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From Macroeconomic Stability to Welfare:

Optimizing Fiscal Rules in Commodity-Dependent Economies

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Abstract

We 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. In contrast, the optimized response to the commodity revenue cycle is procyclical, given the high persistence and the economic dynamics induced by international commodity price shocks. The optimized fiscal rules deliver significant welfare gains of 0.52% of lifetime consumption for non-Ricardian consumers and 0.06% for Ricardian consumers relative to a benchmark acyclical policy. Lump-sum social transfers are the best instrument to implement the fiscal rule, yielding higher welfare gains, enabling reductions in macroeconomic volatility, and producing only moderate additional volatility in government spending.

JEL classifications: E62, Q32, F41

Keywords: Fiscal rules, Raw materials sector, Open economy macroeconomics

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1 Introduction

Can fiscal policy rules stabilize economic cycles while maximizing consumers' welfare in commodity-dependent economies? In this article, we argue that a fiscal rule that reacts strongly countercyclically in response to the business cycle and procyclically in response to fluctuations in commodity revenues can effectively stabilize the economy generating significant welfare gains, especially for liquidity-constrained consumers.

Since Taylor (1993), monetary policy rules have constituted the quintessential macroeconomic tool policymakers use to stabilize business cycle fluctuations. Nevertheless, 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 (see Galí et al., 2007; Leeper et al., 2017). In such an environment, fiscal policy becomes very influential as it directly impacts the consumption-smoothing ability of this share of financially-constrained households (Kumhof and Laxton, 2013).[1]

Moreover, the study of cyclically-adjusted fiscal expenditure rules is especially relevant for commodity-dependent economies where a substantial fraction of output, exports, and fiscal revenues depend on volatile commodity prices. These economies are particularly prone to adopt a general procyclical fiscal stance, also known as balanced-budget rules (BBR), in response to fluctuations in government revenue (Ilzetzki and Végh, 2008). Under a general BBR, the government aligns its expenditure with current revenues, maintaining a constant fiscal budget. Unable to persevere in the face of political pressure in these economies, short-sighted policymakers tend to spend the windfall in good times when fiscal revenues are high and to reduce expenditures during bad times when social programs are needed the most.

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

In this article, we argue for a nuanced approach to fiscal rules illustrating that a strong CCR response to the business cycle and a mildly BBR reaction to the commodity revenue cycle can stabilize the economy, leading to larger welfare gains than other alternative fiscal rules. We build a New Keynesian general equilibrium model of a small and open commodity-dependent economy tailored for Chile to quantitatively evaluate alternative fiscal rules 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 fiscal rules by a grid search over policy parameters determining the reaction of government expenditure to cyclical fluctuations in revenues.

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

First, we optimize a rule using a single fiscal parameter reacting to fluctuations in total revenues. Then, we expand our analysis to two feedback parameters allowing government spending to respond differently to the tax revenue gap (the distance between actual and potential tax revenues) and the commodity revenue gap (the difference between current and long-term commodity revenues). We use the acyclical SBR policy as the reference point in a consumption equivalence exercise evaluating households' welfare gain or loss under alternative policy rules. Provided data on observables of the national accounts, external sector, labor market, fiscal accounts, inflation, and interest rates, we estimate these fiscal policy feedback parameters jointly with the rest of the model's parameters using Bayesian methods.

One of the main contributions of our study is the introduction of a sustainability/feasibility constraint limiting large deviations of public debt from its long-run value, thereby effectively imposing a (time-varying) debt limit in the rule design. 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 a fiscal block, and the feasibility constraint acts as an additional device to avoid the random walk behavior in government debt. In fact, without this feasibility constraint, the model generates a counterfactual government debt that is ten 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, we find that both types of consumers prefer CCR policies. Under their strong CCR-optimized policy, Ricardian consumers accrue welfare gains of 0.05$\%$ of lifetime consumption. Similarly, rule-of-thumb households experience gains of 0.14% under their preferred mildly CCR.

By allowing the government to react differently to the tax and commodity revenue gap, we find that the welfare maximizing fiscal rule for Ricardian and non-Ricardian consumers 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. The added flexibility to the fiscal rule enables more significant welfare gains. For instance, under the Ricardian optimized rule, Ricardian welfare gain increases from 0.05% to 0.06%, while non-Ricardian households go from a loss of 0.54% to a gain of 0.48% of lifetime consumption. Similarly, under the non-Ricardian optimized fiscal policy rule, the gains of Ricardian consumers more than double from 0.02% to 0.05%, and the welfare gains of hand-to-mouth households more than triple, from 0.14% to 0.52%.

A strong CCR response to the tax revenue gap has a macroeconomic stabilization effect compared to alternative fiscal policy rules, enabling significant welfare gains. For instance, a BBR response to tax revenues amplifies economic cycles, increasing the volatility of real GDP growth by 2.8% relative to the SBR benchmark, with welfare losses of 0.04% and 1.14% for Ricardian and non-Ricardian consumers, respectively. In contrast, the Ricardian-optimized CCR response to the tax revenue cycle enables a 4% reduction in the volatility of GDP growth, leading to welfare gains of 0.06% and 0.48%, respectively. In other words, moving from BBR to the optimized CCR improves the well-being of Ricardian and non-Ricardian households by 0.1 percentage points (p.p.) and 1.6 p.p. of lifetime consumption, respectively.

A revenue-specific fiscal rule approach also reveals consumers' preferences for a rather procyclical policy responding to the commodity revenue gap. This outcome can be attributed to fundamental distinctions between commodity-related revenues and tax revenues. Tax revenues are a function of aggregate income or GDP; when households' income is high, government 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 exogenous and persistent commodity price shocks and therefore do not necessarily correlate with the domestic business cycle. Furthermore, as only a third of the commodity cash flow belongs to the government, with the rest going to foreign investors, commodity price fluctuations primarily affect government revenues rather than households income. In this scenario, moving from a strongly countercyclical response regarding the commodity revenue gap to the optimized procyclical rule reduces the volatility of macroeconomic and fiscal variables, improving welfare by 1 p.p. of lifetime consumption for non-Ricardians and by 0.02 p.p. for Ricardian consumers. Finally, the higher the persistence of international commodity price shocks, the more likely consumers prefer a procyclical stance concerning commodity revenues.

We discuss our results further by evaluating the impact of abstracting from the debt sustainability/feasibility constraint. When we ignore the feasibility constraint, Ricardian preferences change drastically, from a strong CRR to a strong BBR policy responding to the tax revenue gap. The alignment of these results to the conventional findings in the literature is noteworthy, considering the absence of a debt sustainability constraint in previous studies. A too-countercyclical policy responding to the tax revenue gap, not disciplined by a debt sustainability constraint, implies an unfeasible large and persistent accumulation of public assets. Consequently, Ricardian consumers are forced to dissave as part of their consumption smoothing strategy, disrupting their precautionary savings motive, increasing consumption volatility by 5.4% and yielding a welfare loss of 0.13% of lifetime consumption. In contrast, in this scenario, a strongly procyclical rule decreases Ricardian consumption volatility by 5.3%, delivering a welfare gain of 0.1%.

Finally, as is common in the literature, we set lump-sum social transfers as the baseline fiscal instrument adjusting to satisfy the rule. However, we also provide results using government investment and consumption as instruments. The most appropriate fiscal instrument to implement the optimal budgetary rule is social transfers, yielding the highest welfare gains, enabling reductions in macroeconomic volatility, and producing only moderate additional volatility in government spending. Alternatively, the utilization of all available fiscal instruments yields similar welfare gains for non-Ricardian consumers, along with more pronounced reductions in macroeconomic volatility. However, this broader approach also entails higher levels of volatility in government spending.

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. Our 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 significantly 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 rich 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 aforementioned papers 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, as our findings also indicate, non-Ricardian households exhibit a preference for a SBR or CCR stance, allowing the government to smooth consumption on their behalf. Notably, our 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 strong BBR stance to a strong CCR 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, restricting public asset accumulation to feasible levels.

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 a 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. Similar to 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 a SBR stance regarding the commodity revenue gap can maximize overall welfare, the potential welfare gains moving from a BBR to a SBR responding to the commodity revenue gap are negligible. Consequently, our results are comparable to Kumhof and Laxton (2013) 's findings, with the difference that our identified optimized response to the commodity revenue gap leans more towards a BBR than a SBR policy. As mentioned, our study builds on the literature presenting a 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, Soto, 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 equilibrium, $W_t^N(j) = W_t^X(j) = W_t(j)$. Instead, physical capital is sector-specific (more details below).

[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]See Galí et al., 2012.

3.1.1 Ricardian Households

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

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

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

[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.

[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 $J \in \{N, X\}$.

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 can't 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 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 Ney 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, $P_t^{Co} = S_tP_t^{Co*}$, where 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

[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} induce 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.

