IDB WORKING PAPER SERIES Nº IDB-WP-1511

From Macroeconomic Stability to Welfare:

Optimizing Fiscal Rules in Commodity-Dependent Economies

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October 2023

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Heresi, Rodrigo.
From macroeconomic stability to welfare: optimizing fiscal rules in commodity-dependent economies / Rodrigo Heresi.
p. cm. — (IDB Working Paper Series ; 1511)
Includes bibliographical references.
1. Fiscal policy-Chile-Econometric models. 2. Welfare economics-Chile-Econometric models. 3. Taxation-Chile-Econometric models. 4. Raw materials-Chile. 5. Macroeconomics-Econometric models. I. Inter-American Development Bank. Department of Research and Chief Economist. II. Title. III. Series.
IDB-WP-1511

http://www.iadb.org

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Abstract

I study the welfare and macroeconomic implications of simple and implementable fiscal policy rules in commodity-dependent economies, where a large share of output, exports, and government revenues depend on exogenous and volatile commodity prices. Using a multi-sector New Keynesian model estimated for the Chilean economy, we find that the welfare-maximizing fiscal policy involves an actively countercyclical response to the tax revenue cycle and a mildly procyclical response to the commodity revenue cycle. Compared to a benchmark acyclical policy, the optimized rule minimizes GDP growth volatility while delivering welfare gains of 0.6% of lifetime consumption to non-Ricardian (financially constrained) households. Government consumption and especially public investment are particularly helpful in stabilizing GDP, while targeted social transfers are essential to smooth the consumption of financially constrained households. Implementing the optimized rule requires moderate additional volatility (fiscal activism) in government spending and public debt.

JEL classifications: E62, Q32, F41
Keywords: Fiscal rules, Raw materials sector, Open economy macroeconomics

The author thanks seminar participants at the 2023 CEBRA annual meeting at Columbia SIPA for helpful comments. I thank Daniela Villacreces for her excellent research assistance. The views expressed here are strictly those of the authors and do not necessarily reflect the views of the Inter-American Development Bank, its Board of Directors, or the countries they represent. Contact author Rodrigo Heresi at rheresi@IADB.ORG.

1 Introduction

Can fiscal policy rules stabilize economic cycles while maximizing consumers' welfare in commodity-dependent economies? In this paper, I argue that a fiscal rule that reacts strongly countercyclically to the domestic business cycle and mildly procyclically in response to exogenous and volatile commodity price cycles can effectively stabilize the economy, generating significant welfare gains, especially for liquidity-constrained (non-Ricardian) households.

The effectiveness of monetary policy, which relies on agents' intertemporal consumption/saving decisions, can be severely compromised when a large share of the population cannot access credit markets to smooth consumption out of exogenous shocks to disposable income (see Galí et al. (2007); Leeper et al. (2017)). In such an environment, fiscal policy becomes a very effective countercyclical tool, lifting real output via government consumption and especially public investment, while smoothing consumption of non-Ricardian households via targeted transfers (Kumhof and Laxton (2013)).[1]

The study of cyclically adjusted fiscal rules is particularly relevant in commodity-dependent economies where a substantial fraction of output, exports, and government revenues often depend on volatile commodity prices. Moreover, these economies tend to have a significant fraction of liquidity-constrained households, by far the most affected by inappropriate fiscal policies. Commodity-dependent economies are particularly prone to so-called balanced-budget rules (BBR), in which the government aligns expenditure with current revenues, maintaining a constant fiscal budget and hence, constant debt. As is well-known, this policy is highly procyclical, amplifying economic fluctuations and reducing welfare (Ilzetzki and Végh (2008)).

Cyclically adjusted fiscal policy rules have long been proposed as commitment devices to avoid discretionary spending and the perils of procyclical policies. At the same time, there is an ongoing debate regarding the proper macroeconomic stabilizing role of the government. Some argue for adopting an acyclical structural budget rule (SBR) that effectively isolates government spending from large fluctuations in public income. This rule enables governments to pay back debt or accumulate assets when revenues are higher-than-normal and to borrow when revenues are lower-than-normal. Over time, the assets accumulated in good times net out with debt accumulated during economic recessions, so fiscal sustainability obtains by design. Other authors make a case for a proactive countercyclical fiscal rule (CCR) which can be interpreted as adopting robust automatic stabilizers, such as progressive taxation, targeted social transfers, or effective unemployment insurance systems.

In this article, we argue for a nuanced approach to fiscal rules, showing quantitatively that a strongly countercyclical response to the business cycle and a mildly procyclical reaction to the commodity revenue cycle can reduce real output volatility and produce more significant welfare gains than alternative fiscal rules. We build a New Keynesian general equilibrium model of a small and open commodity-dependent economy estimated for Chile to evaluate alternative rule designs from a welfare perspective. Analogous to the Taylor rule, which consists of feedback policy parameters governing the response of interest rates to inflation and the output gap, we analyze simple fiscal rules by a grid search over policy parameters determining the reaction of government expenditure to cyclical fluctuations in revenues.

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[1] Also known as non-Ricardian, non-savers, credit-constrained, rule-of-thumb or hand-to-mouth households, these terms are used interchangeably in the paper.

Firstly, we optimize a rule using a single fiscal parameter governing the spending reaction to fluctuations in total government revenues. Then, we evaluate a refined rule with two feedback parameters allowing the government to respond differently to fluctuations in tax revenues (a function of the output gap) and commodity-related revenues (a function of the gap between current and long-term commodity prices). Moreover, we augment the rule design with a feasibility constraint limiting large deviations of public debt from its long-run value, thereby effectively imposing a (time-varying) debt limit (as in practice, many countries do). As is well-known, the equilibrium dynamics of small open economy models possess a random walk component in the private net foreign asset position (NFA). To resolve this issue, Schmitt-Grohé and Uribe (2003) document several modifications to the standard model to break the unit root and induce stationarity. A similar problem arises regarding the government's NFA in models with fiscal debt, and the feasibility constraint acts as an additional device to break the random walk behavior in government debt. Without this feasibility constraint, we show that the model generates counterfactual debt dynamics that are 10 times more volatile than observed in the data. When introducing the feasibility constraint and estimating its key parameter using fiscal observables, the model can reproduce the unconditional volatility, correlation with output, and autocorrelation of the government's NFA position observed in the data.

When optimizing the fiscal rule with a single feedback parameter for total revenues, non-Ricardian households call for countercyclical spending, while Ricardians prefer an acyclical approach. At their preferred policy, non-Ricardian families accrue welfare gains of 0.08% of lifetime consumption. In contrast, the gain is nil for Ricardian agents, for whom any deviation from a structural balance rule is welfare-reducing. Using the refined fiscal rule with revenue-specific (double feedback) parameters increase welfare gains for non-Ricardians to 0.6% of lifetime consumption, that is, $0.6/0.08 = 7.5$ times larger gain than under the basic (single feedback) rule. The reason is that the optimized refined rule is strongly countercyclical to the tax revenue gap, leaning against the wind of the domestic business cycle while maintaining a rather procyclical response to fluctuations in international commodity prices, a more flexible approach the single feedback version of the rule cannot capture.

The latter seemingly counterintuitive result can be attributed to fundamental distinctions between commodity-related revenues and tax revenues. Tax revenues are a function of aggregate income or GDP, so when households' income is high, tax revenues also tend to be high. Thus, a countercyclical response to tax revenues helps stabilize aggregate output. In contrast, commodity revenues are predominantly influenced by volatile and persistent commodity price shocks, which do not necessarily correlate with the domestic business cycle. For instance, Figure 1 presents the time series for the Chilean output and copper price gaps over the last 60 years, revealing a low (18%) cross-correlation, with commodity fluctuations being one order of magnitude more volatile and persistent than the standard business cycle.

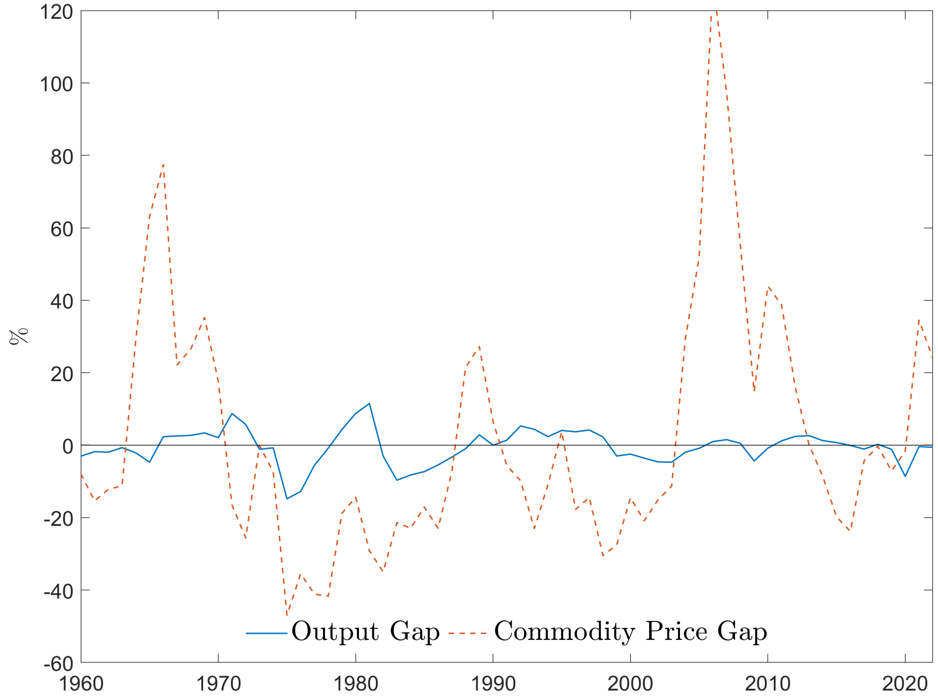
Furthermore, in our calibration for the Chilean economy, only a third of the commodity cash flow belongs to the government, with the rest going to foreign investors (via profits from foreign direct investment) so that commodity price fluctuations primarily affect government revenues with no direct effect on households' income. If, for instance, a positive commodity price shock hits the economy during a domestic recession, a countercyclical response to the positive windfall shock would drag the economy further down, not only preventing an exogenously-induced economic recovery but also amplifying economic cycles. In this scenario, moving from a countercyclical response to the commodity revenue cycle to the optimized mildly procyclical prescription reduces the volatility of macroeconomic and fiscal variables, improving welfare by at least 1 p.p. of lifetime consumption for financially constrained non-Ricardians. The higher the persistence of international commodity price shocks, the more likely consumers prefer a procyclical stance concerning commodity revenues.

On the other hand, a strongly countercyclical (CCR) response to the tax revenue gap has a macroeconomic stabilization effect, enabling significant welfare gains. For instance, a procyclical (BBR) response to tax revenues increases the volatility of real GDP growth by 19% relative to an acyclical SBR benchmark, implying a considerable welfare loss of 2.6% for non-Ricardian consumers. In contrast, the non-Ricardian preferred rule enables a 12% reduction in the volatility of GDP growth, leading to the baseline welfare gain of 0.6% mentioned above.

Finally, we conclude that the most appropriate fiscal instrument to implement the rule is total spending, including government consumption, public investment in productive infrastructure, and targeted social transfers. Government consumption and especially public investment help stabilize real output, while countercyclical transfers are essential to smooth the consumption of financially constrained households. Finally, we report efficiency frontiers to illustrate the optimized rule requires only moderate additional volatility (fiscal activism) in government spending and debt.

The rest of the paper is organized as follows. Section 2 discusses the related literature, section 3 presents the model, while Section 4 describes the parametrization strategy, estimated fiscal rules, and model fit. Section 5 illustrates the model dynamics, while Section 6 presents a detailed welfare evaluation of alternative fiscal rules. Section 7 concludes.

Figure 1: Domestic Business Cycle versus International Commodity Price Cycle



Notes: The output and commodity price gaps are estimated using the Chilean Ministry of Finance methodology. The sample (1960-2022) standard deviation of the output gap is 4.7%, while the standard deviation of the copper price gap is 33.7%. The correlation between the Chilean output gap and the international (real) copper price gap is 18%.

2 Related Literature

This paper contributes to the literature related to the welfare evaluation of fiscal policies in commodity-dependent economies in the presence of non-Ricardian households. The study aligns with two distinct strands of this literature. The first strand centers on analyzing the single optimized fiscal response to revenue fluctuations (García-Cicco and Kawamura (2015), Garcia et al. (2011), and Ojeda-Joya et al. (2016)), while the second strand delves into the examination of welfare-maximizing fiscal rules that respond differently to the tax revenue and commodity revenue gaps (Kumhof and Laxton (2013), and Snudden (2016)). Unlike the previously mentioned papers, we improve the quantitative fit of the model by introducing a feasibility/sustainability constraint to the fiscal rule and estimating model parameters, including those related to the fiscal rule, using Bayesian methods. As in Kumhof and Laxton (2013), we model a detailed public sector allowing for public investment and the addition of government consumption in consumers' utility functions. Similar to Snudden (2016), we also include oil as an input into production and as a consumption good in consumers' baskets. In contrast to the papers mentioned above that assume an exogenous endowment for the commodity sector, we endogenize commodity production as a function of capital, an imported input, oil, and a fixed (natural) resource (also interpretable as land).

Within the existing literature that examines the optimized single parameter fiscal response to public revenue, a consistent finding emerges: Ricardian consumers tend to favor a less interventionist policy approach, aiming to maximize their welfare under a BBR (García-Cicco and Kawamura (2015), Garcia et al. (2011), and Ojeda-Joya et al. (2016)). In contrast, our findings also indicate that non-Ricardian households prefer an SBR or CCR stance, allowing the government to smooth consumption on their behalf. Notably, the model confirms the literature results for Ricardian consumers only when the feasibility constraint is deactivated. However, upon activating the debt sustainability constraint, the preferences of Ricardian consumers shift from a strongly procyclical BBR stance to an acyclical SBR approach. By fixing the feasibility constraint parameter to its estimated value, we effectively limit the action space of fiscal policy rules. Considering that none of the studies mentioned above incorporates the debt sustainability constraint into their quantitative analyses, this exercise offers a new approach to evaluating fiscal policies in a more realistic setting, effectively imposing a public debt limit as many countries operate in practice.

Turning to the literature related to revenue-specific fiscal parameters responding to the tax and commodity-revenue gap, Kumhof and Laxton (2013) and Snudden (2016) coincide with our finding that a CCR response to the tax revenue gap is welfare-maximizing for consumers. Regarding the commodity revenue gap, we find that a mild BBR approach is welfare-maximizing, while Snudden (2016) and Kumhof and Laxton (2013) identify a CCR and an SBR, respectively, is preferred by consumers. In contrast to our analysis, Snudden (2016) examines a small oil-exporting economy calibrated for Colombia, with oil constituting a significant component in the production and consumer baskets. Their research reveals that allowing for a countercyclical response to the oil-royalties gap mitigates the high pass-through of oil prices into headline inflation, thereby stabilizing both inflation and real consumption. However, Kumhof and Laxton (2013) and our paper focus on the impact of copper price shocks in a small copper-exporting economy calibrated for Chile. Like our research, Kumhof and Laxton (2013) find that a CCR response to the commodity revenue gap negatively impacts consumers' welfare. Even though they find that an SBR stance regarding the commodity revenue gap can maximize overall welfare, the potential welfare gains moving from a BBR to an SBR responding to the commodity revenue gap are negligible.

Consequently, our results are comparable to the findings of Kumhof and Laxton (2013), with the difference that our identified optimized response to the commodity revenue gap leans more towards a BBR than an SBR policy. As mentioned, the present study builds on the literature, presenting a quantitatively relevant and more realistic approach to evaluating welfare-maximizing fiscal policy rules.

3 The Model

We present a multi-sector model of a small and open commodity-dependent economy following Medina et al. (2007) and García et al. (2019). At the core of the analysis, there is a government following a fiscal expenditure rule aimed at isolating government spending from the variability of public revenues. Importantly, government revenues came from taxes and the ownership of a share of the country's commodity wealth. In turn, government proceeds are spent on the consumption of goods and services, investment in public infrastructure, and social transfers. Two fiscal policy parameters determine whether the government reacts procyclically or countercyclically to (1) the output gap and (2) the commodity price gap.

On the demand side, the economy features two household types: Ricardian (R) and non-Ricardian (NR). Ricardian households own shares in the productive firms in the economy and have access to the financial market to smooth their consumption of goods and services. By contrast, non-Ricardian households work for a wage and consume their labor income period by period ("hand-to-mouth"). They do not have access to credit and do not own a share of the productive firms in the economy.

