Rethinking Fiscal Rules in Resource-Rich 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 depends on exogenous and volatile commodity prices. Using a multi-sector New Keynesian model estimated for the Chilean economy, we find that the welfare-maximizing fiscal policy involves an actively countercyclical response to the tax revenue cycle and an acyclical response to the commodity revenue cycle. Compared to a benchmark acyclical policy, the optimized rule reduces macroeconomic (GDP growth) volatility while delivering welfare gains of 0.6% of lifetime consumption for the average household (1.2% for hand-to-mouth households). Government consumption and especially public investment are particularly helpful in stabilizing GDP, while targeted social transfers are essential to smooth the consumption of financially constrained households. Implementing the optimized rule requires moderate additional volatility (fiscal activism) in government spending and public debt.

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

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1 Introduction

We revisit the design and implementation of structural balance fiscal rules in small-open resource-rich economies, where fiscal revenues are highly volatile due to exogenous resource-related revenues.[1] In such economies, the presence of financially constrained households and other nominal and real rigidities gives fiscal policy a dual role—acting both as a Keynesian stabilizer and as social insurance—since monetary policy alone cannot fully stabilize the economy.

In this context, we focus on the following questions: First, how can structural balance rules be optimized, considering the tradeoffs between welfare and macroeconomic stabilization? How does data inform their design and limits? Second, what are the possible welfare gains or losses, given the heterogeneity in access to financial markets across households? Third, from a quantitative perspective, which modeling elements matter for welfare evaluation? Fourth, regarding implementation, which fiscal instruments maximize welfare and have the largest fiscal multipliers?

We begin by developing a stylized framework that clarifies the key mechanisms and supports our main quantitative findings. At the core of the analysis is a government with two sources of revenue–domestic income taxes and an exogenous stream of commodity revenues–that finances transfers to support the consumption smoothing of hand-to-mouth households.[2] Fiscal spending is governed by a cyclically adjusted fiscal rule, a commitment device that ensures spending is based on structural rather than current fiscal revenues. We study two versions: The *Simple Rule* characterized by a single policy parameter that determines whether the government responds procyclically (less than one-to-one with revenues), acyclically (in line with long-term revenues), or countercyclically (leaning against the cycle) to total consolidated revenues—combining both taxes and resource income. The *Generalized Rule* is a more flexible version that allows spending to react differently to fluctuations in tax revenues compared to fluctuations in commodity revenues.

Our results show the optimal Generalized Rule responds countercyclically to tax revenues but acyclically to commodity revenues. This design offers stabilization against domestic business cycles and insulates households from fluctuations in the international commodity price cycle. In comparison, the optimal Simple Rule is strictly less countercyclical, as it must balance the desire to lean against the domestic business cycle with the need to respond acyclically toward fluctuations in commodity revenues. A key insight is that the scope for countercyclicality under the Simple Rule depends on the joint cyclical properties of tax and commodity revenue sources. Simple statistics in the data — relative volatilities and pairwise correlations —inform the limits of countercyclicality. Figure 1 illustrates this for Chile, where commodity price cycles are several times more volatile than domestic business cycles and the two display a positive correlation.[3]

To test the predictions of our stylized framework and quantify the welfare and macroeconomic implications of structural balance rules on a typical resource-rich economy, we develop a multi-sector New Keynesian DSGE model featuring a rich fiscal block and a detailed commodity sector.

[1] Cashin et al. (2000); Talvi and Végh (2005); Van der Ploeg and Poelhekke (2009); Frankel et al. (2013); Céspedes and Velasco (2014), among others, provide empirical evidence on fiscal volatility and procyclicality in resource-rich, commodity-exporter economies. In response, and following Chile's pioneering example, countries such as Mexico, Colombia, and Peru have adopted structural balance rules designed to insulate government budgets from commodity-driven revenue fluctuations (see Appendix A for details).

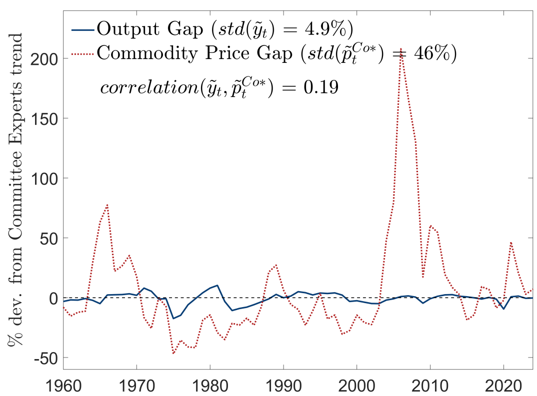
[2] Also known as non-Ricardian, non-savers, credit-constrained, rule-of-thumb or hand-to-mouth households, these terms are used interchangeably in the paper.

[3] Kumhof and Laxton (2013) also study the design of the structural balance rule. We further this analysis by showing how the joint statistical properties of these processes shape the design of both simple and generalized rules.

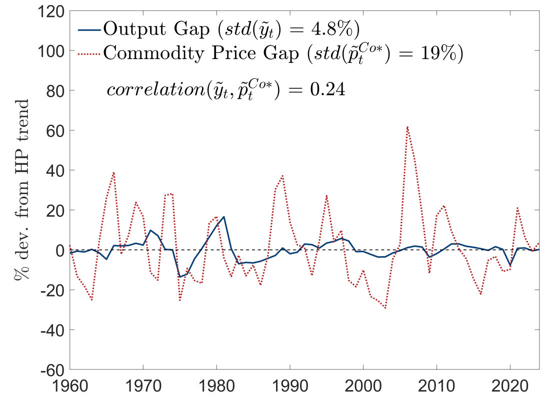
In this setting, the effectiveness of monetary policy is limited by the large share of non-Ricardian households, who cannot smooth consumption intertemporally (Galí et al. (2007); Leeper et al. (2017)). As a result, fiscal policy can stimulate real output in downturns through government consumption and, especially, public investment, while providing social insurance to households through lump-sum transfers (Engel et al. (2013), Kumhof and Laxton (2013)).

Figure 1: Domestic Business Cycle versus International Commodity Price Cycle

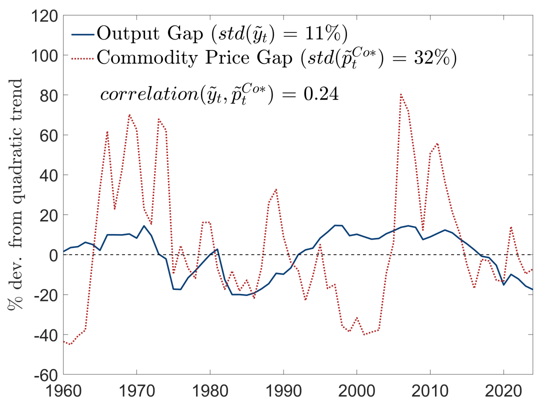
(a) Gaps based on Ministry of Finance



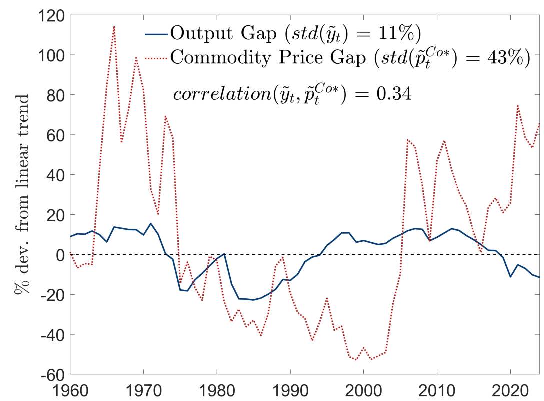
(b) Gaps based on HP filter



(c) Gaps based on a quadratic trend



(d) Gaps based on a linear trend



Notes: The figures compare the output gap and the commodity price gap under alternative metrics. Panel (a) uses cycles estimated by the Chilean Ministry of Finance, while Panels (b)-(d) use the Hodrick-Prescott filter, quadratic, and linear detrending.

We apply the model to Chile, a benchmark case among resource-rich economies, and introduce several innovations crucial for the questions at hand. First, we endogenize commodity production and investment, a critical channel that connects commodity price fluctuations to domestic business cycles. Second, we impose an endogenous and data-informed debt limit, which effectively breaks the near-unit root behavior in the government's net asset position, thereby reconciling model-implied debt dynamics with the data. Third, we incorporate structural revenue adjustments from interest payments on accumulated assets, and from changes in the long-run commodity price.[4]

[4]This feature not only add realism to the model, but also aligns its predictions with the positive marginal propensity

Finally, we conduct a general robustness analysis across a wide range of nested models commonly used in the literature, demonstrating that our main insights remain robust across various specifications. Importantly, this exercise highlights the central role of data, through Bayesian estimation, in disciplining key structural parameters and ensuring credible quantitative results.

Relative to the procyclical Balanced-Budget Rule (BBR), our quantitative results show that Chile's Structural Balance Rule (SBR)—which responds to consolidated revenues—has delivered sizable welfare gains: 3.3% of lifetime consumption for hand-to-mouth households and 1.7% on average across all households.[5] Optimizing the simple rule further reveals that non-Ricardian households benefit from shifting toward a moderately countercyclical stance, gaining an additional 0.55% of lifetime consumption. In contrast, Ricardian households prefer a near-acyclical rule, as they can smooth shocks through financial markets. The optimum for the average household lies in between but leans strongly toward the fiscal stance preferred by non-Ricardians. Overall, the results highlight that fiscal policy matters most for households without market access, who derive substantial welfare benefits from countercyclical government spending.

How important is it, in welfare terms, to grant fiscal policy greater flexibility by generalizing the simple rule? Our results show that a generalized rule roughly doubles the welfare gains for the average household compared to the simple rule, which responds only to consolidated revenues. When decomposing these gains across households, we find that they are driven almost entirely by non-Ricardian households. The flexibility to lean strongly against tax revenue fluctuations while maintaining an acyclical stance toward commodity revenues increases their welfare gains from 0.55% to 1.16% of lifetime consumption. By contrast, Ricardians remain nearly indifferent between the two frameworks, as they can smooth shocks through markets. Importantly, this result is robust across a wide class of nested models commonly used in the literature.

From a quantitative perspective, several modeling decisions are essential for a comprehensive assessment of the fiscal rule. For instance, including productive public capital enhances the government's Keynesian ability to stabilize the economy during economic downturns. Including government consumption in households' utility affects fiscal policy tradeoffs, as excessive fiscal activism disrupts their preference for stable and smooth consumption baskets. On the other hand, abstracting from commodity production and investment assumes a counterfactual zero correlation between the domestic cycle and the commodity price cycle. Which lowers the desired degree of countercyclicality in tax revenues and understates the welfare gains of the optimized rule. Finally, without nominal wage rigidities, the model delivers counterfactual volatility in real wages, an environment in which countercyclical rules appear even more desirable than under the baseline.

What are the best fiscal instruments to implement the optimized policy? The answer depends on the trade-off between household welfare and macroeconomic stabilization. While all fiscal instruments respond countercyclically to tax revenues, lump-sum transfers deliver the largest welfare gains for non-Ricardian households but are less effective at stabilizing macroeconomic aggregates. By contrast, government consumption and public investment are powerful stabilizers of GDP but yield more moderate welfare improvements. Finally, the optimal stance toward commodity revenues remains acyclical, regardless of the chosen fiscal instrument.

On fiscal multipliers, we highlight two insights: First, all spending shocks are expansionary

to spend out of commodity shocks documented by Mendes and Pennings (2025) across resource-rich economies.

[5] These findings align qualitatively with the broader literature. In particular, our result on commodity acyclicality echoes the conclusions of Pieschacón (2012), Kumhof and Laxton (2013), Aguirre (2020), and Mendes and Pennings (2025), all of which find that fiscal insulation from commodity price cycles is welfare-improving.

on impact, but only government consumption and public investment generate output multipliers above one. In particular, public investment shocks produce the largest multipliers with persistent effects due to complementarities with private capital. Second, fiscal multipliers are larger under the optimized rule than under the structural balance benchmark. Here, financing dynamics matter: while the SBR sustains other spending categories (government consumption and transfers), a countercyclical rule enforces savings, limiting fiscal expansion but improving the government's asset position.

The rest of the paper is organized as follows. After briefly discussing the related literature, Section 2 presents the stylized model, while Section 3 describes the quantitative model applied to the data. Section 4 describes the estimation strategy for the model's main parameters (including the fiscal rules), the model fit, and the model dynamics, while Section 5 presents a detailed welfare evaluation of alternative fiscal rules. Section 6 presents an in-depth analysis of fiscal instruments and fiscal multipliers. Section 7 concludes.

Related Literature. This paper contributes to the literature related to the welfare evaluation of fiscal rules in small-open resource-rich economies. The study aligns with two distinct strands of this literature. The first strand centers on analyzing the single optimized fiscal response to revenue fluctuations (García-Cicco and Kawamura (2015), Garcia et al. (2011), Ojeda-Joya et al. (2016)), and more recently Mendes and Pennings (2025). While the second strand delves into the examination of welfare-maximizing fiscal rules that respond differently to the tax revenue and commodity revenue gaps (Pieschacón (2012), Kumhof and Laxton (2013), Céspedes and Velasco (2014), and Snudden (2016)). We contribute to this literature by revisiting the design and implementation of structural balance fiscal rules along two dimensions: first, we demonstrate the central role of data on the cyclical properties of both revenues in guiding the optimal design of simple and generalized fiscal rules. Second, we explicitly compare the performance of simple rules and generalized rules, and show that generalized rules roughly double welfare gains relative to simple rules.

The closest work to ours is Kumhof and Laxton (2013), but our model introduces key innovations that enhance both realism and empirical fit. First, we endogenize commodity production and investment, capturing the link between domestic and commodity revenue cycles absent in their framework. Second, rather than treating debt as another cyclical gap to be optimized, we estimate a debt limit parameter directly from fiscal data, aligning the rule with its intended role of smoothing cyclical revenues while disciplining it with the government's net asset position. Third, we model the long-term law of motion for copper prices in the structural balance rule, replicating the methodology used in practice and aligning our predictions with the positive marginal propensity to spend (MPS) from commodity shocks documented in Mendes and Pennings (2025).

Our results on acyclical fiscal policy echo those of Berg et al. (2012), Frankel et al. (2013), Kumhof and Laxton (2013), Pieschacón (2012), Céspedes and Velasco (2014), who document large welfare losses from procyclical fiscal policy. Importantly, we extend the analysis by showing that moving beyond acyclical rules toward countercyclical fiscal policies can generate even larger welfare gains, particularly by stabilizing households' income and labor market outcomes. On the management of sovereign wealth funds, Melina et al. (2016) model debt constraints to show how binding limits affect the transformation of commodity windfalls into public investment, while we instead emphasize their welfare implications for optimizing fiscal rules.

2 Stylized Model of Income Fluctuations and Fiscal Policy

Consider an economy populated by hand-to-mouth, non-Ricardian (NR) households with no access to capital markets, and a concave preference function $U(\cdot)$ over a consumption good c_t. Every period, they receive a stochastic income endowment, y_t, pay a proportional income tax $\tau \in (0, 1)$, and receive government transfers T_t.[6] Their budget constraint is:

$$c_t = y_t(1 - \tau) + T_t. \tag{1}$$

In this simple environment, a government with debt-issuing capacity can implement a cyclically adjusted spending rule to support NR households in smoothing consumption. We model a government with two sources of income: tax revenues, $\Pi_t^\tau = \tau y_t$, and a stochastic cash flow endowment, F_t^{Co}, which captures exogenous income from its participation in a non-modeled commodity sector. Importantly, these two income sources may be correlated. Government spending, G_t, consists entirely of transfers to NR households, so that $G_t \equiv T_t$. The government's budget constraint is:

$$B_t = (1 + r_{t-1})B_{t-1} + \Pi_t^\tau + F_t^{Co} - G_t, \tag{2}$$

where B_t is the government's net asset position in period t with interest rate r_{t-1}.

We consider a structural balance rule where government spending is a function of the sum of interest payments, current revenues, and a consolidated cyclical adjustment term:[7]

$$G_t = \underbrace{r_{t-1}B_{t-1}}_{\text{interest payments}} + \underbrace{(\Pi_t^\tau + F_t^{Co})}_{\text{current revenues}} + \underbrace{\kappa\left[(\tilde{\Pi}^\tau - \Pi_t^\tau) + (\tilde{F}^{Co} - F_t^{Co})\right]}_{\text{cyclical adjustment}},$$

where the policy parameter κ governs the responsiveness of government spending to cyclical deviations in consolidated tax revenues and commodity revenues from their respective long-run structural levels, $\bar{\Pi}^\tau$ and $\bar{F}^{Co}$.[8] The above spending rule can be generalized to feature two policy parameters κ^τ and κ^{Co}, allowing the government spending to adjust independently to individual cyclical deviations in each gap:

$$G_t = r_{t-1}B_{t-1} + \Pi_t^\tau + F_t^{Co} + \kappa^\tau(\bar{\Pi}^\tau - \Pi_t^\tau) + \kappa^{Co}(\bar{F}^{Co} - F_t^{Co}). \tag{3}$$

[6] In the quantitative model (Section 3), we allow for more general preferences, incorporate an equal share of Ricardian households—agents who optimize intertemporally, can smooth consumption through financial assets, and respond to fiscal policy through general equilibrium effects—and extend the framework beyond transfers to include other fiscal instruments. Our qualitative results remain unchanged in this extended framework, as most of the welfare gains from fiscal policy arise from its effect on non-Ricardian households.

[7] Several resource-rich economies—including Chile, Colombia, Peru, Mexico, and Norway—follow structural balance rules, which adjust for the output gap and commodity price cycles (e.g., copper in Chile, copper and gold in Peru, and oil in Colombia). See Table 8 in the Appendix A for further details.

[8] For example, Chile's fiscal rule mandates setting $\kappa = 1$ consistent with acyclical spending. It also mandates two independent committees to estimate potential GDP and the long-term price of copper, which determines these structural values. We implement these aspects in the quantitative model.

To see the implications of the government's fiscal rule, substitute (3) into (1):

$$\begin{aligned} c_t &= y_t(1-\tau) + \left[\Pi_t^\tau + F_t^{Co} + \kappa^\tau(\bar{\Pi}^\tau - \Pi_t^\tau) + \kappa^{Co}(\bar{F}^{Co} - F_t^{Co})\right], \\ &= (1-\tau\kappa^\tau)y_t + \kappa^\tau\tau\bar{y} + (1-\kappa^{Co})F_t^{Co} + \kappa^{Co}\bar{F}^{Co}, \end{aligned} \tag{4}$$

which highlights how the government's fiscal stance shapes NR households' consumption by altering their exposure to fluctuations in households' income and commodity revenues. For tractability, equation (4) also assumes that the initial government's asset position is zero ($B_{t-1} = 0$).[9] To further understand this transmission, we decompose the variance of NR consumption:

$$\mathbb{V}(c_t) = (1-\tau\kappa^\tau)^2\mathbb{V}(y_t) + (1-\kappa^{Co})^2\mathbb{V}(F_t^{Co}) + 2(1-\tau\kappa^\tau)(1-\kappa^{Co})\mathbf{Cov}(y_t, F_t^{Co}). \tag{5}$$

Expression (5) highlights the role the fiscal rules in shaping the volatility of NR consumption. Since NR households are assumed risk averse, fiscal policies that reduce their consumption volatility will be preferable from a welfare perspective.[10] Next, we study the theoretical implications of commonly studied fiscal stances—procyclical, acyclical, and countercyclical—by appropriately calibrating the policy parameters in the *Simple κ rule* and in the *Generalized $\{\kappa^\tau, \kappa^{Co}\}$ rule*.

