced overseas at a price $S_t P_{F,t}^*$, repackage it, and sell it as a differentiated good in the domestic market. Each importer reoptimizes the price of its good with a probability ϕ_F, setting a price $\tilde{P}_{F,t}(i)$, subject to a sequence of demand constraints. In the absence of reoptimization, the price is adjusted according to the indexation rule:

$$P_{F,t}(i) = (\Pi_{t-1})^{\xi_F} (\bar{\Pi})^{1-\xi_F} P_{F,t-1}(i).$$

Like domestic producers, importers meet the demand for their good at the prevailing price.

2.3 Fiscal Policy

The government purchases goods from both domestic firms and importers. Those purchases are assumed not to have any effect on private utility or productivity. The government allocates its consumption expenditures, given by

$$\int_0^1 P_{H,t}(i) G_{H,t}(i) di + \int_0^1 P_{F,t}(i) G_{F,t}(i) di,$$

among the different goods in order to maximize

$$G_t \equiv \left[(1-\alpha_G)^{\frac{1}{\eta}} G_{H,t}^{1-\frac{1}{\eta}} + (\alpha_G)^{\frac{1}{\eta}} G_{F,t}^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{11}$$

where

$$G_{H,t} \equiv \left[\int_0^1 G_{H,t}(i)^{1-\frac{1}{\varepsilon_G}} di \right]^{\frac{\varepsilon_G}{\varepsilon_G - 1}}$$

and

$$G_{F,t} \equiv \left[\int_0^1 G_{F,t}(i)^{1-\frac{1}{\varepsilon_G}} di \right]^{\frac{\varepsilon_G}{\varepsilon_G - 1}}.$$

The solution to that problem yields a set of demand functions for each good, which have to be added to the demand for private consumption and investment purposes. The associated Lagrange multiplier is the true price index, $P_{G,t}$:

$$P_{G,t}^{1-\eta} = \left(1-\alpha_G\right) P_{H,t}^{1-\eta} + \alpha_G P_{F,t}^{1-\eta}. \tag{12}$$

In addition to purchasing goods, the government taxes consumption, labor income, and profits, transfers resources to consumers, and issues debt in the domestic and foreign goods markets. That activity is summarized in the government budget constraint, which takes the following form:

$$\begin{aligned}
&P_t Tr_t + g_t P_t Y_t + B_t + S_t B_t^* + \left(\mathcal{S}_F - 1\right) P_{F,t} \int_0^1 C_{F,t}\left(h\right) dh \\
&+ \left(\mathcal{S}_F - 1\right) P_{F,t} \int_\lambda^1 I_{F,t}^R\left(h\right) dh + \left(\mathcal{S}_F - 1\right) P_{F,t} G_{F,t} \\
&+ \left(\mathcal{S}_{WR} - 1\right) \int_\lambda^1 W_t^R\left(h\right) L_t^R\left(h\right) dh \\
&+ \left(\mathcal{S}_{WN} - 1\right) \int_0^\lambda W_t^N\left(h\right) L_t^N\left(h\right) dh = \frac{B_{t+1}}{R_t} + \frac{S_t B_{t+1}^*}{R_t^* \mathrm{RP}_t} \qquad (13) \\
&+ \tau_{w,t} \left[\mathcal{S}_{WR} \int_\lambda^1 W_t^R\left(h\right) L_t^R\left(h\right) dh + \mathcal{S}_{WR} \int_0^\lambda W_t^N\left(h\right) L_t^N(h) dh \right] \\
&+ \tau_{\mathrm{Pr},t} \int_\lambda^1 \mathrm{Pr}_t^R\left(h\right) dh + P_t \int_0^1 TX_t\left(h\right) dh + P_{cu,t} \kappa X_{cu,t} Y_t \\
&+ \tau_{cu,t} P_{cu,t} \left(1-\kappa\right) X_{cu,t} Y_t + P_{mo,t} X_{mo,t} Y_t.
\end{aligned}$$

The terms on the left-hand side represent different government outlays. These include transfers,

$$Tr_t \equiv \int_0^1 Tr_t\left(h\right) dh = \int_\lambda^1 Tr_t^R\left(h\right) dh + \int_0^\lambda Tr_t^N\left(h\right) dh;$$

government consumption, $P_{G,t} G_t \equiv g_t P_t Y_t$, where $g_t \equiv P_{G,t} G_t / P_t Y_t$ is the share of government consumption in GDP; repayment of maturing government bonds (both domestic, B_t, and foreign, $S_t B_t^*$); and subsidies on foreign goods expenditures and employment Those outlays are funded through the issuing of new debt (domestic, B_{t+1} / R_t, and foreign, $S_t B^*_{t+1} / R_t^* \text{RP}_t$), labor income taxes, taxes on profits, lump-sum taxes, and copper-related revenues. The latter are briefly explained next.

Copper production is assumed to be stochastic and exogenous. Consistent with the market structure of copper production in Chile, the state-owned company accounts for a share κ of production, all of which accrues to the government as revenue. The remaining share corresponds to foreign companies, which are taxed at a rate of $\tau_{cu,t}$. We assume that world copper prices, $P^*_{cu,t}$, are exogenously given, implying a domestic copper price of $P_{cu,t}$, $= S_t P^*_{cu,t}$. The share of copper production to GDP, $X_{cu,t}$, follows an exogenous process, described below. In addition, $X_{mo,t}$ represents the output of molybdenum (a byproduct of copper production) as a share of GDP. The world molybdenum price is exogenous and given by $P^*_{mo,t}$. All revenues from molybdenum production accrue to the government.