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:

$$s_t^G = \Pi_t^\tau + \gamma^{Co} CF_t^{Co} - G_t, \tag{30}$$

the government budget can be written as follows:

$$B_t^{GT} \equiv S_t B_t^{G*} = S_t r_{t-1}^* B_{t-1}^{G*} + s_t^G, \tag{31}$$

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:

$$\begin{aligned} \tilde{G}_t = & \underbrace{S_t(r_{t-1}^* - 1)B_{t-1}^{G*}}_{\text{interest payments}} + \underbrace{(\Pi_t^\tau + \gamma^{Co} CF_t^{Co})}_{\text{current revenues}} \\ & + \underbrace{\kappa\left[(\tilde{\Pi}_t^\tau - \Pi_t^\tau) + \gamma^{Co}(\tilde{CF}_t^{Co} - CF_t^{Co})\right]}_{\text{cyclical adjustment}} + \underbrace{\kappa^B(B_t^{GT} - B^{GT})}_{\text{feasibility constraint}} \end{aligned} \tag{32}$$

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** 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

[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 ten-years average of the effective commodity price.

[12] To see this, note that if $\kappa = 1$ (and $\kappa^B = 0$), equation (32) 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 (32) 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 equivalent to what in the literature is called the "balanced budget rule (BBR)."

revenue gap (κ^{Co}), as follows:

$$\tilde{G}_t = S_t(r^*_{t-1} - 1)B^{G*}_{t-1} + (\Pi^\tau_t + \gamma^{Co} CF^{Co}_t) \\ + \kappa^\tau(\tilde{\Pi}^\tau_t - \Pi^\tau_t) + \kappa^{Co}\gamma^{Co}(\tilde{CF}^{Co}_t - CF^{Co}_t) + \kappa^B(B^{GT}_t - B^{GT}). \tag{33}$$

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:

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

$$I^G_t = \left[(\gamma_{IG})^{\frac{1}{\varrho_{IG}}} \left(I^{GN}_t\right)^{\frac{\varrho_{IG}-1}{\varrho_{IG}}} + (1-\gamma_{IG})^{\frac{1}{\varrho_{IG}}} \left(I^{GX}_t\right)^{\frac{\varrho_{IG}-1}{\varrho_{IG}}}\right]^{\frac{\varrho_{IG}}{\varrho_{IG}-1}} \tag{35}$$

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:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_R} \left[\left(\frac{\pi^Z_t}{\pi}\right)^{\alpha_\pi} \left(\frac{Y_t}{aY_{t-1}}\right)^{\alpha_y}\right]^{(1-\rho_R)} \xi^m_t \tag{36}$$

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 relative foreign-currency price set by domestic producers $\left(\frac{P^{X*}_t}{P^*_t}\right)$, 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:

$$C_t^{X*} = \left[a_{t-1}C_{t-1}^{X*}\right]^{\rho^{X*}} \left[\left(\frac{P_t^{X*}}{P_t^*}\right)^{-\epsilon^*} Y_t^*\right]^{1-\rho^{X*}} \xi_t^{X*} \tag{37}$$

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 exogenous 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:

$$S_t B_t^* = S_t r_{t-1}^* B_{t-1}^* + TB_t + REN_t \tag{38}$$

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:

$$TB_t = XN_t - MN_t \tag{39}$$

$$XN_t = P_t^X C_t^{X*} + P_t^{Co} Y_t^{Co} \tag{40}$$

$$MN_t = P_{m,t} M_t + P_t^O (C_t^O + O_t^N + O_t^X) \tag{41}$$

$$REN_t = S_t \xi_t^{R*} A_{t-1} - (1-\gamma^{Co}) CF_t^{Co} \tag{42}$$

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:

$$z_t = (1-\rho_z)z + \rho_z z_{t-1} + \sigma_z \varepsilon_{z,t} \tag{43}$$

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 that are either drawn from prior literature or are 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, which encompass those governing the fiscal rule, are estimated using Bayesian methods. All data moments targeted in the calibration are averages over the period 2001-2019. 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 (32) and (33), respectively, under four different model assumptions: (i) the baseline including government consumption c^G in the utility function U and government capital k^G in production, (ii) the baseline without c^G in U, (iii) the baseline without k^G in production, and (iv) the baseline without k^G in production 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 introduced in 2001 and institutionalized under the "Fiscal Responsibility Act" in 2006. Panel (a) shows that the cyclical parameter is estimated at $\kappa \in [1.05 - 1.09]$ 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 ($\kappa^\tau \in [1.13 - 1.22]$) and acyclical regarding the commodity revenue gap ($\kappa^{Co} \in [0.97 - 0.99]$). On the other hand, the feedback parameter concerning public debt is estimated at $\kappa^B \in [0.17 - 0.19]$ depending on model assumptions.

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	**1.05**	0.80	1.32	**0.16**	0.09	0.24
Baseline without c^G in U	**1.07**	0.81	1.33	**0.17**	0.10	0.24
Baseline without k^G	**1.09**	0.81	1.36	**0.19**	0.11	0.26
Baseline without k^G and c^G in U	**1.09**	0.81	1.36	**0.19**	0.10	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	**1.15**	0.69	1.54	**0.99**	0.69	1.29	**0.17**	0.09	0.24
Baseline without c^G in U	**1.13**	0.70	1.52	**0.97**	0.67	1.26	**0.17**	0.09	0.24
Baseline without k^G	**1.22**	0.80	1.58	**0.98**	0.70	1.28	**0.19**	0.11	0.27
Baseline without k^G and c^G in U	**1.22**	0.80	1.64	**0.97**	0.70	1.23	**0.19**	0.12	0.27

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 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 selected macroeconomic variables. The model does a good job of matching the unconditional volatilities of most variables in the model, except for labor market aggregates, which are overestimated, and the trade balance and current account ratios to GDP, which the model underestimates. 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 an autocorrelation of 0.9999 in the ratio of government assets to GDP, which is basically a unit-root process displaying a counterfactual volatility that is ten times larger than in the data. Activating the feasibility constraint reduces the autocorrelation to 0.9959, closer to the data value of 0.9877, helping the model generate credible variation in public debt. Overall, the estimated model can properly match most cross-correlations with the (non-commodity) GDP growth and the first-order autocorrelations in the data.

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	1.18	0.87	0.91	0.25	0.18
$\Delta \log y^{NCo}$	Non-commodity GDP growth	1.06	1.25	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	-0.03
$\Delta \log y^{X}$	Exportable GDP growth	1.94	1.98	0.73	0.71	0.00	-0.09
$\Delta \log y^{N}$	Non-tradable GDP growth	1.03	1.28	0.94	0.84	0.52	0.39
$\Delta \log c$	Private consumption growth	1.01	1.08	0.72	0.57	0.35	0.35
$\Delta \log i$	Total investment growth	3.75	3.17	0.68	0.55	0.33	0.58
$\Delta \log i^{Co}$	Commodity investment growth	7.66	8.07	0.31	0.22	0.38	0.54
tb/y	Nom. trade balance/GDP	5.41	3.51	0.37	0.04	0.79	0.89
ca/y	Nom. current account/GDP	4.11	2.88	0.29	0.16	0.63	0.88
$\Delta \log h$	Hours growth	0.84	1.90	0.49	0.61	0.21	0.00
$\Delta \log w$	Real wage growth	0.48	0.57	0.03	0.07	0.44	0.61
$\Delta \log c^G$	Gov. consumption growth	2.40	2.33	0.06	0.17	-0.29	-0.09
$\Delta \log i^G$	Gov. investment growth	10.97	9.07	0.06	0.36	-0.45	-0.37
$\Delta \log tr^G$	Gov. social transfers growth	3.45	3.83	0.04	0.09	-0.37	-0.08
b^{GT}/y	Total public assets/GDP	6.84	12.24	-0.00	-0.05	0.9877	0.9959
π	Headline inflation	0.62	0.70	0.09	-0.14	0.56	0.56
π^Z	Core inflation	0.53	0.49	-0.26	-0.08	0.80	0.77
π^F	Food inflation	2.12	2.21	0.22	-0.18	0.37	0.16
π^E	Energy inflation	3.44	3.49	0.21	0.03	0.14	0.25
R	Nominal interest rate	0.48	0.56	-0.21	-0.21	0.92	0.92
spr	Spread	0.19	0.25	-0.52	-0.08	0.82	0.89
rer	Real exchange rate	7.71	7.89	0.02	-0.09	0.90	0.88
π^S	Nominal devaluation rate	4.59	5.18	-0.20	-0.00	0.23	-0.04