Balanced Budget Rule (BBR): $\kappa^\tau = \kappa^{Co} = 0$. To see why setting the policy parameters to zero is called a "balanced budget rule", note from (3), the rule mandates spending $G_t = \Pi_t^\tau + F_t^{Co} + r_{t-1}B_{t-1}$. Moreover, equation (2) yields zero surplus and debt accumulation for all t: notably, the balanced-budget rule delivers zero volatility in the fiscal surplus and fiscal debt position, at the expense of procyclical fiscal spending (G_t moves one-to-one with fiscal revenues). However, procyclical spending harms hand-to-mouth households as the volatility of consumption under a BBR becomes:

$$\mathbb{V}^{BBR}(c_t) = \mathbb{V}(y_t) + \mathbb{V}(F_t^{Co}) + 2\mathbf{Cov}(y_t, F_t^{Co}).$$

A BBR not only leaves households fully exposed to aggregate fluctuations in labor income (y_t) but also introduces additional volatility by exposing them to exogenous and volatile commodity revenue cycles (F_t^{Co}). In the Chilean context, non-mining GDP and commodity prices exhibit a positive correlation, which further amplifies consumption volatility via the covariance term. As a result, spending rules like BBR, and more generally, any procyclical rule with $\kappa^\tau, \kappa^{Co} < 1$, are largely undesirable from a welfare perspective.

Structural Balance Rule (SBR): $\kappa^\tau = \kappa^{Co} = 1$. Under the SBR, desired government spending is intended to be acyclical. To see this, note from (3): $G_t = \tau\bar{y} + \bar{F}^{Co}$, i.e., the government spends only its estimated *long-run* or structural revenues (plus debt interests in case the net asset position is non-zero). The volatility of consumption under the SBR becomes:

$$\mathbb{V}^{SBR}(c_t) = (1-\tau)^2\mathbb{V}(y_t).$$

[9] We relax this assumption in the quantitative model and study debt sustainability implications in Section 4.

[10] Given our stylized setting, and because household preferences are concave, maximizing their utility subject to the model's equilibrium conditions is equivalent to minimizing the variance of their consumption.

The SBR represents an improvement over a BBR for two essential reasons. First, it fully isolates households from the commodity revenue cycle. Second, although it still leaves them exposed to the domestic business cycle via $\mathbb{V}(y_t)$, the acyclical policy dampens its effect by a factor of $(1-\tau)^2 < 1$. Intuitively, as long as the government rebates back revenues via transfers, it can provide "consumption smoothing services" to households unable to save intertemporally.

The SBR serves as a key benchmark in our quantitative analysis, reflecting both the official fiscal mandate of the Chilean government and closely aligning with the rule we estimate from the data (see Section 4.2). That said, while the acyclical SBR performs better than the procyclical BBR, our analysis below suggests that fiscal policy can further smooth NR consumption by adopting a countercyclical rule that leans against domestic business cycle fluctuations.

Counter-Cyclical Rule (CCR): $\kappa^{\tau}, \kappa^{Co} > 1$. The core idea of a CCR is to restrain spending during economic bonanza to build buffers that enable Keynesian spending during recessions, thereby reducing NR consumption (and aggregate) volatility. However, when a significant share of government revenue comes from commodities, the effectiveness of a CCR depends critically on the joint cyclical behavior of tax and commodity revenues. Proposition 1 guides optimal fiscal design under two scenarios.

Proposition 1. *Let fiscal policy follow a countercyclical rule (CCR) defined by the parameters $\{\kappa^{\tau}, \kappa^{Co}\}$, and suppose the benchmark is a structurally balanced rule (SBR) with $\kappa^{\tau} = \kappa^{Co} = 1$. By appropriately setting the policy parameters, the CCR strictly reduces the volatility of consumption for non-Ricardian households, i.e., $\mathbf{V}^{CCR}(c_t) < \mathbf{V}^{SBR}(c_t)$.*

A. ***Simple κ rule***. *Whenever the spending rule is constrained to one parameter, $\kappa^{\tau} = \kappa^{Co} = \kappa > 1$, the CCR yields lower NR consumption volatility than the SBR if κ satisfies:*

$$1 < \kappa < 1 + \frac{2(1-\tau)\,\zeta\,(\tau\zeta + \rho)}{1 + \tau^2\zeta^2 + 2\rho\tau\zeta}, \tag{6}$$

where $\zeta \equiv \sigma_y/\sigma_F$ denotes the relative volatility between income and commodity cash flows, respectively, and ρ denotes the correlation coefficient.

Corollary: *Whenever $\rho \to 1$ and $\sigma_F \to \sigma_y$, the admissible set becomes $1 < \kappa < \frac{3-\tau}{1+\tau}$, implying that the scope for countercyclicality expands when tax revenues and commodity revenues feature similar cyclical properties.*[a]

B. ***Generalized $(\kappa^{\tau}, \kappa^{Co})$ rule***. *Whenever the spending rule is such that κ^{τ} and κ^{Co} can be freely set, a sufficient condition for a CCR to dominate the SBR is $1 < \kappa^{\tau} \leq \frac{1}{\tau}$ and $\kappa^{Co} = 1$.*

[a] See Appendix B for the formal proof.

Part A. indicates that when the fiscal authority reacts only to cyclical deviations in total revenues without distinguishing between revenue sources (i.e., $\kappa^{\tau} = \kappa^{Co}$ in (3)), it cannot independently offset the volatility of the commodity component. As a result, the correlation ρ and the relative volatilities σ_y/σ_F of government revenues determine the set of admissible κ values for which a CCR reduces NR consumption volatility relative to an SBR. This highlights a key insight: not all countercyclical rules are welfare-improving. In particular, excessive countercyclicality in tax revenues can inadvertently amplify volatility through the commodity channel, underscoring the trade-offs faced by a constrained government.

Part B. shows that if the government can implement a general spending rule that reacts to deviations from each revenue component– as the one proposed in (3), it can minimize NR consumption volatility by setting $\kappa^{\tau} \in (1, 1/\tau]$ and $\kappa^{Co} = 1$. In practice, this means fully insulating NR households from commodity revenue fluctuations while leaning against the domestic economic cycle. Importantly, even in this setting, excessive countercyclicality can be undesirable.

While our stylized framework highlights the core mechanisms behind standard fiscal rules, assessing the welfare implications of these policies requires a quantitative general equilibrium model. Section 3 introduces such a model. It highlights additional channels through which fiscal policy affects both non-Ricardian and Ricardian households, including its impact on the labor market, public goods, aggregate output, and the interaction with investment and production in the commodity sector. We then utilize this richer framework to first estimate the historical behavior of Chile's fiscal rule and, second, to quantitatively evaluate how policy parameters in a general fiscal rule should be optimally set to maximize welfare across heterogeneous households, assessing its implications for macroeconomic stability.

3 The Quantitative Model

Our model structure nests frameworks that have been used to quantify the macroeconomic implications of fiscal policy, while also expanding on those frameworks by adding nominal and real rigidities, and additional details on the supply and demand sides of the economy.

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

On the demand side, the economy features two household types: Ricardian and non-Ricardian. Ricardians 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 four types of goods: non-tradables, exportables, importables, and a primary commodity. To represent the case of Chile, the commodity good (copper) is fully exported and produced using labor, sector-specific capital, and a fixed resource supply subject to a long-run growth trend.

The economy is "dependent" on copper in two ways. First, a significant fraction of the country's exports is composed of these primary goods. Second, a substantial fraction of government revenues comes 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.

3.1 Households

A unit mass of infinitely-lived households populates the economy. Superscript $l \in \{R, NR\}$ indicates the two types of households: Ricardians (R) and non-Ricardians (NR) with shares $(1-\omega)$ and ω, respectively.[11]

Ricardians households have preferences over a composite consumption basket, $\widehat{C}_t^l$, comprising private consumption, C_t^l, and public consumption, C_t^G, aggregated through a constant elasticity of substitution (CES) function $\widehat{C}_t^l \equiv ((1-\gamma)^{\frac{1}{\varrho}}(C_t^l - \phi_c \breve{C}_{t-1}^l)^{\frac{\varrho-1}{\varrho}} + (\gamma)^{\frac{1}{\varrho}}(C_t^G)^{\frac{\varrho-1}{\varrho}})^{\frac{\varrho}{\varrho-1}}$. The parameter γ governs the degree of complementarity between private and public consumption, while ϱ determines the elasticity of substitution. Households feature habit formation in private consumption relative to the lagged consumption $\breve{C}_{t-1}^l$, with $\phi_c \in [0,1)$ capturing the degree of persistence. Households supply h_t^l hours to a labor union that allocates labor across sectors (see the wage setting below). They maximize expected lifetime utility: $E_0 \sum_{t=0}^{\infty} \beta^t \xi_t^\beta \{ (\widehat{C}_t^l)^{1-\sigma}/(1-\sigma) - \Xi_t^l (h_t^l)^{1+\psi}/(1+\psi)\}$, where ξ_t^β is an intertemporal preference shock, and parameters β, σ, and ψ govern time discount, risk aversion, and the elasticity of labor supply, respectively. The disutility of labor, Ξ_t^l, is specified as $\Xi_t^l \equiv \eta^l \xi_t^h A_{t-1}^{1-\sigma} \Theta_t^l$, where η^l determines steady-state labor shares, ξ_t^h is an intratemporal preference shock, A_t represents the economy's growth trend, and Θ_t^l is engineered to eliminate the wealth effect of labor supply.[12]

Ricardian households have access to the domestic and foreign bond markets; B_t^R and B_t^{R*} represent their stock of domestic and foreign bonds acquired in period t, which pay gross returns r_t and r_t^*, respectively. The nominal value of foreign bonds is converted to domestic currency units using the nominal exchange rate S_t.[13] Their primary income sources are: labor income, rental income from capital stock holdings across production sectors, government transfers, and firm profits. Households allocate this income toward consumption, investment in future capital, and bond purchases. The budget constraint for Ricardian households is:

$$(1+\tau^C)P_t C_t^R + P_t^I(I_t^{R,N} + I_t^{R,X}) + B_t^R + S_t B_t^{R*} = (1-\tau^W)\left[\int_0^1 W_t(j) h_t^d(j) dj\right] +$$
$$\sum_{J\in\{N,X\}} \left[(1-\tau^K)P_t^J r_t^J u_t^J + \tau^K P_t^I(\delta + \Phi(u_t^J))\right] \hat{K}_{t-1}^J + r_{t-1}B_{t-1}^R + S_t r_{t-1}^* B_{t-1}^{R*} + \hat{\Sigma}_t, \tag{7}$$

where P_t is the price of the consumption basket, P_t^I is the price of investment $I_t^{R,J}$, and P_t^J is the price of final goods in production sector $J \in \{N, X\}$ with N and X representing the non-tradable and exportable sectors, respectively. Households pay ad-valorem taxes on consumption (τ^C), labor income (τ^W) and capital income (τ^K). The term $\hat{\Sigma}_t$ consolidates lump-sum transfers TR_t^R, taxes T_t^R, firm profits, and rents from foreign firm ownership.

The capital stock, $\hat{K}_t^J$, earns a gross rental rate r_t^J with depreciation occurring at rate δ. The utilization rate u_t^J determines the effective capital services used in production, defined as $K_t^J =$

[11] 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).

[12] As emphasized by Galí et al. (2012), this feature helps match the joint behavior of employment, consumption, and wages over the business cycle. Detailed derivations are provided in Appendix **??**.

[13] The nominal exchange rate is 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.

$(1-\omega)u_t^J\hat{K}_{t-1}^J$. Using capital intensively (high u_t^J) raises maintenance costs, $\Phi(u_t^J)$.[14] Investment in sector J is defined as $I_t^{R,J} = (\hat{I}_t^J + \Phi(u_t^J)\hat{K}_{t-1}^J)$. Physical capital is sector-specific and evolves according to:

$$\hat{K}_t^J = (1-\delta)\hat{K}_{t-1}^J + \left[1 - \Gamma\left(\frac{\hat{I}_t^J}{\hat{I}_{t-1}^J}\right)\right]\hat{I}_t^J\xi_t^i, \tag{8}$$

where ξ_t^i is an AR(1) shock to the marginal efficiency of investment. Investment adjustment costs are $\Gamma(.) = \frac{\phi_k}{2}(\hat{I}_t^J/\hat{I}_{t-1}^J - a)^2$ with elasticity ϕ_k and the long-run growth rate a.

Non-Ricardian Households share the same preferences as Ricardians, but they cannot borrow in financial markets, and they do not own capital or shares in firms. They receive labor income and government transfers TR_t^{NR} and consume all their disposable income each period. They face the same consumption prices and taxes as Ricardians, and pay lump-sum taxes T_t^{NR}. Their budget constraint is:

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

3.2 The Production Sector

The production sector is organized into two tiers: intermediate and final goods producers across multiple sectors. Final consumption (C_t) and investment goods (I_t) are produced by perfectly competitive firms that aggregate intermediate varieties. There are four types of intermediate goods: non-tradables (N), exportables (X), and importables (M). Additionally, a primary commodity (Co) sector produces goods exclusively for export.

Consumption Goods. The consumption basket, $C_t(C_t^Z, C_t^F)$, is defined as a CES composite of core consumption, C_t^Z, and food consumption, C_t^F. In turn, these consumption baskets follow a similar CES nested structure; core consumption, $C_t^Z(C_t^N, C_t^X, C_t^M)$, is produced combining non-tradable C_t^N, exportable C_t^X, and importable goods C_t^M. The food basket, $C_t^F(C_t^{FX}, C_t^{FM}, z_t^F)$, is similarly constructed as a CES aggregate of exportable C_t^{FX} and importable C_t^{FM} goods, with a disturbance term z_t^F to capture potential volatility in food prices.[15] Each basket C_t^J with $J \in \{N, X, M, FX, FM\}$ is produced by competitive firms specialized in packing a continuum of unique varieties $i \in [0,1]$ with technology: $C_t^J = (\int_0^1 C_t^J(i)^{\frac{\epsilon-1}{\epsilon}}di)^{\frac{\epsilon}{\epsilon-1}}$, where ϵ is the elasticity of substitution across varieties. Each variety i is supplied by a monopolistically competitive firm that uses labor, capital, and intermediate inputs (see details below).

[14] Following García-Cicco et al. (2015), maintenance costs are specified as $\Phi(u_t^J) = \frac{r^J}{\phi_u}\left(e^{\phi_u(u_t^J-1)} - 1\right)$, 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.

[15] See Appendix E for a detailed description of CES functions for each consumption basket. Our detailed structure aligns with disaggregated CPI components, enabling the use of core and food CPI data in the model estimation. This is crucial for accurately fitting the second moments of consumption and inflation across different levels of aggregation, enhancing the model's capacity to assess the impact of fiscal policy on household consumption and welfare dynamics.

Investment Goods. Final investment goods are produced using a CES technology that combines intermediate non-tradables, exportables, and importables: $I_t^P(I_t^N, I_t^X, I_t^M)$. Similarly, the investment basket demanded by the commodity sector is produced by a separate set of competitive firms using a CES technology over non-tradable, exportable, and importable goods: $I_t^{Co}(I_t^{NCo}, I_t^{XCo}, I_t^{MCo})$.

Government Goods. Analogous to the private consumption and investment baskets, government consumption, $C_t^G(C_t^{GN}, C_t^{GX})$, and investment goods, $I_t^G(I_t^{GN}, I_t^{GX})$, are produced using CES technologies, combining nontradable and exportable goods.

Production in the Non-tradable and Exportable Sectors. Each sector $J \in \{N, X\}$ comprises a continuum of firms indexed by $i \in [0,1]$ with a Cobb-Douglas technology combining physical capital $\tilde{K}_t^J(i)$ and labor $h_t^J(i)$ and a fixed resource to produce output: $Y_t^J(i) = z_t^J \left[\tilde{K}_t^J(i)\right]^{\alpha^J} \left[A_t^J h_t^J(i)\right]^{1-\alpha^J}$, where α^J is the capital share, A_t^J is a labor-augmenting non-stationary stochastic trend in productivity, with growth rate $a_t^J \equiv A_t^J/A_{t-1}^J$. Productivity z_t^J follows an AR(1) process. To ensure a balanced growth path, we assume sectoral productivity trends A_t^J cointegrate with the global productivity trend A_t, such that $A_t^J = \left(aA_{t-1}^J\right)^{1-\Gamma^J} \left(A_t\right)^{\Gamma^J}$, with Γ^J governing the speed of adjustment to the common trend.

We assume the government can play a complementary role in production, such that the 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, according to: $\tilde{K}_t^J(i) = ((1-\gamma_G)^{1/\varrho_G}\left(K_t^J(i)\right)^{\varrho_G - 1/\varrho_G} + (\gamma_G)^{1/\varrho_G}\left(K_{t-1}^G\right)^{\varrho_G - 1/\varrho_G})^{\varrho_G/\varrho_G - 1}$, where γ_G is the share of public infrastructure in total capital and ϱ_G is the elasticity of substitution. Public capital K_t^G evolves following the law of motion $K_t^G = (1-\delta_G)K_{t-1}^G + I_t^G$, where δ^G is the government capital depreciation rate.

Production in the Importable Sector. Sector M comprises 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 $Y_t^M(i) = M_t(i)$. 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 $P_{m,t} = MC_t^M$.[16]

Production in the Commodity Sector. The commodity good, Y_t^{Co}, is produced by a representative firm using a Cobb-Douglas technology combining physical capital $\tilde{K}_t^{Co}$ hours worked h_t^{Co} and a fixed supply of natural resources, $\overline{L}$, which are subject to a long-run technology trend A_t^{Co}:

$$Y_t^{Co} = z_t^{Co}\left(\tilde{K}_t^{Co}\right)^{\alpha_{Co}}\left(A_t^{Co}h_t^{Co}\right)^{1-\alpha_{Co}-\alpha_{\overline{L}}}\left(A_t^{Co}\overline{L}\right)^{\alpha_{\overline{L}}} \tag{10}$$

where α_{Co} is the capital share, $\alpha_{\overline{L}}$ is the natural resource share, and z_t^{Co} is a stationary productivity term following an AR(1) process. Analogous to the no-tradable and exportable sectors, the capital used in production is a CES composite between private capital K_t^{Co} and public capital K_t^G as

[16]Note the difference between the price of the imported input $P_{m,t}$ and the average price set by the importable sector $P_t^M = (\int_0^1 \left(P_t^M(i)\right)^{1-\epsilon} di)^{\frac{1}{1-\epsilon}}$.

$\tilde{K}_t^{Co} = ((1-\gamma_G)^{1/\varrho_G}\left(K_t^{Co}\right)^{\varrho_G - 1/\varrho_G} + (\gamma_G)^{1/\varrho_G}\left(K_{t-1}^{G}\right)^{\varrho_G-1/\varrho_G})^{\varrho_G/\varrho_G-1}$, where γ_G and ϱ_G govern the share of public infrastructure and the elasticity of substitution between private and public capital. A distinctive feature of the commodity sector is that the representative firm accumulates its own capital, which evolves according to:

$$\hat{K}_t^{Co} = (1-\delta_{Co})\hat{K}_{t-1}^{Co} + \left[1 - \Gamma\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}}\right)\right]\hat{I}_t^{Co}\xi_t^{iCo}, \tag{11}$$

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 quadratic adjustment costs. Analogous to the non-tradable and exportable sectors, we assume a variable capital utilization, such that the effective capital used in the commodity production is $K_t^{Co} = u_t^{Co}\hat{K}_{t-1}^{Co}$. 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:

$$F_t^{Co} = (1-\tau^{Co})P_t^{Co}Y_t^{Co} - P_t^{ICo}I_t^{Co} - W_t h_t^{Co} \tag{12}$$

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. Total investment spending in the commodity sector (including maintenance costs) is $I_t^{Co} = \hat{I}_t^{Co} + \Phi(u_t^{Co})\hat{K}_{t-1}^{Co}$. Capital maintenance costs $\Phi(u_t^{Co})$ are increasing and convex. By the law of one price, $P_t^{Co} = S_t P_t^{Co*}$, where P_t^{Co*} is the foreign-currency price following an exogenous AR(1) process.