Following Forni, Monteforte, and Sessa (2009), tax rates on wages, benefits, and copper production are allowed to vary

$$\tau_{w,t} = \left(1 - \rho_{\tau_w}\right)\tau_w + \rho_{\tau_w} \tau_{w,t-1} + \varepsilon_{\tau_w,t}, \tag{14}$$

$$\tau_{\text{Pr},t} = \left(1 - \rho_{\tau_{\text{Pr}}}\right)\tau_{\text{Pr}} + \rho_{\tau_{\text{Pr}}} \tau_{\text{Pr},t-1} + \varepsilon_{\tau_{\text{Pr}},t}, \tag{15}$$

$$\tau_{cu,t} = \left(1 - \rho_{\tau_{cu}}\right)\tau_{cu} + \rho_{\tau_{cu}} \tau_{cu,t-1} + \varepsilon_{\tau_{cu},t}, \tag{16}$$

where τ_w, τ_{Pr}, and τ_{cu} are long-run tax rates, ρ_{τ_w}, $\rho_{\tau_{\text{Pr}}}$, and $\rho_{\tau_{cu}}$ explain the degree of persistency, and $\varepsilon_{\tau_w,t}$, $\varepsilon_{\tau_{\text{Pr}},t}$, and $\varepsilon_{\tau_{cu},t}$ are independent and identically distributed (i.i.d.) shocks with zero means and constant variances.

Fiscal policy in Chile is conducted within the framework of a structural balance rule.[16] As discussed in the introduction, the Chilean fiscal rule ties government spending to structural, or

16. Previous papers that analyze the effects of the Chilean fiscal rule in DSGE models include García and Restrepo (2007), Medina and Soto (2007), and Kumhof and Laxton (2009).

permanent, government revenues. The Chilean government has followed this rule explicitly since 2001 and implicitly since the early 1990s.[17] We formalize the rule by assuming that total government spending (including interest payments) plus a time-varying surplus target (SURPLUS) must be equal to structural revenues. Structural revenues correspond to the revenues that the government would collect if (i) the prices of copper and molybdenum were equal to their long-run or reference values (denoted by $P^{ref}_{cu,t}$ and $P^{ref}_{mo,t}$, respectively) and (ii) the economy were producing at its steady-state level (potential output). The surplus target—that is, the difference between government spending and structural revenues—is set by the fiscal authorities. When the fiscal rule was introduced in 2001, the structural surplus target was set at 1 percent of GDP. The idea was to acknowledge that public debt was at a higher level than was considered appropriate for a small open economy facing exogenous credit constraint shocks and given potential future pension liabilities. Although fiscal policy was not conducted using an explicit rule in the 1990s, the "shadow" structural surplus averaged 1 percent of GDP in that decade. Again, the goal behind the structural balance rule was to reduce government debt to some long-run (sustainable) level. Motivated by the observed practice, we assume that the structural surplus (SURPLUS_t) is a function of the difference between current government debt and a long-term target for government debt ($\bar{B} = B + SB^*$):

$$\text{SURPLUS}_t = F\left(\bar{B}_t - \bar{B}\right) + s_t, \tag{17}$$

where $F' > 0$. If government debt is higher than its long-run target, the structural surplus is positive, which reduces government spending given structural revenues. Additionally, we assume that the surplus target depends on an exogenous shock, s_t, that follows an AR(1) process. In particular, we assume that

$$s_t = \rho_s s_{t-1} + \varepsilon_{s,t}, \tag{18}$$

where $\varepsilon_{s,t}$ follows an i.i.d. process with mean zero and constant variance $\sigma^2_{\varepsilon_s}$.

17. By implicitly, we mean that even though there was no explicit commitment to any fiscal policy rule in that period, fiscal policy outcomes in the 1990s resemble the ones that could have been obtained by the implementation of the Chilean fiscal rule of the 2000s.

In practice, we assume that $\bar{B} = 0$ (Chile held a net credit position of around 3 percent of GDP by the end of the last decade). This formulation allows us to have a well-specified fiscal rule (in which government debt is stationary), while capturing the most relevant aspects of the Chilean fiscal rule. A negative surplus shock (that is, a reduction in s) makes room for a rise in total government spending, which can be allocated to transfers or consumption. Under this formulation, the dynamics of debt are described by

$$
\begin{aligned}
\bar{B}_{t+1} - \bar{B}_t = {} & \left(P^{ref}_{cu,t} - P_{cu,t}\right)\kappa X_{cu,t} \\
& + \tau_{cu,t}\left(P^{ref}_{cu,t} - P_{cu,t}\right)\left(1-\kappa\right)X_{cu,t} + \left(P^{ref}_{mo,t} - P_{mo,t}\right)X_{m,t} \\
& + \tau_{w,t}\left[\mathcal{S}_{WR}\int_{\lambda}^{1} W^R(h)L^R(h)dh + \mathcal{S}_{WR}\int_{0}^{\lambda} W^N(h)L^N(h)dh\right] \\
& - \tau_{w,t}\left[\mathcal{S}_{WR}\int_{\lambda}^{1} W^R_t(h)L^R_t(h)dh + \mathcal{S}_{WR}\int_{0}^{\lambda} W^N_t(h)L^N_t(h)dh\right] \\
& + \tau_{\mathrm{Pr},t}\left[\int_{\lambda}^{1}\mathrm{Pr}^R(h)dh - \int_{\lambda}^{1}\mathrm{Pr}^R_t(h)dh\right] - \mathrm{SURPLUS}_t.
\end{aligned}
$$

Clearly, if the current price of copper is above its long-term value, we have a fiscal surplus (a reduction in government debt). The same is true for the other determinants of government revenues.

From this particular specification of the Chilean fiscal rule, we can derive a more traditional fiscal policy representation for the Bayesian estimation of the structural model, along the lines of our empirical strategy. We assume a specification for government consumption and transfers consistent with the representation of the Chilean fiscal rule just described. In particular, we represent government consumption by the next process:

$$
g_t = \left(1-\rho_G\right)g + \rho_G g_{t-1} + \varepsilon_{G,t}, \tag{19}
$$

where ρ_G measures the persistence of the process, g is the long-run government share, $P_G G / PY$, and $\varepsilon_{G,t}$ is an exogenous shock with mean zero and constant variance $\sigma^2_{\varepsilon_G}$. Under this specification, shocks to government consumption imply an increase in government debt in the current period and an adjustment in the structural surplus target (SURPLUS) for the next period. Given our specification, the adjustment in the surplus target translates into an adjustment in government transfers. Shocks to the surplus target (s) consistently translate into one-to-one movements in transfers. In particular, a negative shock to the surplus target increases government transfers. The evolution of transfers mimics the evolution of the surplus target (SURPLUS) determined by equations (17) and (18).