5 Model Dynamics

5.1 Commodity price shock under alternative fiscal rules

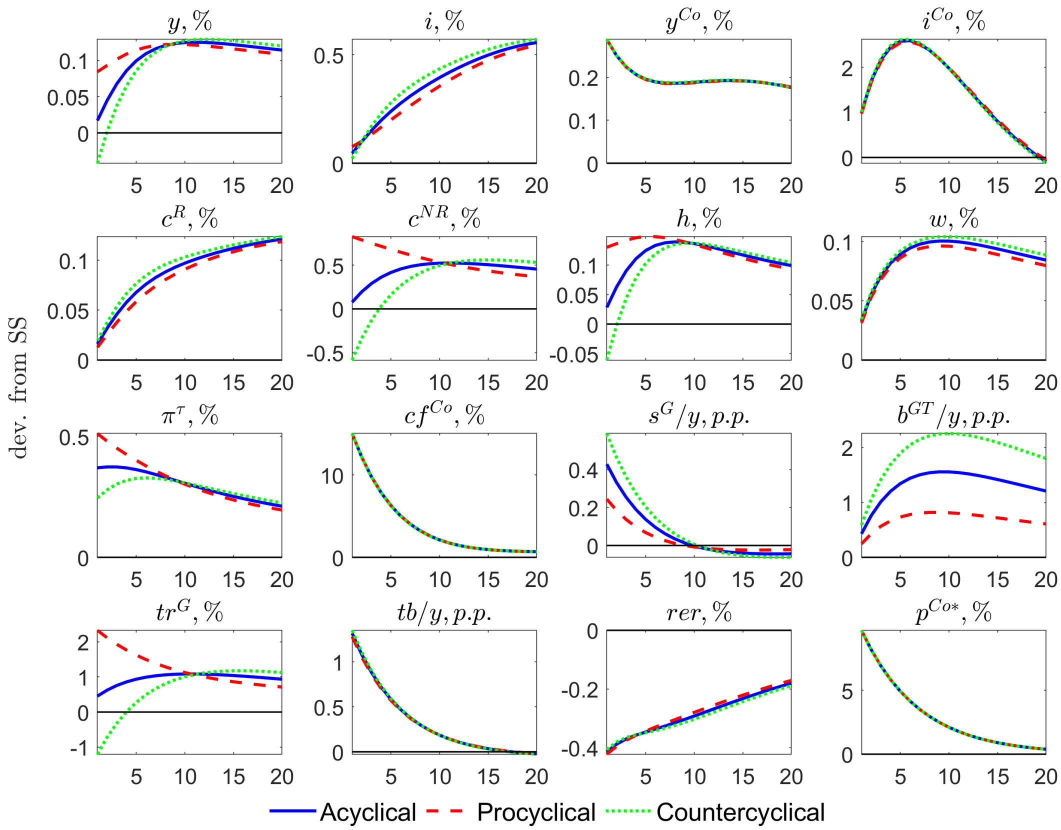
The Chilean economy's commodity dependence manifests at least in three dimensions. First, mining goods, on average (2001-2019), account for 14% of total GDP, fluctuating widely between a minimum of 7% in 2001 and a maximum of 24% in 2006. Second, mining exports represent an average of 53% of total goods 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 1 shows the effects of a 10% (one s.d.) positive shock to the price of the exported commodity (p_t^{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_t^{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 ($\rho_{p^{Co*}} = 0.84$, see Table 11 in Appendix A). As expected, during the first couple of years, output rises more under a procyclical rule, although the effect of additional government expenditure dissipates in the medium run.

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 budgetary 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 commodity shock significantly impacts the fiscal accounts, as approximately one-third of the commodity cash flow accrues to the government, while the remaining portion is received by foreign investors. Commodity-related fiscal revenues (cf^{Co}) experience a large increase of almost 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 budgetary 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). As government transfers (tr^G) are the baseline fiscal instrument, they naturally depend on the cyclical stance of the fiscal rule, increasing 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.

Figure 1: Responses to a positive one s.d. (10%) commodity price shock



Notes: This figure illustrates the equilibrium dynamics of our 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 ($\kappa^\tau = \kappa^{Co} = 2$).

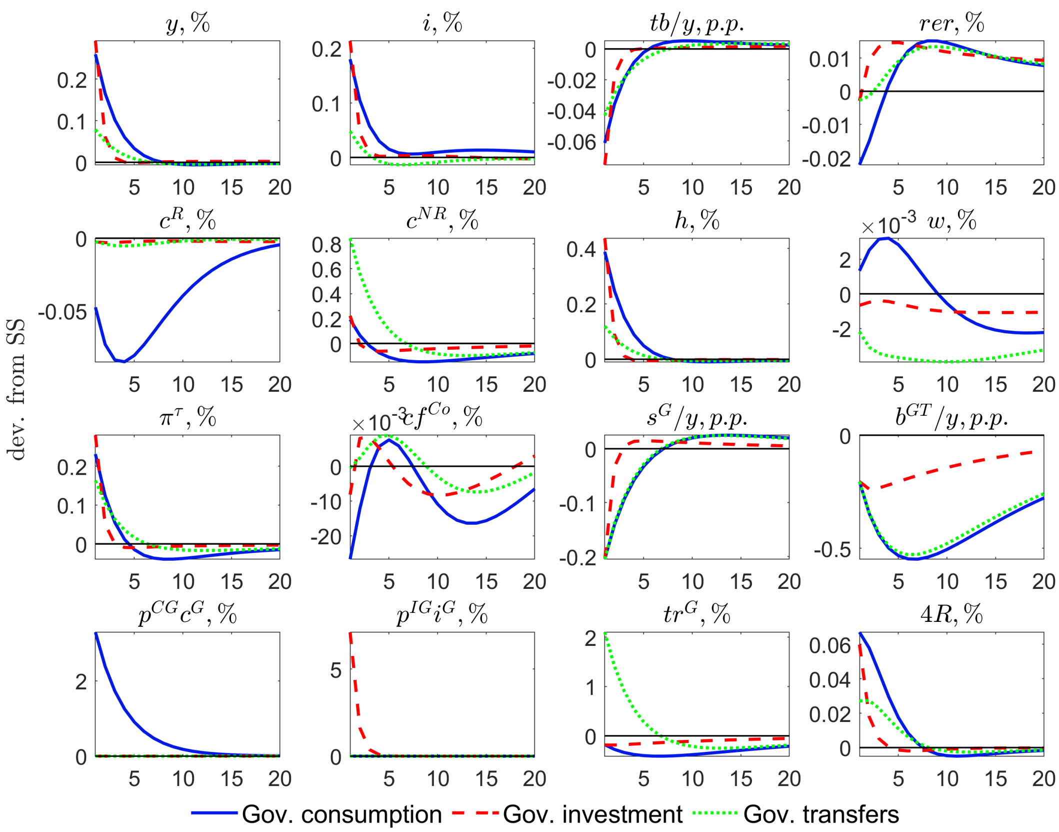
5.2 Government spending shocks

In this subsection, we study the model's dynamic response to three fiscal spending shocks: (a) government consumption shock, investment shock, and lump-sum social 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 $\varrho = 0.8$). Similarly, government capital is a public good, entering all sectorial production functions complementing private capital (calibrated $\varrho_G = 0.6$). Recall also our baseline model uses government transfers as the fiscal instrument to satisfy the rule, which for this exercise, we fix to be the acyclical benchmark ($\kappa^\tau = \kappa^{Co} = 1$).

Figure 2 presents responses to the three shocks normalized to generate the same change in the fiscal deficit-to-GDP ratio at impact, and thereafter allowing for heterogeneous persistence of each shock according to our estimation results. 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 and consumption display the largest fiscal multipliers, implying an increase in output (y) and investment (i) of around 0.25% at impact. Government transfers display the lowest multiplier, raising output by around 0.1% and investment by 0.05% at impact. The latter result is expected because, in our calibration, a fraction $\omega^{TR} = 0.5$ of total transfers pertain to Ricardian households ("savers"), thereby dampening its impact on aggregate demand. The transfer shock significantly affects non-Ricardian consumption (c^{NR}), while Ricardian households (c^R) almost fully smooth out the government gift. Finally, all fiscal expenditure shocks are inflationary, eliciting a rise in the monetary policy interest rate ($4R$), making all these shocks relatively short-lived.

Figure 2: 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.

6 Welfare-maximizing fiscal rules

The simple fiscal rules proposed in equations (32) (single feedback) and (33) (revenue-specific feedback) can be generalized to represent a continuum of possible rules, going from procyclical ($-1 \leq \kappa < 1$) to countercyclical ($1 < \kappa \leq 3$) 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 the welfare of Ricardian, non-Ricardian and the average consumer. We use lump-sum social transfers as the baseline adjusting instrument to satisfy the rule. In section 6.3, we study the robustness of our results to alternative fiscal instruments.

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. Similarly, we compute the consumption equivalent units, λ, as the fraction of lifetime consumption both households sacrifice to be indifferent and evaluate a joint equally weighted welfare objective function.

6.1 Baseline Results

Table 3 presents the optimized fiscal rule feedback parameters for Ricardian and non-Ricardian consumers and the implied welfare gains/losses. The table also reports the change in standard deviations of consumption and hours worked for both types of consumers. All statistics are presented relative to the acyclical benchmark. Panel (a) shows the optimized rules when we restrict the rule to a single feedback parameter (κ), and Panel (b) displays results when the government is allowed to react differently to the tax (κ^τ) and commodity (κ^{Co}) revenue gaps. To ease comparison, we also report the four reference rules introduced above: strong CRR ($\kappa = 3$), CRR ($\kappa = 2$), BBR ($\kappa = 0$), and strong BBR ($\kappa = -1$).