On the supply side, there are five types of goods: non-tradables (N), exportables (X), importables (M), oil (O), and a primary commodity (Co, say, copper). To represent the case of Chile, oil O is fully imported, while copper Co is fully exported. Domestically-produced goods N and X are elaborated by combining physical capital, labor, imported inputs, and oil. The exported commodity Co is produced using sector-specific capital and a fixed land supply, subject to a long-run growth trend. Firms in the importable sector specialize in buying a homogeneous good from foreigners and differentiate it into varieties demanded by households for final consumption and by firms as an intermediate input.

The economy is "dependent" on copper Co in two ways. First, a significant fraction of the country's exports are composed of primary goods. Second, a substantial fraction of government revenues come directly from state-owned commodity-producing companies. Because commodity prices are determined in international markets, external and fiscal accounts depend heavily on exogenously-driven commodity price cycles.

Physical capital for production includes private capital (rented from Ricardian households) and public infrastructure (accumulated via government investment). Private capital is sector-specific. The environment includes Calvo-type nominal rigidities in wages and prices and a Central Bank implementing a Taylor-rule-based monetary policy. Other (real) rigidities include habit formation in consumption, adjustment costs in investment, and variable capital utilization.

3.1 Households

The economy is populated by a unit mass of infinitely-lived households. There are two types of households: Ricardians (R) and non-Ricardians (NR) with shares $(1-\omega)$ and ω, respectively. For any house $l = \{R, NR\}$ expected lifetime utility is given by:[2]

$$E_0 \sum_{t=0}^{\infty} \beta^t \xi_t^{\beta} \left\{ \frac{\left(\widehat{C}_t^l\right)^{1-\sigma}}{1-\sigma} - \Xi_t^l \frac{\left(h_t^l\right)^{1+\psi}}{1+\psi} \right\} \tag{1}$$

where $\widehat{C}_t^l$ is the consumption basket, h_t^l is hours worked, ξ_t^{β} is an intertemporal preference shock, Ξ_t^l is a term that affects the disutility of work (defined below) and parameters β, σ, and ψ govern time discount, risk aversion, and the elasticity of labor supply, respectively. The consumption basket is given by a constant elasticity of substitution (CES) composite between private and public goods consumption as follows:

$$\widehat{C}_t^l = \left[(1-\gamma)^{\frac{1}{\varrho}} (C_t^l - \phi_c \breve{C}_{t-1}^l)^{\frac{\varrho-1}{\varrho}} + (\gamma)^{\frac{1}{\varrho}} (C_t^G)^{\frac{\varrho-1}{\varrho}} \right]^{\frac{\varrho}{\varrho-1}} \tag{2}$$

where $\widehat{C}_t^l \equiv \widehat{C}^l(C_t^l - \phi_c \breve{C}_{t-1}^l, C_t^G)$, $\breve{C}_t^l$ is average consumption,[3] γ and ϱ are the weight and elasticity of substitution, and ϕ_c governs the degree of habit formation in consumption. In turn, the disutility of work term is given by:

$$\Xi_t^l = \eta^l \xi_t^h A_{t-1}^{1-\sigma} \Theta_t^l \tag{3}$$

where η^l is a constant,[4] ξ_t^h is an intratemporal preference shock, A_t is the long-run growth trend of the economy, and the term Θ_t^l is engineered to eliminate the wealth effect of labor supply,[5] as follows:

$$\Theta_t^l = A_{t-1}^{\sigma} \left(\widehat{C}^l(\breve{C}_t^l - \phi_c \breve{C}_{t-1}^l, C_t^G) \right)^{-\sigma} \left(\frac{(1-\gamma)\widehat{C}^l(\breve{C}_t^l - \phi_c \breve{C}_{t-1}^l, C_t^G)}{\breve{C}_t^l - \phi_c \breve{C}_{t-1}^l} \right)^{\frac{1}{\varrho}} \tag{4}$$

Labor decisions are made by a union, which supplies hours under monopolistic competition, to a continuum of labor markets indexed by $j \in [0,1]$, subject to the resource constraint

$$h_t = \int_0^1 h_t^d(j) dj, \tag{5}$$

with $h_t = (1-\omega)h_t^R + \omega h_t^{NR}$; i.e., the total amount of hours supplied by households are optimally distributed by the union across submarkets j, and economic sectors N and X, $h_t^d(j) = h_t^N(j) + h_t^X(j)$. Household members are indifferent between working in sectors $J \in \{N, X\}$, so that in

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[2] Consumption and hours worked are identical across family members. Household preferences are defined by per capita consumption and per capita hours. We use uppercase (Latin and Greek) letters for variables containing a unit root (either because of steady state growth or positive steady state inflation).

[3] In equilibrium, $\breve{C}_t^l = C_t^l$, $l = \{R, NR\}$, but when optimizing, the household takes $\breve{C}_t^l$ as given (external habits).

[4] Constant parameter used to target steady state labor market shares.

[5] As emphasized in Galí et al. (2012), the latter feature helps match the joint behavior of employment, consumption, and wages over the business cycle.

equilibrium, $W_t^N(j) = W_t^X(j) = W_t(j)$. Instead, physical capital is sector-specific (more details below).

3.1.1 Ricardian Households

The budget constraint for Ricardian households, expressed in home currency units, is given by

$$(1+\tau^C)P_tC_t^R + P_t^I(I_t^{R,N} + I_t^{R,X}) + B_t^R + S_tB_t^{R*} = (1-\tau^W)\left[\int_0^1 W_t(j)h_t^d(j)dj\right] + \sum_{J\in\{N,X\}}\left[(1-\tau^K)P_t^Jr_t^Ju_t^J + \tau^KP_t^I(\delta+\Phi(u_t^J))\right]\hat{K}_{t-1}^J + r_{t-1}B_{t-1}^R + S_tr_{t-1}^*B_{t-1}^{R*} + \hat{\Sigma}_t, \tag{6}$$

where P_t is the price of the consumption basket, P_t^I is the price of investment, P_t^J is the price of final goods in sector $J \in \{N, X\}$, and S_t is the nominal exchange rate, defined as the price of one unit of foreign currency in terms of domestic currency—a positive value of $\pi_t^S \equiv \frac{S_t}{S_{t-1}}$ means a devaluation of the domestic currency. The quantity $I_t^{R,J} = \left[\hat{I}_t^J + \Phi(u_t^J)\hat{K}_{t-1}^J\right]$ denotes investment in sector $J \in \{N, X\}$ (including utilization costs, $\Phi(u_t^J)$, defined below), $\hat{K}_t^J$ is the stock of capital, r_t^J is the gross rental rate of capital and u_t^J is the utilization rate of capital. B_t^R and B_t^{R*} are the stock of domestic and foreign bonds acquired in period t that pay non-state contingent gross returns r_t and r_t^*, respectively.

The household pays ad-valorem taxes on consumption (τ^C), labor income (τ^W) and capital income (τ^K). There are also lump-sum transfers TR_t^R and taxes T_t^R from/to the government, embedded in the term $\hat{\Sigma}_t$, which also collects profits from firms operating in sectors N, X and M, and (foreign currency) rents due to ownership of firms abroad (Ξ_t^{R*}, assumed to follow an exogenous AR(1) process).

Physical capital is sector-specific and evolves according to:

$$\hat{K}_t^J = (1-\delta)\hat{K}_{t-1}^J + \left[1 - \Gamma\left(\frac{\hat{I}_t^J}{\hat{I}_{t-1}^J}\right)\right]\hat{I}_t^J\xi_t^i \tag{7}$$

for $J \in \{N, X\}$, where δ is the capital depreciation rate, ξ_t^i is an exogenous AR(1) process affecting the marginal efficiency of investment, and the function $\Gamma(.)$ represents investment adjustment costs.[6]

The stock of capital services effectively used in production, K_t^J, $J \in \{N, X\}$, depends on the utilization rate of capital u_t^J, so that, after aggregation $K_t^J = (1-\omega)u_t^J\hat{K}_{t-1}^J$. Using capital

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[6] The functional form for the investment adjustment costs is given by

$$\Gamma\left(\frac{\hat{I}_t^J}{\hat{I}_{t-1}^J}\right) = \frac{\phi_k}{2}\left(\frac{\hat{I}_t^J}{\hat{I}_{t-1}^J} - a\right)^2,$$

where ϕ_k govern the elasticity and a is the long-run growth rate of the economy.

intensively (high u_t^J) induce higher maintenance costs, $\Phi(u_t^J)$, measured in units of capital.[7]

The interest rate paid on foreign bonds is given by $r_t^* = r_t^{W*} \cdot spr_t$, where r_t^{W*} is the risk-free world interest rate, and spr_t is a country-specific spread, composed by an endogenous component that depends on the economy-wide net foreign asset position, and two exogenous components, (ξ_t^{S*}) (assumed observable) and (ξ_t^{U*}) (interpreted as an unobservable "risk-premium" shock):

$$spr_t = \overline{spr} \cdot \exp\left[-\phi_b\left(\frac{S_t B_t^*}{P_t^Y Y_t} - \bar{b}\right) + \frac{\xi_t^{S*} - \xi^{S*}}{\xi^{S*}} + \frac{\xi_t^{U*} - \xi^{U*}}{\xi^{U*}}\right] \tag{8}$$

where $\overline{spr}$ is the steady state spread, $\left(\frac{S_t B_t^*}{P_t^Y Y_t}\right)$ is the domestic-currency debt-to-output ratio with steady state value $\bar{b}$, and ϕ_b govern the spread elasticity to deviations of the debt-to-output ratio. Here, the debt-elastic spread acts as the closing device to avoid a unit root in the net foreign asset position and induce stationarity in the small-open economy, as in Schmitt-Grohé and Uribe (2003). Variables r_t^{W*}, ξ_t^{S*} and ξ_t^{U*} follow exogenous AR(1) processes.

3.1.2 Non-Ricardian Households

There is a fraction ω of non-Ricardian ("hand-to-mouth") households. Non-Ricardians share the same preference structure as Ricardians, but they cannot borrow in financial markets, and they do not own capital or shares in domestic firms. They use labor income and government transfers TR_t^{NR} to consume the same CPI basket as Ricardians and to pay lump-sum taxes T_t^{NR}. The budget constraint can be written as:

$$(1+\tau^C)P_t C_t^{NR} = (1-\tau^W)\int_0^1 W_t(j)h_t^d(j)dj + TR_t^{NR} - T_t^{NR}. \tag{9}$$

3.2 Consumption Goods

Total consumption is given by the sum of Ricardian and non-Ricardian consumption weighted by their respective shares: $C_t = (1-\omega)C_t^R + \omega C_t^{NR}$. The consumption basket C_t is a CES composite of core consumption (C_t^Z), food consumption (C_t^F) and energy/oil consumption (C_t^O):

$$C_t = \left[(\gamma_Z)^{\frac{1}{\varrho_C}}\left(C_t^Z\right)^{\frac{\varrho_C - 1}{\varrho_C}} + (\gamma_F)^{\frac{1}{\varrho_C}}\left(C_t^F\right)^{\frac{\varrho_C - 1}{\varrho_C}} + (\gamma_O)^{\frac{1}{\varrho_C}}\left(C_t^O\right)^{\frac{\varrho_C - 1}{\varrho_C}}\right]^{\frac{\varrho_C}{\varrho_C - 1}} \tag{10}$$

where ϱ_C is the elasticity of substitution between goods, and $\gamma_Z = 1 - \gamma_F - \gamma_O$, γ_F and γ_O are the shares of each good, respectively. In turn, the core consumption good, C_t^Z, is produced using a

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[7] The functional form for maintenance costs follows García-Cicco et al. (2015):

$$\Phi(u_t^J) = \frac{r^J}{\phi_u}\left(e^{\phi_u(u_t^J - 1)} - 1\right)$$

where $\phi_u \equiv \Phi^{''}(1)/\Phi^{'}(1) > 0$ governs the elasticity of utilization costs, and r^J is the steady state rental rate in sector $J \in \{N, X\}$.

nested CES technology combining C_t^N, C_t^X, and , C_t^M:

$$C_t^Z = \left[(\gamma_N)^{\frac{1}{\varrho_Z}} \left(C_t^N\right)^{\frac{\varrho_Z - 1}{\varrho_Z}} + (\gamma_T)^{\frac{1}{\varrho_Z}} \left(C_t^T\right)^{\frac{\varrho_Z - 1}{\varrho_Z}} \right]^{\frac{\varrho_Z}{\varrho_Z - 1}} \tag{11}$$

$$C_t^T = \left[(\gamma_X)^{\frac{1}{\varrho_T}} \left(C_t^X\right)^{\frac{\varrho_T - 1}{\varrho_T}} + (\gamma_M)^{\frac{1}{\varrho_T}} \left(C_t^M\right)^{\frac{\varrho_T - 1}{\varrho_T}} \right]^{\frac{\varrho_T}{\varrho_T - 1}} \tag{12}$$

where $\gamma_T = 1 - \gamma_N$ and $\gamma_M = 1 - \gamma_X$ are the corresponding shares, and ϱ_Z and ϱ_T govern the elasticities of substitution across goods. In turn, the food basket C_t^F combines exportable C_t^{FX} and importable C_t^{FM} consumption goods:

$$C_t^F = z_t^F \left[(\gamma_{FX})^{\frac{1}{\varrho_F}} \left(C_t^{FX}\right)^{\frac{\varrho_F - 1}{\varrho_F}} + (\gamma_{FM})^{\frac{1}{\varrho_F}} \left(C_t^{FM}\right)^{\frac{\varrho_F - 1}{\varrho_F}} \right]^{\frac{\varrho_F}{\varrho_F - 1}} \tag{13}$$

where $\gamma_{FM} = 1 - \gamma_{FX}$ is the share of imported food consumption and ϱ_F govern the elasticity of substitution. The variable z_t^F is a disturbance aimed to allow for potentially high volatility in food prices. Consumption of energy/oil (C_t^O) is entirely imported at domestic currency price $P_t^O = S_t P_t^{O*}$ (law of one price), where P_t^{O*} is the foreign-currency oil price assumed to follow an exogenous AR(1) process.

On the other hand, each basket C_t^J with $J \in \{N, X, M, FX, FM\}$ is produced by competitive firms specialized in packing all varieties $i \in [0, 1]$ using a technology of the form:

$$C_t^J = \left[\int_0^1 C_t^J(i)^{\frac{\epsilon - 1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon - 1}} \tag{14}$$

where ϵ is the elasticity of substitution across varieties. These unique varieties $i \in [0, 1]$ are produced by monopolistically competitive firms, using labor, capital, intermediate inputs, and oil, and are subject to Calvo-type nominal price rigidities (see details below).

3.3 Investment Goods

Investment goods are produced by a set of competitive firms operating a similar CES technology as the one for core consumption goods, combining nontradables, exportable and importable baskets:

$$I_t^P = \left[(\gamma_I^N)^{\frac{1}{\varrho_I}} \left(I_t^N\right)^{\frac{\varrho_I - 1}{\varrho_I}} + (\gamma_I^X)^{\frac{1}{\varrho_I}} \left(I_t^X\right)^{\frac{\varrho_I - 1}{\varrho_I}} + (\gamma_I^M)^{\frac{1}{\varrho_I}} \left(I_t^M\right)^{\frac{\varrho_I - 1}{\varrho_I}} \right]^{\frac{\varrho_I}{\varrho_I - 1}} \tag{15}$$

where γ_I^N, γ_I^X and $\gamma_I^M = 1 - \gamma_I^N - \gamma_I^X$ are the weights and ϱ_I is the elasticity of substitution. In equilibrium, the investment supplied by these firms must equal the total investment flows demanded by Ricardian households $I_t^P = (1 - \omega)(I_t^{R,N} + I_t^{R,X})$.

The investment basket demanded by the commodity sector (more details below) is analogously produced by another set of competitive firms using a similar CES technology but with potentially different weights and elasticity of substitution across nontradable (N), exportable (X) and imported (M) components:

$$I_t^{Co} = \left[(\gamma_{ICo}^N)^{\frac{1}{\varrho_{ICo}}} \left(I_t^{NCo} \right)^{\frac{\varrho_{ICo}-1}{\varrho_{ICo}}} + (\gamma_{ICo}^X)^{\frac{1}{\varrho_{ICo}}} \left(I_t^{XCo} \right)^{\frac{\varrho_{ICo}-1}{\varrho_{ICo}}} + (\gamma_{ICo}^M)^{\frac{1}{\varrho_{ICo}}} \left(I_t^{MCo} \right)^{\frac{\varrho_{ICo}-1}{\varrho_{ICo}}} \right]^{\frac{\varrho_{ICo}}{\varrho_{ICo}-1}} \tag{16}$$

where γ_{ICo}^N, γ_{ICo}^X and $\gamma_{ICo}^M = 1 - \gamma_{ICo}^N - \gamma_{ICo}^X$ are the respective weights, and ϱ_{ICo} is the elasticity of substitution across N, X and M.