2.4 Monetary Policy

We assume that the Central Bank sets the (gross) nominal interest rate, $R_{rule,t}$ according to a variant of the Taylor rule with partial adjustment, given by

$$R_t = R_{t-1}^{\psi_R} R_{rule,t}^{1-\psi_R} \exp\left(\varepsilon_{m,t}\right) \tag{20}$$

and

$$R_{rule,t} = \left(\frac{\Pi_{A,t}}{\bar{\Pi}_A}\right)^{\psi_\pi} \left(\frac{Y_{r,t}}{\bar{Y}_r}\right)^{\psi_y}, \tag{21}$$

where Ψ_R determines the degree of smoothing and $\varepsilon_{m,t}$ is an exogenous i.i.d. monetary policy shock. The target values are steady-state GDP without the copper sector, $\bar{Y}_r$, and inflation, $\bar{\Pi}_A$, is assumed to be one for simplicity.[18] According to the Taylor principle, the reaction parameter to annualized inflation deviations, Ψ_π, should be larger than one, where $\Pi_{A,t} \equiv \Pi_t^4$, while Ψ_y for quarterly data should be around 0.5/4.

We have also studied an extension of the above rule that allows for a systematic interest rate response to nominal exchange rate variations. That extension could be useful for accommodating the policy regime from 1986:1 to 2001:2, as documented by Medina and Soto (2007). In the analysis that follows we ignore this term since this paper focuses on the sample period from 2001:3 to 2010:1.

18. This is without loss of generality, since in the 2000s the inflation rate in Chile fluctuated quite closely around the three percent inflation target. In the empirical implementation, we subtract this target.

2.5 Equilibrium and Aggregation

We first state clearing conditions in the markets for domestic inputs. For the labor services of household h, the market clearing condition is given by

$$L_t(h) = \int_0^1 L_t(h,i)di,$$

where $L_t(h,i)$ is firm i's demand for labor services from household h. A similar condition must hold for all $h \in (0, 1)$.

Given that only Ricardian households engage in capital accumulation, the market clearing condition in the market for that input is given by

$$K_t = (1-\lambda)K_t^R,$$

where $(1-\lambda)K_t^R = \int_\lambda^1 K_t^R(h)dh$. Similarly, for other asset holdings, we have

$$B_t = (1-\lambda)B_t^R$$

and

$$B_t^* = (1-\lambda)B_t^{R,*} - B_t^{G,*}.$$

Since $B_t^{G,*}$ is the amount of liabilities, a negative sign implies net holdings. In the same manner, aggregate real variables such as consumption and investment are

$$C_t = \lambda C_t^N + (1-\lambda)C_t^R$$

and

$$I_t = (1-\lambda)I_t^R,$$

where C_t^R and C_t^N come from aggregators similar to equation (2) and

$$(1-\lambda)I_t^R = \int_\lambda^1 I_t^R(h)dh.$$

Market clearing in home-produced goods implies that supply, given by the aggregated version of equation (8), equals demand:

$$Y_{H,t} = \Delta_{H,t}\left[T_{H,t}^{-\eta}(1-\alpha)(C_t + I_t) + T_{GH,t}^{-\eta}(1-\alpha_G)G_t\right] + \left(\alpha_C^* + \alpha_I^*\right)\left(\frac{T_{H,t}}{\mathrm{RER}_t}\right)^{-\eta} Y_t^*, \tag{22}$$

where Δ_H is the price dispersion implied by the Calvo pricing scheme for home goods. This number is typically above one for approximations of higher order than one. After some algebra, we can derive the following expression for aggregate output, Y_t, and aggregate output without copper, $Y_{r,t}$:[19]

$$Y_t = \frac{(C_t + I_t)\left[1-\Delta_{F,t}\alpha\left(T_t T_{H,t}\right)^{1-\eta}\right] + \Phi\left(u_t^R\right)K_{t-1}}{1-\mathrm{RER}_t\left(p_{cu,t}^* X_{cu,t}^{share} + p_{mo,t}^* X_{mo,t}^{share}\right) - \left[1-\Delta_{F,t}\alpha_G\left(T_t T_{GH,t}\right)^{1-\eta}\right]g_t}, \tag{23}$$

where Δ_F is the price dispersion implied by the Calvo pricing scheme for foreign goods (again, this number is typically above one for approximations of higher order than one); and

$$Y_{r,t} = \frac{(C_t + I_t)\left[1-\Delta_{F,t}\alpha\left(T_t T_{H,t}\right)^{1-\eta}\right] + \Phi\left(u_t^R\right)K_{t-1}}{1-\left[1-\Delta_{F,t}\alpha_G\left(T_t T_{GH,t}\right)^{1-\eta}\right]g_t}. \tag{24}$$

The Central Bank targets $Y_{r,t}$ instead of Y_t. From equation (23), we can find out the domestic private demand (consumption and investment) as follows:

$$C_t + I_t = \frac{Y_t\left\{\begin{array}{l} 1-\mathrm{RER}_t\left(p_{cu,t}^* X_{cu,t}^{share} + p_{mo,t}^* X_{mo,t}^{share}\right) \\ -\left[1-\Delta_{F,t}\alpha_G\left(T_t T_{GH,t}\right)^{1-\eta}\right]g_t \end{array}\right\} - \Phi\left(u_t^R\right)K_{t-1}}{\left[1-\Delta_{F,t}\alpha\left(T_t T_{H,t}\right)^{1-\eta}\right]}. \tag{25}$$

19. For details, see the derivation in section 8.2 of the appendix in the working paper version (Céspedes, Fornero, and Galí, 2012).