When the government response is limited to a single feedback parameter in Panel (a), Ricardian and non-Ricardian households benefit from a countercyclical fiscal policy. Ricardian households face a trade-off: while fiscal activism in the form of a strong CCR policy increases their consumption volatility by 0.9% relative to the acyclical benchmark, it also effectively stabilizes economic cycles, resulting in a 2.5% 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 0.05% of lifetime consumption under a strong CCR ($\kappa = 3$). In contrast, non-Ricardian households do not face such a trade-off. By adopting their milder optimized-CCR with $\kappa = 1.6$, hand-to-mouth consumers experience a welfare gain of 0.14%, achieved through reductions of 1.8% and 0.9% in consumption and hours worked volatility, respectively.

Table 3: Optimizing the fiscal policy rule

	Fiscal rule		Welfare gains			Ricardian consumption	Non-Ricardian consumption	Both hours worked
a) Single parameter	κ		λ	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Strong BBR	-1.0		-2.16	-0.09	-3.50	-0.9	20.6	3.8
BBR	0.0		-0.66	-0.04	-1.07	-0.5	7.4	1.7
CCR	2.0		0.06	0.03	0.08	0.4	-2.0	-1.4
Strong CCR	3.0		-0.31	0.05	-0.54	0.9	0.4	-2.5
Max. Ricardian	3.0		-0.31	**0.05**	-0.54	**0.9**	0.4	-2.5
Max. Non-Ricardian	1.6		0.09	0.02	**0.14**	0.3	**-1.8**	-0.9
b) Double parameter	κ^τ	κ^{Co}	λ	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Strong BBR	-1.0	-1.0	-2.30	-0.09	-3.72	-0.9	19.9	3.8
BBR	0.0	0.0	-0.70	-0.04	-1.14	-0.5	7.1	1.7
CCR	2.0	2.0	0.07	0.03	0.10	0.4	-2.0	-1.4
Strong CCR	3.0	3.0	-0.31	0.04	-0.54	0.9	0.2	-2.5
Max. Ricardian	3.0	0.1	0.31	**0.06**	0.48	**0.6**	-6.3	-2.6
Max. Non-Ricardian	3.0	0.6	0.33	0.05	**0.52**	0.7	**-6.1**	-2.6

Notes: This table presents the optimized fiscal parameters that maximize Ricardian and non-Ricardian welfare functions with their respective welfare gains/losses, including the gains/losses of a joint maximization function for both kinds of consumers (λ), i.e., the average consumer. This table also reports four fiscal policy benchmarks: Strong BBR, BBR, CCR and strong CCR. All the results are presented using a pure acyclical rule as the baseline; $\kappa = 1$ for the models with a single fiscal parameter and $\kappa^\tau = \kappa^{Co} = 1$ for the models with a double fiscal parameter. The following columns illustrate the change in the standard deviations of consumption for Ricardian and hand-to-mouth consumers. The last column shows the standard deviation of hours worked, which is the same for both consumers. Panel (a) presents our results restricting the fiscal response to a single fiscal parameter, and Panel (b) shows our results when there are two public feedback parameters.

Table 4: Macroeconomic and fiscal stability

	Fiscal rule		Macroeconomic variables					Public variables		
			Real GDP growth	Inflation	Interest rate	Real ex. rate	Nom. devaluation	Gov. expenditure	Gov. NFA	Ricardian NFA
	κ^{τ}	κ^{Co}	Δ std	Δ std	Δ std	Δ std	Δ std	Δ std	Δ std	Δ std
Strong BBR	-1.0	-1.0	6.5	-0.01	0.14	0.17	0.24	28.6	-64.7	11.0
BBR	0.0	0.0	2.8	-0.02	0.01	0.09	0.12	7.6	-41.5	5.3
CCR	2.0	2.0	-2.0	0.04	0.08	-0.09	-0.11	5.0	44.2	-4.8
Strong CCR	3.0	3.0	-3.5	0.10	0.23	-0.19	-0.22	18.5	88.7	-9.1
Max. Ricardian	3.0	0.1	-4.0	-0.11	0.11	-0.38	-0.23	7.7	64.1	-7.6
Max. Non-Ricardian	3.0	0.6	-4.0	-0.08	0.11	-0.35	-0.23	7.6	67.6	-7.9

Notes: This table presents the change in volatility of key macroeconomic and fiscal variables under the Ricardian and non-Ricardian optimized fiscal rules and four benchmark rules. All changes are relative to the volatilities obtained under the acyclical benchmark ($\kappa^{\tau} = \kappa^{Co} = 1$). In this table, we focus on the baseline model with revenue-specific feedback parameters.

Under the revenue-specific rule reported in Panel (b), the welfare-maximizing fiscal policy for both consumers is to strongly lean against the wind in response to the tax revenue gap ($\kappa^{\tau} = 3$) while maintaining a rather procyclical stance regarding the commodity revenue gap ($\kappa^{Co} = 0.1$ for Ricardians and $\kappa^{Co} = 0.6$ for non-Ricardians).[14] Table 3 illustrates that the double feedback rule unambiguously yields higher welfare gains than the single feedback policy, especially for non-Ricardian consumers. On the one hand, under the Ricardian optimized rule, Ricardian welfare gain, λ^R, increases by 20%, from 0.05% in Panel (a) to 0.06% in Panel (b). More importantly, the welfare implications for non-Ricardian households change radically from a loss of 0.54% to a gain of 0.48% of lifetime consumption. On the other hand, under the non-Ricardian preferred policy, non-Ricardian welfare gains more than triples (from 0.14% in Panel (a) to 0.52% in Panel (b)), while Ricardian welfare gains more than doubles (from 0.02% to 0.05%).

Allowing for a more flexible fiscal rule with revenue-specific feedback parameters is beneficial for all agents in the economy. For instance, when looking at the average consumer in Panel (b), the welfare gain, λ, is estimated at roughly 0.3% consumption equivalent units regardless of which household is being maximized. In contrast, the average consumer in Panel (a) experience a loss of 0.31% under the Ricardian optimized rule and a gain of just 0.09% under the non-Ricardian preferred policy. In general, non-Ricardian welfare gains have a larger influence on the average household well-being due to the larger welfare gains/losses faced by hand-to-mouth households compared to Ricardian consumers.

To better understand the optimized policies chosen by each type of consumer, Table 4 explore the effects of alternative rules on the volatility of key macroeconomic and fiscal variables. As before, all stats are relative to the acyclical SBR benchmark ($\kappa^{\tau} = \kappa^{Co} = 1$). As is well-known, procyclical fiscal rules amplify economic cycles. For instance, under BBR ($\kappa^{\tau} = \kappa^{Co} = 0$), the volatility of real GDP growth increases by 2.8%, and the volatilities of both the real exchange rate and the nominal devaluation rate also increase by roughly 0.1%. This heightened macroeconomic instability leads to a 1.7% increase in the volatility of hours worked, resulting in welfare losses

[14] Notice that fiscal rules restricted to a single feedback parameter (κ) closely follow the prescription for the fiscal parameter responding to the output gap (κ^{τ}). This remark is not surprising given that in our data sample, between $80 - 90\%$ of fiscal revenues come from taxes and the remaining $10 - 20\%$ from direct ownership of the commodity.

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 5.3% and reducing their consumption volatility by 0.5%. Overall, the detrimental impact of increased hours worked volatility outweighs the benefits of consumption smoothing, resulting in a Ricardian welfare loss of 0.04%. The implications of procyclical policies are even starker for financially constrained consumers. In their case, a BBR significantly increases the volatility of consumption by 7.1%, causing a 1.14% loss in lifetime consumption.

Conversely, the optimized rules for both households tend to minimize macroeconomic volatility. A CCR response via κ^{τ} plays a vital role in macroeconomic stabilization as this counterbalances the business cycle through government spending adjustments, as evidenced by Kumhof and Laxton (2013) and Snudden (2016). Under the Ricardian optimized fiscal rule, the volatility of GDP growth falls by 4% relative to an acyclical benchmark (see Table 4). There is also a drop in the volatility of inflation, real exchange rate, and nominal devaluation rate of 0.11%, 0.38%, and 0.23%, respectively. This enhanced macroeconomic stability enables welfare gains of 0.06% and 0.48% for Ricardian and non-Ricardian households, respectively. Hence, moving from a general BBR policy ($\kappa^{\tau} = \kappa^{Co} = 0$) to the Ricardian optimized rule ($\kappa^{\tau} = 3$ and $\kappa^{Co} = 0.1$) enables extra gains of $0.1.$ p.p. and 1.6 p.p. of lifetime consumption, respectively, as shown in Table 3.

Differently, the optimal rule responding to the commodity revenue gap is not to be countercyclical but rather procyclical. This result is explained by the intrinsically different nature of commodity-related revenues relative to tax revenues. Considering that 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 copper prices, which do not (necessarily) correlate with the domestic business cycle. Moreover, as only one-third of the commodity cash flow belongs to the government and the rest to foreign investors, commodity price shocks manifest in the economy primarily as higher than usual government revenues, with no direct effect on households' income.