3.4 Wage Setting

In each sector $J \in \{N, X\}$, there is a continuum of labor markets indexed by $j \in [0, 1]$. In each labor market j, wages are set by a monopolistically competitive union, subject to a downward-sloping demand curve for labor varieties of the form:

$$h_t^d(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w} h_t^d \tag{17}$$

where $h_t^d(j)$ is hours worked and $W_t(j)$ is the nominal wage charged by the union in labor market j, with $h_t^d = \int_0^1 h_t^d(j)dj$ denoting the economy-wide labor demand, and

$$W_t \equiv \left[\int_0^1 (W_t(j))^{1-\epsilon_w} dj \right]^{\frac{1}{1-\epsilon_w}} \tag{18}$$

is the aggregate wage. In setting optimal wages $\tilde{W}_t(j)$, the union takes W_t and h_t^d as given, satisfy the demand $h_t^d(j) = h_t^N(j) + h_t^X(j)$ in all sub-markets $j \in [0, 1]$, and the resource constraint (5): $h_t = (1 - \omega)h_t^R + \omega h_t^{NR} = h_t^d$.

Each period, the union faces a probability $(1 - \theta_w)$ of re-optimizing its nominal wage. Because supply and demand technologies are the same $\forall j$, a fraction $(1 - \theta_w)$ chooses the same optimal wage $\tilde{W}_t$. Firms understand that after setting $\tilde{W}_t$, they will stick with that nominal level for s periods with probability $(\theta_w)^s$. When not reoptimizing, firms set their wages using a passive updater rule based on past and steady-state inflation rates.

3.5 Production in Sectors $J \in \{N, X\}$

Each sector $J \in \{N, X\}$ consists of a continuum of firms indexed by $i \in [0, 1]$ with a CES technology that combines value added $V_t^J(i)$, imported inputs $M_t^J(i)$, and oil $O_t^J(i)$ to produce gross output $Y_t^J(i)$ as follows:

$$Y_t^J(i) = z_t^J \left[(\gamma_V^J)^{\frac{1}{\varrho^J}} \left(V_t^J(i) \right)^{\frac{\varrho^J-1}{\varrho^J}} + (\gamma_M^J)^{\frac{1}{\varrho^J}} \left(M_t^J(i) \right)^{\frac{\varrho^J-1}{\varrho^J}} + (\gamma_O^J)^{\frac{1}{\varrho^J}} \left(O_t^J(i) \right)^{\frac{\varrho^J-1}{\varrho^J}} \right]^{\frac{\varrho^J}{\varrho^J-1}} \tag{19}$$

where γ_V^J, γ_M^J and $\gamma_O^J = 1 - \gamma_V^J - \gamma_M^J$ are the respective weights, ϱ^J is the elasticity of substitution across goods, z_t^J is a sector-specific productivity term following a stationary AR(1) process, and $M_t^J(i)$ is a composite of the continuum of importable varieties available in the economy (more details below).

In turn, firm's i value added is produced using a Cobb-Douglas technology combining physical capital $\tilde{K}_t^J(i)$ and labor $h_t^J(i)$, as follows:

$$V_t^J(i) = \left[\tilde{K}_t^J(i)\right]^{\alpha^J} \left[A_t^J h_t^J(i)\right]^{1-\alpha^J} \tag{20}$$

where α^J is the capital share, A_t^J is a (labor-augmenting) non-stationary stochastic trend in productivity, with growth rate given by $a_t^J \equiv \frac{A_t^J}{A_{t-1}^J}$. To maintain a balanced growth path, we assume sectoral productivity trends A_t^J cointegrate with the global productivity trend A_t, so that, for each $J \in \{N, X\}$:

$$A_t^J = \left(aA_{t-1}^J\right)^{1-\Gamma^J} \left(A_t\right)^{\Gamma^J} \tag{21}$$

where Γ^J govern the speed of adjustment to the common trend.

Physical capital used in production is a CES composite of private capital $K_t^J(i)$ rented from Ricardian households and public capital K_t^G accumulated by the government (more details below), as follows:

$$\tilde{K}_t^J(i) = \left[(1-\gamma_G)^{\frac{1}{\varrho_G}} \left(K_t^J(i)\right)^{\frac{\varrho_G-1}{\varrho_G}} + (\gamma_G)^{\frac{1}{\varrho_G}} \left(K_{t-1}^G\right)^{\frac{\varrho_G-1}{\varrho_G}}\right]^{\frac{\varrho_G}{\varrho_G-1}} \tag{22}$$

where γ_G is the share of public infrastructure in total capital and ϱ_G is the elasticity of substitution between both types of capital.

Firms have monopolistic power over their respective variety $i \in [0, 1]$, set prices à la Calvo, and choose inputs to minimize costs.

3.6 Production in Sector M

Sector M consists of a continuum of firms indexed by $i \in [0, 1]$ with a simple technology to transform an *homogeneous* imported input $M_t(i)$ into a *differentiated* variety $Y_t^M(i)$ as follows:

$$Y_t^M(i) = M_t(i) \tag{23}$$

The price of the homogeneous imported input is given by $P_{m.t}$. By the law of one price $P_{m,t} = S_t P_t^{M*}$, where P_t^{M*} is the foreign-currency price of imported goods and follows an AR(1) process. Cost minimization implies that the input price equals the firms' marginal cost $P_{m.t} = MC_t^M$. Note the difference between the price of the imported input $P_{m,t}$ and the average price set by the importable sector $P_t^M = \left[\int_0^1 \left(P_t^M(i)\right)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$.

3.7 Price Setting in Sectors $J \in \{N, X, M\}$

Firms in each sector $J \in \{N, X, M\}$ have monopolistic power over their respective variety $i \in [0, 1]$ and set prices à la Calvo (1983). Each period, firms face a probability $(1 - \theta^J)$ of re-optimizing its nominal price $\tilde{P}_t^J(i)$ to maximize expected profits, taking the demand for its variety and marginal costs as given. With probability θ^J firms cannot choose prices optimally and use a passive price updater which depends on a weighted average of lagged CPI inflation and the Central Bank's inflation target π, with weights ζ^J: $\left[(\pi_{t-1})^{\zeta^J} (\pi)^{1-\zeta^J}\right]$. This standard setup gives rise to traditional New Keynesian Phillips curves describing the relationship between current inflation and marginal costs, adjusted by past and expected future inflation.

3.8 Commodity Good Co

The Commodity good is produced by a representative firm using a Cobb-Douglas technology combining physical capital $\tilde{K}_t^{Co}$ and a fixed supply of natural resources, $\overline{L}$, which is subject to a long-run technology trend A_t^{Co}:

$$Y_t^{Co} = z_t^{Co}\big(\tilde{K}_t^{Co}\big)^{\alpha_{Co}}\big(A_t^{Co}\overline{L}\big)^{1-\alpha_{Co}} \tag{24}$$

where α_{Co} is the capital share and z_t^{Co} is a stationary productivity term following an AR(1) process. Because commodity production is very capital-intensive, we abstract here from labor inputs. Analogous to sectors N and X, the capital used in production is a CES composite between private capital K_t^{Co} and public capital K_t^G as follows:

$$\tilde{K}_t^{Co} = \left[(1-\gamma_G)^{\frac{1}{\varrho_G}}\left(K_t^{Co}\right)^{\frac{\varrho_G-1}{\varrho_G}} + (\gamma_G)^{\frac{1}{\varrho_G}}\left(K_{t-1}^{G}\right)^{\frac{\varrho_G-1}{\varrho_G}}\right]^{\frac{\varrho_G}{\varrho_G-1}} \tag{25}$$

where γ_G and ϱ_G govern the share of public infrastructure and the elasticity of substitution between private and public capital. Unlike in sectors N and X, the representative commodity firm accumulates its own capital with law of motion given by:

$$\hat{K}_t^{Co} = (1-\delta_{Co})\hat{K}_{t-1}^{Co} + \left[1-\Gamma\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}}\right)\right]\hat{I}_t^{Co}\xi_t^{iCo} \tag{26}$$

where δ_{Co} is the capital depreciation rate, $\hat{I}_t^{Co}$ is commodity investment, ξ_t^{iCo} is an exogenous shock to the marginal efficiency of commodity investment, and $\Gamma(.)$ are standard adjustment costs.[8] As in sectors N and X, there is variable capital utilization rate u_t^{Co}, so that, the effective capital used in the production of the commodity good is given by $K_t^{Co} = u_t^{Co}\hat{K}_{t-1}^{Co}$.[9]

The firm chooses $\{Y_t^{Co}, \hat{K}_t^{Co}, \hat{I}_t^{Co}, u_t^{Co}\}$ to maximize the commodity cash flow, given by:

$$CF_t^{Co} = (1-\tau^{Co})P_t^{Co}Y_t^{Co} - P_t^{ICo}[\hat{I}_t^{Co} + \Phi(u_t^{Co})\hat{K}_{t-1}^{Co}] \tag{29}$$

where τ^{Co} is the corporate tax rate, P_t^{ICo} is the price of commodity investment, and P_t^{Co} is the domestic-currency price of the commodity good. By the law of one price, $P_t^{Co} = S_t P_t^{Co*}$, where

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[8] The functional form of adjustment costs is quadratic:

$$\Gamma\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}}\right) = \frac{\phi_k^{Co}}{2}\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}} - a\right)^2. \tag{27}$$

where ϕ_k^{Co} is the elasticity parameter.

[9] As before, utilization rate u_t^{Co} induces maintenance costs $\Phi(u_t^{Co})$, with increasing and convex functional form

$$\Phi(u_t^{Co}) = \frac{\tilde{r}^{Co}}{\phi_u^{Co}}\left(e^{\phi_u^{Co}(u_t^{Co}-1)} - 1\right) \tag{28}$$

where $\tilde{r}^{Co}$ is the steady state rental rate of capital in the commodity sector and ϕ_u^{Co} is the elasticity parameter.

P_t^{Co*} is the foreign-currency price following an exogenous AR(1) process.

3.9 Fiscal Policy

The government follows a fiscal rule intended to isolate fiscal spending from cyclical fluctuations in government income. Total government spending G_t includes consumption of final goods C_t^G, government investment I_t^G, and lump-sum transfers to households TR_t^G. Fiscal income includes tax revenues Π_t^τ and a share $\gamma^{Co} \in [0,1]$ of the commodity sector cash flow CF_t^{Co} (see equation (29)). Defining the fiscal surplus as $s_t^G = \Pi_t^\tau + \gamma^{Co} CF_t^{Co} - G_t$, the government budget can be written as follows:

$$B_t^{GT} \equiv S_t B_t^{G*} = S_t r_{t-1}^* B_{t-1}^{G*} + s_t^G, \tag{30}$$

where B_t^{GT} and B_t^{G*} denote the government net foreign asset position in pesos and dollars, respectively. Tax revenues include consumption (VAT), labor and capital taxes, and taxation on the private share of commodity profits.[10] Public capital K_t^G evolves according to a standard law of motion $K_t^G = (1-\delta_G)K_{t-1}^G + I_t^G$.

The structural fiscal rule is modeled as a spending rule that, on average, runs a fiscal surplus and accumulates assets when fiscal revenues (either tax revenues or commodity revenues) are "higher-than-normal" while running deficits and accumulating debt in bad times when revenues are "lower-than-normal." The desired spending under the rule, $\tilde{G}_t$, can be written as the sum of interest payments, current revenues, and a cyclical adjustment, as follows:

$$\begin{aligned}\tilde{G}_t = {} & \underbrace{S_t(r_{t-1}^* - 1)B_{t-1}^{G*}}_{\text{interest payments}} + \underbrace{(\Pi_t^\tau + \gamma^{Co} CF_t^{Co})}_{\text{current revenues}} \\ & + \underbrace{\kappa\left[(\tilde{\Pi}_t^\tau - \Pi_t^\tau) + \gamma^{Co}(\tilde{CF}_t^{Co} - CF_t^{Co})\right]}_{\text{cyclical adjustment}} + \underbrace{\kappa^B(B_{t-1}^{GT} - B^{GT})}_{\text{feasibility constraint}} \end{aligned} \tag{31}$$

where $\tilde{\Pi}_t^\tau$ and $\tilde{CF}_t^{Co}$ are fiscal revenues in "normal" times,[11], κ is the feedback parameter that determines the cyclical stance of the fiscal rule, and $\kappa^B > 0$ aims to limit large deviations of the government's net foreign asset position relative to its long-run value, thereby effectively imposing a "debt limit" to implement the rule. When $\kappa = 1$, the fiscal rule is **acyclical**.[12] In turn, values of $\kappa < 1$ imply **procyclical** rules.[13] Analogously, values of $\kappa > 1$ imply increasingly **countercyclical**

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[10] More specifically:

$$\Pi_t^\tau = \tau^C P_t C_t + \tau^W W_t h_t + \tau^{Co}\Pi_t^{Co} + (1-\omega)\tau^K \sum_{J\in\{N,X\}} \left(P_t^J r_t^J u_t^J - P_t^I(\delta + \Phi(u_t^J))\right)\hat{K}_{t-1}^J + T_t^G,$$

where T_t^G are lump-sum taxes.

[11] Long-run or "normal" tax revenues are given by the steady state of tax revenues ($\tilde{\Pi}_t^\tau = \Pi^\tau$). In turn, the long-run commodity cash flow is given by equation (29) evaluated at the long-run commodity price, which is defined as the expected 10-year average of the effective commodity price.

[12] To see this, note that if $\kappa = 1$ (and $\kappa^B = 0$), equation (31) becomes: $\tilde{G}_t = S_t(r_{t-1}^* - 1)B_{t-1}^{G*} + \tilde{\Pi}_t^\tau + \gamma^{Co}\tilde{CF}_t^{Co}$, that is, the government should spend only its *long-run* or structural revenues (plus interests).

[13] For instance, in the illustrative case when $\kappa = 0$ (and $\kappa^B = 0$), equation (31) now becomes: $\tilde{G}_t = S_t(r_{t-1}^* - 1)B_{t-1}^{G*} + \Pi_t^\tau + \gamma^{Co} CF_t^{Co}$, that is, each period the government spends its *current* revenues (plus interests). $\kappa = 0$ is

spending rules.

We allow for a generalized version of the rule in which the government may have a different cyclical stance regarding the tax revenue gap (with feedback parameter κ^{τ}) versus the commodity revenue gap (κ^{Co}), as follows:

$$\begin{aligned}\tilde{G}_t &= S_t(r^*_{t-1}-1)B^{G*}_{t-1} + (\Pi^{\tau}_t + \gamma^{Co} CF^{Co}_t) \\ &\quad + \kappa^{\tau}(\tilde{\Pi}^{\tau}_t - \Pi^{\tau}_t) + \kappa^{Co}\gamma^{Co}(\tilde{CF}^{Co}_t - CF^{Co}_t) + \kappa^{B}(B^{GT}_{t-1} - B^{GT}).\end{aligned} \tag{32}$$

The expenditure components C^G_t, I^G_t and TR^G_t are assumed to be time-varying shares of total desired expenditures, with α^{CG}, α^{IG} and $(1-\alpha^{CG}-\alpha^{IG})$ denoting the long-run shares and ξ^{CG}_t, ξ^{IG}_t and ξ^{TR}_t representing (unit-mean) exogenous disturbances to those shares, and following independent AR(1) processes. On the other hand, analogous to the private consumption and investment baskets, government consumption and investment goods are produced using CES technologies combining nontradable and exportable goods:

$$C^G_t = \left[(\gamma_{CG})^{\frac{1}{\varrho_{CG}}}\left(C^{GN}_t\right)^{\frac{\varrho_{CG}-1}{\varrho_{CG}}} + (1-\gamma_{CG})^{\frac{1}{\varrho_{CG}}}\left(C^{GX}_t\right)^{\frac{\varrho_{CG}-1}{\varrho_{CG}}}\right]^{\frac{\varrho_{CG}}{\varrho_{CG}-1}} \tag{33}$$

$$I^G_t = \left[(\gamma_{IG})^{\frac{1}{\varrho_{IG}}}\left(I^{GN}_t\right)^{\frac{\varrho_{IG}-1}{\varrho_{IG}}} + (1-\gamma_{IG})^{\frac{1}{\varrho_{IG}}}\left(I^{GX}_t\right)^{\frac{\varrho_{IG}-1}{\varrho_{IG}}}\right]^{\frac{\varrho_{IG}}{\varrho_{IG}-1}} \tag{34}$$

where γ_{CG} and γ_{IG} control the share of the N good in each basket, while ϱ_{CG} and ϱ_{IG} are the elasticities of substitution between N and X goods, respectively.