The evolution of net foreign assets under incomplete international asset markets is[20]

$$\frac{S_{t-1}B_t^*}{P_{t-1}}\frac{S_t}{S_{t-1}}\frac{1}{\Pi_t}+NX_t=\frac{1}{R_t^*\mathrm{RP}_t(\cdot,\cdot,\cdot)}\frac{S_tB_{t+1}^*}{P_t}, \tag{26}$$

where we employed the following net exports definition:

$$\begin{aligned} NX_t \equiv\ & \mathrm{RER}_t\left(p_{cu,t}^*\kappa X_{cu,t}^{share}+p_{mo,t}^*X_{mo,t}^{share}\right)Y_t \\ & +\Delta_{H,t}\left[\frac{T_{H,t}^{1-\eta}}{MC_{H,t}}(1-\alpha)(C_t+I_t)+\frac{T_{GH,t}^{1-\eta}}{MC_{H,t}}(1-\alpha_G)g_tY_t\right] \\ & +\frac{T_{H,t}}{MC_{H,t}}\left(\alpha_C^*+\alpha_I^*\right)\frac{T_{H,t}^{-\eta}}{\mathrm{RER}_t^{-\eta}}Y_t^*-T_HFC_H \\ & -\Delta_{H,t}(C_t+I_t)-g_tY_t-\Phi\left(u_t^R\right)K_{t-1}. \end{aligned} \tag{27}$$

Here we take into account that $C_t + I_t$ come from equation (25).

The model has seventeen exogenous driving forces, which are collected in the following vector:

$$\mathbf{v}_t=\begin{pmatrix} \upsilon_{m,t},\zeta_t,\mathrm{RER}_{F,t},\Pi_t^*,Y_t^*,A_{H,t},x_{cu,t}^{share},x_{mo,t}^{share}, \\ R_t^*,\phi_{,t},\varepsilon_{I,t},g_t,\tau_{w,t},\tau_{\mathrm{Pr},t},\tau_{cu,t},p_{cu,t}^*,p_{mo,t}^* \end{pmatrix}.$$

Strictly, the exógenous variable s_t (equation 18) should be included, but since we think that fiscal credibility in the rule is incompatible with variability of the surplus target, we omitted it (in other words, we think that s_t has a small variance).

The vector is assumed to follow the process

$$\underset{(17\times1)}{\mathbf{v}_t}=\underset{(17\times17)}{\mathbf{r}}\underset{(17\times1)}{\mathbf{v}_{t-1}}+\underset{(17\times1)}{\mathbf{e}_t},$$

where $\mathbf{r}$ is a diagonal matrix containing the corresponding autoregressive coefficients and $\{\mathbf{e}_t\}$ is the vector of exogenous serially uncorrelated shocks with zero mean and diagonal variance-covariance matrix $\mathbf{S_e}$.

20. For further details on the derivation, see section 8.3 of the appendix in the working paper version (Céspedes, Fornero, and Galí, 2012).

3. Calibration and Estimation

We estimate the above model using Bayesian methods. First, we define the measurement equation that links the observed variables with the model's solution or law of motion.[21] We then use the Kalman filter to evaluate the posterior density (which is proportional to the product of the likelihood and the assumed prior densities).[22]

To be consistent with the assumptions involving technology in the model, we get rid of the trend of nonstationary variables by filtering the data with a (deterministic) quadratic trend (in accordance with our VAR estimation). We also lower the observed inflation rate by the inflation target, namely, 3 percent annually. For the interest rate, we subtract a neutral interest rate of 5 percent (the inflation target plus an assumed steady-state real rate of 2 percent). We restrict estimation to the sample period 2001:3–2010:1, which was characterized by a well-defined monetary policy based on an inflation target and a flexible exchange rate.

We calibrate a subset of parameters. These are $\beta = 0.9878$, which is consistent with a neutral annual interest rate of 5 percent. Import shares, $\alpha = \alpha_G = 0.3$, approximate the import/GDP ratio. The settings $\alpha_C^* = \alpha_I^* = 0.0004$ are consistent with the share of Chilean GDP in world GDP (0.35 percent). The elasticities of substitution among varieties of intermediate and final imported goods are $\varepsilon_H = \varepsilon_F = 11$, consistent with markups $\mu_H = \mu_F = S_F = 1.1$. The elasticities of substitution among varieties of labor types are $\varepsilon_{LR} = \varepsilon_{LN} = 9$, which imply markups $\mu_{WR} = S_{WR} = \mu_{WN} = S_{WN} = 1.125$. In addition, $\overline{\zeta} = 7.5$ as in Adolfson and others (2007), the annual depreciation rate is assumed to be 10 percent ($\delta = 0.025$), and some steady-state ratios and relative prices are $X_{cu}^{share} = 0.044$, $X_{mo}^{share} = 0.01$, $g = 0.094$, $A_H = 1$, $\tau_w = 0.2$, $\tau_{\mathrm{Pr}} = 0.17$, and $T = T_H = T_{GH} = 1$. We also left calibrated the Calvo price and wage probabilities because of lack of identification under usual priors. Furthermore, the habit formation parameter affects the steady state due to the assumption of internal habit formation; we therefore calibrate it to 0.8. For the exogenous processes of copper and molybdenum shares that are not identified, ρ_{xcu} and ρ_{xmo}, we assume an autoregressive coefficient of 0.1.[23] Finally, the elasticity η is calibrated to 2.

21. Calculations are performed with the set of routines included in DYNARE (Adjemian and others, 2011).

22. For details on these aspects, see Fornero (2010).

23. We also tried a VAR(1) for foreign variables, as is usually done in the literature; however, off-diagonal elements of the persistency matrix turned out to be not statistically different from zero. Thus, we specify AR(1) processes for R^*, Π^*, and Y^*.

The crucial parameter λ is left calibrated to 0.50 due to lack of identification. Data from the Household Financial Survey implemented by the Central Bank of Chile in 2007 suggest a λ value of 0.29. This value is computed by adding the fraction of households that requested a financial credit and were rejected one or more times, the fraction that did not apply for any financial credit because they expected to be rejected, and the fraction that considered themselves unable to afford the credit payments. However, we calibrate λ to a conservative 0.50 since the data from the Household Financial Survey correspond to a period in which credit expanded rapidly toward first time credit holders.[24]

The prior densities are quite standard (see table 5). We choose a gamma density for the friction parameter of investment, Ψ, with prior mean 50 and a standard deviation of 20. The prior mean for the elasticity of the risk premium (RP) function respect to the asset position is 0.04 with prior standard deviation of one-tenth of the mean with beta distribution. A similar density type is chosen for persistence parameters (such as Ψ_R and ρ) with mean 0.5 and variance 0.2. The priors for Taylor rule parameters are quite standard (see Smets and Wouters, 2003). For variances of standard errors and measurement errors, we assume inverted gamma distributions with 20 and 1 degrees of freedom, depending on whether the errors refer to variables or shares (which vary less), respectively (see table 6).