3.3 Price and Wage Setting

Price Setting. Intermediate 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 their nominal price $\tilde{P}_t^J(i)$ to maximize expected profits, taking the demand for their variety and marginal costs as given. With probability θ^J firms are unable to re-optimize and instead update prices using a weighted index of lagged CPI inflation and the economy's inflation target π: $(\pi_{t-1})^{\zeta^J}(\pi)^{1-\zeta^J}$, where ζ^J governs the relative weight placed on past versus target inflation. This setup generates a standard New Keynesian Phillips curve, linking current inflation and marginal costs, and adjusted by past and expected future inflation. Similarly, private capital firms also have monopolistic power over their respective variety $K_t^J(i), \forall i \in [0,1]$. They set prices à la Calvo and choose inputs to minimize costs.

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: $h_t^d(j) = (\frac{W_t(j)}{W_t})^{-\epsilon_w}h_t^d$, 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 $W_t \equiv (\int_0^1 (W_t(j))^{1-\epsilon_w}dj)^{\frac{1}{1-\epsilon_w}}$ 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: $h_t \equiv (1-\omega)h_t^R + \omega h_t^{NR} = h_t^d$. 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.

3.4 Fiscal Policy and Monetary Policy

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, so that:

$$G_t = P_t^{CG} C_t^G + P_t^{IG} I_t^G + TR_t^G. \tag{13}$$

where P_t^{CG} and P_t^{IG} are the deflators for government consumption and investment, respectively. Let B_t^G and B_t^{G*} denote the government net asset positions in domestic and foreign currency, respectively. The government budget is given by:

$$B_t^{GT} \equiv B_t^G + S_t B_t^{G*} = r_{t-1} B_{t-1}^G + S_t r_{t-1}^* B_{t-1}^{G*} + \Pi_t^\tau + \Pi_t^{Co} - G_t \tag{14}$$

where B_t^{GT} is total debt, Π_t^τ is tax revenues and Π_t^{Co} denotes fiscal revenues coming from the commodity sector. Tax revenues include ad-valorem consumption τ_t^C, labor τ_t^W and capital τ_t^K taxes as well as lump-sum taxes T_t^G (described below):

$$\Pi_t^\tau = \tau_t^C P_t C_t + \tau_t^W W_t h_t + (1-\omega)\tau_t^K \sum_{J\in\{N,X\}} \left(P_t^J r_t^J u_t^J - P_t^I(\delta + \Phi(u_t^J))\right) \hat{K}_{t-1}^J + T_t^G, \tag{15}$$

Commodity revenues include a share γ^{Co} of the commodity sector cash flows plus the royalty tax (τ^{Co}) charged on gross sales:

$$\Pi_t^{Co} = \gamma^{Co} F_t^{Co} + \tau^{Co} P_t^{Co} Y_t^{Co}. \tag{16}$$

For the composition of debt, we assume the government finances a constant share α^D of its debt in foreign currency: $S_t B_t^{G*} = \alpha^D (B_t^G + S_t B_t^{G*})$.

The Fiscal Rule. The baseline structural fiscal rule is modeled as a spending rule that takes into account the time-varying gap between current and potential fiscal revenues. On top, the rule considers a fiscal target $\bar{s}_G$, measured as a share of nominal GDP. Let $\tilde{G}_t$ denote the desired spending under the rule. Thus, the desired government asset position associated with the rule is:

$$\tilde{B}_t^G + S_t \tilde{B}_t^{G*} = r_{t-1} B_{t-1}^G + S_t r_{t-1}^* B_{t-1}^{G*} + \Pi_t^\tau + \Pi_t^{Co} - \tilde{G}_t \tag{17}$$

The deviation of the desired fiscal surplus relative to the target $\bar{s}_G$ is a function of the gap between current and structural consolidated revenues:

$$\frac{\tilde{B}_t^G + S_t \tilde{B}_t^{G*} - B_{t-1}^G - S_t B_{t-1}^{G*}}{P_t^Y Y_t} - \bar{s}_G = \kappa \left[\frac{(\Pi_t^\tau - \Pi^\tau) + (\Pi_t^{Co} - \tilde{\Pi}_t^{Co})}{P_t^Y Y_t} \right], \tag{18}$$

where the structural tax revenues is set to the steady-state Π^{τ}, while the "structural" commodity revenues ($\tilde{\Pi}_t^{Co}$) are defined as:

$$\tilde{\Pi}_t^{Co} = \gamma^{Co}\tilde{F}_t^{Co} + \tau^{Co}S_t\tilde{P}_t^{Co*}Y_t^{Co} \tag{19}$$
$$\tilde{F}_t^{Co} = (1-\tau^{Co})S_t\tilde{P}_t^{Co*}Y_t^{Co} - P_t^{ICo}I_t^{Co} - W_t h_t^{Co}. \tag{20}$$

Here, $\tilde{P}_t^{Co*}$ is the long-run commodity price defined as the forward-looking ten-year average of the commodity price:

$$\tilde{P}_t^{Co*} = \frac{1}{N+1}\sum_{i=0}^{N} E_t P_{t+i}^{Co*}. \tag{21}$$

This law of motion is consistent with the Chilean fiscal rule mandate, where long-term commodity revenues are projected over a ten-year horizon (Marcel et al. (2001); Fuentes et al. (2021)). Modeling time variation in the long-run commodity price allows structural commodity revenues to automatically adjust in response to long and persistent commodity price shocks.[17]

The desired spending consistent with the rule is obtained combining (17) and (18):

$$\begin{aligned}\tilde{G}_t &= r_{t-1}B_{t-1}^G + S_t r_{t-1}^* B_{t-1}^{G*} + \Pi_t^{\tau} + \Pi_t^{Co} \\ &- \kappa\left[(\Pi_t^{\tau} - \Pi^{\tau}) + (\Pi_t^{Co} - \tilde{\Pi}_t^{Co})\right] - \overline{s}_G P_t^Y Y_t.\end{aligned} \tag{22}$$

The spending rule in (22) accommodates different fiscal regimes.[18] An acyclical rule obtains when $\kappa = 1$, implying that the government should spend only its *long-run* or structural revenues plus interests: $\tilde{G}_t = r_{t-1}B_{t-1}^G + S_t r_{t-1}^* B_{t-1}^{G*} + \tilde{\Pi}^{\tau} + \tilde{\Pi}_t^{Co}$. Values of $\kappa < 1$ indicate procyclical rules. For instance, setting $\kappa = 0$ results in a balanced budget rule (BBR), where the government spends its *current* revenues each period, including interest payments: $\tilde{G}_t = r_{t-1}B_{t-1}^G + S_t r_{t-1}^* B_{t-1}^{G*} + +\Pi_t^{\tau} + \Pi_t^{Co}$. Similarly, values of $\kappa > 1$ indicate increasingly countercyclical spending rules.

We generalize the rule in (22) in two dimensions. First, we allow the government to respond differently to each revenue gap, introducing feedback parameters κ^{τ} and κ^{Co}. Second, we introduce a feedback response to deviations in the stock of debt from its steady-state value. Here, $\kappa^B > 0$ limits 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:[19]

$$\begin{aligned}\tilde{G}_t &= r_{t-1}B_{t-1}^G + S_t r_{t-1}^* B_{t-1}^{G*} + \Pi_t^{\tau} + \Pi_t^{Co} \\ &- \kappa^{\tau}(\Pi_t^{\tau} - \Pi^{\tau}) - \kappa^{Co}(\Pi_t^{Co} - \tilde{\Pi}_t^{Co}) + \kappa^B(B_{t-1}^{GT} - B^{GT}) - \overline{s}_G P_t^Y Y_t.\end{aligned} \tag{23}$$

The expenditure components C_t^G, I_t^G and TR_t^G are assumed to be time-varying shares of total

[17]This feature also aligns the model's predictions with empirical estimates of governments' marginal propensity to spend (MPS) observed following commodity price shocks, as documented by Mendes and Pennings (2025).

[18]The spending rule introduced in the stylized model, in Section 2, is a simplified version of the desired spending in (22).

[19]Although there is no explicit debt limit in the Chilean rule, it is well established that debt-to-GDP ratios above 40% trigger red flags in international organizations and foreign markets. Parameter κ^B allows us to reduce excessive debt volatility and bring the level and dynamics of fiscal debt closer to the data, see Section 4.

desired expenditures, with α^{CG}, α^{IG} and $(1-\alpha^{CG}-\alpha^{IG})$ denoting the long-run shares and ξ_t^{CG}, ξ_t^{IG} and ξ_t^{TR} represent (unit-mean) exogenous disturbances to those shares, and following independent AR(1) processes.

Lump-sum taxes, T_t^G, assumed to be a constant share α^T of nominal GDP, i.e., $T_t^G = \alpha^T P_t^Y Y_t$. 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_t^G are assigned to households in constant proportions ω^{TR} and $(1-\omega^{TR})$.

Monetary Policy. Monetary policy follows a standard Taylor rule of the form:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_R} \left[\left(\frac{\pi_t^Z}{\pi}\right)^{\alpha_\pi} \left(\frac{Y_t}{aY_{t-1}}\right)^{\alpha_y}\right]^{(1-\rho_R)} \xi_t^m \tag{24}$$

with $\rho_R \in (0,1)$, $\alpha_y \geq 0$, $\alpha_\pi > 1$, and where $\pi_t^Z = \frac{P_t^Z}{P_{t-1}^Z}$ 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 rate a, and ξ_t^m is a random AR(1) shock.

3.5 Rest of the World

The rest of the world buys a bundle of the exportable varieties produced by the small open economy. Total foreign demand for the domestic exportable good C_t^{X*} depends on the relative foreign-currency price (P_t^{X*}/P_t^*), the rest of the world economic output (Y_t^*), and an i.i.d. demand shock ξ_t^{X*}: $C_t^{X*} = (a_{t-1}C_{t-1}^{X*})^{\rho^{X*}}((P_t^{X*}/P_t^*)^{-\epsilon^*}Y_t^*)^{1-\rho^{X*}}\xi_t^{X*}$, where ϵ^* is the price elasticity, ρ^{X*} is a parameter inducing persistence, and P_t^* is the global price level. Foreign output evolves according to $Y_t^* = A_t z_t^*$, where A_t is the global productivity trend, $a_t = A_t/A_{t-1}$ is the growth of the trend (modeled as AR(1)), and z_t^* is a productivity shock (also AR(1)). Foreign inflation $\pi_t^* = P_t^*/P_{t-1}^*$ follows an AR(1) as well. We define the real exchange rate as $rer_t = S_t P_t^*/P_t$ (where an increase indicates depreciation), and the nominal devaluation rate $\pi_t^S = S_t/S_{t-1}$ satisfies: $\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}$.

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:

$$spr_t = \overline{spr} \cdot \exp\left[-\phi_b\left(\frac{S_t B_t^*}{P_t^Y Y_t} - \bar{b}\right) + \frac{\xi_t^{S*} - \xi^{S*}}{\xi^{S*}} + \frac{\xi_t^{U*} - \xi^{U*}}{\xi^{U*}}\right] \tag{25}$$

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.

3.6 Aggregation and Market Clearing

The model is closed by a series of aggregation and market-clearing conditions. Aggregate consumption is the weighted sum of Ricardian and non-Ricardian consumption: $C_t = (1-\omega)C_t^R + \omega C_t^{NR}$ (analogous for labor). Since only Ricardian households have access to capital markets, the supply of final investment goods must equal their total investment demand: $I_t^P = (1-\omega)(I_t^{R,N} + I_t^{R,X})$. On the other hand, the domestic markets for nontradable, exportable, and importable goods clear in equilibrium. The aggregate resources constraint from the demand side is $Y_t = C_t + I_t^P + G_t + TB_t$, where the trade balance is given by $TB_t = P_t^X C_t^{X*} + P_t^{Co} Y_t^{Co} - P_{m,t} M_t$. See Appendix E for further details.

4 Estimation, Welfare and Macroeconomic Performance

4.1 Model Estimation and Validation

The calibration strategy includes three sets of parameters. Firstly, we include a set of standard parameters drawn from prior literature or set to align with their average data analog. A second set of parameters is internally calibrated within the steady state algorithm to ensure alignment with critical macroeconomic and sectoral targets. Finally, the remaining parameters encompassing those governing the fiscal rule are jointly estimated using state-of-the-art Bayesian techniques (see An and Schorfheide (2007)). All targeted moments in the calibration are annual averages over the period 1996-2019. We focus here on the results for the estimated fiscal rule, leaving the details on the calibrated and estimated parameters for the Appendix C.

Our first quantitative result indicates that the Chilean authorities have closely adhered to the acyclical spending rule introduced in 2001 and institutionalized under the "Fiscal Responsibility Act" in 2006. The posterior mean of the policy rule parameter is estimated at $\kappa = 1.08$ with a 90% credible set $[0.88, 1.27]$ well covering the acyclical value of $\kappa = 1$ mandated by law (see Table 1). Given the precision of these estimates, we interpret values in the range 0.8–1.2 as consistent with an acyclical or "nearly-acyclical" fiscal stance.

Table 1: The Estimated Fiscal Rule

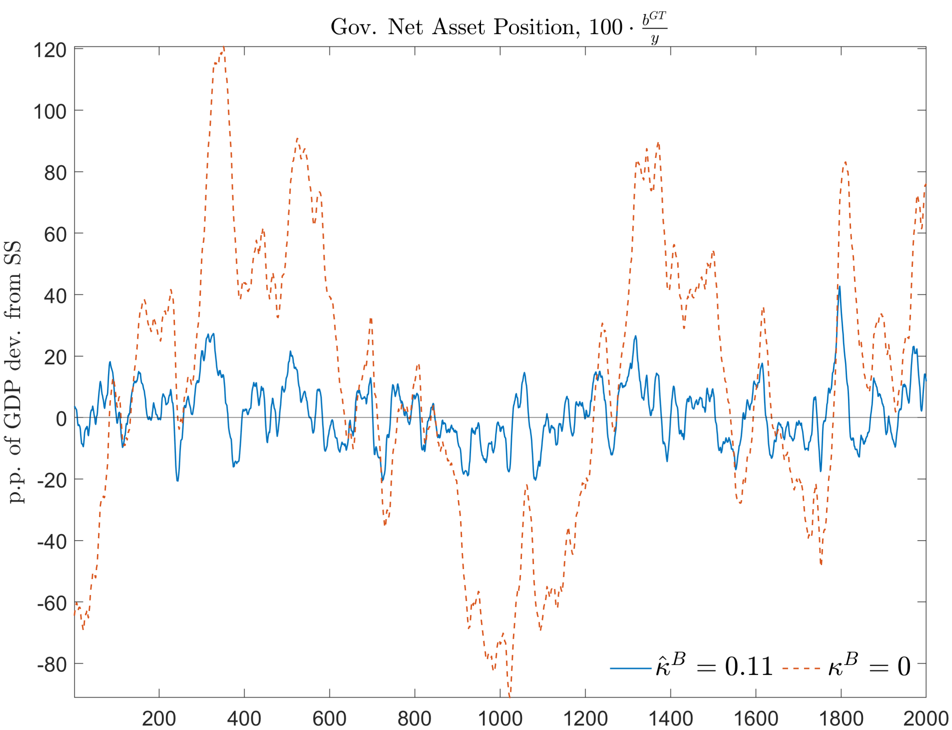
		Prior Distribution			Posterior Distribution		
	Parameter	dist	mean	s.d.	mean	p5	p95
Response to total revenue	κ	G	1.00	0.25	**1.08**	0.88	1.27
Response to debt position	κ^B	G	0.50	0.25	**0.11**	0.06	0.15

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

As in Leeper et al. (2017), we also estimate the government response to the stock of fiscal debt within the Bayesian step, informed by data on fiscal-to-GDP, obtaining a tightly estimated coefficient $\kappa^B = 0.11$ regardless of the fiscal rule considered, a value we kept fixed across all quantitative experiments below. Recall that the latter coefficient is not an explicit objective in the original Chilean mandate but rather a mechanism to impose a natural (and data-consistent) debt limit. Other articles treat this parameter as another coefficient to be optimized, obtaining values ranging from "close to zero" in Kumhof and Laxton (2013) to 0.025 in Mendes and Pennings (2025). By contrast, we view it as a structural parameter that reflects the borrowing constraints imposed by capital markets. This approach ensures that the model captures feasible data-consistent limits on government indebtedness.

To illustrate the critical role of what we label "feasibility constraint" or "debt limit" ($\kappa^B > 0$) in reconciling the model dynamics with the data, Figure 2 compares a sample simulation of the government's debt-to-GDP ratio from the baseline model with $\kappa^B > 0$ versus an alternative with $\kappa^B = 0$ (feeding the same sequence of shocks). The fiscal rule is kept acyclical ($\kappa^\tau = \kappa^{Co} = 1$) for this illustration. The simulation under $\kappa^B = 0$ is indistinguishable from a unit-root process, with public debt fluctuating around unsustainable levels for unfeasibly long periods. In contrast, under the estimated coefficient $\hat{\kappa}^B = 0.11$, public debt fluctuates between minus/plus 30% of GDP, consistent with the time series observed in the data, and fed to the model in the estimation step (see Appendix C for details).

Figure 2: The Debt Limit on the Government's Net Asset position



Notes: The figure compares two model-simulated time series (2000 periods) of the public net asset position as % of GDP under an acyclical spending policy ($\kappa = 1$). The simulations differ only in the coefficient of the fiscal rule's debt limit constraint: the solid-blue line uses the estimated value $\hat{\kappa}^B = 0.11$, while the dashed-orange line shuts down the debt limit by setting $\kappa^B = 0$. Both simulations are subjected to the same sequence of random shocks.

Table 2 demonstrates the model's ability to replicate key second moments observed in the data, including standard deviations, correlations with non-commodity GDP, and first-order autocorrelations. The model effectively captures the volatility and cyclical behavior of core macroeconomic aggregates. For instance, the standard deviation of non-commodity GDP growth is 1.4% in the model, closely matching the data value of 1.1%. Similarly, the model reproduces the volatility of exportable GDP growth (1.8% vs. 1.9% in the data) and consumption growth (1.3% vs. 1.0%), while preserving their strong positive correlations with output (0.8 and 0.6, respectively). Investment volatility is slightly underestimated (3.3% vs. 3.7%), but the model captures its procyclical nature well (correlation of 0.5). Core inflation volatility is 0.57% in the model versus 0.53% in the data, with autocorrelations of 0.6 and 0.7, respectively. The nominal interest rate and real exchange rate also exhibit realistic dynamics, with autocorrelations of 0.9 and standard deviations of 0.53% and 6.9%, respectively.