Finally, lump-sum taxes T^G_t are assumed to be a constant share α^T of nominal GDP, that is, $T^G_t = \alpha^T P^Y_t Y_t$. These taxes are levied from non-Ricardian and Ricardian households in constant proportions ω^T and $(1-\omega^T)$. Analogously, lump-sum government transfers TR^G_t are assigned to households in constant proportions ω^{TR} and $(1-\omega^{TR})$.

3.10 Monetary Policy

Monetary policy follows a standard Taylor rule of the form:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_R}\left[\left(\frac{\pi^Z_t}{\pi}\right)^{\alpha_\pi}\left(\frac{Y_t}{aY_{t-1}}\right)^{\alpha_y}\right]^{(1-\rho_R)}\xi^m_t \tag{35}$$

with $\rho_R \in (0,1)$, $\alpha_y \geq 0$, $\alpha_\pi > 1$, and where $\pi^Z_t = \frac{P^Z_t}{P^Z_{t-1}}$ and $\pi_t = \frac{P_t}{P_{t-1}}$ are core and headline inflation (with positive steady state value π), and $\frac{Y_t}{Y_{t-1}}$ is the growth rate of real GDP (defined below), with long-run steady state growth a, and ξ^m_t is a random AR(1) shock.

3.11 Rest of the World

The rest of the world buys a bundle of the continuum of exportable varieties produced by the small open economy. The total foreign demand for the domestic exportable good C^{X*}_t depends on the

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equivalent to what in the literature is called the ”balanced budget rule (BBR).”

relative foreign-currency price set by domestic producers $\left(\frac{P_t^{X*}}{P_t^*}\right)$, the rest of the world economic output (Y_t^*), and an i.i.d. demand shock for local exportable goods ξ_t^{X*}, as follows:

$$C_t^{X*} = \left[a_{t-1}C_{t-1}^{X*}\right]^{\rho^{X*}} \left[\left(\frac{P_t^{X*}}{P_t^*}\right)^{-\epsilon^*} Y_t^*\right]^{1-\rho^{X*}} \xi_t^{X*} \tag{36}$$

where ϵ^* is the price elasticity, ρ^{X*} is a parameter inducing persistence, and P_t^* is the worldwide price level. Foreign output evolves according to $Y_t^* = A_t z_t^*$, where A_t is the global productivity trend, $a_t = \frac{A_t}{A_{t-1}}$ is the growth of the trend (following an AR(1) process), and z_t^* is a productivity shock following an AR(1) process. Foreign inflation $\pi_t^* = \frac{P_t^*}{P_{t-1}^*}$ follows an AR(1) as well.

Finally, we define the real exchange rate as $rer_t = \frac{S_t P_t^*}{P_t}$ (increase means depreciation), so that, the nominal devaluation rate $\pi_t^S = \frac{S_t}{S_{t-1}}$ satisfies $\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}$.

3.12 Aggregation and Market Clearing

The model is closed by a series of aggregating equations and market-clearing conditions. In particular, the goods markets in sectors N, X, and M, as well as the labor market clear in equilibrium. The balance of payments equation can be written as follows:

$$S_t B_t^* = S_t r_{t-1}^* B_{t-1}^* + TB_t + REN_t \tag{37}$$

where the following definitions for the trade balance TB_t, nominal exports XN_t, nominal imports MN_t, and rents payments REN_t, all in domestic currency terms, apply:

$$TB_t = XN_t - MN_t \tag{38}$$

$$XN_t = P_t^X C_t^{X*} + P_t^{Co} Y_t^{Co} \tag{39}$$

$$MN_t = P_{m,t} M_t + P_t^O (C_t^O + O_t^N + O_t^X) \tag{40}$$

$$REN_t = S_t \xi_t^{R*} A_{t-1} - (1-\gamma^{Co}) CF_t^{Co} \tag{41}$$

where ξ_t^{R*} is an exogenous shock to private rents following an AR(1) process.

3.13 Exogenous Processes

Let z_t be the vector of exogenous processes in the model:

$$z_t = \{a_t, z_t^N, z_t^X, z_t^{Co}, z^F, \xi_t^O, \xi_t^i, \xi_t^{iCo}, \xi_t^\beta, \xi_t^h, \xi_t^m, \xi_t^{CG}, \xi_t^{IG}, \xi_t^{TR}, \\ \xi_t^{S*}, \xi_t^{U*}, \xi_t^{R*}, z_t^*, \pi_t^*, p_t^{M*}, p_t^{O*}, p_t^{Co*}, \xi_t^{X*}, r_t^{W*}\}$$

Each element of z_t follows an independent AR(1) process given by:

$$z_t = (1-\rho_z)z + \rho_z z_{t-1} + \sigma_z \varepsilon_{z,t} \tag{42}$$

with $\rho_z \in (0,1)$, $\sigma_z > 0$, $\varepsilon_{z,t} \sim N(0,1)$.

4 Parameterization and Model Fit

The calibration strategy includes three sets of parameters. Firstly, we include a set of standard parameters drawn from prior literature or determined to align with the sample averages observed in the data. Secondly, we use a set of parameters internally calibrated within the steady state algorithm to ensure alignment with crucial macroeconomic and sectoral targets. Finally, the remaining parameters encompassing those governing the fiscal rule and are estimated using Bayesian methods. All data moments targeted in the calibration are averages over the period 1996-2019. Appendix A contains a detailed discussion of the calibrated and estimated parameters.

In this section, we highlight the results obtained for the feedback parameters determining the cyclical stance of the Chilean fiscal policy rule and the feasibility constraint in the last two decades. Panels (a) and (b) of Table 1 present the estimated fiscal rule parameters for equations (31) and (32), respectively, under four different model assumptions: (i) the baseline including government consumption in the utility function ("c^G in U") and government capital in production ("k^G in Y"), (ii) the baseline without c^G in U ($\gamma = 0$ in equation (2)), (iii) the baseline without k^G in Y ($\gamma_G = 0$ in equation (22)), and (iv) the baseline without k^G in Y and c^G in U. As detailed in Appendix A, the government-related observable variables used to inform the model estimation are the three types of fiscal expenditures (consumption, investment, and transfers) and the government's net debt-to-GDP ratio.

The results show that in the last two decades, Chilean authorities have closely followed the acyclical mandate ($\kappa = 1$) introduced in 2001 and institutionalized under the "Fiscal Responsibility Act" in 2006. Panel (a) shows that the policy parameter is estimated at $\kappa \in [0.95, 0.97]$ depending on model assumptions. In the more flexible rule with revenue-specific feedback (Panel (b)), we find that government spending has been mildly countercyclical concerning the tax revenue gap ($\kappa^\tau \in [1.08, 1.17]$) and mildly procyclical regarding the commodity revenue gap ($\kappa^{Co} \in [0.87, 0.89]$). On the other hand, the feedback parameter concerning public debt is tightly estimated at $\kappa^B = 0.19$, a value we kept fixed across all quantitative experiments below.

Table 1: Estimated Fiscal Rule

Models	κ			κ^B		
a) Single parameter	mean	5^{th} pctl.	95^{th} pctl.	mean	5^{th} pctl.	95^{th} pctl.
Baseline	**0.95**	0.72	1.17	**0.19**	0.12	0.26
Baseline, No c^G in U	**0.96**	0.70	1.19	**0.19**	0.12	0.26
Baseline, No k^G in Y	**0.96**	0.74	1.21	**0.19**	0.11	0.26
Baseline, No c^G in U, No k^G in Y	**0.97**	0.75	1.18	**0.19**	0.11	0.27

	κ^τ			κ^{Co}			κ^B		
b) Double parameter	mean	5^{th} pctl.	95^{th} pctl.	mean	5^{th} pctl.	95^{th} pctl.	mean	5^{th} pctl.	95^{th} pctl.
Baseline	**1.09**	0.75	1.47	**0.89**	0.63	1.17	**0.19**	0.11	0.26
Baseline, No c^G in U	**1.08**	0.71	1.46	**0.89**	0.63	1.16	**0.19**	0.12	0.26
Baseline, No k^G in Y	**1.17**	0.77	1.54	**0.89**	0.66	1.17	**0.19**	0.11	0.25
Baseline, No c^G in U, No k^G in Y	**1.14**	0.75	1.51	**0.87**	0.59	1.14	**0.19**	0.11	0.26

Notes: The table shows posterior distributions obtained from a random walk Metropolis Hasting chain with 100,000 draws after a burn-in of 50,000 draws. The estimation sample is 1996q2-2019q3. The prior used for κ, κ^τ, and κ^{Co} is a gamma distribution with a mean of 1 and a standard deviation of 0.25. The prior used for κ^B is a gamma distribution with a mean of 0.5 and a standard deviation of 0.25.

Table 2 illustrates the model's ability to replicate second moments observed in the data, including the standard deviation, the correlation with (non-commodity) GDP, and the first-order autocorrelations for key macroeconomic variables. The model does a good job of matching the unconditional volatilities of most variables, except for labor market aggregates, which are overestimated, and the trade balance and current account ratios to GDP, which are slightly underestimated.

Table 2: Second Moments

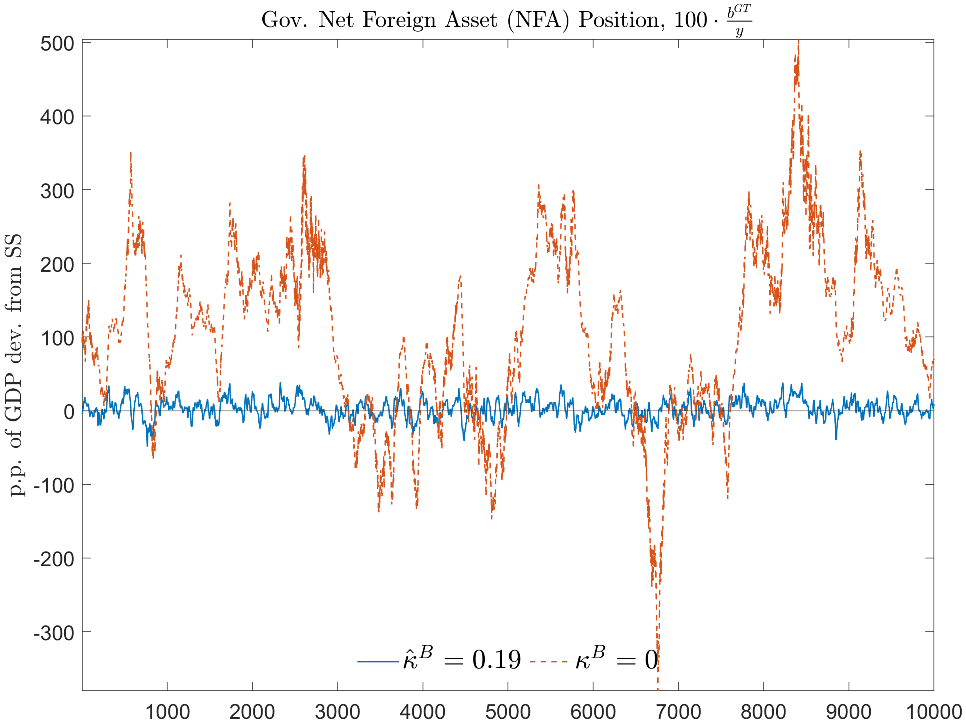
		100*s.d.(x_t)		corr(x_t, $\Delta \log y^{NCo}$)		corr(x_t, x_{t-1})	
x_t	Description	data	model	data	model	data	model
$\Delta \log y$	GDP growth	1.01	1.19	0.87	0.91	0.25	0.18
$\Delta \log y^R$	Non-commodity GDP growth	1.06	1.26	1.00	1.00	0.46	0.21
$\Delta \log y^{Co}$	Commodity GDP growth	3.33	3.17	0.00	0.03	0.02	-0.04
$\Delta \log y^X$	Exportable GDP growth	1.94	1.97	0.73	0.71	0.00	-0.09
$\Delta \log y^N$	Non-tradable GDP growth	1.03	1.30	0.94	0.84	0.52	0.38
$\Delta \log c$	Private consumption growth	1.01	1.09	0.72	0.58	0.35	0.34
$\Delta \log i$	Total investment growth	3.75	3.21	0.68	0.56	0.33	0.57
$\Delta \log i^{Co}$	Commodity investment growth	7.66	7.97	0.31	0.22	0.38	0.54
tb/y	Nom. trade balance/GDP	5.41	3.54	0.37	0.04	0.79	0.89
ca/y	Nom. current account/GDP	4.11	2.91	0.29	0.15	0.63	0.88
$\Delta \log h$	Hours growth	0.84	1.91	0.49	0.61	0.21	0.00
$\Delta \log w$	Real wage growth	0.48	0.55	0.03	0.07	0.44	0.61
$\Delta \log c^G$	Gov. consumption growth	2.40	2.34	0.06	0.18	-0.29	-0.10
$\Delta \log i^G$	Gov. investment growth	10.97	9.07	0.06	0.37	-0.45	-0.37
$\Delta \log tr^G$	Gov. social transfers growth	3.45	3.71	0.04	0.09	-0.37	-0.06
b^{GT}/y	Total public assets/GDP	6.84	11.34	-0.00	-0.05	0.988	0.995
π	Headline inflation	0.62	0.69	0.09	-0.14	0.56	0.56
π^Z	Core inflation	0.53	0.49	-0.26	-0.07	0.80	0.77
π^F	Food inflation	2.12	2.20	0.22	-0.17	0.37	0.16
π^E	Energy inflation	3.44	3.52	0.21	0.04	0.14	0.24
R	Nominal interest rate	0.48	0.57	-0.21	-0.20	0.92	0.92
spr	Spread	0.20	0.25	-0.52	-0.08	0.82	0.89
rer	Real exchange rate	7.71	7.87	0.02	-0.09	0.90	0.88
π^S	Nominal devaluation rate	4.59	5.21	-0.20	-0.00	0.23	-0.04

Notes: The table presents three statistics for a set of observable variables: the standard deviation (percent), the cross-correlation with (non-commodity) GDP, and the first-order autocorrelation.

The model also overestimates the standard deviation of the government's net foreign asset position-to-GDP ratio (12% vs. 7%), but this is still a significant improvement relative to other papers in the literature which do not discipline this moment by using data on government debt and incorporating a feasibility constraint ($\kappa^B > 0$) in the fiscal rule. In fact, shutting off the feasibility constraint ($\kappa^B = 0$) produces a counterfactual volatility of 120% in the public debt to GDP ratio, one order of magnitude above the data moment, with an autocorrelation of 0.9999, indistinguishable from a unit-root process. Instead, activating the feasibility constraint at its estimated value reduces the autocorrelation to 0.995, closer to the data value of 0.988, thus helping the model generate credible variation in public debt (see Table 2).

To illustrate the key role of the feasibility constraint in reconciling the model dynamics with the data, Figure 2 displays a sample simulation of the government's NFA from the model with and without the feasibility constraint. The simulation under $\kappa^B = 0$ is indistinguishable from a unit-root process, with public debt wandering around unsustainable values that can reach several annual GDPs, and for unfeasible long periods of time. In contrast, under the estimated coefficient $\hat{\kappa}^B = 0.19$, public debt fluctuates between minus/plus one-half GDP, consistent with the time series observed in the data.

Figure 2: The Impact of the Feasibility Constraint on the Government's NFA Position



Notes: The figure shows the public net foreign asset positions (NFA, % of GDP) under a neutral acyclical policy ($\kappa^\tau = \kappa^{Co} = 1$) from two simulations of the model, which only differ in the coefficient of the fiscal rule's feasibility constraint: the solid-blue line uses the estimated value $\hat{\kappa}^B = 0.19$, while the dashed-orange line shuts-off the feasibility constraint $\kappa^B = 0$. Both simulations are subjected to the same sequence of random shocks.