The set of observed variables includes 11 time series, which are gathered in the vector $\mathbf{oZ}_t = (oY_{r,t}, oY_t^*, oC_t, oI_t, o\Pi_t, o\Pi_t^*, oR_t, oR_t^*, ow_t, o\mathrm{RER}_t, og_t)'$. Since the current model version does not have a balanced growth path, the data have been filtered using a linear quadratic trend or, if the resulting detrended time series is not stationary, the Hodrick-Prescott filter. We then scaled variables with the SS values. In addition, we allow for measurement errors, which are included in the vector $\mathbf{meZ}_t = (\mathrm{me}Y_{r,t}, \mathrm{me}Y_t^*, \mathrm{me}C_t, \mathrm{me}I_t, \mathrm{me}\Pi_t, \mathrm{me}\Pi_t^*, \mathrm{me}R_t, \mathrm{me}R_t^*, \mathrm{me}w_t, \mathrm{meRER}_t, \mathrm{me}g_t)'$. In the case of interest rates and inflation, which are not filtered, we subtract the neutral interest rates and inflation targets (foreign inflation is demeaned). Measurement errors are assumed to be i.i.d.

24. Ruiz-Tagle (2009) definescredit-constrained households as those who do not have access to low-cost credit and hence end up using high-cost credit (credit cards). He finds that at least 41 percent of Chilean households were credit constrained in 2004.

Table 5. Estimation Results for Chilean Fiscal Rule

Parameter	*Prior density*	*Prior mean*	*Prior std. dev.*	*Posterior mean*	*Confidence level 0.05*	*Confidence level 0.95*
Ψ	Γ	50.000	20.000	64.3307	37.3497	91.4607
ϕ_a	β	0.040	0.004	0.0393	0.0326	0.0465
θ	N	1.000	0.250	0.9359	0.5269	1.4169
ψ_R	β	0.500	0.150	0.8441	0.6771	0.9445
ψ_{ϖ}	N	1.500	0.150	1.2490	0.9751	1.5452
ψ_{yr}	β	0.125	0.050	0.1729	0.0670	0.2745
ρ_{ς}	β	0.500	0.200	0.7033	0.3380	0.9501
ρ_{RERF}	β	0.500	0.200	0.9338	0.8781	0.9740
ρ_{ς}	β	0.500	0.200	0.5098	0.1845	0.8135
ρ_{ς}	β	0.500	0.200	0.4853	0.3284	0.6360
ρ_{y*}	β	0.500	0.200	0.4913	0.1717	0.8071
ρ_{AH}	β	0.500	0.200	0.7555	0.4927	0.9325
ρ_G	β	0.500	0.200	0.7138	0.5341	0.8921
ρ_{R*}	β	0.500	0.200	0.4861	0.2121	0.7808
$\rho_{\varepsilon I}$	β	0.500	0.200	0.5875	0.2482	0.8941
$\rho_{\upsilon tr}$	β	0.500	0.200	0.5565	0.2293	0.8551

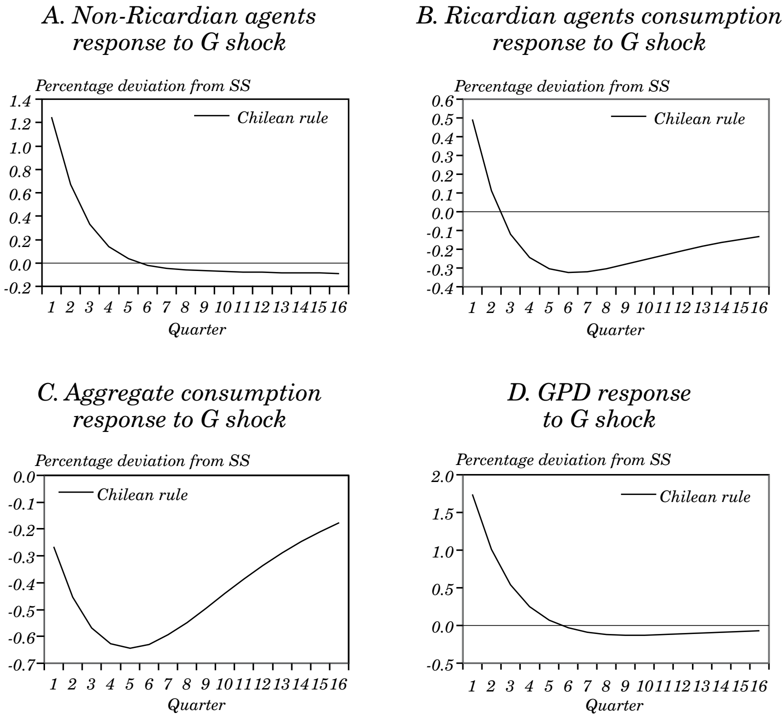
Source: Authors' computations.

Table 6. Estimation Results for Chilean Fiscal Rule: Errors and Measurement Errors