Table 2: Second Moments

		100*s.d.(x_t)		corr$(x_t, \Delta \log y)$		corr(x_t, x_{t-1})	
x_t	Description	Data	Model	Data	Model	Data	Model
$\Delta \log y$	GDP (Non-Co) growth	1.1	1.4	1.0	1.0	0.5	0.1
$\Delta \log y^{Co}$	Commodity GDP growth	3.3	3.7	0.0	0.2	0.0	-0.0
$\Delta \log y^{X}$	Exportable GDP growth	1.9	1.8	0.7	0.8	0.0	-0.1
$\Delta \log y^{N}$	Nontradable GDP growth	1.0	1.5	0.9	0.8	0.5	0.3
$\Delta \log c$	Consumption growth	1.0	1.3	0.7	0.6	0.4	0.4
$\Delta \log i$	Investment growth	3.7	3.3	0.7	0.5	0.3	0.6
$\Delta \log i^{Co}$	Investment Co growth	7.7	8.3	0.3	0.2	0.4	0.6
tb/y	Trade Balance-to-GDP	5.4	3.9	0.4	0.0	0.8	0.9
$\Delta \log h$	Hours growth	0.8	2.1	0.5	0.7	0.2	-0.1
$\Delta \log w$	Real Wage growth	0.48	0.69	0.0	-0.1	0.4	0.6
$\Delta \log c^{G}$	Gov. Consumption growth	2.4	2.9	0.1	0.1	-0.3	-0.0
$\Delta \log i^{G}$	Gov. Investment growth	11.0	9.2	0.1	0.4	-0.5	-0.3
$\Delta \log tr^{G}$	Gov. Transfers growth	3.4	3.7	0.0	0.1	-0.4	-0.1
b^{GT}/y	Gov. Net Asset-to-GDP	6.8	11.3	-0.0	-0.1	0.988	0.994
π	Headline Inflation Rate	0.62	0.72	0.1	-0.2	0.6	0.6
π^{Z}	Core Inflation Rate	0.53	0.57	-0.3	-0.1	0.8	0.7
π^{F}	Food Inflation Rate	2.1	2.0	0.2	-0.2	0.4	0.2
R	Nominal Interest Rate	0.48	0.53	-0.2	-0.2	0.9	0.9
spr	Spread	0.19	0.24	-0.5	-0.1	0.8	0.9
rer	Real Exchange Rate	7.7	6.9	0.0	-0.1	0.9	0.9
π^{S}	Nominal Devaluation Rate	4.6	4.9	-0.2	0.0	0.2	-0.0

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

The model also performs well in replicating the statistical properties of fiscal debt. The estimated feedback parameter on the debt position, $\kappa^B = 0.11$, effectively imposes a debt limit, reducing the autocorrelation of public debt from 0.9997 (under $\kappa^B = 0$) to 0.994, close to the empirical value of 0.988. Similarly, the debt limit reduces the volatility of the public debt-to-GDP ratio from 68% to 11%, much closer to the observed volatility of 6.8%. This constraint is not part of the legal fiscal rule but serves as a technical device to reconcile model-based debt dynamics with observed data.

The latter is a significant improvement relative to existing studies, which typically do not discipline this moment by using data on government debt nor incorporate an explicit debt limit ($\kappa^B > 0$) into the fiscal rule. As illustrated in Figure 2, shutting off the feasibility constraint ($\kappa^B = 0$) produces a counterfactual volatility in the public debt to GDP ratio, one order of magnitude above the data moment and indistinguishable from a unit-root process. Finally, regarding fiscal spending components, the model accurately captures that, as in the data, government investment is significantly more volatile (9%) than government consumption (2.9%) and social transfers (3.4%). While the model overestimates the observed procyclicality of public investment, it notably captures the negative autocorrelations observed across fiscal spending components.

4.2 Quantifying Welfare Gains from the Optimized Rule

How does the estimated Chilean fiscal rule compare to alternative regimes in welfare terms? Our quantitative DSGE model provides a rigorous laboratory to address this question by evaluating welfare under alternative fiscal regimes. As shown in the previous section, Chile's fiscal spending rule over the past two decades is best described as acyclical, consistent with a structural balance rule (SBR). We adopt this SBR as the benchmark as it allows us to interpret the welfare implications of departures from the current fiscal stance. Regarding the fiscal instrument, we consider total spending (including consumption, investment, and transfers) as the baseline case and provide robustness to alternative instruments in Section 6.

Let $V^i(\kappa) \equiv E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^i(\kappa), h_t^i(\kappa))$ denote the expected lifetime utility of household type $i \in \{R, NR\}$ under a fiscal regime characterized by policy parameter κ. We measure welfare changes using the consumption equivalent variation (CEV), λ^i, defined as the constant fraction of lifetime consumption that household i is willing to give up under the benchmark acyclical rule ($\hat{\kappa} = 1$) to be indifferent to regime κ. Formally,

$$V^i(\kappa) = V^i(\hat{\kappa}; \lambda^i) \equiv E_0 \sum_{t=0}^{\infty} \beta^t U((1+\lambda^i) c_t^i(\hat{\kappa}), h_t^i(\hat{\kappa})), \tag{26}$$

where a negative λ^i indicates welfare losses– as the household is willing to sacrifice benchmark consumption to remain indifferent with the alternative, while a positive one implies welfare gains.

To evaluate the aggregate welfare effect of optimized fiscal rules, we first determine the fiscal regime κ^* that maximizes the population-weighted lifetime utility across household types:

$$\kappa^* \equiv \max_{\kappa \in \mathcal{K}} \left[(1-\omega) V^R(\kappa) + \omega V^{NR}(\kappa) \right], \tag{27}$$

where $\omega \in [0, 1]$ denotes the population share of non-Ricardian households and $\mathcal{K}$ is the feasible parameter set. The average CEV across households, λ, is then defined by:

$$(1-\omega) V^R(\kappa^*) + \omega V^{NR}(\kappa^*) = (1-\omega) V^R(\hat{\kappa}; \lambda) + \omega V^{NR}(\hat{\kappa}; \lambda). \tag{28}$$

We numerically approximate all value functions using a second-order Taylor expansion of the model around the non-stochastic steady state, which captures the impact of shocks on the variance of key variables such as consumption, hours worked, and output.

Table 3 presents a comprehensive welfare evaluation of alternative fiscal regimes, comparing fiscal rules commonly found in the literature with three optimized fiscal rules tailored to different household types. The first block of the table reports the welfare implications of three illustrative regimes: a procyclical balanced budget rule (BBR, $\kappa = 0$), the benchmark acyclical structural balance rule (SBR, $\kappa = 1$), and a countercyclical rule (CCR, $\kappa = 2$). These regimes highlight the trade-offs between macroeconomic stabilization and welfare outcomes.

Table 3: Welfare implications of the Simple κ fiscal rule

Illustrative Rules	κ	λ^R	λ^{NR}	$\Delta std(c^R)$	$\Delta std(c^{NR})$	$\Delta std(h)$
BBR (procyclical)	0	-0.17	-3.31	-2.6	14.9	13.1
SBR (acyclical)	1	0	0	0	0	0
CCR (countercyclical)	2	-0.05	0.54	3.2	-6.4	-7.9
Optimized Rules						
Ricardian Household	**1.2**	**0.004**	0.25	0.6	-1.8	-1.9
Non-Ricardian Household	**1.9**	-0.04	**0.55**	2.9	-6.0	-7.3
Weighted Household	**1.8**	**0.28**	**0.28**	2.5	-5.6	-6.6

Notes: This table presents the performance of alternative benchmark fiscal rules and the optimized rule in the baseline model with a single feedback parameter κ for total revenues, the debt limit parameter fixed at its estimated value $\kappa^B = 0.11$, and total government spending (including consumption, investment, and untargeted transfers) as the fiscal instrument. Columns (1) to (3) report the rule under analysis and its implied welfare gain/loss for Ricardians (λ^R) and non-Ricardians (λ^{NR}), in percent $\%$ Consumption Equivalent units. Columns (4) to (6) show the percent change in volatility of consumption and hours worked, where $\Delta std(x) = 1$ indicates that the fiscal rule under analysis yields 1% higher volatility for variable x than under the SBR benchmark.

Our first result indicates that the Chilean SBR has generated significant welfare gains– particularly for financially-constrained non-Ricardians– by insulating households from cyclical fluctuations that would otherwise be amplified under a BBR. The first block in Table 3 shows that the BBR amplifies consumption and labor market volatility, resulting in substantial welfare losses—Ricardians lose 0.17% and Non-Ricardians lose 3.3%, on average, all households lose 1.74% of lifetime consumption. In contrast, the CCR ($\kappa = 2$) improves outcomes for Non-Ricardians ($\lambda^{NR} = 0.54\%$) while slightly reducing Ricardian welfare ($\lambda^R = -0.05\%$).

Our second result suggests that transitioning from the benchmark SBR to a moderately countercyclical spending stance could yield additional welfare gains for the average household, particularly benefiting those facing constraints on self-insurance against income fluctuations. The second block of the Table 3 reports the welfare-maximizing fiscal rule under three distinct optimization criteria: maximizing Ricardian welfare, maximizing Non-Ricardian welfare, and maximizing population-weighted household welfare. These optimized rules differ in their degree of desired countercyclicality. Ricardians prefer a near-acyclical rule ($\kappa = 1.2$), which balances minor disruptions to their consumption smoothing behavior ($\Delta std(c^R) = 0.6\%$) with a small macroeconomic stabilization effect ($\Delta std(h) = -1.9\%$). Note, however, that Ricardian welfare gains are nil ($\lambda^R = 0.004\%$) even at their optimized policy, since they can rationally smooth away any (reasonable) fiscal rule. Instead, non-Ricardian households benefit from a more aggressive countercyclical stance ($\kappa = 1.9$), which reduces more significantly consumption ($\Delta std(c^{NR}) = -6\%$) and labor market volatility ($\Delta std(h) = -7.3\%$), producing a welfare gain of $\lambda^{NR} = 0.55\%$. The population-weighted optimal rule lies in between ($\kappa = 1.8$), with a strong tilt towards Non-Ricardian preferences. These results underscore the importance of tailoring fiscal rules to the heterogeneity of household constraints. While Ricardians are relatively insensitive to fiscal policy due to their access to financial markets, Non-Ricardians derive substantial welfare benefits from countercyclical government spending.

In summary, our quantitative results highlight that the benefits of implementing a moderately countercyclical spending stance ($\kappa \in [1.2, 1.9]$) induce lower volatility of hours worked and, consequently, aggregate output, as well as a reduction in consumption volatility for non-Ricardians. The preference for moderate countercyclicality is consistent with the theoretical predictions of our stylized model (Proposition 1, Part A.): when fiscal policy is restricted to a one-parameter total revenue rule, only a subset of κ values ensures that a CCR outperforms an SBR. The simple (κ) rule restrains the government from being too countercyclical, since, as emphasized in Proposition 1, an excessively countercyclical stance regarding commodity revenues introduces exogenous volatility into the budget constraint of households, increasing consumption volatility and reducing welfare.

4.3 Macroeconomic Performance to a Commodity Price Shock

This section evaluates the macroeconomic performance of the fiscal rules analyzed in Section 3.2 in response to a commodity price shock— a particularly relevant exercise given Chile's dependence on commodities, which manifests in three key dimensions. First, mining goods accounted for 14% of GDP between 2001 and 2019, ranging from a low of 7% in 2001 and to a peak of 24% in 2006. Second, mining exports represented an average of 53% of total goods exports, fluctuating between 40% in 2002 and 62% in 2007. Third, a substantial and volatile fraction of government revenues originated from a state-owned commodity-producing company, with contributions ranging from a low of 2% of total revenues in 2001 and 2019, and reaching record highs of 21% in 2006. Since commodity prices are determined in international markets, Chile's national, external, and fiscal accounts are highly sensitive to exogenous commodity price shocks.[20]

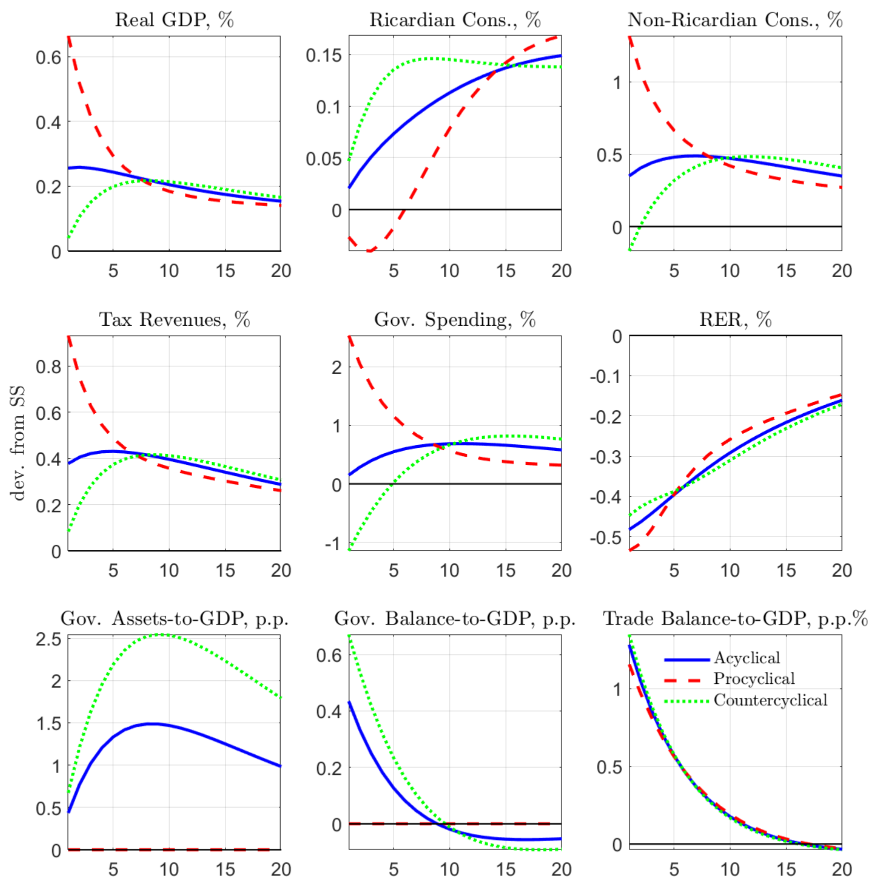
Figure 3 illustrates the macroeconomic effects of a one standard deviation positive shock to the price of the exported commodity (p^{Co*}) under three fiscal regimes: (a) the SBR benchmark (acyclical spending) with $\kappa = 1$, (b) a balanced budget rule (procyclical spending) with $\kappa = 0$, and (c) the optimized countercyclical spending rule with $\kappa = 1.8$.

Short-term output and consumption respond widely differently to commodity shocks across fiscal rules, as shown on the top row of Figure 3. Under BBR, real GDP rises sharply (0.66% on impact) as procyclical fiscal spending amplifies the exogenously induced economic boom. In contrast, GDP rises 0.26% on impact under the acyclical SBR. In the optimized rule, the government counter-cyclically restrains spending during the first year after the shock, inducing a more gradual buildup of output response, driven by smoother consumption dynamics and greater labor market stability. Over time, government spending increases above trend regardless of the fiscal rule due to interest payments on the cumulated government's net foreign assets. Pro-cyclical spending induces

[20] This shock explains 40% of the variance of the trade-balance-to-GDP ratio and 35% of the government's net asset-to-GDP ratio.

a GDP "over-expansion" (relative to either SBR or the optimal CCR) that lasts for two years (eight quarters), after which the three policy rules converge and evolve together thereafter.

Figure 3: Responses to a one std. dev. (10%) Commodity Price Shock



Notes: This figure illustrates selected model impulse responses to a positive one standard deviation commodity price shock under three fiscal policy rules: Acyclical refers to the benchmark SBR with $\kappa = 1$, Procyclical refers to a BBR with $\kappa = 0$, and Countercyclical refers to the optimized CCR with $\kappa = 1.8$. All variables are in percent (%) deviation from the steady state, except for the Gov. Assets-to-GDP, Gov. Balance-to-GDP, and Trade Balance-to-GDP ratios, which are in percentage points (p.p.) of GDP.

Private consumption responses differ markedly across household types. Non-Ricardian households are highly dependent on the fiscal stance. Under BBR, their consumption increases by 1.3% on impact, due to the combined effect of procyclical transfers and higher labor income. Under the acyclical rule, that is, excluding procyclical transfers, GDP rises 0.35% only on impact. In contrast, the optimized countercyclical rule mandates to "save in good times" so that government transfers are restrained. Despite higher wages, consumption marginally declines initially, before gradually recovering and remaining persistently above trend, along with rising GDP and government transfers. In sharp contrast, the effects on Ricardian households' consumption are one order of magnitude less significant, as their access to financial markets allows them to smooth out any (reasonable) fiscal rule. At a conceptual level, Ricardian households behave more closely to the permanent income hypothesis, accommodating the positive wealth effect induced by the shock by smoothly increasing consumption over time.

The commodity shock has a substantial impact on fiscal accounts. Tax revenues increase from 0.1% to 0.9% on impact, depending on whether fiscal policy is countercyclical or procyclical, respectively. Commodity-related revenues (≈10% of total revenues) jump by about 14% irrespective of the fiscal rule (not shown). Government spending dynamics vary significantly across fiscal regimes, rising by 2.5% under the BBR and falling by 1% under the optimized countercyclical rule. The BBR, by design, mandates that expenditures match revenues exactly, resulting in no change in the asset-to-GDP ratio. Both the acyclical and countercyclical regimes yield improvements in the fiscal balance—by 0.43 and 0.67 percentage points of GDP, respectively. These gains support a gradual accumulation of government net foreign assets, or, depending on the initial stock, a reduction in fiscal debt.

Finally, given its large share in total exports, the commodity shock persistently improves the trade-balance-to-GDP ratio, regardless of the fiscal rule in place (not shown). Consistent with the windfall shock and its implied positive wealth effect, the economy faces a 0.5% real exchange rate appreciation that persists for several years.

5 The Generalized Fiscal Rule

5.1 Welfare-Maximizing Fiscal Rules

We now extend the welfare analysis to the generalized (κ^τ, κ^{Co}) fiscal rule that allows for differentiated responses to the domestic tax revenue cycle and the commodity revenue cycle. The goal is to test and quantify the theoretical predictions of Proposition 1 and assess whether tailoring the fiscal response to each revenue stream improves economic outcomes.

Our results show that aggregate welfare is maximized when the government adopts a strongly countercyclical stance on tax revenues ($\kappa^\tau = 2.7$), while maintaining an acyclical response to commodity revenues ($\kappa^{Co} = 1.1$), as indicated by the red asterisk in Panel (a) of Figure 4.[21] Moreover, as predicted by Part B of Proposition 1 of our stylized model, the optimal policy regarding κ^τ features limits to countercyclicality: welfare curves feature a pronounced plateau around $\kappa^\tau \approx 3$ and a decreasing pattern for higher values. Excessive fiscal activism introduces additional volatility in prices and wages without proportional welfare gains. Regardless of the value of κ^{Co}, there is always an *upper bound* for κ^τ from which the rule overshoots, eroding welfare. Figure 4 illustrates this findings by showing the welfare gains (Panel (a)) and volatility implications (Panels (b) to (d)) of a wide menu of fiscal rules characterized by policy parameters κ^τ, varying over the x-axis, and κ^{Co} (colored lines described in the legend).

We also find substantial welfare losses associated with procyclical spending—for example, Panel (a) in Figure 4 estimates a 2.5% reduction in lifetime consumption for the average household under the balanced budget rule ($\kappa^\tau = \kappa^{Co} = 0$).[22] On the other hand, excessive countercyclicality

[21] Appendix D presents analogous figures comparing Ricardian and non-Ricardian households.