In such a scenario, if the economy is hit by a positive copper price shock during an economic recession, a countercyclical fiscal response to the shock via κ^{Co} would drag the economy further down, amplifying economic cycles. Indeed, Table 4 shows that moving from a strong CCR benchmark ($\kappa^{\tau} = \kappa^{Co} = 3$) to either optimized fiscal rule ($\kappa^{\tau} = 3$ and $\kappa^{Co} \in \{0.1, 0.6\}$) generates lower volatility in all macroeconomic and fiscal variables reported. In turn, the lower macroeconomic volatility enables more considerable welfare gains of 0.02 p.p. and more than 1 p.p. of lifetime consumption for Ricardian and non-Ricardian consumers, respectively.

Finally, it is worth noting that the higher the persistence of commodity shocks, the more likely consumers prefer a procyclical stance regarding commodity revenues. When a persistent commodity boom hits the economy, the government runs budget surpluses for an extended period under a countercyclical policy rule, protractedly improving its net foreign asset position. In this scenario, a welfare-improving approach is to transfer a fraction of these resources to consumers and save the rest in a sovereign fund following a mildly procyclical response.

6.2 The impact of the feasibility constraint

This section highlights the impact of the feasibility/sustainability constraint ($\kappa^B > 0$) on households' optimized rules and the magnitude of welfare gains. This quantitative exercise is relevant as most papers in the literature evaluate models where the feasibility constraint is deactivated ($\kappa^B = 0$). In contrast, our baseline model assumes debt sustainability as an important constraint limiting the action space of fiscal policy rules. In a nutshell, the feasibility constraint prevents the government from accumulating too much debt (or assets) for a long period of time, thereby yielding simple and implementable fiscal policy rules. Table 5 presents optimized fiscal rules over κ^τ and κ^{Co} under $\kappa^B = 0$. We also report the four benchmark rules introduced above for comparison: strong CRR, CRR, BBR, and strong BBR.

When the debt sustainability constraint is shut off, the optimized rule concerning the tax revenue gap for Ricardian consumers shifts from a strong CCR ($\kappa^\tau = 3$) to a strong BBR ($\kappa^\tau = -1$). Hence, we obtain the classic results in the literature regarding consumer preferences for fiscal policy rules (García-Cicco and Kawamura, 2015, Garcia et al., 2011 and, Ojeda-Joya et al., 2016). As Ricardian consumers can smooth their consumption through direct access to financial markets, they prefer the least activism possible from the government. Under their preferred strong BBR, Ricardian consumption volatility falls by 5.3%, accruing a welfare gain of 0.1%. In contrast, under this policy rule, financially constrained consumers suffer substantial losses of more than 4%, as it significantly increases their consumption volatility by more than 60%.

Table 5: Optimizing the fiscal rule without the feasibility constraint

	Fiscal rule		Welfare gains			Ricardian consumption	Non-Ricardian consumption	Both hours worked
	κ^τ	κ^{Co}	λ	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Strong BBR	-1.0	-1.0	-2.42	0.10	-4.04	-5.3	60.6	4.2
BBR	0.0	0.0	-0.78	0.05	-1.33	-2.7	24.4	1.9
CCR	2.0	2.0	0.16	-0.06	0.31	2.7	-9.0	-1.5
Strong CCR	3.0	3.0	-0.12	-0.13	-0.12	5.4	-2.5	-2.7
Max. Ricardian	-1.0	-1.0	-2.42	**0.10**	-4.04	**-5.3**	60.6	4.2
Max. Non-Ricardian	3.0	0.7	0.44	-0.08	**0.78**	4.6	**-18.8**	-2.9

Notes: This table presents the optimal fiscal parameters that optimize the Ricardian and non-Ricardian maximization functions with their respective welfare gains/losses when the feasibility constraint is deactivated ($\kappa^B = 0$). The table also includes the gains/losses of a joint maximization function for both kinds of consumers (λ), i.e., the average consumer. This table also reports four fiscal policy benchmarks: Strong BBR, BBR, CCR, and strong CCR. The following columns illustrate the standard deviation of consumption for Ricardian and hand-to-mouth consumers. The last column shows the standard deviation of work hours for both consumers. All the results are presented using a pure acyclical rule as the baseline ($\kappa^\tau = \kappa^{Co} = 1$).

Credit-constrained households' preferences remain constant, opting for a strong CCR policy concerning the tax revenue gap, as it enables the government to smooth their consumption via social transfers or any other automatic stabilizer. Under $\kappa^B = 0$, the non-Ricardian optimized rule ($\kappa^\tau = 3$ and $\kappa^{Co} = 0.7$) yields a sizable decline of 18.8% in their consumption volatility and a further decline of 2.9% in the volatility of hours worked, leading to welfare gains of 0.78%. Conversely, Ricardian consumers suffer slight welfare losses of 0.08% under the non-Ricardian welfare-maximizing rule as their consumption volatility increases by 4.6%. As also illustrated by

Snudden (2016), too much fiscal activism can hurt Ricardian consumers when government debt is not feasible, as it heavily disrupts their ability to smooth consumption and maintain precautionary savings.

To shed light on the relevance of the debt sustainability constraint and on why Ricardian households change their optimized fiscal rule so radically, Figure 3 illustrates the time evolution of the model-implied public and private net foreign asset positions over a long simulation spanning 400 periods (100 years). More specifically, using the same sequences for all random shocks in the model, we simulate two counterfactual economies: one with the feasibility constraint activated ($\kappa^B > 0$ in Panel I) and another with it deactivated ($\kappa^B = 0$ in Panel II). In each case, we compare two selected fiscal rules: the rule chosen by Ricardians under $\kappa^B > 0$ ($\kappa^\tau = 3$, $\kappa^{Co} = 0$) and the rule chosen by Ricardians but under $\kappa^B = 0$ ($\kappa^\tau = \kappa^{Co} = -1$).

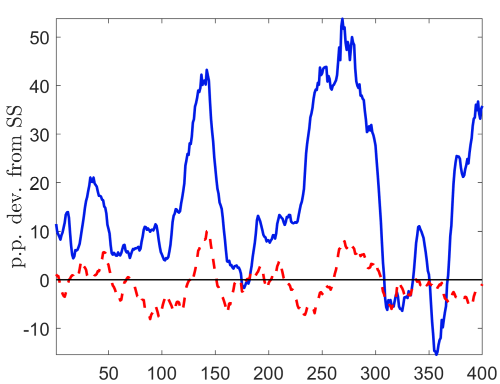
As expected, fiscal activism requires greater volatility in government foreign asset position under $\kappa^\tau = 3$ and $\kappa^{Co} = 0$, reaching peaks of above 50% of GDP (see Subpanel (a), Panel I, in Figure 3). In contrast, under a strong BBR policy $\kappa^\tau = \kappa^{Co} = -1$, the government limits its asset accumulation to the range of -10% and 10% of GDP. When the feasibility constraint is activated ($\kappa^B > 0$), Ricardian households display a strong precautionary savings motive, regardless of the alternative fiscal policy rule, accumulating assets during most of the simulated period (see Subpanel (b), Panel I). The slightly higher volatility of assets' position under a strong BBR policy partly justifies Ricardian preferences for a countercyclical rule concerning the tax revenue gap.

When the feasibility constraint is deactivated, the government's asset position behaves like a unit root, maintaining positive or negative values for unsustainable long periods of time. Especially when the fiscal rule is strongly countercyclical ($\kappa^\tau = 3$), the government behaves so cautiously that it accumulates between 3 and 5 annual GDPs for more than 100 consecutive years (see Subpanel (c), Panel II, in Figure 3). Consequently, Ricardian households have to respond in a mirrored fashion by accumulating the large amounts of debt the economy requires to take advantage of investment opportunities. In doing so, Ricardian consumers lose their ability to hold the precautionary savings they would otherwise maintain under a feasible and sustainable fiscal policy rule (see Subpanel (d), Panel II).