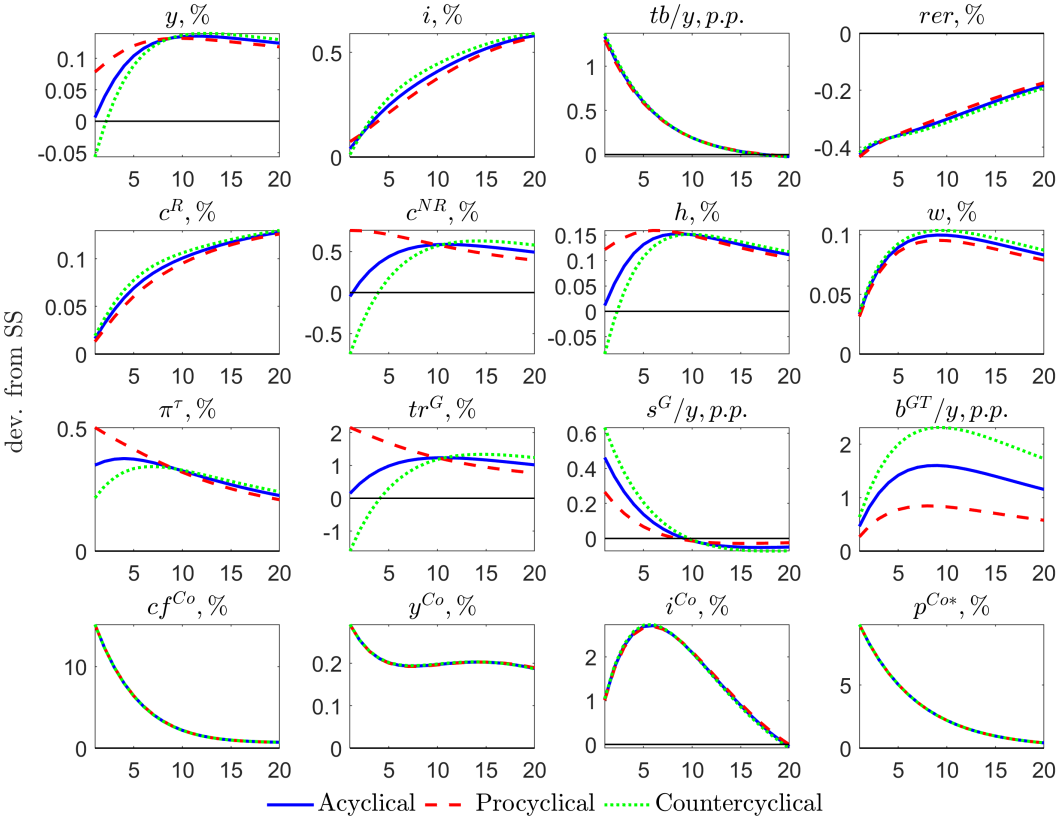
5 Model Dynamics

5.1 Commodity Price Shock under Alternative Fiscal Rules

The Chilean economy's commodity dependence manifests at least in three dimensions. First, mining goods, on average (2001-2019), account for 14% of total GDP, fluctuating widely between a minimum of 7% in 2001 and a maximum of 24% in 2006. Second, mining exports represent an average of 53% of total goods exports, ranging from 40% in 2002 to 62% in 2007. Third, a substantial and volatile fraction of government revenues come directly from a state-owned commodity-producing company, fluctuating between 2% of total revenues in, for instance, the years 2001 or 2019 and reaching record highs of 21% of total revenues in 2006. Because commodity prices are determined in international markets, national, external, and fiscal accounts depend heavily on exogenously driven commodity price cycles.

To illustrate this dependence on commodity (copper) prices, Figure 3 shows the effects of a 10% (one s.d.) positive shock to the price of the exported commodity (p^{Co*}) under three alternative economies regarding the cyclical stance of the fiscal rule: (a) a structural budget **acyclical** rule ($\kappa^{\tau} = \kappa^{Co} = 1$), (b) a **procyclical** balanced budget rule ($\kappa^{\tau} = \kappa^{Co} = 0$), and (c) a **countercyclical** fiscal rule ($\kappa^{\tau} = \kappa^{Co} = 2$). On the supply side, the favorable commodity price shock (p^{Co*}) protractedly stimulate real output (y) with a peak effect of more than 0.1% two and a half years (10 quarters) after the shock, consistent with the considerable persistence estimated for the exported commodity price ($\rho_{p^{Co*}} = 0.85$, see Table 9 in Appendix A). As expected, during the first couple of years, output rises more under a procyclical rule, although the effect of additional government spending on output dissipates in the medium run.

Figure 3: Responses to a Positive One S.D. (10%) commodity Price Shock



Notes: This figure illustrates the equilibrium dynamics of the model in response to a positive commodity price shock under three alternative fiscal policy rules: acyclical ($\kappa^{\tau} = \kappa^{Co} = 1$), procyclical ($\kappa^{\tau} = \kappa^{Co} = 0$), and countercyclical ($\kappa^{\tau} = \kappa^{Co} = 2$). Most variables are in percent (%) deviation from the steady state, except for the trade balance tb/y, fiscal surplus s^G/y, and the government's net foreign asset position b^{GT}/y, which are in percentage points (p.p.) of GDP deviation from steady state.

On the demand side of the economy, the shock generates wealth and substitution effects consistent with an increase in consumption and capital formation, especially investment in the commodity sector (i^{Co}). Consumption by Ricardian households (c^R) increases over time, regardless of the fiscal policy rule. Instead, non-Ricardian consumption (c^{NR}) largely depends on the cyclical stance of fiscal policy. If the fiscal rule is procyclical, non-Ricardian consumption increases by about 0.8% on impact as these consumers enjoy a booming economy (higher hours worked and wages), and procyclical government transfers (tr^G) that increase by more than 2%. In contrast, when the fiscal rule is countercyclical, a 1% fall in government transfers offsets the above-normal wage (w), leading to a reduction of consumers' income and a subsequent 0.5% fall in consumption (c^{NR}). On the other hand, given its large share in total exports, the commodity shock significantly improves the trade balance (tb/y), which rises by 1.3 percentage points (p.p.) of GDP at impact, regardless of the fiscal rule in place. Consistent with the windfall shock and its implied positive wealth effect, the economy faces a 0.4% real exchange rate (rer) appreciation that persists for several years.

The fiscal accounts are significantly impacted by the commodity shock, as approximately one-third of the commodity cash flow accrues to the government, while the remaining portion is received by foreign investors. Commodity-related revenues (cf^{Co}) experience a large increase of 14% at impact, regardless of the fiscal rule in place. In turn, tax revenues (π^τ) rise between 0.25% and 0.5% depending on whether the fiscal rule is countercyclical or procyclical. Accordingly, the fiscal surplus (s^G/y) rises between 0.2 (procyclical) and 0.6 (countercyclical) p.p. of GDP, thus protractedly improving the government's net foreign asset position (b^{GT}/y). Government transfers (tr^G) increase more than 2% under a procyclical rule while decreasing around 1% under a countercyclical approach. Under a neutral acyclical rule, social transfers still increase over time as the commodity boom raises structural spending via the interest payments on the improved net foreign asset position.

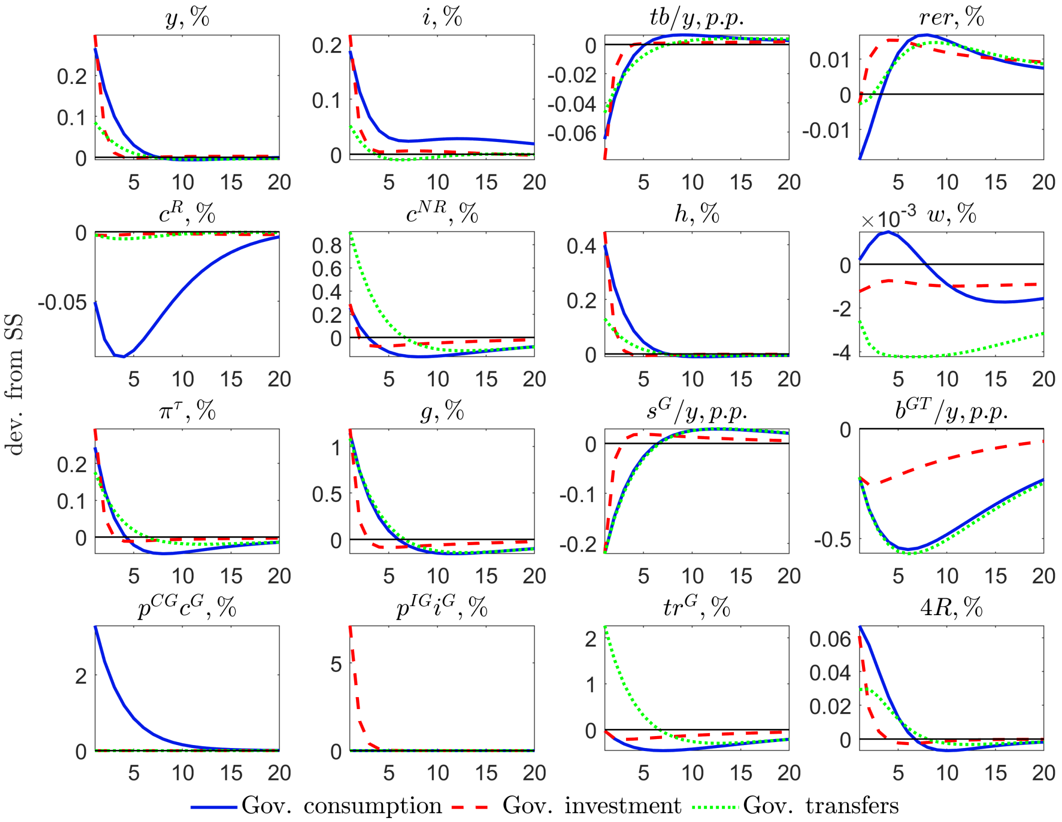
5.2 Government Spending Shocks

In this subsection, we study the model's dynamic response to three types of fiscal spending shocks: (a) government consumption, investment, and lump-sum transfers. Notice that in the baseline model, government consumption enters the utility function, and according to our Bayesian estimation results, it enters as a (mild) complement to private consumption (posterior mean elasticity of substitution $\varrho = 0.84$). Similarly, government capital is a public good, entering all sectoral production functions complementing private capital (calibrated $\varrho_G = 0.6$). For this exercise, we set government transfers as the only fiscal instrument to satisfy the rule, which for this exercise, we fix to be the acyclical benchmark ($\kappa^\tau = \kappa^{Co} = 1$).

Figure 4 presents responses to the three shocks normalized to generate the same change in the fiscal deficit-to-GDP ratio at impact, and allowing for heterogeneous persistence (according to our estimation results) after that. In particular, we fix the government investment shock ($p^{IG}i^G$) to one s.d. and re-scale the consumption ($p^{CG}c^G$) and transfer (tr^G) shocks to produce the same -0.2 p.p. of GDP increase in the fiscal deficit (s^G/y).

While all spending shocks are expansionary, government investment displays the largest fiscal multiplier with an impact effect of 0.3% on real output (y) and 0.2% on real investment (i). In contrast, government transfers display the lowest multiplier, raising output by less than 0.1% and investment by 0.05% at impact. In our calibration, a fraction $\omega^{TR} = 0.5$ of total transfers pertain to Ricardian households ("savers"), thereby dampening their impact on aggregate demand. The transfer shock significantly affects non-Ricardian consumption (c^{NR}), while Ricardian households (c^R) almost entirely smooth out the government subsidy. Finally, all fiscal expenditure shocks are mildly inflationary (not reported), eliciting a rise in the monetary policy interest rate ($4R$) and making all these shocks relatively short-lived.

Figure 4: Responses to Normalized Government Spending Shocks



Notes: This figure illustrates the equilibrium dynamics of the model in response to different positive exogenous government spending shocks: consumption, investment, and social transfers. The three shocks are normalized to generate the same change in the fiscal deficit-to-GDP ratio at impact. We fix the government investment shock to one s.d. and then re-scale the consumption and transfer shocks accordingly. Most variables are in percent (%) deviation from the steady state, except for the trade balance tb/y, fiscal surplus s^G/y, and the government's net foreign asset position b^{GT}/y, which are in percentage points (p.p.) of GDP deviation from steady state.

6 Welfare-Maximizing Fiscal Rules

The simple fiscal rules proposed in equations (31) (single feedback) and (32) (revenue-specific feedback) can be generalized to represent a continuum of possible rules, going from procyclical ($\kappa < 1$) to countercyclical ($\kappa > 1$) stances. Automatic government stabilizers react more robustly to the cycle as the government approaches a strong CCR policy with $\kappa = 3$ than when the government sets its fiscal parameter to a CCR policy of $\kappa = 2$. A BBR policy of $\kappa = 0$ refers to the pure procyclical policy rule where the government spends its current income, maintaining a balanced budget. When fiscal parameters approach a strong BBR policy of $\kappa = -1$, the government not only spends all the excess revenues in good times but also worsens its foreign asset position. We consider these alternative fiscal policy rules in a grid search and quantitatively evaluate their effects on households' welfare. In the baseline case, the government proportionally adjusts total expenditures (including consumption, investment, and social transfers) to satisfy the rule. In Section 6.2, we study the robustness of our results to alternative fiscal instruments. The baseline results allow government consumption in the utility function (c^G in U) and productive public capital (k^G in Y). In Section 6.4, we study the robustness of our results to alternative model assumptions.

Let $V_0^i(\kappa)$ denote the expected lifetime utility of household type $i \in \{R, NR\}$ under any given fiscal policy parameter values $\kappa = (\kappa^\tau, \kappa^{Co})$:

$$V_0^i(\kappa) = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^i(\kappa), h_t^i(\kappa)) \tag{1}$$

We numerically approximate these value functions using a second-order Taylor approximation of the model around the non-stochastic steady state. We use the acyclical ($\kappa = 1$ if single feedback and $\kappa^\tau = \kappa^{Co} = 1$ if double feedback) structural balance rule (SBR) as the benchmark. Because Chile's current estimated fiscal policy stance is close to acyclical, this benchmark allows us to interpret our results as welfare implications of deviating from the current fiscal policy rule. In particular, for any given policy κ, we compute consumption equivalent units, λ^i, as the fraction of lifetime consumption a household of type $i \in \{R, NR\}$ is willing to give up in order to be indifferent between the rule under analysis (κ) and the acyclical rule ($\kappa = 1$):

$$V_0^i(\kappa) = E_0 \sum_{t=0}^{\infty} \beta^t U((1 + \lambda^i) c_t^i(\kappa = 1), h_t^i(\kappa = 1)) \tag{2}$$

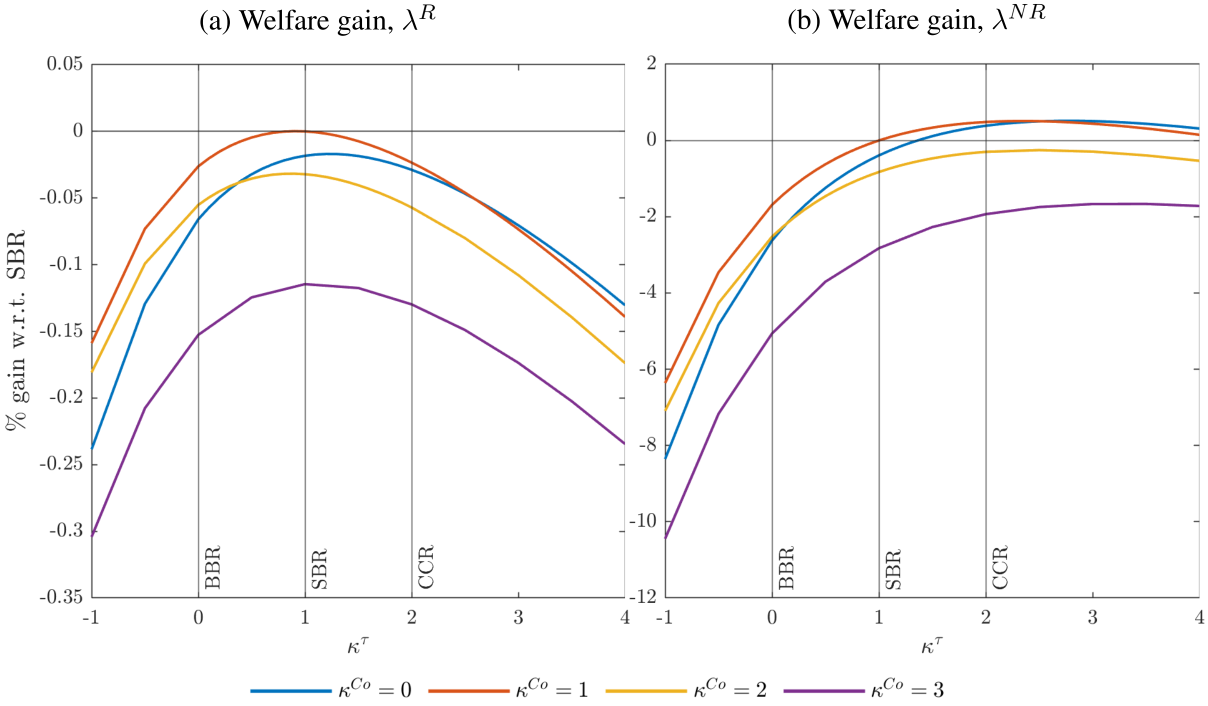
where $V_0^i(\kappa)$ is given by (1). A negative value of λ^i means household $i \in \{R, NR\}$ strictly prefers the acyclical rule $\kappa = 1$ over the alternative. In other words, a positive value of λ^i means the rule under analysis yields welfare gains relative to the acyclical rule.