[22] Other studies also document large gains from abandoning procyclical fiscal policy. Pieschacón (2012) estimates welfare gains of 7.6% for Mexico from insulating the economy from commodity volatility, and losses of 14.5% for Norway from adopting a procyclical rule. Frankel et al. (2013) similarly argue that countries moving away from procyclicality achieve substantial macroeconomic stabilization gains.

in response to commodity revenues can also be welfare decreasing: setting $\kappa^{Co} \geq 3$ increases volatility in hours worked (Panel (b)), and consumption for non-Ricardians (Panel (c)), eroding welfare gains (Panel (a)). In contrast, Ricardians are unaffected by κ^{Co} and marginally affected by changes in κ^{τ} due to their ability to smooth consumption intertemporally (Panel (d)).

These findings align qualitatively with the broader literature. In particular, our result on commodity acyclicality echoes the conclusions of Pieschacón (2012), Kumhof and Laxton (2013), and Mendes and Pennings (2025), all of which find that fiscal insulation from commodity price cycles is welfare-improving. We emphasize that fiscal policy can achieve even greater gains by also acting strongly countercyclically regarding tax revenues and ensuring debt sustainability through an endogenous debt limit. Importantly, in Section 5.3, we demonstrate that this result holds across a broad class of models. In a similar model but adding sovereign default risk, Bianchi et al. (2023) shows the optimal fiscal policy trades off the benefit of fiscal stimulus with raising sovereign default risk.

A key insight in our analysis is that a generalized fiscal rule that adjusts separately to each revenue gap through the policy parameters κ^{τ} and κ^{Co} delivers roughly double the welfare gains compared to the simple κ-rule, where spending responds only to the consolidated revenue gap. Table 4 summarizes the welfare performance of optimized rules, contrasting the simple κ rule from Section 3.2 with the generalized $(\kappa^{\tau}, \kappa^{Co})$ specification. For non-Ricardian households, the key advantage of the generalized rule is that it allows the government to *lean strongly against the wind* in response to fluctuations in tax revenues ($\kappa^{\tau} = 2.9$), while maintaining an acyclical stance toward commodity revenues ($\kappa^{Co} = 1.1$)– this flexibility doubles welfare gains from 0.55% to 1.16%. As anticipated by Proposition 1, when the government is not constrained to a simple κ rule, the optimal policy for non-Ricardians shifts substantially toward stronger countercyclicality in taxes.

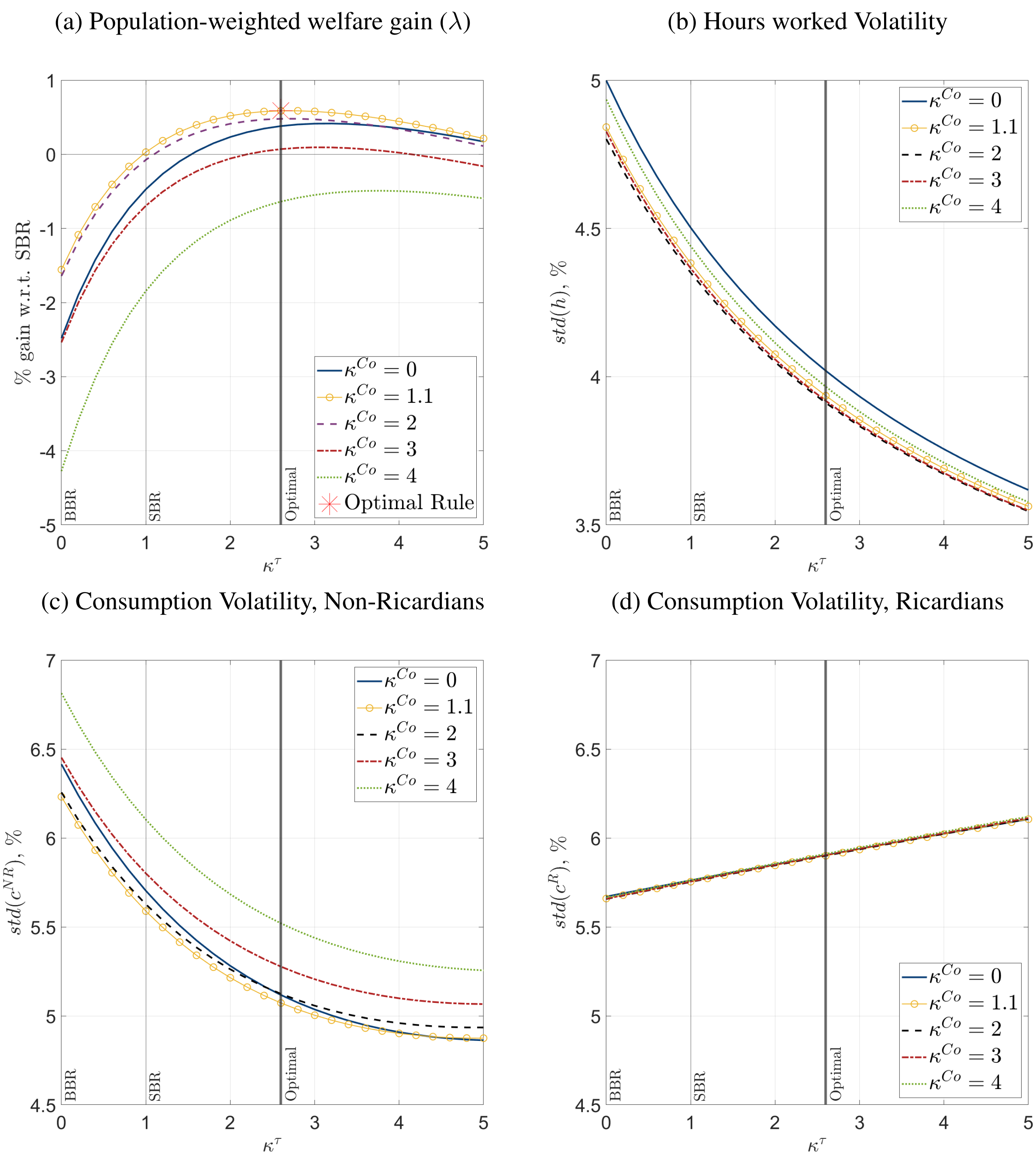
The welfare implications of optimizing fiscal policy are substantially different for both types of households. At a quantitative level, the welfare gains are one order of magnitude larger for non-Ricardian households. Instead, for Ricardian households, almost any deviation from the acyclical (SBR) benchmark is welfare-decreasing. At a qualitative level, countercyclical rules are a win-win for financially-constrained households, as they benefit from lower volatility in consumption and hours worked (that is, higher macroeconomic stability). In contrast, Ricardian households face a trade-off. While fiscal activism in the form of countercyclical rules increases their consumption volatility, it also effectively stabilizes economic cycles, reducing the volatility of hours worked (see also Panels (b) and (d) of Figure 4).[23]

These results underscore the importance of tailoring fiscal rules to the heterogeneity of household constraints and the empirical properties of revenue cycles. The larger the share of financially constrained households and the lower the commodity dependence in fiscal revenues, the more desirable are strong automatic stabilizers, such as countercyclical social transfers or (productive) public investment to lift the economy in bad times. More broadly, the welfare performance of fiscal rules depends critically on how well their design accounts for the distinct cyclical behavior of tax and commodity revenues. When these sources differ in volatility, persistence, and correlation with the domestic cycle, generalized rules that respond separately to each gap can yield superior

[23]Our framework abstracts from labor market considerations, such as skill heterogeneity across households. Including this would not alter our qualitative results but could affect welfare estimates, as these vary depending on the degree of skill substitutability, the mapping of skills across households, and the fiscal instruments considered.

outcomes.

Figure 4: Fiscal Rules and their Welfare Implications



Notes: The figures present the (weighted) average welfare gain (Panel (a)) and implied consumption and hours worked volatilities (Panels (b)-(d)) for alternative fiscal rules. In each panel, κ^{τ} varies on the horizontal x-axis, while each line in the legend represents an illustrative value for κ^{Co} (including the optimized value, $\kappa^{Co} = 1.1$). The vertical lines indicate the values of κ^{τ} that imply a procyclical Balanced-Budget Rule (BBR, $\kappa^{\tau} = 0$), an acyclical Structural Budget Rule (SBR, $\kappa^{\tau} = 1$), and the Optimal rule ($\kappa^{\tau} = 2.7$). Results are in percent consumption equivalent units relative to the acyclical (SBR) benchmark ($\kappa^{\tau} = \kappa^{Co} = 1$). The debt limit parameter is fixed at its estimated value $\kappa^{B} = 0.11$. The baseline fiscal instrument is total government spending (g).

Table 4: Optimized Rules: Simple Rule vs. Generalized Rule

	Weighted HH.		Ricardian HH.		Non-Ricardian HH.	
	κ-Rule	κ^{τ}, κ^{Co}-Rule	κ-Rule	κ^{τ}, κ^{Co}-Rule	κ-Rule	κ^{τ}, κ^{Co}-Rule
Response to tax revenue, κ^{τ}	1.8	2.7	1.2	1.2	1.9	2.9
Response to Co revenue, κ^{Co}		1.1		1.3		1.1
Welfare gain R, λ^{R}	0.28	0.59	0.004	0.006	-0.04	-0.09
Welfare gain NR, λ^{NR}			0.25	0.34	0.55	1.16

Notes: This table compares the optimized Simple κ Rule versus the Generalized $\kappa^{\tau}, \kappa^{Co}$ Rule for the weighted average household, Ricardians, and non-Ricardians. The debt limit parameter is fixed at its estimated value $\kappa^{B} = 0.11$, and total government spending is the fiscal instrument.

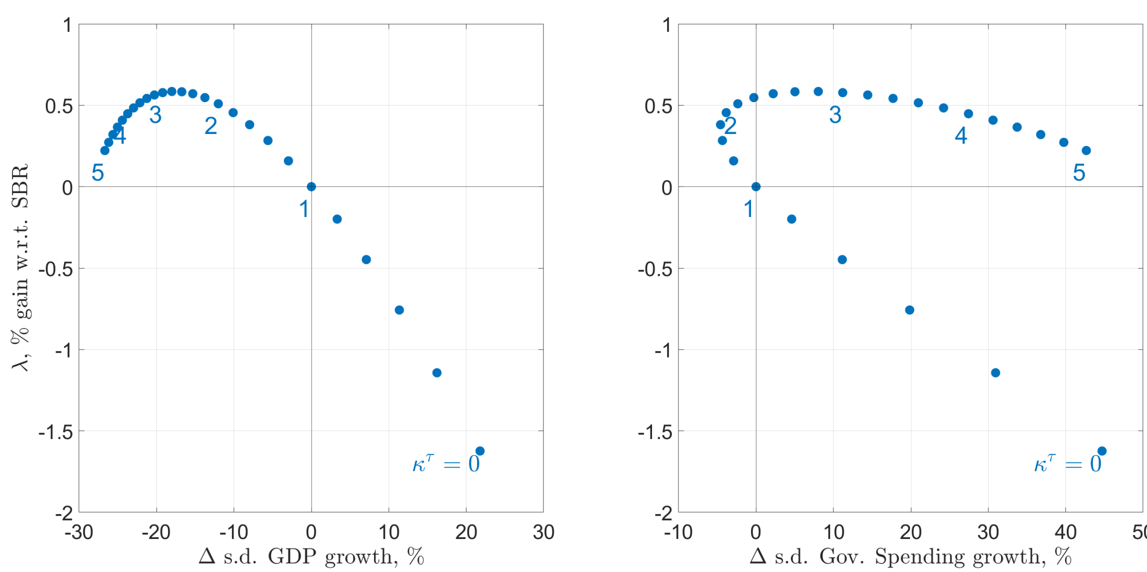
5.2 The Trade-off between Macro Stability and Fiscal Stability

In practice, the desirability of a fiscal rule depends not only on its welfare implications but also on the implied volatility it generates on macro and fiscal variables. Figure 5 shows the attainable welfare gains for the weighted household along with the implied volatility in GDP growth (Panel (a)) and government spending (Panel (b)) for a continuum of fiscal rules. Each dot represents an ordered value for κ^{τ}, while keeping κ^{Co} fixed at the acyclical (and optimal) value of one.

Figure 5: Fiscal Policy Trade-Offs

(a) Macroeconomic Volatility

(b) Instrument Volatility



Notes: The figures depict the combinations of welfare gains and implied changes in the volatility of real GDP growth (Panel (a)) and government spending growth (Panel (b)) resulting from alternative fiscal policy rules. Each marker represents a different value for κ^{τ} in the range [0,5], keeping $\kappa^{Co} = 1$ fixed at the acyclical benchmark. The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^{B} = 0.11$. The fiscal instrument is total spending. As before, welfare gains and changes in volatility are measured relative to an acyclical benchmark rule. The y-axis in both figures focuses on the welfare gain for the weighted household (λ).

Moving from a procyclical ($\kappa^\tau = 0$) to an acyclical ($\kappa^\tau = 1$) rule regarding tax revenues is a win-win strategy, reducing macroeconomic volatility (22% in Panel (a)), also reducing instrument volatility (45% in Panel (b)), while significantly improving average welfare ($\Delta\lambda = 1.7\%$). Moreover, moving from the acyclical ($\kappa^\tau = 1$) to a moderately countercyclical rule (such as $\kappa^\tau = 2$) delivers additional welfare gains of $\lambda = 0.6\%$, while reducing further macroeconomic and fiscal instrument volatility. Only for values $\kappa^\tau > 2$, fiscal authorities start facing a trade-off between welfare gains, which keep increasing until $\kappa^\tau \approx 2.7$, and rising government spending volatility, which increases fast for values larger than 2. Finally, an excessively countercyclical policy ($\kappa^\tau > 3$) eventually generates welfare losses, requiring excessive instrument volatility, for very modest gains in terms of macroeconomic stabilization.

We argue that implementing the welfare-maximizing fiscal policy, $\kappa^\tau = 2.7$ and $\kappa^{Co} = 1.1$, helps stabilize the economy at a very low cost: a less than 10% increase in the volatility of the fiscal instrument, in this case, total government spending. In the next sections, we study the robustness of these conclusions to alternative model assumptions and budgetary instruments.

5.3 Robustness to Alternative Model Assumptions

Our quantitative framework nests and extends models commonly used in the literature to evaluate the implications of fiscal rules in small open, resource-rich economies. In this section, we assess the robustness of our findings to alternative model assumptions and benchmark them against other contributions in the literature. Table 5 presents optimal policy rules estimated for a menu of alternative models. Following Leeper et al. (2017), our baseline model assumes that households derive utility from both private and public consumption, and that public investment accumulates into productive capital that complements private capital in production. Since many existing studies omit one or both of these channels, we sequentially remove them and evaluate how results change. We also check the sensitivity of our main results to critical model features not considered in previous articles, such as endogenizing commodity production and investment (Model 3), allowing for volatile components in the CPI (Model 4), and nominal wage rigidities (Model 5).[24]

Across all model variants, the optimal fiscal rule remains qualitatively robust, consistently prescribing a countercyclical response to tax revenues ($\kappa^\tau > 2$) and an acyclical reaction to commodity revenues ($\kappa^{Co} \approx 1$). This confirms the theoretical predictions of Proposition 1 and underscores the importance of distinguishing between domestic and external cycles when designing fiscal rules.

In the absence of productive public investment (Model 2), the optimized fiscal rule is moderately less countercyclical ($\kappa^\tau = 2.3$) than in the baseline ($\kappa^\tau = 2.7$). In contrast, the estimated welfare gain from the optimized policy reduces to $\lambda = 0.37\%$ relative to the baseline $\lambda = 0.59\%$. Intuitively, the presence of public investment complementing private capital enhances the benefits of countercyclical spending, by adding a Keynesian feature by which fiscal policy can lift the economy in the presence of nominal and real rigidities.

The magnitude of welfare gains, however, varies significantly across specifications. In the baseline model (Model 1), which includes both government consumption in utility and productive public investment, the (weighted) average welfare gain from the optimized rule is 0.59% of lifetime consumption. Removing public investment (Model 2) reduces the welfare gain to 0.37%, while removing endogenous commodity production (Model 3) lowers it further to 0.31%. When we

[24]We maintain total spending as the baseline fiscal instrument across all models.

exclude volatile components from the CPI basket (Model 4), the welfare gain drops to 0.37%, suggesting that countercyclical spending is especially desirable when the household is exposed to volatile goods in the consumption basket.

Table 5: Optimized Fiscal Rules for Nested Models

	Models with $U(c, c^G)$			Models with $U(c)$		
	κ^τ	κ^{Co}	λ	κ^τ	κ^{Co}	λ
1. Baseline	2.7	1.1	0.59	3.8	1.1	1.68
2. No public capital	2.3	1.2	0.37	3.1	1.2	0.98
3. No commodity production	2.3	1.0	0.31	3.4	0.9	1.56
4. No food in inflation	2.6	1.0	0.37	4.2	1.0	0.93
5. No wage rigidities	3.0	0.8	0.38	5.0	0.9	4.54
6. = 3)+4)+5)	1.6	1.0	0.08	2.4	1.0	0.42

Notes: This table presents the optimized rule (κ^τ, κ^{Co}) and welfare gains (λ) under alternative model assumptions: 1) baseline model, 2) No endogenous commodity production, 3) No public investment/capital, 4) No food (volatiles) in consumption basket, 5) No nominal wage rigidities, and 6) Combined 3)+4)+5). The left and right panels present models with and without government consumption in the utility function. Welfare gains (λ) for the average household relative to the acyclical benchmark ($\kappa^\tau = \kappa^{Co} = 1$).

On the other hand, we argue that allowing for nominal wage rigidities is essential for Keynesian spending policies to be an effective macroeconomic stabilization tool. At a quantitative level, wage rigidities improve the model's fit along labor market variables, which are crucial for quantifying gains and losses from consumption smoothing. Table 5 shows that removing nominal wage rigidities (Model 5) requires optimal policy to be more strongly countercyclical than under the baseline, especially in models without government consumption in the utility function.

Model 6 combines the exclusion of public investment, food price volatility, and wage rigidities—effectively resembling as much as possible the structure of Kumhof and Laxton (2013). In this stripped-down version, the optimal rule becomes significantly less countercyclical regarding tax revenues ($\kappa^\tau = 1.6$) than under the baseline ($\kappa^\tau = 2.7$) and the value reported by Kumhof and Laxton (2013) ($\kappa^\tau \approx 3$). Notably, however, our Model 6 does replicate the one order of magnitude lower welfare gains reported there ($\lambda \approx 0.08\%$), thereby suggesting that our model's innovations to improve the quantitative fit are key to generating quantitatively meaningful macroeconomic dynamics and, consequently, welfare implications.

Finally, the right panel of Table 5 also reveals that our main results are even starker in the model versions without government consumption in the utility function. Intuitively, in such an environment, the economy can afford more fiscal activism in the form of countercyclical spending ($\kappa^\tau >> 1$) without disrupting the household's preference for smooth consumption. On the other hand, the optimality of $\kappa^{Co} \approx 1$ is quite robust across models with and without government consumption in the utility function.

In sum, the robustness exercises confirm that specific modeling choices do not drive our main findings. Instead, they reflect fundamental economic mechanisms: countercyclical fiscal policy stabilizes domestic income and labor markets, while acyclical treatment of commodity revenues avoids amplifying exogenous volatility. The richer the model in terms of capturing these mechanisms—through public investment, wage rigidities, and realistic CPI composition—the larger the welfare gains from optimized fiscal rules.