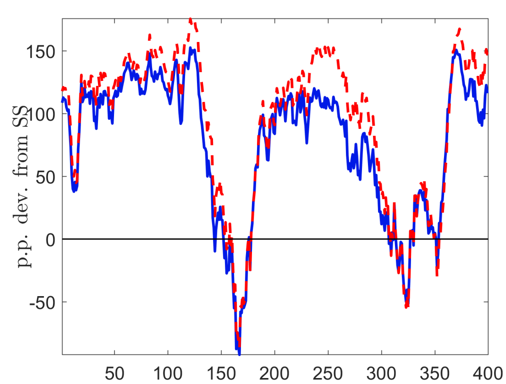
Figure 3: The feasibility constraint on asset positions

I. Baseline model ($\kappa^B > 0$)

(a) Government NFA / GDP

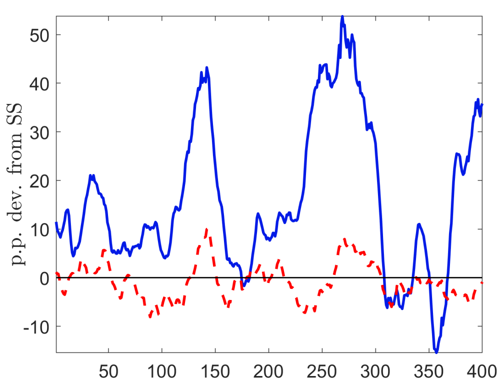


(b) Ricardian NFA / GDP

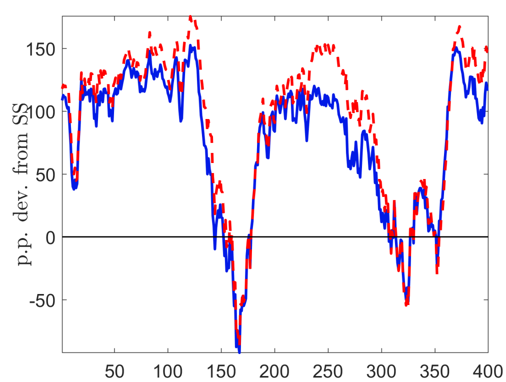


II. Baseline model with $\kappa^B = 0$

(c) Government NFA / GDP



(d) Ricardian NFA / GDP



$\kappa^\tau = 3$, $\kappa^{Co} = 0$ $\kappa^\tau = -1$, $\kappa^{Co} = -1$

Notes: The Figures show the public and private net foreign asset positions (NFA, as % of GDP) from a sample simulation of the model under different fiscal rules. All simulations are subjected to the same sequence of random shocks. Panel I reports time paths under $\kappa^B > 0$, while Panel II under $\kappa^B = 0$. Solid-blue lines report results for $\kappa^\tau = 3$ and $\kappa^{Co} = 0$, and red-dashed lines uses $\kappa^\tau = \kappa^{Co} = -1$.

6.3 Fiscal instruments

The results discussed so far follow the literature in using lump-sum transfers as the only budgetary tool to implement the fiscal rule introduced in equation (33). Table 6 reports the optimized rules for Ricardian (Panel I) and non-Ricardian (Panel II) consumers under four alternative budgetary instruments: government consumption (c^G), investment (i^G)[15], lump-sum transfers (tr^G, baseline),

[15]We did not obtain stable computational solutions when the fiscal instrument is investment alone, as this option requires extreme variation in public investment to satisfy the rule. Hence, we adjust this instrument alongside

and the simultaneous adjustment of the three government spending components ($All\ ins.$).

Table 6: 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	λ^{R}	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
c^G	0.7	1.0	-0.04	**0.00**	-0.02	**-0.4**	0.5	1.0
i^{G*}	1.1	0.9	0.03	**0.00**	0.01	**0.1**	-0.3	-0.5
tr^G	3.0	0.1	0.31	**0.06**	0.48	**0.6**	-6.5	-2.7
$All\ ins.$	1.8	0.9	0.25	**0.01**	0.36	**0.9**	-3.9	-4.0
II. Max. non-Ricardian								
c^G	2.1	0.3	-0.05	-0.05	**0.04**	1.3	**-2.0**	-3.4
i^{G*}	2.9	0.1	0.03	-0.07	**0.11**	2.3	**-4.2**	-7.8
tr^G	3.0	0.6	0.33	0.05	**0.52**	0.7	**-6.3**	-2.7
$All\ ins.$	2.7	0.7	0.28	0.00	**0.48**	1.9	**-6.3**	-7.8

Notes: This table illustrates the optimized fiscal policy rule choices of Ricardian (Panel I) and non-Ricardian (Panel II) consumers under different adjusting fiscal instruments: government consumption (c^G), investment (i^{G*}), direct social transfer (tr^G), and the simultaneous adjustment of all the previously mentioned instruments ($All\ ins.$). i^{G*} refers to government investment and consumption activated simultaneously. Columns κ^{τ} and κ^{Co} illustrate the optimal response to the tax and commodity revenue gap, respectively. The table includes the welfare gains/losses for Ricardian and non-Ricardian households, including a joint maximization function for both kinds of consumers (λ), i.e., the average consumer. The following columns illustrate the standard deviation of consumption for Ricardian and hand-to-mouth consumers. The last column shows the standard deviation of work hours for both consumers.

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 6 illustrates that Ricardian households prefer a CCR response to the tax revenue gap and a BBR response to the commodity revenue gap only when tr^G is employed. Otherwise, they prefer a κ^{τ} leaning to a mildly procyclical response or an acyclical rule when c^G or i^G respond to the fiscal regime, respectively. Regarding κ^{Co}, Ricardian consumers prefer an acyclical response when any alternative fiscal instruments, other than tr^G, are employed.

Table 6 demonstrates that the most substantial welfare improvements for both types of consumers are observed when employing tr^G, followed closely by the simultaneous adjustment of all expenditure components ($All\ ins.$). For example, although Ricardian consumption volatility increases by 0.9% when all fiscal tools are employed simultaneously, the volatility of hours worked decreases by more than 4%, leading to a welfare gain of 0.01% of Ricardian lifetime consumption. These gains are six times smaller than when social transfers adjust alone. Similarly, Table 6 shows that the largest welfare gains for non-Ricardian households are reached when using tr^G as the instrument (0.52%), followed closely by $All\ ins.$ (0.48%), and much below, by i^G (0.11%) and c^G (0.04%).

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 4 shows the attainable welfare gains for Ricardian and non-Ricardian consumers, along with the implied volatility in GDP

government consumption.

growth (Panel I) and government expenditures (Panel II), for a continuum of fiscal rules under each possible fiscal instrument. Each line in the plot represents a fiscal instrument, while each point in the line represents a different value for κ^{τ} in [-1,3]. In this exercise, we kept κ^{Co} fixed at the estimated value of one.

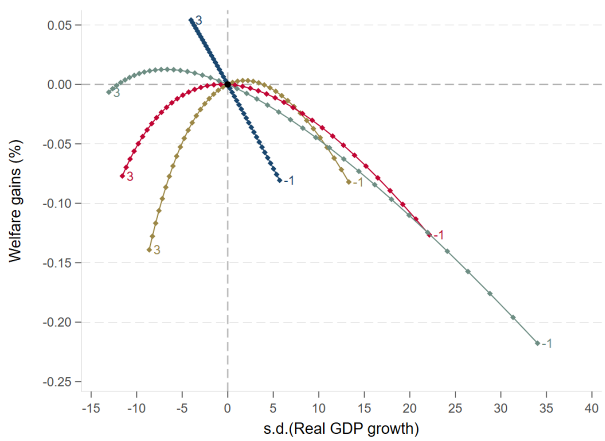
Panel I of Figure 4 shows that a procyclical response to tax revenues unambiguously increases the volatility of GDP growth, producing welfare losses for both types of households regardless of the fiscal instrument, but especially so when $All\ ins.$ are used simultaneously. Notably, non-Ricardian welfare implications (Subplot (b)) are one order of magnitude more significant than those experienced by Ricardian consumers (Subplot (a)). For instance, when tr^G adjusts to $\kappa^{\tau} = 3$, hand-to-mouth consumers experience gains ten times larger than those experienced by Ricardian consumers; when $All\ ins.$ adjust to $\kappa^{\tau} = -1$ they experience losses almost twenty times larger. Even though social transfers yield the most significant welfare gains for both consumers, this instrument enables only moderate reductions in macroeconomic volatility as κ^{τ} approaches a more countercyclical response. When $all\ ins.$ are employed, there are larger reductions in macroeconomic instability while enabling similarly high welfare gains for non-Ricardian consumers (Subplot (b)). However, these gains are much smaller for Ricardian consumers (Subplot (a)).

Turning to the effects of alternative fiscal instruments on the volatility of government spending in Panel II of Figure 4, we find that moving from a procyclical to an acyclical κ^{τ} is a win-win strategy, as this decreases welfare losses and the volatility of government spending under any fiscal instrument considered. Conversely, fiscal authorities face a trade-off between welfare gains and increasing government spending volatility when κ^{τ} behaves countercyclically, especially when considering non-Ricardian welfare. tr^G yields the most significant welfare gains for both consumers at the cost of only moderate increases in government spending volatility. Nevertheless, this result is followed closely by $All\ ins.$ when observing non-Ricardian preferences (Subplot (d)). Hence, similar to the findings in Kumhof and Laxton (2013), social transfers are the most appropriate instrument to implement the fiscal rule, yielding the highest welfare gains, enabling reductions in macroeconomic volatility, and producing only moderate additional volatility in government spending. We also find that $All\ ins.$ enables similar welfare gains for non-Ricardian consumers with even more significant reductions to macroeconomic volatility but at the cost of larger volatility in government spending.