6.1 Baseline Results

Figure 5 illustrates the welfare gains/losses for Ricardian and non-Ricardian households under alternative fiscal policy rules. Panel (b) shows that non-Ricardians welfare is maximized under a countercyclical stance regarding the tax revenue gap while keeping an acyclical or moderately procyclical stance on the commodity revenue gap. Panel (a) reveals the results for Ricardian consumers are qualitatively and quantitatively different. On the one hand, almost any deviation from the acyclical (SBR) benchmark is welfare-decreasing for these households with access to capital markets. On the other hand, as Ricardians can smooth consumption in the capital markets, their welfare implications are one order of magnitude lower than for financially constrained households. Overall, Figure 5 shows that procyclical fiscal spending unambiguously harms all economic agents. However, this does not mean that countercyclical policies are, *per se*, welfare-improving, as the relationship is nonlinear and dependent on the type of consumer being analyzed.

Table 3 summarizes the optimized fiscal rules, their welfare implications, and the changes in consumption and hours worked volatility implied by each rule relative to the acyclical benchmark. Panel (a) shows the optimized policies when restricting the rule to a single feedback parameter (κ), while Panel (b) displays results under the more flexible rule in which the government is allowed to react differently to the tax (κ^τ) and commodity (κ^{Co}) revenue gaps (as in the illustrations of Figure 5). To ease comparison, the table also reports the four reference rules introduced above: strong CCR ($\kappa = 3$), CCR ($\kappa = 2$), BBR ($\kappa = 0$), and strong BBR ($\kappa = -1$).

Figure 5: Fiscal Rules and Their Welfare Implications


(a) Welfare gain, λ^R

(b) Welfare gain, λ^{NR}

Notes: The figures present welfare gains for Ricardian (Panel (a)) and non-Ricardian households (Panel (b)) under alternative fiscal rules. In each panel, only κ^τ varies on the horizontal x-axis, while each line fixes an illustrative value for $\kappa^{Co} \in \{0, 1, 2, 3\}$. The vertical lines indicate the values of κ^τ that imply a procyclical Balanced-Budget Rule (BBR, $\kappa^\tau = 0$) and an acyclical Structural Budget Rule (SBR, $\kappa^\tau = 1$). Results are in percent consumption equivalent units relative to the acyclical (SBR) benchmark ($\kappa^\tau = \kappa^{Co} = 1$). The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.19$. The baseline fiscal instrument is total government spending (g).

When the fiscal rule is constrained to a single feedback parameter in Panel (a), non-Ricardian households ask for a mildly countercyclical ($\kappa = 1.3$) fiscal policy rule yielding a welfare gain of $\lambda^{NR} = 0.08\%$ of lifetime consumption. In contrast, Ricardian households' best option is so close to the acyclical benchmark ($\kappa = 0.9$) that their welfare gains are nil. As seen across the benchmark rules, Ricardian households face a trade-off. While fiscal activism in the form of CCR or strong CCR policies increases their consumption volatility, it also effectively stabilizes economic cycles, reducing the volatility of hours worked. Instead, non-Ricardian households do not face such a trade-off for moderately countercyclical rules. For instance, under CCR ($\kappa = 2$), non-Ricardians enjoy reductions of 0.4% and 4.1% in their consumption volatility and hours worked volatility, respectively. However, too much fiscal activism is not desirable. For instance, under strong CCR ($\kappa = 3$), non-Ricardians start facing a trade-off between (4.2%) higher consumption volatility and 6.1% lower volatility in hours worked. Below we show this pattern is related to the inability of the government to react differently to the tax revenue cycle and the commodity revenue cycle.

Table 3: Optimized Fiscal Rules

	Fiscal rule		Welfare gains		Ricardian consumption	Non-Ricardian consumption	Both hours worked
a) Single parameter	κ		λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Strong BBR	-1.0		-0.38	-9.59	-2.6	34.2	21.3
BBR	0.0		-0.06	-1.95	-1.4	9.5	7.5
CCR	2.0		-0.05	-0.20	1.4	-0.4	-4.1
Strong CCR	3.0		-0.15	-1.21	2.9	4.2	-6.1
Max. Ricardian	0.9		**0.00**	-0.06	**-0.1**	0.5	0.6
Max. Non-Ricardian	1.3		-0.01	**0.08**	0.4	**-0.9**	-1.5
b) Double parameter	κ^τ	κ^{Co}	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Strong BBR	-1.0	-1.0	-0.42	-12.82	-2.3	35.7	22.3
BBR	0.0	0.0	-0.07	-2.63	-1.2	9.9	7.8
CCR	2.0	2.0	-0.06	-0.30	1.2	-0.5	-4.2
Strong CCR	3.0	3.0	-0.17	-1.67	2.5	4.0	-6.3
Max. Ricardian	0.9	0.9	**0.00**	-0.08	**-0.1**	0.5	0.6
Max. Non-Ricardian	2.5	0.5	-0.04	**0.60**	1.6	**-5.1**	-6.8

Notes: This table presents the optimized fiscal rule feedback parameters that maximize Ricardian and non-Ricardian lifetime utility: Panel (a) presents results restricting the fiscal rule to a single parameter (κ) while Panel (b) displays results under revenue-specific (κ^τ and κ^{Co}) feedback parameters. The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.19$. Columns three and four present the implied welfare gains/losses for Ricardians (λ^R) and non-Ricardians (λ^{NR}) relative to the acyclical benchmark ($\kappa = 1$ for the model with a single fiscal parameter and $\kappa^\tau = \kappa^{Co} = 1$ for the model with revenue-specific feedback parameters). The last three columns illustrate the percent change in the volatility (Δ s.d.) of consumption and hours worked: Δ s.d.$= x > 0$ means the fiscal rule under analysis yields $x\%$ higher volatility than the acyclical benchmark. Recall hours worked are the same for both households. The table also reports four benchmark fiscal rules: Strong BBR, BBR, CCR, and strong CCR. All results use total government spending (including consumption, investment, and social transfers) as the fiscal instrument to satisfy the rule.

Panel (b) of Table 3 displays analogous results under the augmented (revenue-specific) fiscal rule. While the outcomes for Ricardian households are unchanged, the results for non-Ricardians change significantly. First, the welfare-maximizing fiscal policy is now to **strongly** *lean against the wind* in response to the tax revenue gap ($\kappa^\tau = 2.5$) while maintaining a rather procyclical stance regarding the commodity revenue gap ($\kappa^{Co} = 0.5$). Second, the welfare gain for non-Ricardians under their optimized rule is 0.6% of lifetime consumption, that is, $0.6/0.08 = 7.5$ times larger gain than under the constrained (single κ) rule. Optimizing the refined (double κ) fiscal policy allows non-Ricardians to reduce the volatilities of consumption and hours worked by 5.1% and 6.8%, respectively, relative to the acyclical benchmark. In sum, a more flexible rule that allows the government to respond differently to the domestic business cycle and the international commodity price cycle significantly improves its ability to stabilize the economy and deliver welfare gains for the "poor" hand-to-mouth agents.

As is well-known, procyclical fiscal policies amplify economic cycles. For instance, under BBR ($\kappa^\tau = \kappa^{Co} = 0$), the volatility of real GDP growth increases by 19.2%. This heightened macroeconomic instability leads to a 7.8% increase in the volatility of hours worked, resulting in welfare losses for both types of consumers (as reported in Table 3). In such a scenario, Ricardian households respond by adopting a proactive approach to consumption smoothing, increasing their foreign asset position volatility by 6.6% and reducing their consumption volatility by 1.2%. Overall, the detrimental impact of increased hours worked volatility outweighs the benefits of consumption smoothing, resulting in a Ricardian welfare loss of 0.07%. The implications of procyclical policies are even starker for financially constrained consumers. In their case, a BBR significantly increases consumption volatility by 9.9%, causing a 2.63% loss in lifetime consumption.

Conversely, under CCR ($\kappa^{\tau} = \kappa^{Co} = 2$) or strong CCR ($\kappa^{\tau} = \kappa^{Co} = 3$), the volatility of real GDP growth decreases by 5.4% and 4.4%, respectively. Notably, the non-Ricardian optimized rule ($\kappa^{\tau} = 2.5$ and $\kappa^{Co} = 0.5$) implies an even more pronounced 11.8% reduction in the volatility of GDP growth, which partly reveals why the government should not respond in a countercyclical fashion to the commodity revenue cycle. This counterintuitive result is explained by the intrinsically different nature of commodity-related revenues relative to tax revenues. Since tax revenues are a function of GDP, households' income and tax revenues are simultaneously higher than normal when the economy is booming. So intuitively, a countercyclical κ^{τ} is desirable as it stabilizes aggregate output and thus households' income and consumption. In contrast, commodity revenues are mainly a function of *exogenous and persistent* fluctuations in international commodity prices, which do not (necessarily) correlate with the domestic business cycle. Moreover, in our calibration for the Chilean economy, only one third of the commodity cash flow belongs to the government and the rest to foreign investors. Thus, commodity price shocks manifest in the economy primarily as higher than usual government revenues, with no direct effect on households' income.[14] In such a scenario, if a positive commodity price shock hits the economy during an economic recession, a countercyclical fiscal response to the shock via κ^{Co} would drag the economy further down, amplifying economic cycles.

6.2 Robustness to Alternative Fiscal Instruments

The results discussed so far have used total government spending (including consumption, investment, and lump-sum transfers) as the baseline instrument to implement the cyclically-adjusted fiscal rule introduced in equation (32). An obvious research question arising is whether the government can improve households' welfare by using, for instance, targeted social transfers only as the fiscal instrument, or using productive government investment to support the economy in bad times. Table 4 summarizes the optimized rules for Ricardian (Panel I) and non-Ricardian (Panel II) consumers under four alternative budgetary instruments to fulfill the rule: government consumption (c^G), investment (i^G)[15], lump-sum transfers (tr^G), and the simultaneous and proportional adjustment of the three government spending components (g, the baseline).

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[14] The correlation between the Chilean output gap and the international copper price gap is only 18% in the annual sample 1960-2022. The output and commodity price gaps are estimated using the Chilean Ministry of Finance methodology. The standard deviation of the output gap is 4.7%, while the standard deviation of the copper price gap is 33.7% (see Figure 1).

[15] We did not obtain stable computational solutions when the fiscal instrument is investment alone, as this option represents a relatively small fraction of total spending, and therefore requires extreme variation in public investment to satisfy the rule. Hence, we adjust this instrument alongside government consumption.

Table 4: Optimized Fiscal Rules with Alternative Instruments

	Fiscal rule		Welfare gains		Ricardian consumption	Non-Ricardian consumption	Both hours worked
I. Max. Ricardian	κ^{τ}	κ^{Co}	λ^{R}	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Gov. consumption, c^G	-0.1	0.9	**0.04**	-0.13	**-1.3**	2.1	4.0
Gov. investment, i^{G*}	0.0	0.9	**0.03**	-0.21	**-1.2**	2.8	5.5
Gov. transfers, tr^G	5.0	-0.6	**0.09**	-0.05	**1.1**	-3.7	-4.8
Total spending, g	0.9	0.9	**0.00**	-0.08	**-0.1**	0.5	0.6
II. Max. Non-Ricardian							
Gov. consumption, c^G	2.2	0.0	-0.11	**0.06**	1.5	**-2.2**	-3.6
Gov. investment, i^{G*}	3.1	-0.1	-0.17	**0.16**	2.6	**-4.8**	-8.2
Gov. transfers, tr^G	2.8	0.4	0.05	**0.60**	0.5	**-5.2**	-2.5
Total spending, g	2.5	0.5	-0.04	**0.60**	1.6	**-5.1**	-6.8

Notes: This table presents the optimized fiscal rule feedback parameters that maximize Ricardian (Panel I) and non-Ricardian (Panel II) lifetime utility under alternative fiscal instruments: government consumption (c^G), government investment (i^G), lump-sum social transfer (tr^G). The table also reports the baseline case with total government spending (g) as the instrument to ease comparison. i^{G*} refers to government investment and consumption activated simultaneously (see details in footnote 15). The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.19$. Columns three and four present the implied welfare gains/losses for Ricardians (λ^R) and non-Ricardians (λ^{NR}) relative to the acyclical benchmark ($\kappa^\tau = \kappa^{Co} = 1$). The last three columns illustrate the percent change in the volatility (Δ s.d.) of consumption and hours worked: Δ s.d.$= x > 0$ means the fiscal rule under analysis yields $x\%$ higher volatility than the acyclical benchmark. Recall hours worked are the same for both households.

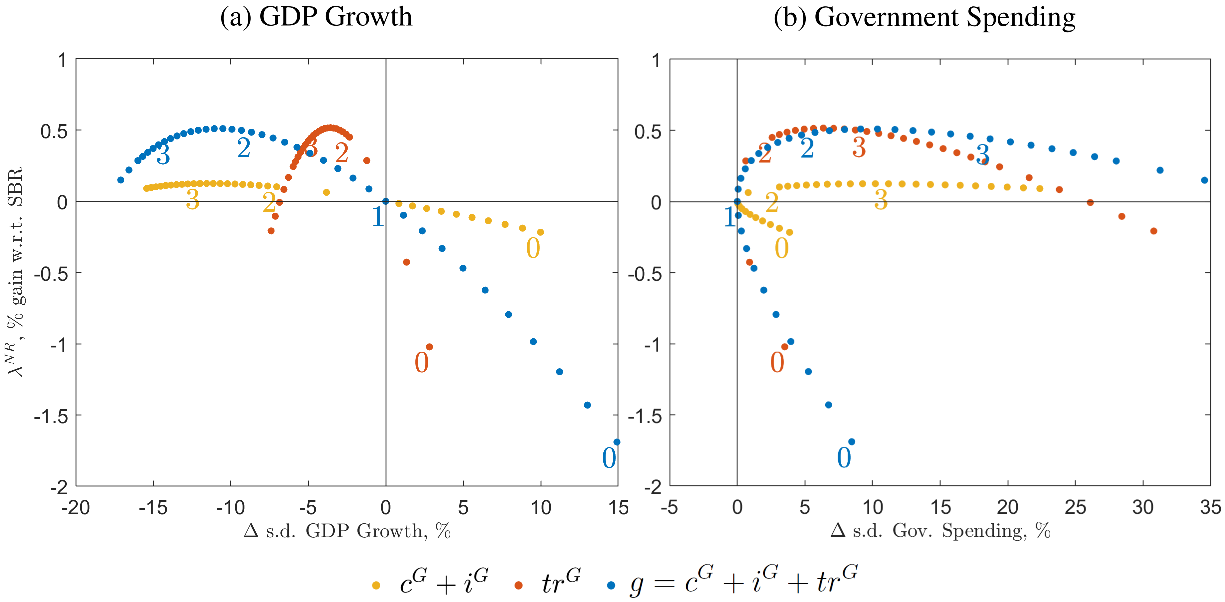
The optimizing fiscal policy for Ricardian consumers is contingent upon the specific fiscal instrument employed, whereas the preference of non-Ricardian households for a countercyclical response to the tax revenue gap and a rather procyclical approach to the commodity revenue gap remains consistent regardless of the choice of fiscal instrument. Panel I in Table 4 illustrates that Ricardian households would choose a BBR ($\kappa^\tau \approx 0$) response to the tax revenue gap and a close to SBR ($\kappa^\tau \approx 1$) response to the commodity revenue gap when the fiscal instrument is either c^G and/or i^G. In sharp contrast, if the fiscal instrument is lump-sum transfers (tr^G), they would choose a highly countercyclical response to the tax revenue cycle ($\kappa^\tau = 5$, the upper bound of the grid) combined with a highly procyclical response to the commodity revenue cycle. Indeed, Ricardian households face a trade-off: while fiscal activism in the form of strong countercyclical transfers increases their consumption volatility by 1.1% relative to the acyclical benchmark, it also effectively stabilizes economic cycles, resulting in a 4.8% reduction in the volatility of hours worked. The benefit from lower hours worked volatility outweighs the cost of higher consumption volatility, maximizing Ricardian welfare with a gain of 0.09% of lifetime consumption. Finally, Table 4 demonstrates that the most substantial welfare improvements for both types of consumers are observed when employing tr^G, although non-Ricardians are equally happy when total spending is used as the instrument.