6 Government Spending Instruments

6.1 Optimizing Rules to Alternative Fiscal Instruments

The results discussed so far have used total government spending (including consumption, investment, and lump-sum transfers) as the baseline instrument to implement the cyclically-adjusted fiscal rule introduced in equation (23). In this subsection, we address the question of whether the government can improve the cost-benefit balance of each rule by using, for instance, targeted social transfers as the sole fiscal instrument or by employing productive government investment to stimulate the economy during economic downturns. Table 6 summarizes the optimized rules for the weighted average household under four alternative fiscal instruments: total spending ($g = c^G + i^G + tr^G$, the baseline), government consumption only (c^G), government investment and consumption ($c^G + i^G$), and lump-sum transfers (tr^G).[25]

Table 6: Optimized Fiscal Rules with Alternative Instruments

	Fiscal Instrument			
	g	c^G	$c^G + i^G$	tr^G
Response to tax revenue, κ^τ	2.7	1.9	2.5	4.2
Response to Co revenue, κ^{Co}	1.1	1.3	1.3	1.2
Welfare gain w.r.t. SBR, λ	0.59	0.07	0.20	0.75
Vol. change w.r.t. SBR, $\Delta std(c^R)$	2.7	2.0	3.0	1.0
Vol. change w.r.t. SBR, $\Delta std(c^{NR})$	-9.7	-3.1	-6.1	-12.7
Vol. change w.r.t. SBR, $\Delta std(h)$	-10.9	-4.8	-9.9	-3.2

Notes: This table presents the optimized fiscal rule and welfare implications for the weighted average household under alternative fiscal instruments: total spending ($g = c^G + i^G + tr^G$, the baseline), government consumption (c^G), government investment ($c^G + i^G$), and lump-sum transfers (tr^G). Government investment is combined with consumption to avoid numerical issues (see details in footnote 25). The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.11$. Welfare gains and volatility changes are relative to the benchmark SBR.

The results deliver three important policy implications. First, the desired degree of countercyclicality regarding tax revenues depends heavily on the spending instrument. The optimal policy is especially countercyclical in lump-sum transfers (tr^G in column (4), $\kappa^\tau = 4.2$), as the government effectively provides insurance to uninsured non-Ricardian households. In contrast, when government consumption is used in isolation (c^G in column (2)), the optimized rule implies a more moderately countercyclical stance ($\kappa^\tau = 1.9$), as too much variability in c^G would disrupt the household's preference for smoothing the consumption basket. The models that include public

[25] We did not obtain stable computational solutions when using investment as the only fiscal instrument, since it represents a relatively small fraction of total spending. Hence, we allow for both consumption and investment components to adjust proportionally.

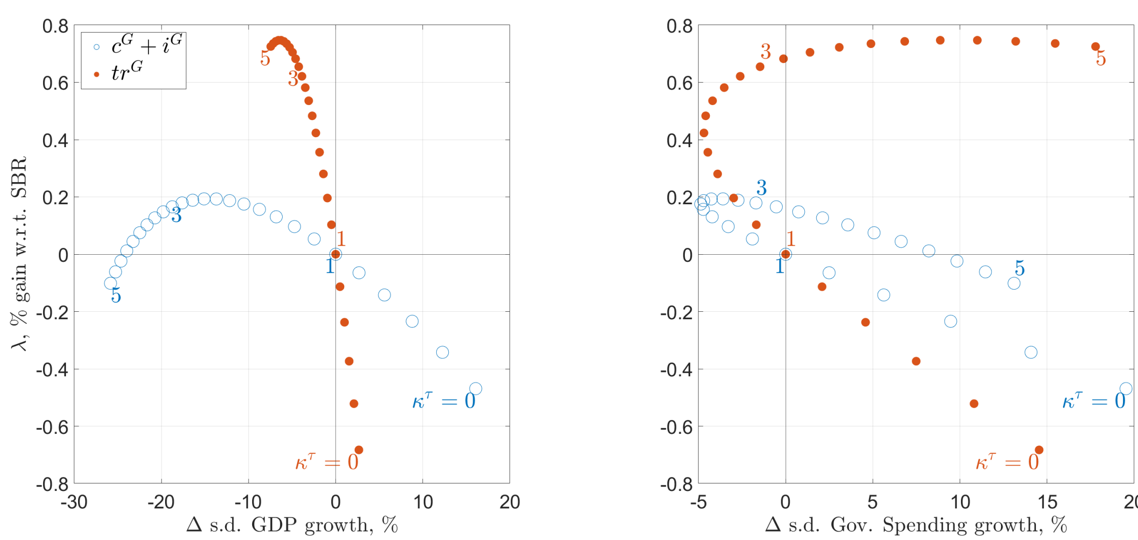
capital (columns (1) and (3)) lie in between ($\kappa^{\tau} \in \{2.5, 2.7\}$), indicating that countercyclical public investment is more desirable than public consumption (but less than transfers) in bad times. Second, the optimal response to commodity revenues is mostly acyclical ($\kappa^{Co} \in \{1.1, 1.3\}$).[26]

Third, when investment (i^G) is used as the fiscal instrument (columns (1) and (3)), the fiscal policy generates significant gains from macroeconomic stabilization via reductions in the volatility of hours ($\Delta std(h) \approx -10\%$) and hence aggregate GDP. When transfers are used as the sole instrument, the rule generates significantly higher welfare gains ($\lambda \in \{0.59, 0.75\}$) than otherwise (($\lambda \in \{0.07, 0.20\}$)). Hence, the baseline model with total spending $g = c^G + i^G + tr^G$ combines the stabilization properties of government investment with the welfare gains of automatic stabilizers, modeled here as countercyclical transfers, but potentially implemented also via negative taxes on selected goods, or unemployment insurance policies.

Figure 6 revisits the policy trade-offs between welfare gains, macro stability, and instrument volatility in the context of the alternative fiscal instrument. Panel (a) confirms that countercyclical transfers are effective in generating welfare gains; however, they are very ineffective in stabilizing macroeconomic aggregates such as GDP. In contrast, government consumption and public investment are effective in stabilizing GDP, but generating more moderate welfare gains. Panel (b) shows that implementing the optimal policy using transfers as the sole instrument ($\kappa^{\tau} = 4.2$) implies approximately 10% higher volatility in total spending. Instead, the optimal policy using consumption and investment ($\kappa^{\tau} = 2.5$) generates both a significant 15% reduction in macro fluctuations (Panel (a)) and a slight reduction in government spending volatility (Panel (b)).

Figure 6: Fiscal Policy Trade-Offs with alternative fiscal instruments

(a) Macroeconomic Volatility | (b) Instrument Volatility



Notes: The figures depict the combinations of welfare gains and implied changes in the volatility of real GDP growth (Panel (a)) and government spending growth (Panel (b)) resulting from alternative fiscal policy rules. Each marker represents a different value for κ^{τ} in the range [0,5], keeping $\kappa^{Co} = 1$ fixed at the acyclical benchmark. The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.11$. Panels (a) and (b) are with c^G and i^G as the fiscal instrument, while Panels (c) and (d) are under transfers. Welfare gains and changes in volatility are measured relative to the SBR benchmark.

[26] We guide our interpretation of the κ's cyclical stance based on the confidence band estimated in Section 4.

6.2 Government Spending Shocks and Fiscal Multipliers

To better understand the properties of different fiscal rules, this section examines the implications of different government spending shocks: public investment, government consumption, and lump-sum transfers. As their effects on the economy are inherently dynamic, we start by estimating government spending multipliers on aggregate output (GDP) following Leeper et al. (2017). Present value multipliers (PVMs) are particularly useful as they incorporate the full dynamic response of the economy and appropriately discount future effects.[27] Intuitively, it tells us how much additional output is produced for a one percent increase in government spending in present value terms. Formally, it quantifies the present value of additional output, over a k-period horizon, in response to an exogenous increase in the present value of government spending:

$$PVM_k = \frac{\sum_{j=0}^{k} \left(\Pi_{j=0}^{k}(1 + r_{t+j})^{-1}\right) \Delta Y_{t+j}}{\sum_{j=0}^{k} \left(\Pi_{j=0}^{k}(1 + r_{t+j})^{-1}\right) \Delta G_{t+j}}, \tag{29}$$

where ΔY_{t+j} and ΔG_{t+j} represent deviations in output and government expenditures from their steady-state levels. The discounting terms, $\Pi_{j=0}^{i}(1 + r_{t+j})_{t+j}^{-1}$, are model-based, constructed from real interest rates along the transition path.

Table 7 presents output PVMs for each fiscal shock, conditional on an exogenous increase in government spending equivalent to 1 percentage point above its steady-state level. As a companion, Figure 7 depicts responses to the three shocks normalized to generate the same change in total government spending at impact, and allowing for heterogeneous persistence (according to our estimation results) after that.

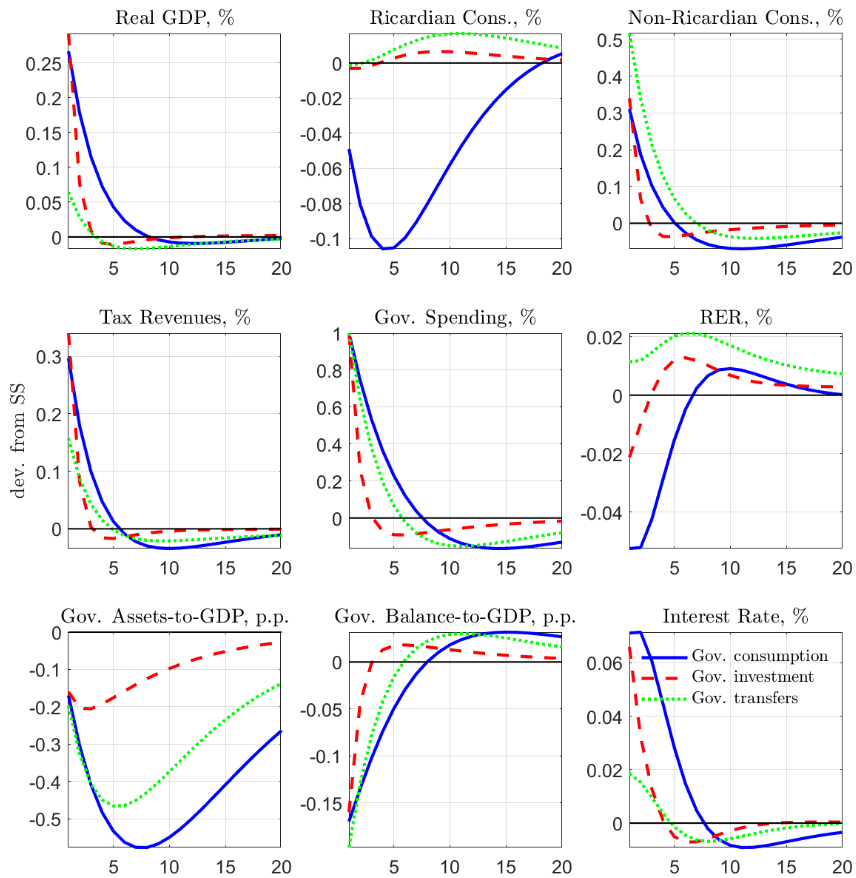
Table 7: Present Value Multipliers for Output

	Fiscal Instrument		
	c^G	i^G	tr^G
a. CCR Optimized (κ^τ, κ^{Co})			
Impact	1.31	1.52	0.17
1 year	1.06	1.60	0.06
5 year	1.81	3.76	-0.64
b. SBR Benchmark ($\kappa^\tau = \kappa^{Co} = 1$)			
Impact	1.13	1.24	0.27
1 year	0.99	1.36	0.15
5 year	2.13	3.66	-0.49

Notes: This table reports present-value multipliers on output (GDP) for both the SBR benchmark and the optimized fiscal rule, following three types of fiscal shocks: government consumption (ξ_{c^G}), public investment (ξi^G), and lump-sum transfers (ξtr^G). The feasibility constraint feedback parameter is held constant at its estimated value, $\kappa^B = 0.11$.

[27] Mountford and Uhlig (2009) and Leeper et al. (2010) introduce the concept of present-value multipliers by measuring the cumulative impact of fiscal stimulus on output, for a given period, considering the entire path of responses. This approach captures the dynamic consequences of deficit-financed spending, particularly over extended horizons.

Figure 7: Responses to Normalized Government Spending Shocks



Notes: Equilibrium responses to three types of government spending shocks: government consumption of goods and services, public investment, and social transfers. The three shocks are normalized to generate a 1% change in total government spending (g_t) at impact. Most variables are expressed as percent (%) deviation from the steady state, except for the Government's debt-to-GDP and balance-to-GDP ratios, which are expressed in percentage points (p.p.) of GDP deviation from the steady state.

We highlight two key insights. First, while all spending shocks are expansionary on impact, government consumption and investment yield output multipliers above one, with persistent effects over time. This is consistent with our previous results indicating that these spending components are especially effective in stabilizing output fluctuations. Investment shocks generate the largest and most prolonged stimulus, with multipliers exceeding three after five years. A public investment shock raises output because public capital is complementary to private capital, inducing Ricardian households to increase private investment. This in turn boosts labor demand, household income, and consumption, so that all GDP components—private consumption, private investment, and government spending—contribute to the expansion, as illustrated by the dashed-red lines in Figure 7. Government consumption also yields lasting positive effects, though with smaller long-term multipliers compared to investment. Transfer shocks behave very differently: while slightly expansionary on impact, their effect quickly vanishes and turns negative in the longer term, reflecting weak propagation through demand– while they significantly expand non-Ricardian consumption, Ricardian households smooth out the transfer almost entirely. Figure 7 also shows that all these fiscal expenditure shocks are mildly inflationary (not reported), eliciting a rise in the monetary policy interest rate. Overall, the results highlight that productive spending (investment and, to a lesser extent, consumption) generates much stronger and more durable stimulus than policies relying on household transfers.

Our second result shows that, under the optimized fiscal rule ($\kappa^{\tau} = 2.7, \kappa^{Co} = 1.1$), the present-value multipliers for public investment and government consumption exceed those under the SBR benchmark ($\kappa^{\tau} = \kappa^{Co} = 1$), compare Panel a to Panel b in Table 7. These differences arise solely from the distinct spending and financing mechanisms of each fiscal regime, as both economies share identical structural parameters aside from the fiscal rule specifications. Specifically, under the SBR, rising output increases tax revenues, allowing the government to maintain transfers and consumption, which amplifies the contribution of government expenditure to output. By contrast, the CCR-optimized rule mandates savings when output expands, reducing other outlays and limiting debt issuance, which produces a smaller fiscal expansion but strengthens the government's asset position.

These dynamics affect forward-looking Ricardian households. Under the CCR, for instance, a public investment expansion is financed mainly by reallocating existing spending rather than by issuing debt, implying minimal future tax changes and encouraging higher private investment. Under the SBR, debt issuance finances a larger share of the shock, with smaller cuts to other outlays, leading Ricardians to moderate consumption and investment in anticipation of higher future taxes. Consequently, output under the SBR is driven primarily by government expenditure, whereas under the CCR, private consumption and investment play a larger role. This illustrates that fiscal rules shape not only welfare but also the composition and propagation of output responses.

7 Conclusions

This paper revisits the design of fiscal rules in commodity-dependent economies, emphasizing the welfare and macroeconomic trade-offs faced by governments operating under revenue volatility and household heterogeneity. Using a multisector New Keynesian model estimated for Chile, we show that simple, implementable fiscal rules can be optimized to deliver substantial welfare gains and improved macroeconomic stability—particularly for financially constrained households.

Our main finding is that the welfare-maximizing fiscal rule responds strongly countercyclically to domestic tax revenue fluctuations while remaining acyclical with respect to commodity revenues. This design minimizes the transmission of external shocks to domestic consumption and labor markets, and avoids amplifying volatility through fiscal channels. Compared to Chile's benchmark acyclical structural balance rule, the optimized rule doubles the welfare gains for non-Ricardian households and improves aggregate welfare without requiring excessive fiscal activism.

We also show that the effectiveness of fiscal rules depends critically on the choice of fiscal instruments. Public investment and targeted transfers are especially powerful in stabilizing output and smoothing consumption, respectively. Moreover, the model highlights the importance of incorporating a debt sustainability constraint into the rule design. This feature disciplines the dynamics of public debt and reconciles model-based predictions with observed fiscal behavior. Our results are robust across a wide range of model specifications and policy environments. They underscore the importance of tailoring fiscal rules to the empirical properties of revenue sources and the constraints faced by different household types. In particular, the larger the share of financially constrained households and the lower the commodity dependence in fiscal revenues, the greater the welfare gains from countercyclical fiscal policy.

While our analysis focuses on Chile, the framework and insights are broadly applicable to other emerging economies with similar structural features. The paper contributes to the growing literature on fiscal rule design by providing analytical bounds, quantitative benchmarks, and policy guidance grounded in data and institutional realism.

Future research should explore the political economy and institutional feasibility of implementing optimized fiscal rules, especially in contexts where rule credibility and enforcement are weak. Understanding how institutional quality interacts with rule performance remains a key challenge for translating technical optimality into durable policy outcomes.