Error	*Prior density*	*Prior mean*	*Degrees of freedom*	*Posterior mean*	*Confidence level*	
					0.05	*0.95*
Standard errors						
υ_m	Γ^{-1}	0.010	20	0.0038	0.0020	0.0052
ε_{ς}	Γ^{-1}	0.010	20	0.0424	0.0029	0.0689
ε_{RERF}	Γ^{-1}	0.010	20	0.0032	0.0020	0.0043
$\varepsilon_{\varpi*}$	Γ^{-1}	0.037	20	0.0140	0.0111	0.0169
ε_{AH}	Γ^{-1}	0.010	20	0.0054	0.0036	0.0074
$\varepsilon_{\phi a}$	Γ^{-1}	0.010	20	0.0044	0.0023	0.0064
ε_I	Γ^{-1}	0.010	20	0.0122	0.0027	0.0260
ε_G	Γ^{-1}	0.001	1	0.0038	0.0026	0.0052
ε_{tr}	Γ^{-1}	0.010	20	0.0061	0.0025	0.0098
ε_s	Γ^{-1}	0.010	1	0.0085	0.0026	0.0150
Measurement errors						
me_{YR}	Γ^{-1}	0.001	1	0.0010	0.0003	0.0016
me_C	Γ^{-1}	0.001	1	0.0007	0.0003	0.0011
me_I	Γ^{-1}	0.001	1	0.0711	0.0558	0.0847
me_{ϖ}	Γ^{-1}	0.001	1	0.0037	0.0002	0.0193
me_R	Γ^{-1}	0.001	1	0.0006	0.0002	0.0009
me_W	Γ^{-1}	0.001	1	0.0256	0.0182	0.0330
me_{RER}	Γ^{-1}	0.001	1	0.0468	0.0352	0.0592
me_{Y*}	Γ^{-1}	0.001	1	0.0007	0.0003	0.0012
$me_{\varpi*}$	Γ^{-1}	0.001	1	0.0006	0.0002	0.0011
me_{R*}	Γ^{-1}	0.001	1	0.0007	0.0003	0.0012
me_g	Γ^{-1}	0.001	1	0.0021	0.0009	0.0037

Source: Authors' computations.

Figure 5. A Positive Shock to g_t of One Percent



Source: Authors' computations.

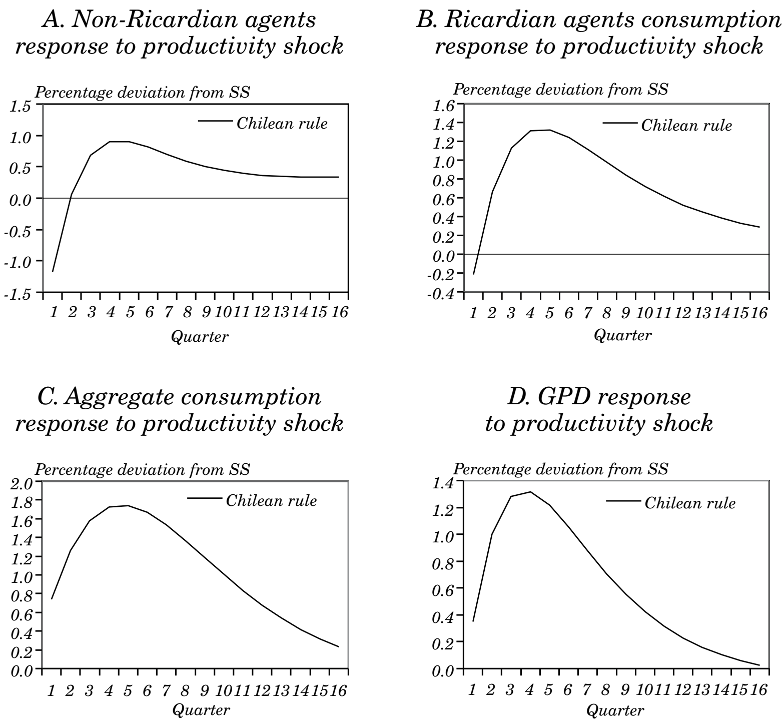
4. Simulations

In this section we present impulse response functions to various shocks under the structural balance fiscal rule introduced above. We then calculate the estimated model's fiscal multipliers.

4.1 Impulse Response Functions

Our analysis of the impulse response functions focuses on the implied size of the consumption and output fiscal multipliers. Figure 5 presents the dynamic response of the economy for a government spending (consumption) shock, ε_G, equal to 1 percent of GDP. The impact on output and consumption is positive.

Figure 6. A Positive Productivity Shock of One Percent

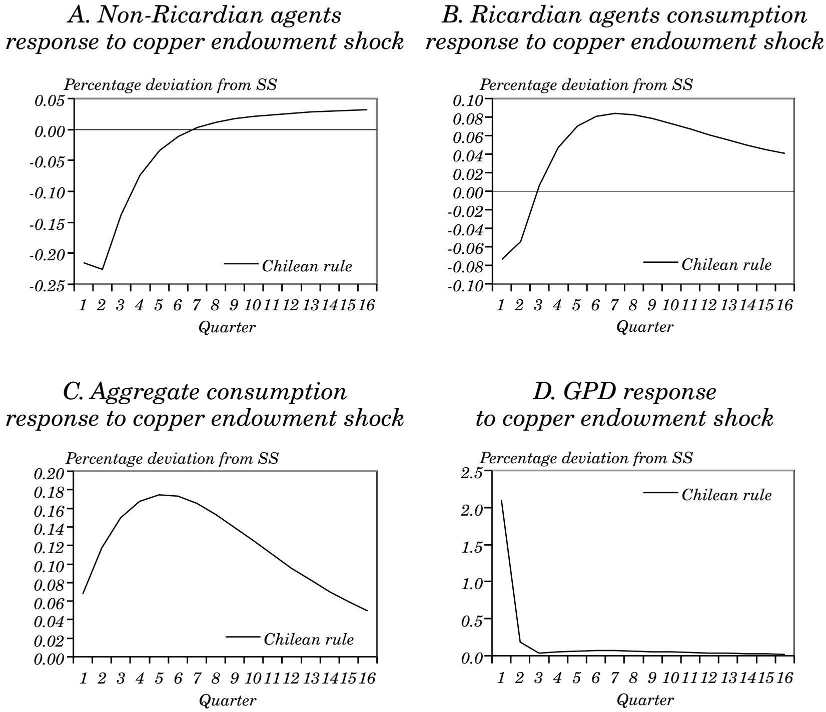


Source: Authors' computations.

Government expenditure increases following equation (19). Since transfers only respond gradually to offset the increase in spending, through changes in the surplus target, the shock is more expansionary and stimulates consumption and output. This is a critical difference with the case in which the government follows a structural balance rule. Under this formulation, the transfers will have to adjust to fully offset the increase in government consumption. This impulse response is consistent with the VAR evidence reported in a previous section.