6.3 The Trade-off between Macro Stability and Fiscal Stability

In practice, the desirability of a fiscal rule depends not only on its welfare implications but also on the implied volatility they generate on macro and fiscal variables. Figure 6 shows the attainable welfare gains for non-Ricardian households along with the implied volatility in GDP growth (Panel (a)) and government spending (Panel (b)) for a continuum of fiscal rules. Each line in the plot represents a fiscal instrument, while each marker in the line represents a different value for κ^{τ} in the range [0,4]. In this exercise, we kept κ^{Co} fixed at the estimated acyclical value of one.

Panel (a) of Figure 6 shows that a procyclical response to tax revenues (e.g., $\kappa^{\tau} = 0$) unambiguously increases the volatility of GDP growth and reduces welfare regardless of the fiscal instrument. Intuitively, being procyclical using total government spending is particularly damaging in amplifying economic cycles (Δ s.d. $= 15\%$), followed by consumption and investment (Δ s.d. $= 11\%$), and to a much lesser extent, social transfers (Δ s.d. $= 2.5\%$). Similarly, procyclical total spending (again, say $\kappa^{\tau} = 0$) is especially harmful to non-Ricardians, generating a welfare loss of $\lambda^{NR} = -1.7\%$ of lifetime consumption relative to the acyclical benchmark; followed closely by procyclical transfers ($\lambda^{NR} = -1.1\%$).

Figure 6: Evaluating Fiscal Policy Instruments


(a) GDP Growth

(b) Government Spending

Notes: The figures depict the combinations of welfare gains and implied changes in the volatility of real GDP growth (Panel (a)) and government spending (Panel (b)) resulting from alternative fiscal policy rules. Each line/color represents a fiscal instrument, while each marker in the line represents a different value for κ^{τ} in the range [0,4]. In this exercise, we keep $\kappa^{Co} = 1$ fixed at the acyclical benchmark (very close to the estimated value). The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^{B} = 0.19$. As before, welfare gains and changes in volatility are measured relative to an acyclical benchmark rule. The figures focus on welfare gains by non-Ricardian households (λ^{NR}).

On the other hand, Panel (a) of Figure 6 reveals that being countercyclical in total spending is the most efficient way to stabilize the economy while simultaneously delivering the most significant welfare gains. Countercyclical transfers are especially efficient in yielding welfare gains, although they are quite ineffective in reducing macroeconomic (GDP growth) volatility. In contrast, countercyclical government consumption and public investment are beneficial in reducing macroeconomic volatility while generating relatively small welfare gains. In sum, countercyclical total spending combines the benefits of each expenditure component, resulting in a win-win strategy.

In turn, Panel (b) of Figure 6 illustrates the effects of alternative fiscal rules on the volatility of government spending. As with the case of GDP growth, moving from a procyclical ($\kappa^{\tau} = 0$) to an acyclical $\kappa^{\tau} = 1$ is also a win-win strategy, as this decreases welfare losses and the volatility of government spending under any fiscal instrument considered. For values of $\kappa^{\tau} > 1$, fiscal authorities face a trade-off between welfare gains and increasing government spending (and government debt) volatility. For instance, when using transfers (tr^G) as the fiscal instrument, non-Ricardian welfare is maximized when $\kappa^{\tau} = 2.8$: more countercyclical (larger) values of κ^{τ} only induces higher instrument volatility and a rapid decline in welfare. Analogously, when using total spending (g) as the instrument, welfare is maximized when $\kappa^{\tau} = 2.5$. In this case, larger values of κ^{τ} also induce higher instrument volatility but with much more stable welfare gains.

We conclude total spending is the most appropriate instrument to implement a cyclically adjusted fiscal rule, yielding the highest welfare gains, enabling reductions in macroeconomic volatility, and producing only moderate additional volatility in government spending and public debt. Government consumption and especially public investment are helpful in stabilizing GDP, while targeted social transfers are key to smoothing consumption of financially constrained households.

6.4 Robustness to Alternative Model Assumptions

In this section, we check the robustness of our main results to alternative model assumptions regarding key fiscal variables. The baseline model assumes consumers value government consumption in their utility function. Moreover, we allow government investment to accumulate public capital, which complements private capital in producing final goods. Since not many articles in the literature share these assumptions simultaneously, we check the sensitivity of our main results to alternative model specifications.[16]

Table 5 illustrates the welfare maximizing fiscal policies for Ricardian and non-Ricardian consumers when we abstract from government consumption in the utility function, when we abstract from public investment, and when both assumptions are dropped from the model. We fix total spending as the baseline fiscal instrument across all model versions. As usual, welfare gains and changes in volatility are computed relative to the acyclical ($\kappa^{\tau} = \kappa^{Co} = 1$) benchmark rule.

Panel I shows that the optimized rule for Ricardian households can change qualitatively and quantitatively, depending on model assumptions. For instance, in both versions of the model in which we drop the c^G in U assumption, these households lean towards a more countercyclical rule regarding κ^{τ} and a more procyclical rule in κ^{Co}, relative to the baseline model. The latter is especially the case when dropping c^G in U but keeping k^G in Y. Recall that when government consumption enters the utility function, it does so as a complement of private consumption: when government consumption is high, private consumption tends to be high as well. Therefore, under c^G in U, too much fiscal activism in the form of countercyclical spending is undesired for Ricardian consumers, as it disrupts their private consumption decisions. Instead, when dropping c^G in U, Ricardians are willing to accept higher degrees of fiscal activism, as this stabilizes the economy, especially when productive public capital is activated (the second row of each panel).

Turning to non-Ricardian households, Panel II shows their preferred rules are quite robust across models, asking for a strongly countercyclical stance regarding $\kappa^{\tau} \in [2.2, 2.8]$ combined

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[16] To the best of our knowledge, Kumhof and Laxton (2013) is the only article considering these two assumptions simultaneously, although they do not report comparative results.

with a mildly procyclical approach regarding $\kappa^{Co} \in [0.4, 0.6]$. Notably, the model without complementarity between private and government consumption (No c^G in U) but with productive public capital delivers the largest welfare gains for both households ($\lambda^{NR} = 0.66$ and $\lambda^R = 0.09$). In contrast, the model without public capital (No k^G in Y) but with c^G in U delivers the lower welfare gain under the optimized rule ($\lambda^{NR} = 0.28$), thus highlighting the importance of productive government investment in the design of an effective countercyclical fiscal policy rule.

Table 5: Optimized Fiscal Rules under Alternative Model Assumptions

	Fiscal rule		Welfare gains		Ricardian consumption	Non-Ricardian consumption	Both hours worked
I. Max. Ricardian	κ^τ	κ^{Co}	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Baseline	0.9	0.9	**0.00**	-0.08	**-0.1**	0.5	0.6
Baseline, No c^G in U	5.0	-0.1	**0.09**	0.32	**2.6**	-4.7	-13.9
Baseline, No k^G in Y	0.7	0.9	**0.00**	-0.19	**-0.4**	1.6	1.3
Baseline, No c^G in U, No k^G in Y	1.6	0.6	**0.00**	0.37	**0.3**	-2.8	-2.4
II. Max. Non-Ricardian	κ^τ	κ^{Co}	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Baseline	2.5	0.5	-0.04	**0.60**	1.6	**-5.1**	-6.8
Baseline, No c^G in U	2.8	0.4	0.06	**0.66**	1.3	**-5.7**	-8.2
Baseline, No k^G in Y	2.2	0.6	-0.04	**0.28**	1.4	**-3.6**	-4.3
Baseline, No c^G in U, No k^G in Y	2.5	0.5	-0.00	**0.53**	0.7	**-4.4**	-5.4

Notes: This table presents the optimized fiscal rule feedback parameters that maximize Ricardian (Panel I) and non-Ricardian (Panel II) lifetime utility under four alternative versions of the model: the baseline model with c^G in U and k^G in Y, the baseline with no c^G in U, the baseline with no k^G in Y, and the baseline with no c^G in U and no k^G in Y. Columns three and four present the implied welfare gains/losses for Ricardians (λ^R) and non-Ricardians (λ^{NR}) relative to the acyclical benchmark ($\kappa^\tau = \kappa^{Co} = 1$). The last three columns illustrate the percent change in the volatility (Δ s.d.) of consumption and hours worked: Δ s.d.$= x > 0$ means the fiscal rule under analysis yields $x\%$ higher volatility than the acyclical benchmark. Recall hours worked are the same for both households. All results use total government spending (including consumption, investment, and social transfers) as the fiscal instrument to satisfy the rule.

7 Conclusions

This paper studies the welfare and macroeconomic implications of simple and implementable fiscal policy rules in commodity-dependent economies, where a large share of output, exports, and government revenues depend on exogenous commodity prices. We argue that a fiscal rule that reacts strongly countercyclical to the domestic business cycle and mildly procyclical in response to volatile and persistent commodity price cycles can effectively stabilize output growth while generating significant welfare gains, especially for liquidity-constrained (non-Ricardian households). Government consumption and especially public investment are particularly helpful in stabilizing GDP, while targeted social transfers are essential to smooth the consumption of financially constrained households. We show the optimized rule requires moderate additional volatility (fiscal activism) in government spending and debt.

We propose flexible fiscal rules distinguishing the domestic tax revenue cycle from persistent international commodity price cycles, showing they deliver several times larger welfare gains than standard rules proposed in the literature. Moreover, to break the unit-root behavior on the government's net foreign asset position, we augment the rule with a feasibility/sustainability constraint, limiting large deviations of public debt from its long-run value, thereby effectively imposing a debt limit in the rule design, and reconciling the model-based evolution of government debt with the data.

Cyclically-adjusted fiscal rules are valuable tools for stabilizing the economy and achieving development goals, particularly for emerging commodity-exporting economies with a large share of hand-to-mouth households. These rules are comparable in usefulness to monetary policy, making them a relevant tool for policymakers. However, implementing and maintaining fiscal rules can be challenging, especially in Latin American and Caribbean countries, where poor institutional quality often leads to discretionary spending by short-sighted governments. The feasibility of cyclically-adjusted rules depends greatly on institutional quality, which is beyond the scope of this study but a fruitful topic for future research.

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Appendix

A Calibration Strategy and Estimated Parameters

A combination of calibration and estimation assigns the values of the parameters in the model. Table 6 presents the values of parameters fixed a priori, based on previous literature, or to match sample averages in the data. We set the long-run productivity growth of the economy at $a = 1\%$ (annual, per capita), consistent with an average GDP growth of 3.5% and an average labor force growth of 2.5%. The long-run inflation rate is fixed at $\pi = 3\%$ (annual), the Chilean Central Bank's inflation target. The risk-free interest rate is set to $r^W = 2.1\%$ (annual) and the steady-state spread $\overline{spr} = 1.5\%$ (annual), the sample averages for the LIBOR and the Chilean EMBI, respectively.

We set the risk aversion parameter to $\sigma = 1.5$, the middle point between the values of one and two typically used in the literature, implying an intertemporal elasticity of substitution equal to $IES = 1/\sigma = 2/3$. We follow Medina et al. (2007) and García et al. (2019) in calibrating the share of Non-Ricardian households ($\omega = \omega^T = \omega^{TR} = 0.5$), the elasticities of substitution across varieties ($\epsilon = \epsilon_w = 11$, implying a markup of $10\% = \epsilon/(\epsilon - 1)$), and capital depreciation rates ($\delta = \delta_{Co} = 0.015$ quarterly).

Table 6: Calibrated Deep Parameters

Parameter	Value	Description	Source
$a^4 - 1$	1.0	Trend growth rate (annual)	Data: Per Capita Growth
$\pi^4 - 1$	3.0	Inflation rate (annual)	CB's Inflation Target
$(R^{W*})^4 - 1$	2.1	Foreign risk-free interest rate (annual)	Data: LIBOR interest rate
$spr^4 - 1$	1.5	Country spread (annual)	Data: EMBI spread
σ	1.5	Inverse elasticity of intertemporal substitution	Literature
ω	0.5	Share of non-Ricardian households	Medina et al. (2007)
ω^T	0.5	Share of non-Ricardians in gov. taxes	García et al. (2019)
ω^{TR}	0.5	Share of non-Ricardians in gov. transfers	García et al. (2019)
$\epsilon = \epsilon_w$	11	Elasticity of subst. across goods and labor varieties	Medina et al. (2007)
$\delta = \delta_{Co}$	0.015	Depreciation rate private sectors (quarterly)	García et al. (2019)
γ_F	0.19	Share of food in CPI basket	Data: CPI basket weights
γ_O	0.06	Share of oil in CPI basket	Data: CPI basket weights
γ_M^N	0.06	Share of M inputs in production N sector	I-O Matrix
γ_M^X	0.18	Share of M inputs in production X sector	I-O Matrix
γ_M^{Co}	0.01	Share of M inputs in production Co sector	I-O Matrix
$\gamma_O^N = \gamma_O^X = \gamma_O^{Co}$	0.02	Share of O input in production	Medina et al. (2007)
$\gamma_{CG} = \gamma_{IG}$	0.5	Share of N goods in gov. baskets	García et al. (2019)
γ^{Co}	0.33	Government share in Co sector	García et al. (2019)
γ	0.36	Share of gov. consumption in $U(c, c^G)$	García et al. (2019)
γ_G	0.1	Share of public capital in productive capital	García et al. (2019)
ϱ_G	0.60	Elasticity of subst. private and public capital	García et al. (2019)
$\varrho^N = \varrho^X = \varrho^{Co}$	0.54	Elasticity of subst. in production	García et al. (2019)
$\overline{L}$	1	Commodity production fixed factor	Normalized
p^{M*}	1	SS imported goods price (foreign currency)	Normalized
p^{Co*}	1	SS exported commodity price (foreign currency)	Normalized

The food and energy/oil shares in the consumption bundle are taken directly from the CPI basket weights in the data. Similarly, the shares of imported input in the production of the three sectors are taken from the Chilean Input-Output matrix. The share of oil/energy input in production is taken from Medina et al. (2007).

We assume full home bias in the government consumption and investment baskets, with a neutral share of 0.5 between N and X goods. Following García et al. (2019), the government share in total commodity wealth is set to $\gamma^{Co} = 0.33$, the average production share of the state-owned copper mining company (Codelco). Following Coenen et al. (2012), the share of government consumption in the utility function and the share of public capital in production are set to equalize the marginal utility of private and government consumption and the marginal product of private and public capital, respectively. Finally, we calibrate a few parameters not well identified by our dataset in the Bayesian estimation procedure. In particular, the elasticity of substitution between private and public capital and between value-added and imported inputs in production are taken from García et al. (2019).

Table 7 presents a set of parameters endogenously determined in the steady-state algorithm to match key macroeconomic ratios. The subjective discount factor is set to $\beta = 0.99997$ to hit a nominal interest rate of $R = 4.5\%$, consistent with recent estimates for the Chilean neutral real interest rate of $R - \pi = 1.5\%$ (see Ceballos et al. (2017)). The scale parameters governing the disutility of work for Ricardian and non-Ricardian households are set to normalize total hours to $h = 1$ and non-Ricardian hours to $h^{NR} = \omega = 0.5$.

The capital shares in production in the N and X sectors are set to $\alpha^N = \alpha^X = 0.35$ to hit a steady-state investment-to-GDP ratio of 25%. In the case of the commodity sector, we set $\alpha^{Co} = 0.41$ to match the share of commodity capital in the aggregate of 16.5%. On the other hand, we set the public capital depreciation rate at $\delta^G = 0.015$ to match the 14% share of public capital in the economy-wide capital stock estimated by the IMF.

The steady-state productivity level in the N sector is normalized to $z^N = 1$, while $z^X = 0.996$ is required to hit the observed trade balance-to-GDP ratio of 3.7%. Similarly, productivity in the commodity sector $z^{Co} = 0.25$ is set to match the 13.9% share of commodity GDP in aggregate GDP. The steady-state foreign productivity level $z^* = 1.26$ is set to match an imports-to-GDP ratio of 33%. The steady-state oil price is set to approximately match the oil imports share in total imports, while steady-state private rents are set to hit the average -1.3% deficit in the current account-to-GDP ratio.