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Appendix

A Structural Balance Fiscal Rules

Table 8: Structural Balance Fiscal Rules. Cross-Country Comparison

Country	**Target Variable**	**Cyclical Adjustments**	**Notes**
Chile	Structural balance of central government	Output gap; Long-term copper & molybdenum prices	Pioneer of structural balance rule since 2001. Includes a sovereign stabilization fund.[a]
Peru	Structural balance of non-financial public sector	Output gap; Long-term copper & gold prices	Adopted in 2013, adapting the Chilean framework. Includes a fiscal stabilization fund.[b]
Colombia	Structural balance of central government	Output gap; Long-term oil prices	Implemented since 2011. Includes a sovereign wealth fund to save excess revenues.[c]
Mexico	Balanced budget (structural oil revenue rule)	Output gap; Long-term oil prices	Since 2006, requires the budget to be balanced in structural terms. Includes an oil stabilization fund.[d]
Norway	Structural non-oil central government deficit	Oil revenues fully saved; spend only fund's real return	Formally adopted in 2001. Oil revenues saved in global government pension fund.[e]

[a]See Marcel et al. (2001); Frankel (2011)
[b]See Céspedes and Velasco (2014)
[c]Lozano and Toro (2007); International Monetary Fund (2019)
[d]Hernández-Trillo (2013); OECD (2015)
[e]Cappelen and Mjøset (2009); International Monetary Fund (2013)

B Proof of Proposition 1

Part A. For a spending rule with parameters $(\kappa^\tau, \kappa^{Co})$, the variance of non-Ricardian consumption is

$$\mathbb{V}(c_t^{NR}) = (1-\tau\kappa^\tau)^2\,\sigma_y^2 + (1-\kappa^{Co})^2\,\sigma_F^2 + 2(1-\tau\kappa^\tau)(1-\kappa^{Co})\,\rho\,\sigma_y\sigma_F, \tag{1}$$

where $\sigma_y^2 = \mathbb{V}(w_t)$, $\sigma_F^2 = \mathbb{V}(F_t^{Co})$, and $\rho = \mathrm{Corr}(w_t, F_t^{Co})$. Under the SBR benchmark, where $\kappa^\tau = \kappa^{Co} = 1$, the variance reduces to:

$$\mathbb{V}^{SBR}(c_t^{NR}) = (1-\tau)^2\sigma_y^2. \tag{2}$$

We compare the variance of non-Ricardian consumption under a one-parameter countercyclical rule (CCR) where $\kappa^\tau = \kappa^{Co} = \kappa$,

$$\mathbb{V}^{CCR}(c_t^{NR}) = (1-\tau\kappa)^2\sigma_y^2 + (1-\kappa)^2\sigma_F^2 + 2(1-\tau\kappa)(1-\kappa)\rho\sigma_y\sigma_F, \tag{3}$$

to the variance under the SBR ($\kappa = 1$). Define the variance difference $\Delta \equiv \mathbb{V}^{CCR} - \mathbb{V}^{SBR}$. We seek conditions such that $\Delta < 0$. Set $x \equiv \kappa - 1$ (so $x > 0$ corresponds to $\kappa > 1$). Note that $1-\kappa = -x$ and $1-\tau\kappa = (1-\tau) - \tau x$. Substituting and rearranging gives

$$\begin{aligned}\Delta &= \big[(1-\tau-\tau x)^2 - (1-\tau)^2\big]\sigma_y^2 + x^2\sigma_F^2 + 2\rho\sigma_y\sigma_F\big[-(1-\tau)x + \tau x^2\big] \\ &= -2(1-\tau)\tau x\,\sigma_y^2 + \tau^2x^2\sigma_y^2 + x^2\sigma_F^2 - 2\rho(1-\tau)x\sigma_y\sigma_F + 2\rho\tau x^2\sigma_y\sigma_F.\end{aligned} \tag{4}$$

Collecting terms yields a simple quadratic in x:

$$\Delta = x\Big[xA - B\Big],$$

where

$$A \equiv \tau^2\sigma_y^2 + \sigma_F^2 + 2\rho\tau\sigma_y\sigma_F, \tag{5}$$
$$B \equiv 2(1-\tau)\big(\tau\sigma_y^2 + \rho\sigma_y\sigma_F\big). \tag{6}$$

Since $A > 0$ for admissible parameter values, $\Delta < 0$ for $x > 0$ if and only if

$$0 < x < \frac{B}{A}.$$

Returning to $\kappa = 1 + x$, the sufficient condition for the CCR to yield lower variance than the SBR is

$$1 < \kappa < 1 + \frac{B}{A} = 1 + \frac{2(1-\tau)\big(\tau\sigma_y^2 + \rho\sigma_y\sigma_F\big)}{\tau^2\sigma_y^2 + \sigma_F^2 + 2\rho\tau\sigma_y\sigma_F}. \tag{7}$$

Equivalently, letting $\zeta \equiv \sigma_y/\sigma_F$,

$$1 < \kappa < 1 + \frac{2(1-\tau)\,\zeta\,(\tau\zeta + \rho)}{1 + \tau^2\zeta^2 + 2\rho\tau\zeta}.$$

This establishes the upper bound in Proposition 1 (Part A). Note that the bound depends on the correlation ρ and the relative volatility ζ, and it satisfies $\kappa < 1/\tau$ for admissible parameter values.

Corollary (special limit). If $\rho \to 1$ and $\sigma_F = \sigma_y$ (so $\zeta = 1$), then

$$A = (\tau^2 + 1 + 2\tau)\sigma_y^2 = (1+\tau)^2\sigma_y^2,$$
$$B = 2(1-\tau)(\tau+1)\sigma_y^2 = 2(1-\tau)(1+\tau)\sigma_y^2,$$

hence

$$\frac{B}{A} = \frac{2(1-\tau)}{1+\tau}.$$

Then a one-parameter CCR dominates the SBR whenever

$$1 < \kappa < 1 + \frac{2(1-\tau)}{1+\tau} \;=\; \frac{3-\tau}{1+\tau}\,.$$

Note that the upper bound for κ in the limiting case is above the upper bound derived in (7), i.e. $1 + \frac{B}{A} < \frac{3-\tau}{1+\tau} < \frac{1}{\tau}$, suggesting that the scope for countercyclicality expands when the tax and commodity revenue streams feature higher correlation.

Part B. It is easy to see that when setting $\kappa^{Co} = 1$ in (1), the variance of NR consumption simplifies to $\mathbb{V}^{CCR}(c_t^{NR}) = (1-\tau\kappa^{\tau})^2\sigma_y^2$. Under the SBR benchmark $(\kappa^{\tau}, \kappa^{Co}) = (1,1)$, the variance is $\mathbb{V}^{SBR}(c_t^{NR}) = (1-\tau)^2\sigma_y^2$. Thus, CCR delivers lower consumption volatility than SBR whenever

$$(1-\tau\kappa^{\tau})^2 < (1-\tau)^2. \tag{8}$$

Since $\tau \in (0,1)$, inequality (8) holds for the nonempty interval $\kappa^{\tau} \in \left(1,\ \frac{2}{\tau} - 1\right)$. In particular, the economically relevant $\kappa^{\tau} \in (1,\ 1/\tau]$ strictly improves on SBR, and the choice $\kappa^{\tau} = 1/\tau$ drives the variance to zero in this stylized environment.

C Calibration Strategy and Estimated Parameters

A combination of calibration and estimation assigns the values of the parameters in the model. Table 9 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 $r^W = 3.2\%$ (annual) and the steady-state spread $\overline{spr} = 1.7\%$ (annual), the sample averages for the LIBOR and the Chilean EMBI, respectively.

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

Table 9: 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
$(R^{W*})^4 - 1$	3.2	Foreign risk-free interest rate (annual)	Data: LIBOR interest rate
$spr^4 - 1$	1.7	Country spread (annual)	Data: EMBI spread
σ	1.5	Inverse elasticity of intertemporal substitution	Literature
ω	0.5	Share of non-Ricardian households	Medina et al. (2007)
ω^T	0.5	Share of non-Ricardians in gov. taxes	García et al. (2019)
ω^{TR}	0.5	Share of non-Ricardians in gov. transfers	García et al. (2019)
$\epsilon = \epsilon_w$	11	Elasticity of subst. across goods and labor varieties	Medina et al. (2007)
$\delta = \delta_{Co}$	0.015	Depreciation rate private sectors (quarterly)	García et al. (2019)
γ_F	0.25	Share of food and energy in CPI basket	Data: CPI basket weights
$\gamma_{CG} = \gamma_{IG}$	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)
$\overline{L}$	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 (volatiles) share in the consumption bundle is taken directly from the CPI basket weights in the data. 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 ($\gamma = 0.36$) and the share of public capital in production ($\gamma_G = 0.1$) 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 that are not well identified by our dataset using the Bayesian estimation procedure. In particular, the elasticity of substitution between private and public capital is taken from García et al. (2019).

Table 10 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 $h^{NR} = \omega = 0.5$.

Table 10: 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	4.54	Disutility of work Ricardians	Normalize Total Hours	n.a.	1
η^{NR}	5.12	Disutility of work non-Ricardians	Normalize NR Hours	n.a.	0.5
δ_G	0.01	Depreciation rate public capital (quarterly)	Public Capital share	14.0	17.4
$\alpha^N = \alpha^X$	0.36	Capital share in production N and X sectors	Investment-to-GDP	25.7	26.2
α_{Co}	0.47	Capital share in production Co sector	Commodity Capital share	16.5	16.5
$\alpha_{\overline{L}}$	0.41	Resource share in production Co sector	Commodity Labor share	2.7	2.9
z^N	1	SS productivity N sector	Normalize z^N	n.a.	1
z^X	0.99	SS productivity X sector	Trade Balance-to-GDP	2.7	2.7
z^{Co}	0.22	SS productivity Co sector	Commodity Output share	12.5	12.9
z^*	0.74	SS foreign productivity	Imports-to-GDP	32.7	32.7
ξ^{R*}	0.04	SS foreign rents shock	Current Account-to-GDP	-1.6	-1.6
$(\pi^*)^4 - 1$	3.4	Foreign inflation rate	Normalize p^M/p^I share	n.a.	1
γ_N	0.60	Share of N goods in core consumption	Normalize p^X/p^I share	n.a.	1
$\gamma_M = \gamma_{FM}$	0.88	Share of M in tradable/food consumption	Consumption-to-GDP	59.3	58.8
$\gamma_I^N = \gamma_{ICo}^N$	0.65	Share of N goods in investment basket	Nontradable Output-to-GDP	67.4	59.9
$\gamma_I^M = \gamma_{ICo}^M$	0.29	Share of M goods in investment basket	Imports investment share	21.2	21.1
α^{CG}	0.36	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	0.02	Share of lump-sum taxes in GDP	Tax-to-GDP	21.0	21.0
τ^C	0.18	Tax rate on consumption	VAT revenue share	57.0	56.8
τ^W	0.07	Tax rate on labor income	Labor tax share	20.0	19.9
τ^K	0.49	Tax rate on capital income	Capital tax share	23.0	23.3
τ^{Co}	0.02	Tax rate on foreign Co profits	Royaltie Tax Rate	n.a.	n.a.

The capital shares in production in the N and X sectors are set to $\alpha^N = \alpha^X = 0.36$ to hit a steady-state investment-to-GDP ratio of 26%. In the case of the commodity sector, we set $\alpha^{Co} = 0.47$ 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 approximately 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 $z^X = 0.99$ is required to hit the observed trade balance-to-GDP ratio of 2.7%. Similarly, productivity in the commodity sector $z^{Co} = 0.22$ is set to match the 13% share of commodity GDP in aggregate GDP. The steady-state foreign productivity level $z^* = 0.74$ is set to match an imports-to-GDP ratio of 33%. The steady-state foreign rents are set to hit the average -1.6% 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 sectoral relative prices. The share of imported goods in the tradable and food consumption baskets $\gamma_M = \gamma_{FM}$ are assumed 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 ($\gamma_I^N = \gamma_{ICo}^N = 0.65$) to match as closely 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 expenditure shares 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 closely 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 $\tau^{Co} = 0.02$.

The remaining parameters are estimated using Bayesian methods following An and Schorfheide (2007). The set of observables used to inform the model comprises 25 macroeconomic variables at a quarterly frequency, covering the period from 1996Q2 to 2019Q3.[28] 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.

- **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

[28]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.

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 11 and 12 report prior and posterior distributions for structural parameters and AR(1) processes, respectively.

Table 11: Prior and Posterior Distributions: Structural Parameters.

Parameters	Description	Prior Distribution			Posterior Distribution		
		dist	mean	s.d.	mean	p5	p95
ψ	Inverse Frisch Elast.	G	1.50	0.50	0.98	0.45	1.49
ϱ	Elast. of Subst. private vs gov. cons.	G	1.00	0.50	1.15	0.37	2.00
ϱ^C	Elast. of Subst. cons.	G	1.00	0.25	0.64	0.38	0.91
ϱ^Z	Elast. of Subst. core cons.	G	1.00	0.25	1.84	1.16	2.55
ϱ^T	Elast. of Subst. tradable cons.	G	1.00	0.25	1.03	0.63	1.45
ϱ^F	Elast. of Subst. food cons.	G	1.00	0.25	1.03	0.60	1.42
ϱ^I	Elast. of Subst. inv.	G	1.00	0.25	1.36	0.79	1.90
ϱ^{ICo}	Elast. of Subst. Co inv.	G	1.00	0.25	1.09	0.61	1.57
ϱ^{CG}	Elast. of Subst. gov. cons.	G	1.00	0.25	1.31	0.80	1.83
ϱ^{IG}	Elast. of Subst. gov. inv.	G	1.00	0.25	1.11	0.69	1.54
κ	Gov. response to tax revenue	G	1.00	0.25	1.08	0.88	1.27
κ^B	Gov. response to debt position	G	0.50	0.25	0.11	0.06	0.15
ϵ^*	Elast. foreign demand	IG	0.20	0.05	0.19	0.12	0.25
ϕ_c	Habit in consumption	B	0.75	0.10	0.83	0.74	0.92
ϕ_b	Country premium debt Elast.	IG	1.00	Inf	0.29	0.19	0.37
ϕ_k	Inv. adjustment cost Elast.	G	5.00	1.50	4.05	2.15	5.80
ϕ_k^{Co}	Inv. Co adjustment cost Elast.	G	2.00	0.50	2.58	1.81	3.35
ϕ_u	Capital utilization	G	1.50	0.25	1.67	1.26	2.04
θ^N	Calvo probability, N	B	0.75	0.07	0.49	0.39	0.59
θ^X	Calvo probability, X domestic	B	0.75	0.07	0.40	0.29	0.50
θ^M	Calvo probability, M	B	0.75	0.07	0.84	0.81	0.88
θ^{X*}	Calvo probability, X exported	B	0.75	0.07	0.87	0.79	0.98
θ_w	Calvo probability, wages	B	0.75	0.07	0.88	0.84	0.93
α_y	Taylor rule, GDP growth	N	0.12	0.05	0.14	0.08	0.21
α_π	Taylor rule, Inflation	N	1.70	0.10	1.64	1.50	1.78
ρ^R	Taylor rule, smoothing	B	0.85	0.05	0.80	0.77	0.84
$\rho_{c^{X*}}$	Persistence in foreign demand	B	0.50	0.20	0.69	0.49	0.90
Γ^N	Global pass through, N	B	0.50	0.20	0.34	0.05	0.60
Γ^X	Global pass through, X	B	0.50	0.20	0.51	0.22	0.84
Γ^{Co}	Global pass through, Co	B	0.50	0.20	0.48	0.14	0.79

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

Table 12: Prior and Posterior Distributions: Exogenous AR(1) processes.

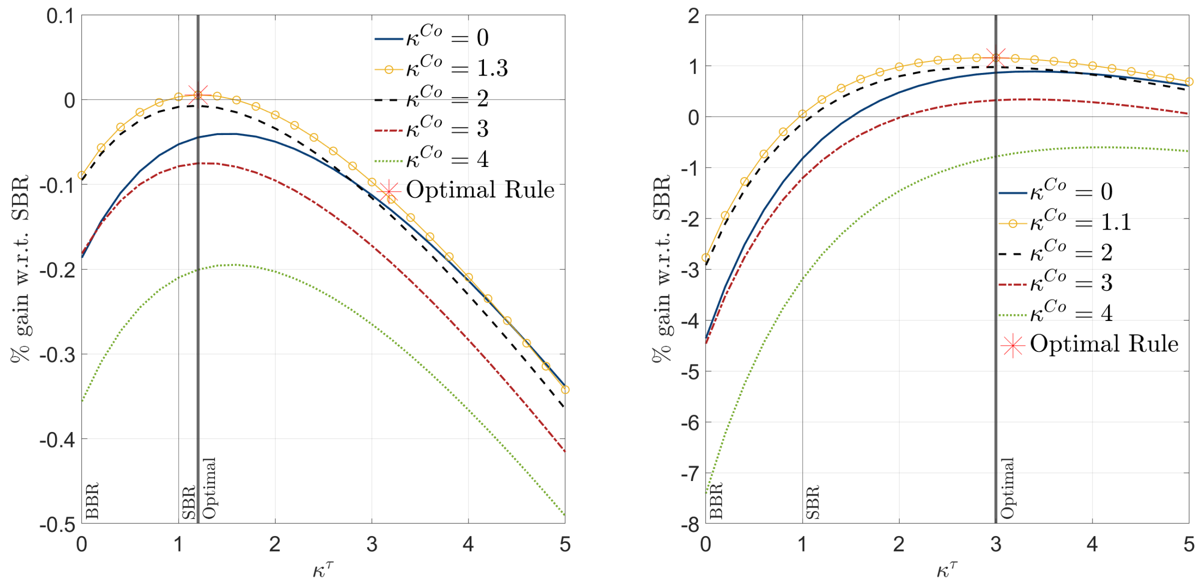
		Prior Distribution			Posterior Distribution		
Parameters	Description	dist	mean	s.d.	mean	p5	p95
Persistences							
ρ_a	Trend growth rate	B	0.50	0.20	0.65	0.50	0.79
ρ_{z^N}	Productivity shock, N	B	0.85	0.07	0.91	0.84	0.97
ρ_{z^X}	Productivity shock, X	B	0.85	0.07	0.92	0.87	0.97
$\rho_{z^{Co}}$	Productivity shock, Co	B	0.85	0.07	0.92	0.86	0.97
ρ_{z^F}	Productivity shock, F	B	0.75	0.07	0.93	0.90	0.96
ρ_{ξ_b}	Preference shock	B	0.50	0.20	0.59	0.38	0.79
ρ_{ξ_h}	Labor wedge shock	B	0.50	0.20	0.33	0.07	0.59
ρ_{ξ_i}	Investment shock	B	0.75	0.07	0.66	0.56	0.76
$\rho_{\xi_{iCo}}$	Investment Co shock	B	0.50	0.20	0.63	0.51	0.77
ρ_{c^G}	Gov. consumption shock	B	0.75	0.07	0.82	0.73	0.92
ρ_{i^G}	Gov. investment shock	B	0.50	0.20	0.34	0.09	0.56
ρ_{tr^G}	Gov. transfers shock	B	0.75	0.07	0.74	0.62	0.87
$\rho_{\xi^{S*}}$	Spread shock (observable)	B	0.75	0.07	0.82	0.75	0.90
$\rho_{\xi^{U*}}$	Spread shock (unobservable)	B	0.75	0.07	0.90	0.85	0.95
$\rho_{\xi^{R*}}$	Foreign rents shock	B	0.50	0.20	0.50	0.15	0.81
ρ_{π^*}	Foreign inflation shock	B	0.50	0.20	0.39	0.32	0.47
$\rho_{p^{M*}}$	Foreign import price shock	B	0.50	0.20	0.59	0.40	0.78
$\rho_{p^{Co*}}$	Foreign commodity price shock	B	0.50	0.20	0.86	0.81	0.90
$\rho_{R^{W*}}$	Foreign interest rate shock	B	0.50	0.20	0.92	0.88	0.95
ρ_{z^*}	Foreign productivity shock	B	0.85	0.07	0.88	0.80	0.96
Volatilities							
σ_a	Trend growth rate	IG	0.50	Inf	0.27	0.20	0.33
σ_{z^N}	Productivity shock, N	IG	0.50	Inf	0.62	0.46	0.80
σ_{z^X}	Productivity shock, X	IG	0.50	Inf	2.36	2.02	2.72
$\sigma_{z^{Co}}$	Productivity shock, Co	IG	0.50	Inf	2.92	2.52	3.29
σ_{z^F}	Productivity shock, F	IG	0.50	Inf	1.91	1.67	2.18
σ_{ξ_b}	Preference shock	IG	0.50	Inf	9.43	4.81	13.86
σ_{ξ_h}	Labor wedge shock	IG	0.50	Inf	22.17	3.48	41.97
σ_{ξ_i}	Investment shock	IG	0.50	Inf	6.20	3.39	8.78
$\sigma_{\xi_{iCo}}$	Investment Co shock	IG	0.50	Inf	8.44	5.05	11.79
σ_{ξ_m}	Monetary policy shock (iid)	IG	0.50	Inf	0.18	0.16	0.20
σ_{c^G}	Gov. consumption shock	IG	0.50	Inf	2.32	1.98	2.63
σ_{i^G}	Gov. investment shock	IG	0.50	Inf	7.48	6.20	8.65
σ_{tr^G}	Gov. transfers shock	IG	0.50	Inf	3.15	2.73	3.63
$\sigma_{\xi^{X*}}$	Exports demand shock (iid)	IG	0.50	Inf	2.21	1.84	2.57
$\sigma_{\xi^{S*}}$	Spread shock (observable)	IG	0.50	Inf	0.11	0.09	0.13
$\sigma_{\xi^{U*}}$	Spread shock (unobservable)	IG	0.50	Inf	0.31	0.18	0.45
$\sigma_{\xi^{R*}}$	Foreign rents shock	IG	0.50	Inf	0.48	0.12	1.01
σ_{π^*}	Foreign inflation shock	IG	0.50	Inf	2.09	1.81	2.33
$\sigma_{p^{M*}}$	Foreign import price shock	IG	0.50	Inf	1.35	1.08	1.60
$\sigma_{p^{Co*}}$	Foreign commodity price shock	IG	0.50	Inf	9.84	8.56	11.21
$\sigma_{R^{W*}}$	Foreign interest rate shock	IG	0.50	Inf	0.14	0.12	0.17
σ_{z^*}	Foreign productivity shock	IG	0.50	Inf	0.23	0.14	0.31

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

D Additional Welfare Results

Figure 8: Welfare gains, by type of household

(a) Ricardian household (λ^R) (b) Non-Ricardian household (λ^{NR})



Notes: The figures present the welfare gain for Ricardian (Panel (a)) and non-Ricardian households (Panel (b)) for alternative fiscal rules. In each panel, κ^τ varies on the horizontal x-axis, while each line in the legend represents an illustrative value for κ^{Co} (including the optimized value, $\kappa^{Co} = 1.3$ for Ricardians and $\kappa^{Co} = 1.1$ for non-Ricardians). The vertical lines indicate the values of κ^τ that imply a procyclical Balanced-Budget Rule (BBR, $\kappa^\tau = 0$), an acyclical Structural Budget Rule (SBR, $\kappa^\tau = 1$), and the Optimal rule ($\kappa^\tau = 1.2$ for Ricardians and $\kappa^\tau = 2.9$ for non-Ricardians). Results are in percent consumption equivalent units relative to the acyclical (SBR) benchmark ($\kappa^\tau = \kappa^{Co} = 1$). The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.11$. The baseline fiscal instrument is total government spending (g).