Figure 6 displays the impulse response functions to a positive shock to total factor productivity. As a result of that shock, marginal costs decrease; nominal wages tend to increase, but since they are sticky they cannot react immediately; and real wages rise due to

Figure 7. A Positive Shock to the Copper-to-GDP Share of One Percent

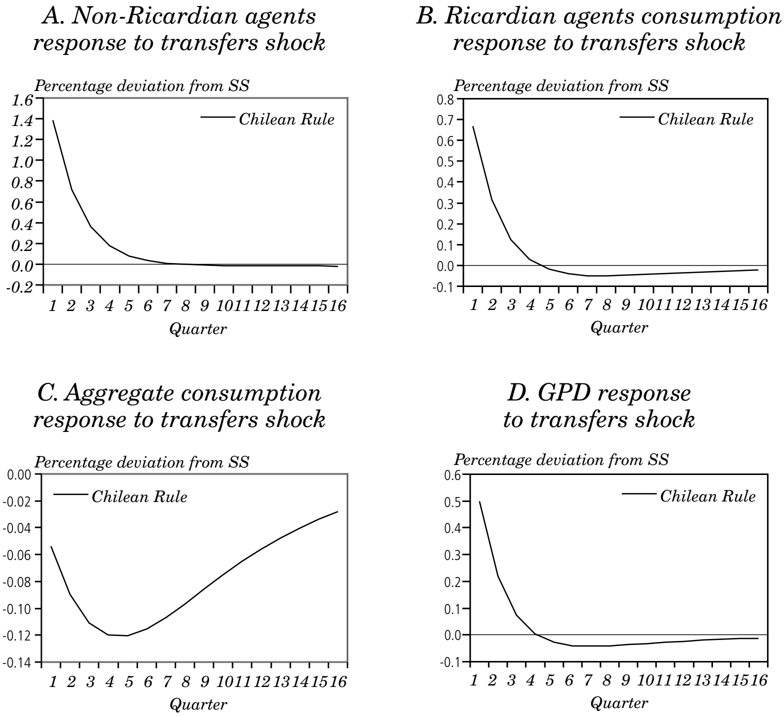


Source: Authors' computations.

deflationary pressures caused by the shock. The real exchange rate appreciates, which mitigates the expansion of exports. Consumption by Ricardian agents reacts positively, whereas non-Ricardian agents' consumption remains negative for two quarters. The higher consumption by Ricardian agents under the Chilean fiscal rule can be associated with the fact that under this specification of fiscal policy, agents understand that the government is going to save, so they consume more.

Figure 7 illustrates a shock in the copper-to-GDP share of 1 percentage point. The GDP multiplier is positive. Consumption by Ricardian agents increases. A fraction of this increase is explained by the fact that under the Chilean fiscal rule, the government is saving the temporary increase in revenues, which is compatible with

Figure 8. A Positive Transfers Shock of One Percent

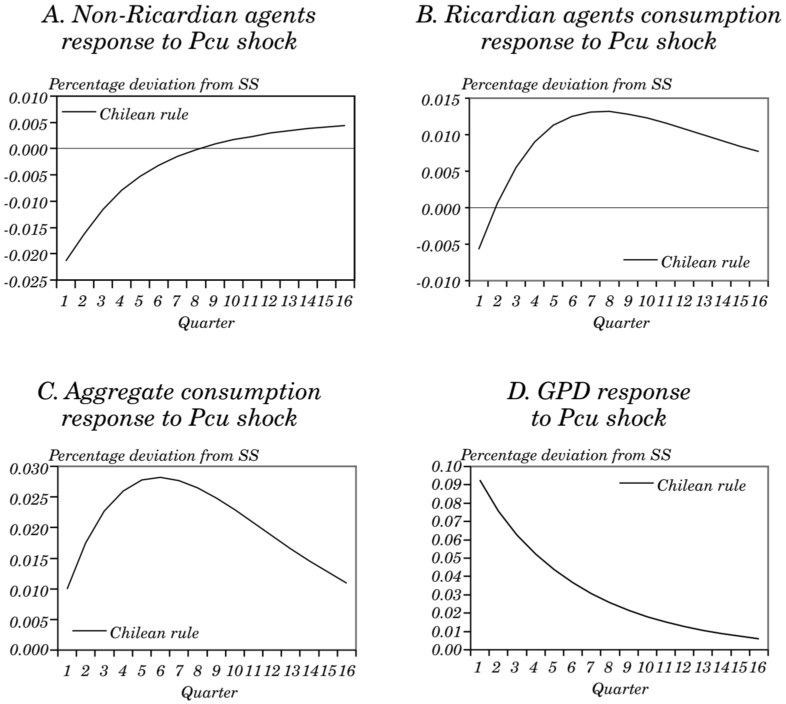


Source: Authors' computations.

larger consumption levels for Ricardian agents. The response of non-Ricardian agents' consumption is interesting to analyze. Under a balanced budget rule, all the temporary increase in revenues would be transferred to the public, leading to a large increase in consumption by non-Ricardian households in the short run (as opposed to Ricardian agents, who smooth consumption and hence save much of the transfer). By contrast, the Chilean rule would fix the expenditure to a constant, such that government savings would increase.

Figure 8 considers a shock to transfers of 1 percent. Note that the estimated persistence of the AR(1) process for transfers is 0.56. Ricardian consumers save the temporary increase in transfers, whereas non-Ricardian agents consume all of it. The positive response of consumption by non-Ricardian agents leads to an aggregate