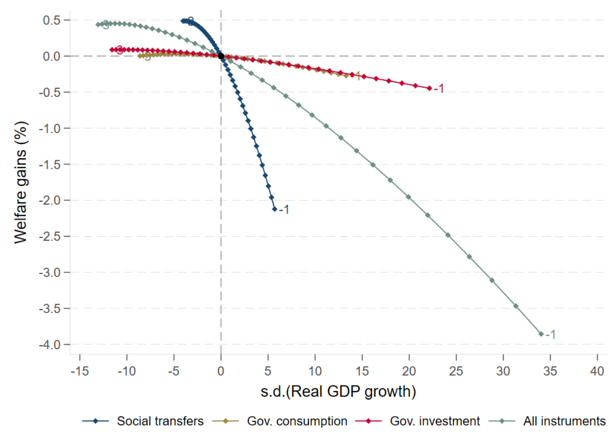
Figure 4: Evaluating fiscal policy instruments

I. Macroeconomic volatility

(a) Ricardian households

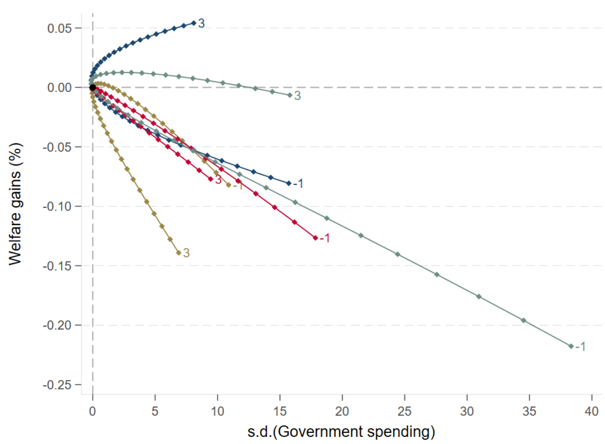


(b) Non-Ricardian households

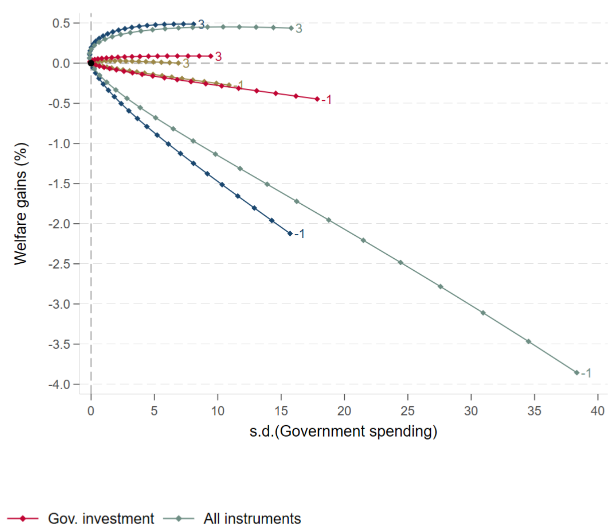


II. Government spending volatility

(c) Ricardian households



(d) Non-Ricardian households



Notes: Panel I depicts the variation in real GDP growth volatility, while Panel II displays the fluctuations in government spending volatility resulting from alternative fiscal policy rules using different budgetary instruments. Changes in percentage welfare gains for Ricarian (Subplot (a) and (c)) or non-Ricardian (Subplot (b) and (d)) consumers, real GDP growth variability, and government spending volatility are presented relative to the results under an acyclical rule. Each dot illustrates an alternative budgetary approach in which the feedback parameter concerning the commodity revenue gap is set to be acyclical ($\kappa^{Co} = 1$), and the feedback parameter concerning the tax revenue gap goes from a strong BBR ($\kappa^{\tau} = -1$) to a strong CCR fiscal policy rule ($\kappa^{\tau} = 3$).

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. Our 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 only a few articles share these assumptions simultaneously, we check the sensitivity of our main results to alternative model specifications.[16]

Table 7 illustrates the welfare maximizing fiscal policies for Ricardian and non-Ricardian consumers when we abstract from the government consumption in consumer's utility function (Panel I), when we abstract from public investment (Panel II) and when both of these assumptions are not considered in the model (Panel III). We use lump-sum social transfers as the baseline adjusting instrument. All the stats are presented relative to an acyclical fiscal stance ($\kappa^{\tau} = \kappa^{Co} = 1$).

Our main results are robust across models, with consumers preferring a strong CCR response to the tax revenue gap and a mildly procyclical reaction to the commodity revenue gap. The magnitude of payoffs changes as we abstract these assumptions. Welfare gains for both consumers under their optimized fiscal rules almost double when we subtract government consumption from the consumers' utility functions. These payoffs are reduced when we do not model public investment. Ultimately, when we exclude both assumptions, the welfare gains revert to a magnitude similar to that of our baseline model, as the impact of omitting these two assumptions offsets each other.

Table 7: Welfare evaluation: optimal fiscal policy rule in different models

	Fiscal rule		Welfare gains			Ricardian consumption	Non-Ricardian consumption	Both hours worked
I. Baseline model without c^G in U	κ^{τ}	κ^{Co}	λ	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Max. Ricardian	3.0	0.0	0.55	**0.09**	0.80	**0.6**	-6.3	-2.6
Max. Non-Ricardian	3.0	0.6	0.62	0.09	**0.90**	0.6	**-6.2**	-2.6
II. Baseline model without k^G	κ^{τ}	κ^{Co}	λ	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Max. Ricardian	3.0	0.1	0.19	**0.04**	0.30	**0.6**	-5.1	-2.8
Max. Non-Ricardian	2.7	0.7	0.23	0.03	**0.37**	0.5	**-4.8**	-2.5
III. Baseline model without c^G in U and k^G	κ^{τ}	κ^{Co}	λ	λ^R	λ^{NR}	Δ s.d.	Δ s.d.	Δ s.d.
Max. Ricardian	3.0	0.2	0.35	**0.07**	0.51	**0.5**	-5.1	-2.9
Max. Non-Ricardian	2.7	0.7	0.39	0.06	**0.59**	0.5	**-4.8**	-2.6

Notes: This table presents the optimal fiscal parameters that maximize Ricardian, non-Ricardian, and a joint maximization function for both kinds of consumers, i.e., the average consumer, with the respective welfare gains/losses, and the standard deviation of consumption for Ricardian and hand-to-mouth consumers. Moreover, the last column illustrates the standard deviation of hours worked for both consumers. Panel I shows the results for our baseline model without government consumption (c^G) in the consumer utility function (U), while Panel II illustrates the results for our model without public investment (k^G). Panel III shows the results for our model abstracting from both assumptions, c^G in U and k^G.

7 Conclusions

This paper evaluates the welfare implications of alternative rule-based fiscal policies in commodity-dependent economies, where a large share of output, exports, and fiscal revenues depend on exogenous and volatile commodity prices. To do so, we build a general equilibrium model of a small and open commodity-dependent economy tailored for Chile, in which a large fraction of consumers are financially-constrained, thereby giving a non-trivial role for fiscal policy rules. We begin by examining alternative single fiscal parameter rules responding to fluctuations in fiscal revenue. We

[16] To the best of our knowledge, Kumhof and Laxton (2013) is the only article considering these two assumptions simultaneously in the literature.

then expand our analysis to two budgetary parameters, allowing government spending to react differently to the tax and commodity revenue gaps. As the accumulation of government assets in response to fiscal rules cannot be unbounded, we consider a debt sustainability constraint when evaluating consumers' optimized fiscal policy rules.

Our findings show that both Ricardian and non-Ricardian consumers prefer CCR policies reacting to fluctuations in public revenue. When evaluating a budgetary policy with two parameters, the welfare-maximizing fiscal policy rule is actively countercyclical, leaning against the wind of the economic cycle when fiscal revenues fluctuate due to the tax revenue gap and mildly procyclical in response to exogenous international commodity prices. The optimized fiscal policy rule has a stabilizing effect on the macroeconomy, enabling more considerable welfare gains. When we move from a single to a double parameter policy rule under the rule-of-thumb optimized fiscal policy rule, the gains of Ricardian and non-Ricardian households more than double and triple, respectively.

The stability and credibility of our findings rely heavily on imposing a feasibility constraint limiting the action space of fiscal policy to sustainable debt levels. Shutting off this constraint renders public debt close to a unit root process, severely deteriorating the model's fit and the rule's ability to stabilize the economy. Moreover, we show that abstracting from the feasibility constraint leads to a drastic change in Ricardian consumer preferences, who switch from a strongly countercyclical to a strongly procyclical policy responding to the tax revenue gap, thus recovering the classic result in the literature and highlighting the importance of the debt constraint in our analysis. Lastly, social transfers are the best fiscal instrument to implement the optimal fiscal rule, yielding higher welfare gains while reducing macroeconomic volatility to the cost of only moderate increases in government spending volatility. Employing all instruments is also viable as it enables similarly large welfare gains for hand-to-mouth consumers with an even more significant reduction in macroeconomic volatility. Nevertheless, this broader approach produces more significant increases in government spending volatility.

Cyclically-adjusted fiscal rules are valuable tools for stabilizing small economies 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 8 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, Soto, 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 8: 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, Soto, 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, Soto, 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, Soto, 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, Soto, 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 9 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 9: 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.

[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 10 and 11 report prior and posterior distributions for structural parameters and AR(1) processes, respectively.

Table 10: Prior and Posterior Distributions: Structural Parameters.