The steady-state foreign inflation and the share of N goods in core consumption are set to normalize a couple of relative prices, which helps simplify the steady solution algorithm. The share of imported goods in the tradable and food consumption baskets $\gamma_M = \gamma_{FM}$ are assumed to be equal and set to hit the average consumption-to-GDP ratio of 59%.

In turn, the share of N goods in the investment baskets is set to ($\gamma_I^N = \gamma_{ICo}^N = 0.65$) in order to match as close as possible the share of N output in total GDP (67%). Similarly, the share of M goods in the investment baskets is calibrated at ($\gamma_I^M = \gamma_{ICo}^M = 0.31$) to match the share of imported capital goods in total imports (21%).

The government consumption and investment expenditures share are endogenously determined to hit the observed government consumption and investment to GDP ratios observed in the data, 8.3% and 4%, respectively, which requires $\alpha^{CG} = 0.35$ and $\alpha^{IG} = 0.17$. The share of lump-sum taxes in GDP is set to match the Chilean total tax burden of 21% of GDP. Finally, ad-valorem tax rates are calibrated to match the corresponding average revenue-to-tax base ratios observed in the data, which yields $\tau^C = 0.18$, $\tau^W = 0.08$, $\tau^K = 0.45$ and $\tau^{Co} = 0.02$.

Table 7: Parameters Calibrated to Match Macroeconomic Targets

Parameter	Value	Description	Target	Data	Model
β	0.99997	Subjective time discount factor (quarterly)	Real Interest Rate	1.5	1.5
η^R	1.38	Disutility of work Ricardians	Normalize Total Hours	n.a.	1
η^{NR}	3.46	Disutility of work non-Ricardians	Normalize NR Hours	n.a.	0.5
δ_G	0.0148	Depreciation rate public capital (quarterly)	Public Capital share	14.0	14.0
$\alpha^N = \alpha^X$	0.35	Capital share in production N and X sectors	Investment-to-GDP	25.3	24.9
α^{Co}	0.41	Capital share in production Co sector	Commodity Capital share	16.5	16.5
z^N	1	SS productivity N sector	Normalize z^N	n.a.	1
z^X	0.996	SS productivity X sector	Trade Balance-to-GDP	3.7	3.8
z^{Co}	0.25	SS productivity Co sector	Commodity Output share	13.9	13.5
z^*	1.26	SS foreign productivity	Imports-to-GDP	33.4	32.9
p^{O*}	0.78	SS imported oil price (foreign currency)	Imports oil share	18.3	15.2
ξ^{R*}	1.12	SS foreign rents shock	Current Account-to-GDP	-1.3	-1.3
$(\pi^*)^4 - 1$	2.1	Foreign inflation rate	Normalize p^M/p^I share	n.a.	1
γ_N	0.91	Share of N goods in core consumption	Normalize p^X/p^I share	n.a.	1
$\gamma_M = \gamma_{FM}$	0.88	Shares of M goods in tradable consumption	Consumption-to-GDP	58.7	59.0
$\gamma_I^N = \gamma_{ICo}^N$	0.65	Share of N goods in investment basket	Nontradable Output-to-GDP	67.4	59.9
$\gamma_I^M = \gamma_{ICo}^M$	0.31	Share of M goods in investment basket	Imports investment share	21.2	21.4
α^{CG}	0.35	Share of consumption in gov. expenditure	Gov. Consumption-to-GDP	8.3	8.3
α^{IG}	0.17	Share of investment in gov. expenditure	Gov. Investment-to-GDP	4.0	4.0
α^T	0.03	Share of lump-sum taxes in GDP	Tax-to-GDP	21.0	22.0
τ^C	0.18	Tax rate on consumption	VAT revenue share	57.0	58.6
τ^W	0.08	Tax rate on labor income	Labor tax share	20.0	20.3
τ^K	0.45	Tax rate on capital income	Capital tax share	22.0	19.6
τ^{Co}	0.02	Tax rate on foreign Co profits	Corporate tax share	1.0	1.5

The remaining parameters are estimated using Bayesian methods following An and Schorfheide (2007). The set of observables used to inform the model consists of 25 macroeconomic variables at quarterly frequency covering 1996Q2-2019Q3.[17] These variables include:

- **GDP supply side:** real growth rate of (1) commodity GDP (Co: mining), (2) exportable GDP (X: agriculture and manufacturing), and (3) nontradable GDP (N: construction, wholesale and retail trade, transport, information and communication, financial services, personal services, and public administration).

- **GDP demand side:** real growth rate of (4) non-durable consumption goods and services, (5) total investment, (6) commodity investment; and (7) the ratio of the nominal trade balance to GDP.

- **Fiscal variables:** real growth rate of (8) government consumption, (9) government investment, and (10) government social transfers; and (11) the ratio of the nominal government debt to GDP.

- **Labor market:** real growth rate of (12) hours worked and (13) nominal wages.

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[17] The source for all variables is the Central Bank of Chile. Variables are seasonally adjusted and demeaned. All growth rates are changes from two consecutive quarters.

- **Macro prices:** inflation rate of (14) core CPI, (15) food CPI and (16) energy CPI; as well as (17) the monetary policy nominal interest rate, (18) the country premium (EMBI spread), and (19) the nominal devaluation rate

- **External variables:** (20) foreign (trade partners) GDP growth rate, (21) foreign (risk-free) interest rate, (22) foreign (trade partners) inflation rate, and the dollar-denominated (23) commodity, (24) oil, and (25) import prices inflation rates.

The estimation procedure includes i.i.d. measurement errors for all observables except for the monetary policy interest rate. The variance of the measurement errors is calibrated to 10% of the variance of the corresponding observable. We follow García et al. (2019) in setting the shapes, means, and standard deviations for the priors. Posterior distributions are obtained from a random walk Metropolis Hasting chain with 100,000 draws after a burn-in of 50,000 draws. We also follow García et al. (2019) in scaling the elasticity of the spread with respect to the country's net foreign asset position and the AR(1) processes' standard deviations to have similar parameter magnitudes, thereby improving the efficiency of the joint optimization. Tables 8 and 9 report prior and posterior distributions for structural parameters and AR(1) processes, respectively.

Table 8: Prior and Posterior Distributions: Structural Parameters.

Parameters	Description	Initial Prior			Posterior		
		distr.	mean	s.d.	mean	pct. 5	pct. 95
φ	Inverse Frisch elasticity	Gamma	1.50	0.50	**0.84**	0.38	1.26
ϱ	Elast. of subst. private vs. gov. cons.	Gamma	1.00	0.50	**0.84**	0.26	1.36
ϱ^C	Elast. of subst. in cons.	Gamma	1.00	0.25	**0.48**	0.30	0.64
ϱ^Z	Elast. of subst. in core cons.	Gamma	1.00	0.25	**1.21**	0.70	1.69
ϱ^T	Elast. of subst. in tradables cons.	Gamma	1.00	0.25	**0.98**	0.63	1.35
ϱ^F	Elast. of subst. in food cons.	Gamma	1.00	0.25	**0.97**	0.56	1.33
ϱ^I	Elast. of subst. in investment	Gamma	1.00	0.25	**1.17**	0.75	1.60
ϱ^{ICo}	Elast. of subst. in Co investment	Gamma	1.00	0.25	**1.05**	0.65	1.44
ϱ^{CG}	Elast. of subst. in gov. cons.	Gamma	1.00	0.25	**0.93**	0.58	1.32
ϱ^{IG}	Elast. of subst. in gov. investment	Gamma	1.00	0.25	**0.94**	0.58	1.32
κ^τ	Gov. reaction to tax revenue cycle	Gamma	1.00	0.25	**1.09**	0.75	1.47
κ^{Co}	Gov. reaction to comm. revenue cycle	Gamma	1.00	0.25	**0.89**	0.63	1.17
κ^B	Feasibility constraint (public assets)	Gamma	0.50	0.25	**0.19**	0.11	0.26
ϵ^*	Elasticity of foreign demand	Inv-Gamma	0.20	0.05	**0.20**	0.13	0.28
ϕ_c	Habit formation	Beta	0.75	0.10	**0.82**	0.74	0.92
ϕ_b	Country premium debt elas.	Inv-Gamma	1.00	Inf.	**0.23**	0.17	0.28
ϕ_k	Inv. adjustment cost elast.	Gamma	5.00	1.50	**3.98**	2.09	5.82
ϕ_k^{Co}	Inv. adjustment cost elast., mining	Gamma	2.00	0.50	**2.38**	1.65	3.15
ϕ_u	Capital utilization cost, N and X	Gamma	1.50	0.25	**1.53**	1.11	1.88
θ^N	Calvo probability N	Beta	0.75	0.07	**0.68**	0.61	0.75
θ^X	Calvo probability X domestic	Beta	0.75	0.07	**0.93**	0.88	0.97
θ^M	Calvo probability M	Beta	0.75	0.07	**0.74**	0.68	0.80
θ^{X*}	Calvo probability X foreign	Beta	0.75	0.07	**0.76**	0.65	0.88
θ_w	Calvo probability wages	Beta	0.75	0.07	**0.87**	0.84	0.91
α_y	Taylor rule response to GDP growth	Normal	0.12	0.05	**0.09**	0.03	0.16
α_π	Taylor rule response to total inflation	Normal	1.70	0.10	**1.71**	1.55	1.86
ρ^R	Taylor rule smoothing parameter	Beta	0.85	0.05	**0.70**	0.63	0.76
$\rho_{c^{X*}}$	Persistence in foreign demand	Beta	0.50	0.20	**0.77**	0.62	0.91
ρ_1^O	Oil price smoothing param. 1	Beta	0.50	0.20	**0.81**	0.78	0.85
ρ_2^O	Oil price smoothing param. 2	Beta	0.50	0.20	**0.48**	0.33	0.62
Γ^N	Global pass through, N	Beta	0.50	0.20	**0.51**	0.21	0.79
Γ^X	Global pass through, X	Beta	0.50	0.20	**0.49**	0.17	0.79
Γ^{Co}	Global pass through, Co	Beta	0.50	0.20	**0.52**	0.18	0.87

Notes: The table shows posterior distributions obtained from a random walk Metropolis Hasting chain with 100,000 draws after a burn-in of 50,000 draws. The estimation sample is 1996q2-2019q3.

Table 9: Prior and Posterior Distributions: Exogenous AR(1) processes.

Parameters	Description	Initial Prior			Posterior		
		distr.	mean	s.d.	mean	pct. 5	pct. 95
AR(1) coefficient							
ρ_a	Global unit root tech. shock	Beta	0.50	0.20	**0.67**	0.54	0.81
ρ_{z^N}	Productivity shock, N	Beta	0.85	0.07	**0.93**	0.88	0.98
ρ_{z^X}	Productivity shock, X	Beta	0.85	0.07	**0.94**	0.91	0.98
$\rho_{z^{Co}}$	Productivity shock, Co	Beta	0.85	0.07	**0.91**	0.85	0.96
ρ_{z^F}	Productivity shock, Food	Beta	0.75	0.07	**0.94**	0.91	0.97
ρ_{ξ^O}	Domestic oil price shock	Beta	0.50	0.20	**0.34**	0.08	0.57
ρ_{ξ^β}	Preference shock	Beta	0.50	0.20	**0.44**	0.23	0.64
ρ_{ξ^h}	Labor supply shock	Beta	0.50	0.20	**0.36**	0.14	0.58
ρ_{ξ^i}	Inv. prod. shock, N and X	Beta	0.75	0.07	**0.58**	0.46	0.67
$\rho_{\xi^{iCo}}$	Inv. prod. shock, Co	Beta	0.50	0.20	**0.59**	0.46	0.73
ρ_{ξ^m}	Monetary policy shock	Beta	0.50	0.20	**0.55**	0.40	0.69
$\rho_{\xi^{CG}}$	Public consumption shock	Beta	0.75	0.07	**0.71**	0.60	0.83
$\rho_{\xi^{IG}}$	Public investment shock	Beta	0.50	0.20	**0.24**	0.05	0.42
$\rho_{\xi^{TR}}$	Public transfer shock	Beta	0.75	0.07	**0.76**	0.64	0.87
ρ_{z^*}	Foreign productivity shock	Beta	0.85	0.07	**0.87**	0.78	0.97
ρ_{ξ^*}	Foreign inflation shock	Beta	0.50	0.20	**0.31**	0.23	0.40
$\rho_{\xi^{M*}}$	Import price shock	Beta	0.50	0.20	**0.63**	0.45	0.83
$\rho_{\xi^{O*}}$	Fuel price shock	Beta	0.50	0.20	**0.90**	0.83	0.98
$\rho_{\xi^{Co*}}$	Co price shock	Beta	0.50	0.20	**0.85**	0.81	0.89
$\rho_{R^{W*}}$	Foreign interest rate shock	Beta	0.50	0.20	**0.90**	0.86	0.93
$\rho_{\xi^{S*}}$	Spread shock (observed)	Beta	0.75	0.07	**0.82**	0.76	0.89
$\rho_{\xi^{U*}}$	Spread shock (unobserved)	Beta	0.75	0.07	**0.83**	0.74	0.93
Innovation s.d.							
σ_a	Global unit root tech. shock	Inv-Gamma	0.50	Inf.	**0.27**	0.20	0.33
σ_{z^N}	Productivity shock, N	Inv-Gamma	0.50	Inf.	**0.67**	0.52	0.83
σ_{z^X}	Productivity shock, X	Inv-Gamma	0.50	Inf.	**2.66**	2.26	3.07
$\sigma_{z^{Co}}$	Productivity shock, Co	Inv-Gamma	0.50	Inf.	**3.00**	2.60	3.36
σ_{z^F}	Productivity shock, Food	Inv-Gamma	0.50	Inf.	**1.95**	1.67	2.22
σ_{ξ^O}	Domestic oil price shock	Inv-Gamma	0.50	Inf.	**1.69**	1.35	2.02
σ_{ξ^β}	Preference shock	Inv-Gamma	0.50	Inf.	**7.97**	3.59	12.21
σ_{ξ^h}	Labor supply shock	Inv-Gamma	0.50	Inf.	**14.42**	6.51	21.78
σ_{ξ^i}	Inv. prod. shock, N and X	Inv-Gamma	0.50	Inf.	**6.43**	3.18	9.33
$\sigma_{\xi^{iCo}}$	Inv. prod. shock, Co	Inv-Gamma	0.50	Inf.	**8.57**	5.22	11.81
σ_{ξ^m}	Monetary policy shock	Inv-Gamma	0.50	Inf.	**0.15**	0.13	0.18
$\sigma_{\xi^{CG}}$	Public consumption shock	Inv-Gamma	0.50	Inf.	**2.09**	1.76	2.38
$\sigma_{\xi^{IG}}$	Public investment shock	Inv-Gamma	0.50	Inf.	**7.13**	5.97	8.23
$\sigma_{\xi^{TR}}$	Public transfer shock	Inv-Gamma	0.50	Inf.	**3.11**	2.72	3.51
$\sigma_{\xi^{X*}}$	Foreign demand shock	Inv-Gamma	0.50	Inf.	**2.34**	2.01	2.63
σ_{z^*}	Foreign productivity shock	Inv-Gamma	0.50	Inf.	**0.23**	0.15	0.31
σ_{ξ^*}	Foreign inflation shock	Inv-Gamma	0.50	Inf.	**2.17**	1.88	2.46
$\sigma_{\xi^{M*}}$	Import price shock	Inv-Gamma	0.50	Inf.	**1.28**	0.99	1.56
$\sigma_{\xi^{O*}}$	Fuel price shock	Inv-Gamma	0.50	Inf.	**12.43**	10.65	14.15
$\sigma_{\xi^{Co*}}$	Co price shock	Inv-Gamma	0.50	Inf.	**9.78**	8.39	11.19
$\sigma_{R^{W*}}$	Foreign interest rate shock	Inv-Gamma	0.50	Inf.	**0.15**	0.12	0.18
$\sigma_{\xi^{S*}}$	Spread shock (observed)	Inv-Gamma	0.50	Inf.	**0.11**	0.09	0.12
$\sigma_{\xi^{U*}}$	Spread shock (unobserved)	Inv-Gamma	0.50	Inf.	**0.42**	0.20	0.65

Notes: The table shows posterior distributions obtained from a random walk Metropolis Hasting chain with 100,000 draws after a burn-in of 50,000 draws. The estimation sample is 1996q2-2019q3.