Figure 9. A Positive Shock to the Copper Price of One Percent



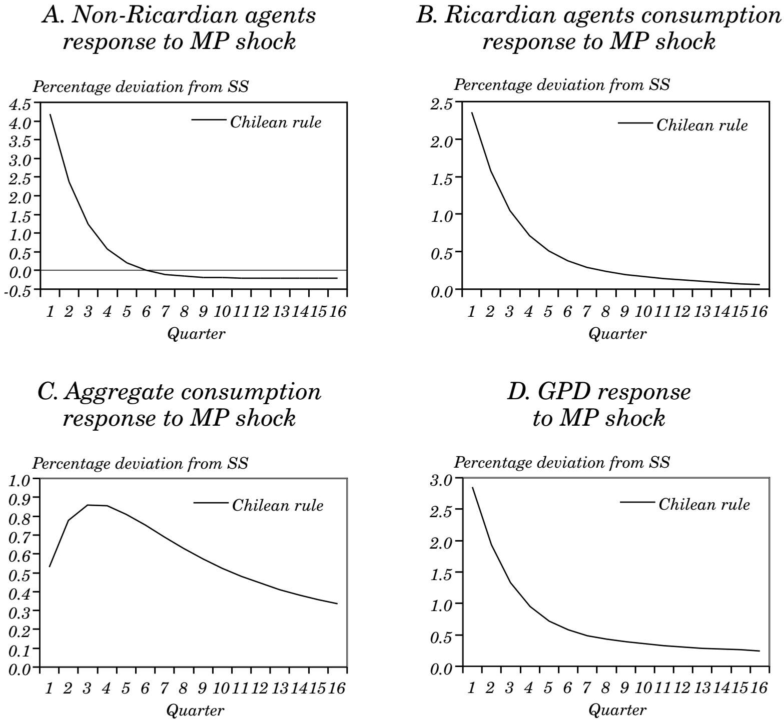
Source: Authors' computations.

consumption multiplier that is positive for about one year. GDP increases as well, and the response path suggests a larger multiplier than consumption.

Figure 9 reports a positive shock of 1 percent in the price of copper relative to the foreign price index. The results are qualitatively similar to those observed in figure 5. The GDP multiplier is positive, as is Ricardian consumption. Non-Ricardian consumption decreases under the Chilean rule, because the government saves for a while by buying public debt.[25]

25. The GDP multiplier also remains positive in the case of a zero-deficit rule (results not shown). Non-Ricardian consumption increases under a zero deficit rule because the government distributes higher transfers.

Figure 10. An Expansive Monetary Policy: A Shock to the Interest Rate Instrument of One Percent



Source: Authors' computations.

Figure 10 reports the responses to an expansive monetary policy under estimated parameters. The drop of interest rates causes a hump-shaped consumption pattern for Ricardian agents, while the responses of non-Ricardian households are monotonic. Overall aggregate consumption and GDP expand, as expected in any New Keynesian model like ours. Non-Ricardian consumption expands due to increases in wages and tax revenues (which are distributed through transfers, which in turn are mitigated by the Chilean fiscal rule). The drop in interest rates makes it less attractive to invest in domestic fixed-income assets in comparison with foreign assets, leading to a depreciation of the domestic currency.

4.2 Model's Fiscal Multipliers

Consistent with the impulse response functions just described, this section calculates fiscal multipliers for an expansionary fiscal policy with the estimated model. Table 7 illustrates both dynamic and dynamic cumulative multipliers, so these figures are comparable with those reported in tables 1 and 2.

Our earlier implementation of a variety of structural VARs showed that the fiscal multipliers were over one. Overall, we confirm these findings with our estimated model: the results resemble those of the open economy or large VAR. In particular, table 7 points to important non-Ricardian effects in aggregate output and consumption of an expansionary fiscal policy (hours worked also increase).

What do the consumption multipliers look like for each of the two agent types? To address this, we further calculate dC^R / dG and dC^N / dG (and their cumulative versions). Aggregate consumption increases for a while because consumption by constrained agents rises and offsets the drop in consumption by Ricardian agents. Cumulative multipliers suggest that aggregate consumption is 0.24 of the initial fiscal impulse by the end of the year. At the same horizon, this is explained by a positive effect in consumption by non-Ricardian agents (2.39) that outweighs the negative effect of the Ricardian consumers (–1.92).

5. Conclusions

This paper presents VAR evidence on fiscal multipliers that are large and robust for Chile. The evidence we present indicates that aggregate real consumption and real GDP expand significantly when transfers or government expenditure (or both) rise. Results from small VARs (four variables) suggest that basic consumption multipliers peak in the second quarter with values larger than one, while output multipliers peak slightly later and are larger in magnitude. Cumulative multipliers grow steadily and peak between four and six quarters, and then the expansionary effect comes to a halt and starts to fall. Values range from 2.4 to 3.5 for consumption and 3.2 to 3.5 for output. Large VARs that explicitly take into account the fact that Chile is a small open economy by including three additional variables (namely, copper price as exogenous, total private investment, and the real exchange rate) produce consumption

Table 7. Model's Fiscal Multipliers: Increase in Public Spending

Time / multipliers	*Multipliers*				*Cumulative multipliers*			
	dY/dG	dC/dG	dCR/dG	dCN/dG	dY/dG	dC/dG	dCR/dG	dCN/dG
$t = 1$	1.74	0.49	−0.27	1.25	1.74	0.49	−0.27	1.25
$t = 2$	1.01	0.11	−0.45	0.67	2.75	0.60	−0.72	1.92
$t = 4$	0.25	−0.25	−0.63	0.14	3.54	0.24	−1.92	2.39
$t = 6$	−0.03	−0.32	−0.63	−0.02	3.58	−0.39	−3.19	2.41
$t = 8$	−0.12	−0.30	−0.55	−0.06	3.37	−1.02	−4.33	2.30

Source: Authors' computations.

and output responses that are stronger in the face of a shock to government purchases. The large VAR with transfers shocks exhibits fiscal multipliers similar to the ones obtained from the smalWe confront this evidence with the prediction of a DSGE model for the Chilean economy. The model features two household types: Ricardian and non-Ricardian. The former solve a typical dynamic programming problem, whereas non-Ricardian households consume labor income and transfers within the period. We assume a standard specification for monetary policy, but allow for a fiscal policy that approximates the Chilean fiscal policy rule, characterized by expenditure flows responding to structural or long-run revenues. The results indicate that when a balanced budget rule is instrumented by transfers (leaving public expenditure exogenous), a public transfer shock yields positive fiscal multipliers of consumption and output. On the other hand, if government purchases are shocked instead, the balanced budget rule causes a negative fiscal multiplier for consumption, but a positive one for GDP. Interestingly, the implementation of a fiscal policy rule that approximates the Chilean fiscal rule in the model leads to the finding that both the consumption and output fiscal multipliers are positive in the short run.

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