Parameters	Description	Initial Prior			Posterior		
		distr.	mean	s.d.	mean	pct. 5	pct. 95
ψ	Inverse Frisch elasticity	G	1.50	0.50	**0.95**	0.40	1.53
ϱ	Elast. of subst. private vs. gov. cons.	G	1	0.50	**0.80**	0.28	1.32
ϱ_C	Elast. of subst. in cons.	G	1	0.25	**0.46**	0.29	0.64
ϱ_Z	Elast. of subst. in core cons.	G	1	0.25	**1.17**	0.72	1.62
ϱ_T	Elast. of subst. in tradables cons.	G	1	0.25	**1**	0.62	1.40
ϱ_F	Elast. of subst. in food cons.	G	1	0.25	**0.96**	0.56	1.34
ϱ_I	Elast. of subst. in investment	G	1	0.25	**1.20**	0.73	1.63
ϱ_{ICo}	Elast. of subst. in Co investment	G	1	0.25	**1.05**	0.60	1.44
ϱ_{CG}	Elast. of subst. in gov. cons.	G	1	0.25	**0.89**	0.54	1.23
ϱ_{IG}	Elast. of subst. in gov. investment	G	1	0.25	**0.98**	0.56	1.37
κ^τ	Gov. reaction to tax revenue cycle	G	1	0.25	**1.15**	0.69	1.54
κ^{Co}	Gov. reaction to comm. revenue cycle	G	1	0.25	**0.99**	0.69	1.29
κ^B	Feasibility constraint (public assets)	G	0.50	0.25	**0.17**	0.09	0.24
ϵ^*	Elasticity of foreign demand	IG	0.20	0.05	**0.19**	0.13	0.26
ϕ_c	Habit formation	B	0.75	0.10	**0.81**	0.72	0.89
$100\phi_b$	Country premium debt elas.	IG	1	Inf.	**0.22**	0.17	0.28
ϕ_k	Inv. adjustment cost elast.	G	5	1.50	**3.92**	2.16	5.57
ϕ_k^{Co}	Inv. adjustment cost elast., mining	G	2	0.50	**2.37**	1.62	3.02
ϕ_u	Capital utilization cost, N and X	G	1.50	0.25	**1.50**	1.10	1.88
θ^N	Calvo probability N	B	0.75	0.08	**0.67**	0.62	0.74
θ^X	Calvo probability X domestic	B	0.75	0.08	**0.95**	0.93	0.97
θ^M	Calvo probability M	B	0.75	0.08	**0.74**	0.67	0.79
θ^{X*}	Calvo probability X foreign	B	0.75	0.08	**0.77**	0.65	0.88
θ_w	Calvo probability wages	B	0.75	0.08	**0.87**	0.84	0.91
α_y	Taylor rule response to GDP growth	N	0.12	0.05	**0.09**	0.03	0.15
α_π	Taylor rule response to total inflation	N	1.70	0.10	**1.71**	1.56	1.86
ρ^R	Taylor rule smoothing parameter	B	0.85	0.05	**0.70**	0.64	0.76
ρ^{X*}	Persistence in foreign demand	B	0.50	0.20	**0.78**	0.67	0.91
ρ_1^O	Oil price smoothing param. 1	B	0.50	0.20	**0.81**	0.78	0.85
ρ_2^O	Oil price smoothing param. 2	B	0.50	0.20	**0.47**	0.32	0.63
Γ^N	Global pass through, N	B	0.50	0.20	**0.54**	0.25	0.84
Γ^X	Global pass through, X	B	0.50	0.20	**0.50**	0.19	0.81
Γ^{Co}	Global pass through, Co	B	0.50	0.20	**0.50**	0.15	0.82

Table 11: 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	B	0.50	0.20	**0.67**	0.53	0.83
ρ_{z^N}	Productivity shock, N	B	0.85	0.08	**0.93**	0.88	0.98
ρ_{z^X}	Productivity shock, X	B	0.85	0.08	**0.95**	0.91	0.98
$\rho_{z^{Co}}$	Productivity shock, Co	B	0.85	0.08	**0.91**	0.86	0.96
ρ_{z^F}	Productivity shock, Food	B	0.75	0.08	**0.94**	0.91	0.97
ρ_{ξ^O}	Domestic oil price shock	B	0.50	0.20	**0.33**	0.08	0.55
ρ_{ξ^β}	Preference shock	B	0.50	0.20	**0.47**	0.26	0.69
ρ_{ξ^h}	Labor supply shock	B	0.50	0.20	**0.38**	0.15	0.61
ρ_{ξ^i}	Inv. prod. shock, N and X	B	0.75	0.08	**0.58**	0.47	0.69
$\rho_{\xi^{iCo}}$	Inv. prod. shock, Co	B	0.50	0.20	**0.59**	0.44	0.73
ρ_{ξ^m}	Monetary policy shock	B	0.50	0.20	**0.55**	0.40	0.70
$\rho_{\xi^{CG}}$	Public consumption shock	B	0.75	0.08	**0.72**	0.61	0.84
$\rho_{\xi^{IG}}$	Public investment shock	B	0.50	0.20	**0.23**	0.04	0.39
$\rho_{\xi^{TR}}$	Public transfer shock	B	0.75	0.08	**0.74**	0.63	0.86
ρ_{z^*}	Foreign productivity shock	B	0.85	0.08	**0.87**	0.78	0.97
ρ_{π^*}	Foreign inflation shock	B	0.50	0.20	**0.31**	0.23	0.39
$\rho_{p^{M*}}$	Import price shock	B	0.50	0.20	**0.62**	0.44	0.82
$\rho_{p^{O*}}$	Fuel price shock	B	0.50	0.20	**0.90**	0.83	0.97
$\rho_{p^{Co*}}$	Co price shock	B	0.50	0.20	**0.84**	0.80	0.89
$\rho_{R^{W*}}$	Foreign interest rate shock	B	0.50	0.20	**0.90**	0.87	0.93
$\rho_{\xi^{S*}}$	Spread shock (observed)	B	0.75	0.08	**0.82**	0.75	0.89
$\rho_{\xi^{U*}}$	Spread shock (unobserved)	B	0.75	0.08	**0.83**	0.74	0.93
Innovation s.d.							
$100\sigma_a$	Global unit root tech. shock	IG	0.50	Inf.	**0.26**	0.19	0.33
$100\sigma_{z^N}$	Productivity shock, N	IG	0.50	Inf.	**0.65**	0.52	0.78
$100\sigma_{z^X}$	Productivity shock, X	IG	0.50	Inf.	**2.69**	2.31	3.11
$100\sigma_{z^{Co}}$	Productivity shock, Co	IG	0.50	Inf.	**3**	2.60	3.42
$100\sigma_{z^F}$	Productivity shock, Food	IG	0.50	Inf.	**1.95**	1.70	2.23
$100\sigma_{\xi^O}$	Domestic oil price shock	IG	0.50	Inf.	**1.67**	1.33	2.02
$100\sigma_{\xi^\beta}$	Preference shock	IG	0.50	Inf.	**7.18**	3.52	10.58
$100\sigma_{\xi^h}$	Labor supply shock	IG	0.50	Inf.	**15.43**	5.19	25.37
$100\sigma_{\xi^i}$	Inv. prod. shock, N and X	IG	0.50	Inf.	**6.14**	3.37	8.60
$100\sigma_{\xi^{iCo}}$	Inv. prod. shock, Co	IG	0.50	Inf.	**8.72**	5.01	12.30
$100\sigma_{\xi^m}$	Monetary policy shock	IG	0.50	Inf.	**0.15**	0.13	0.17
$100\sigma_{\xi^{CG}}$	Public consumption shock	IG	0.50	Inf.	**2.09**	1.84	2.39
$100\sigma_{\xi^{IG}}$	Public investment shock	IG	0.50	Inf.	**7.11**	5.95	8.15
$100\sigma_{\xi^{TR}}$	Public transfer shock	IG	0.50	Inf.	**3.47**	2.95	3.99
$100\sigma_{\xi^{X*}}$	Foreign demand shock	IG	0.50	Inf.	**2.36**	2.02	2.68
$100\sigma_{z^*}$	Foreign productivity shock	IG	0.50	Inf.	**0.23**	0.15	0.31
$100\sigma_{\xi^*}$	Foreign inflation shock	IG	0.50	Inf.	**2.17**	1.88	2.47
$100\sigma_{\xi^{M*}}$	Import price shock	IG	0.50	Inf.	**1.28**	1	1.56
$100\sigma_{\xi^{O*}}$	Fuel price shock	IG	0.50	Inf.	**12.47**	10.87	14.26
$100\sigma_{\xi^{Co*}}$	Co price shock	IG	0.50	Inf.	**9.69**	8.39	11
$100\sigma_{R^{W*}}$	Foreign interest rate shock	IG	0.50	Inf.	**0.15**	0.12	0.18
$100\sigma_{\xi^{S*}}$	Spread shock (observed)	IG	0.50	Inf.	**0.11**	0.09	0.12
$100\sigma_{\xi^{U*}}$	Spread shock (unobserved)	IG	0.50	Inf.	**0.40**	0.19	0.61