Table 13: Optimized Fiscal Rules with Alternative Instruments, by Household Type

	Weighted HH.				Ricardian HH.				Non-Ricardian HH.			
	g	c^G	c^G+i^G	tr^G	g	c^G	c^G+i^G	tr^G	g	c^G	c^G+i^G	tr^G
Response to tax revenue, κ^τ	2.7	1.9	2.5	4.2	1.2	0.4	0.7	5.0	2.9	2.6	3.0	4.2
Response to Co revenue, κ^{Co}	1.1	1.3	1.3	1.2	1.3	1.2	1.3	3.2	1.1	1.3	1.3	1.2
Welfare gain w.r.t. SBR, λ^R	0.59	0.07	0.20	0.75	0.01	0.02	0.01	0.11	-0.09	-0.23	-0.22	0.09
Welfare gain w.r.t. SBR, λ^{NR}					0.34	-0.23	-0.16	0.77	1.16	0.26	0.52	1.31
Vol. change w.r.t. SBR, $\Delta std(c^R)$	2.7	2.0	3.0	1.0	0.3	-1.3	-0.6	1.3	3.0	3.6	4.0	1.0
Vol. change w.r.t. SBR, $\Delta std(c^{NR})$	-9.7	-3.1	-6.1	-12.7	-1.7	2.1	1.3	-10.0	-10.3	-5.1	-7.7	-12.7
Vol. change w.r.t. SBR, $\Delta std(h)$	-10.9	-4.8	-9.9	-3.2	-2.1	3.2	2.0	-4.1	-11.8	-7.8	-12.4	-3.2

Notes: This table presents the optimized fiscal rule and welfare implications for each household type under alternative fiscal instruments: total spending (g, the baseline), government consumption (c^G), government investment (c^G+i^G), and lump-sum transfers (tr^G). Government investment is combined with consumption to avoid numerical issues (see details in footnote 25). The feasibility constraint's feedback parameter is fixed at its estimated value $\kappa^B = 0.11$. Welfare gains and volatility changes are relative to the benchmark acyclical SBR ($\kappa^\tau = \kappa^{Co} = 1$).

Table 14: Optimized Fiscal Rules for Nested Models: **Weighted Household**

Models with c^G in U	κ^{τ}	κ^{Co}	λ	$\Delta std(c^R)$	$\Delta std(c^{NR})$	$\Delta std(h)$	$std(c^R)$	$std(c^{NR})$	$std(h)$
1. Baseline	2.7	1.1	0.59	2.7	-9.7	-10.9	5.9	5.1	3.9
2. No public capital	2.3	1.2	0.37	2.3	-7.8	-7.1	5.7	5.2	4.1
3. No commodity production	2.3	1.0	0.31	1.3	-10.4	-9.8	5.8	4.4	3.9
4. No food in inflation	2.6	1.0	0.37	6.1	-11.6	-11.9	5.4	5.4	4.3
5. No wage rigidities	3.0	0.8	0.38	-2.7	-23.4	-15.3	6.2	5.6	3.0
6. = 3)+4)+5)	1.6	1.0	0.08	1.0	-4.3	-2.6	21.7	8.6	7.4
Models without c^G in U									
1. Baseline	3.8	1.1	1.68	1.0	-12.1	-15.2	5.6	4.8	3.7
2. No public capital	3.1	1.2	0.98	0.9	-10.5	-10.3	5.4	5.0	3.9
3. No commodity production	3.4	0.9	1.56	1.0	-14.1	-14.4	5.3	4.2	3.6
4. No food in inflation	4.2	1.0	0.93	1.7	-17.7	-20.0	4.7	4.9	3.8
5. No wage rigidities	5.0	0.9	4.54	1.3	-21.7	-14.9	5.8	5.0	3.2
6. = 3)+4)+5)	2.4	1.0	0.42	0.7	-8.6	-5.4	21.6	8.3	7.2

Notes: This table compares summary statistics for the 1) baseline model against alternative nested models dropping 2) Endogenous commodity production, 3) Public investment/capital, 4) Food (volatiles) in consumption basket, 5) Nominal wage rigidities, and 6) Combined 3)+4)+5). The first two columns report the optimized policy rule for the revenue and commodity gaps, respectively. Column three presents the implied welfare gains/losses for the average household relative to the acyclical benchmark ($\kappa^{\tau} = \kappa^{Co} = 1$). The last three columns report the standard deviations of consumption and hours worked in each alternative economy. Recall hours worked are the same for both households. All results use total government spending (including consumption, investment, and social transfers) as the fiscal instrument to satisfy the rule.

Table 15: Optimized Fiscal Rules for Nested Models: **All Households Types**

	Weighted HH.			Ricardian HH.			Non-Ricardian HH.		
Models with c^G in U	κ^{τ}	κ^{Co}	λ	κ^{τ}	κ^{Co}	λ^R	κ^{τ}	κ^{Co}	λ^{NR}
1. Baseline	2.7	1.1	0.59	1.2	1.3	0.01	2.9	1.1	1.16
2. No public capital	2.3	1.2	0.37	1.1	1.3	0.00	2.4	1.2	0.74
3. No commodity production	2.3	1.0	0.31	0.8	1.2	0.00	2.4	1.0	0.63
4. No food in inflation	2.6	1.0	0.37	2.2	1.1	0.07	2.7	1.0	0.63
5. No wage rigidities	3.0	0.8	0.38	1.7	1.0	0.04	3.0	0.9	0.74
6. = 3)+4)+5)	1.6	1.0	0.08	-0.4	1.2	0.12	1.8	1.0	0.25
Models without c^G in U									
1. Baseline	3.8	1.1	1.68	4.8	1.9	0.22	3.8	1.1	2.83
2. No public capital	3.1	1.2	0.98	5.0	1.9	0.22	3.0	1.2	1.61
3. No commodity production	3.4	0.9	1.56	4.8	0.9	0.16	3.4	0.9	2.64
4. No food in inflation	4.2	1.0	0.93	5.0	1.9	0.32	4.0	1.0	1.43
5. No wage rigidities	5.0	0.9	4.54	2.6	5.0	0.04	5.0	0.9	8.24
6. = 3)+4)+5)	2.4	1.0	0.42	5.0	-1.0	0.14	2.4	1.0	0.71

Notes: This table compares summary statistics for the 1) baseline model against alternative nested models dropping 2) Endogenous commodity production, 3) Public investment/capital, 4) Food (volatiles) in consumption basket, 5) Nominal wage rigidities, 6) Combined 2)+4)+5), 7) Combined 6)+No capital. The first two columns report the optimized policy rule for the revenue and commodity gaps, respectively. Column three presents the implied welfare gains/losses for the average household relative to the acyclical benchmark ($\kappa^{\tau} = \kappa^{Co} = 1$). The last three columns report the standard deviations of consumption and hours worked in each alternative economy. Recall hours worked are the same for both households. All results use total government spending (including consumption, investment, and social transfers) as the fiscal instrument to satisfy the rule.

E The Model in detail

E.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:

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

The consumption basket is given by a constant elasticity of substitution (CES) composite between private and public goods consumption:

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

for ease of notation let $\widehat{C}_t^l \equiv \widehat{C}^l(C_t^l - \phi_c \breve{C}_{t-1}^l, C_t^G)$. The disutility of work term is given by $\Xi_t^l = \eta^l \xi_t^h A_{t-1}^{1-\sigma} \Theta_t^l$, where the term Θ_t^l is engineered to eliminate the wealth effect of labor supply Galí et al. (2012), as follows:

$$\Theta_t^l = A_{t-1}^{\sigma} \left(\widehat{C}^l(\breve{C}_t^l - \phi_c \breve{C}_{t-1}^l, C_t^G) \right)^{-\sigma} \left(\frac{(1-\gamma)\widehat{C}^l(\breve{C}_t^l - \phi_c \breve{C}_{t-1}^l, C_t^G)}{\breve{C}_t^l - \phi_c \breve{C}_{t-1}^l} \right)^{\frac{1}{\varrho}} \tag{3}$$

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

$$h_t = \int_0^1 h_t^d(j) dj, \tag{4}$$

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, $W_t^N(j) = W_t^X(j) = W_t(j)$.

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

$$\begin{aligned} (1+\tau^C)P_t C_t^R + P_t^I(I_t^{R,N} + I_t^{R,X}) + B_t^R + S_t B_t^{R*} = (1-\tau^W) \left[\int_0^1 W_t(j) h_t^d(j) dj \right] + \\ \sum_{J \in \{N,X\}} \left[(1-\tau^K) P_t^J r_t^J u_t^J + \tau^K P_t^I (\delta + \Phi(u_t^J)) \right] \hat{K}_{t-1}^J + r_{t-1} B_{t-1}^R + S_t r_{t-1}^* B_{t-1}^{R*} + \hat{\Sigma}_t, \end{aligned} \tag{5}$$

where 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.

Physical capital is sector-specific and evolves according to:

$$\hat{K}_t^J = (1-\delta)\hat{K}_{t-1}^J + \left[1 - \Gamma\left(\frac{\hat{I}_t^J}{\hat{I}_{t-1}^J}\right)\right]\hat{I}_t^J \xi_t^i, \tag{6}$$

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.

The stock of capital services effectively used in production: $K_t^J = (1-\omega)u_t^J \hat{K}_{t-1}^J$. The functional form for maintenance costs follows García-Cicco et al. (2015):

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

Non-Ricardian households' budget constraint can be written as:

$$(1+\tau^C)P_t C_t^{NR} = (1-\tau^W)\int_0^1 W_t(j)h_t^d(j)dj + TR_t^{NR} - T_t^{NR}. \tag{7}$$

E.2 The Production Sector

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):

$$C_t = \left[(\gamma_Z)^{\frac{1}{\varrho_C}}\left(C_t^Z\right)^{\frac{\varrho_C - 1}{\varrho_C}} + (\gamma_F)^{\frac{1}{\varrho_C}}\left(C_t^F\right)^{\frac{\varrho_C - 1}{\varrho_C}}\right]^{\frac{\varrho_C}{\varrho_C - 1}} \tag{8}$$

where ϱ_C is the elasticity of substitution between goods, and $\gamma_Z = 1 - \gamma_F$, γ_F 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:

$$C_t^Z = \left[(\gamma_N)^{\frac{1}{\varrho_Z}}\left(C_t^N\right)^{\frac{\varrho_Z - 1}{\varrho_Z}} + (\gamma_T)^{\frac{1}{\varrho_Z}}\left(C_t^T\right)^{\frac{\varrho_Z - 1}{\varrho_Z}}\right]^{\frac{\varrho_Z}{\varrho_Z - 1}} \tag{9}$$

$$C_t^T = \left[(\gamma_X)^{\frac{1}{\varrho_T}}\left(C_t^X\right)^{\frac{\varrho_T - 1}{\varrho_T}} + (\gamma_M)^{\frac{1}{\varrho_T}}\left(C_t^M\right)^{\frac{\varrho_T - 1}{\varrho_T}}\right]^{\frac{\varrho_T}{\varrho_T - 1}} \tag{10}$$

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:

$$C_t^F = z_t^F \left[(\gamma_{FX})^{\frac{1}{\varrho_F}} \left(C_t^{FX} \right)^{\frac{\varrho_F - 1}{\varrho_F}} + (\gamma_{FM})^{\frac{1}{\varrho_F}} \left(C_t^{FM} \right)^{\frac{\varrho_F - 1}{\varrho_F}} \right]^{\frac{\varrho_F}{\varrho_F - 1}} \tag{11}$$

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 fitting high volatility in food prices.

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:

$$C_t^J = \left[\int_0^1 C_t^J(i)^{\frac{\epsilon - 1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon - 1}} \tag{12}$$

where ϵ is the elasticity of substitution across varieties.

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:

$$I_t^P = \left[(\gamma_I^N)^{\frac{1}{\varrho_I}} \left(I_t^N \right)^{\frac{\varrho_I - 1}{\varrho_I}} + (\gamma_I^X)^{\frac{1}{\varrho_I}} \left(I_t^X \right)^{\frac{\varrho_I - 1}{\varrho_I}} + (\gamma_I^M)^{\frac{1}{\varrho_I}} \left(I_t^M \right)^{\frac{\varrho_I - 1}{\varrho_I}} \right]^{\frac{\varrho_I}{\varrho_I - 1}} \tag{13}$$

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:

$$I_t^{Co} = \left[(\gamma_{ICo}^N)^{\frac{1}{\varrho_{ICo}}} \left(I_t^{NCo} \right)^{\frac{\varrho_{ICo} - 1}{\varrho_{ICo}}} + (\gamma_{ICo}^X)^{\frac{1}{\varrho_{ICo}}} \left(I_t^{XCo} \right)^{\frac{\varrho_{ICo} - 1}{\varrho_{ICo}}} + (\gamma_{ICo}^M)^{\frac{1}{\varrho_{ICo}}} \left(I_t^{MCo} \right)^{\frac{\varrho_{ICo} - 1}{\varrho_{ICo}}} \right]^{\frac{\varrho_{ICo}}{\varrho_{ICo} - 1}} \tag{14}$$

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.

Government Goods. Analogous to the private consumption and investment baskets, government consumption and investment goods are produced using CES technologies combining nontradable and exportable goods:

$$C_t^G = \left[(\gamma_{CG})^{\frac{1}{\varrho_{CG}}} \left(C_t^{GN} \right)^{\frac{\varrho_{CG} - 1}{\varrho_{CG}}} + (1 - \gamma_{CG})^{\frac{1}{\varrho_{CG}}} \left(C_t^{GX} \right)^{\frac{\varrho_{CG} - 1}{\varrho_{CG}}} \right]^{\frac{\varrho_{CG}}{\varrho_{CG} - 1}} \tag{15}$$

$$I_t^G = \left[(\gamma_{IG})^{\frac{1}{\varrho_{IG}}} \left(I_t^{GN} \right)^{\frac{\varrho_{IG} - 1}{\varrho_{IG}}} + (1 - \gamma_{IG})^{\frac{1}{\varrho_{IG}}} \left(I_t^{GX} \right)^{\frac{\varrho_{IG} - 1}{\varrho_{IG}}} \right]^{\frac{\varrho_{IG}}{\varrho_{IG} - 1}} \tag{16}$$

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.

E.3 Production in Sectors $J \in \{N, X\}$

Each sector $J \in \{N, X\}$ consists of a continuum of firms indexed by $i \in [0, 1]$. Firm's i value added $Y_t^J(i)$ in sector J is produced using a Cobb-Douglas technology combining physical capital $\tilde{K}_t^J(i)$ and labor $h_t^J(i)$, as follows

$$Y_t^J(i) = z_t^J \left[\tilde{K}_t^J(i)\right]^{\alpha^J} \left[A_t^J h_t^J(i)\right]^{1-\alpha^J} \tag{17}$$

where α^J is the capital share, z_t^J is a sector-specific productivity term following a stationary AR(1) process, 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 $J \in \{N, X\}$:

$$A_t^J = \left(aA_{t-1}^J\right)^{1-\Gamma^J} (A_t)^{\Gamma^J} \tag{18}$$

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

$$V_t^J(i) = \left[\tilde{K}_t^J(i)\right]^{\alpha^J} \left[A_t^J h_t^J(i)\right]^{1-\alpha^J}, \tag{19}$$

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 $J \in \{N, X\}$:

$$A_t^J = \left(aA_{t-1}^J\right)^{1-\Gamma^J} (A_t)^{\Gamma^J} \tag{20}$$

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:

$$\tilde{K}_t^J(i) = \left[(1-\gamma_G)^{\frac{1}{\varrho_G}} \left(K_t^J(i)\right)^{\frac{\varrho_G - 1}{\varrho_G}} + (\gamma_G)^{\frac{1}{\varrho_G}} \left(K_{t-1}^G\right)^{\frac{\varrho_G - 1}{\varrho_G}}\right]^{\frac{\varrho_G}{\varrho_G - 1}} \tag{21}$$

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.

E.4 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:

$$Y_t^M(i) = M_t(i) \tag{22}$$

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 $P_t^M = \left[\int_0^1 \left(P_t^M(i)\right)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$.

E.5 Commodity Good Co

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

$$Y_t^{Co} = z_t^{Co}\left(\tilde{K}_t^{Co}\right)^{\alpha_{Co}}\left(A_t^{Co}h_t^{Co}\right)^{1-\alpha_{Co}-\alpha_{\overline{L}}}\left(A_t^{Co}\overline{L}\right)^{\alpha_{\overline{L}}} \tag{23}$$

where α_{Co} is the capital share, $\alpha_{\overline{L}}$ is the natural resource share, and z_t^{Co} is a stationary productivity term following an AR(1) process. 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:

$$\tilde{K}_t^{Co} = \left[(1-\gamma_G)^{\frac{1}{\varrho_G}}\left(K_t^{Co}\right)^{\frac{\varrho_G-1}{\varrho_G}} + (\gamma_G)^{\frac{1}{\varrho_G}}\left(K_{t-1}^G\right)^{\frac{\varrho_G-1}{\varrho_G}}\right]^{\frac{\varrho_G}{\varrho_G-1}} \tag{24}$$

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:

$$\hat{K}_t^{Co} = (1-\delta_{Co})\hat{K}_{t-1}^{Co} + \left[1-\Gamma\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}}\right)\right]\hat{I}_t^{Co}\xi_t^{iCo} \tag{25}$$

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.[29] 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 $K_t^{Co} = u_t^{Co}\hat{K}_{t-1}^{Co}$.[30]

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:

$$F_t^{Co} = (1-\tau^{Co})P_t^{Co}Y_t^{Co} - P_t^{ICo}I_t^{Co} - W_t h_t^{Co} \tag{28}$$

where τ^{Co} is the corporate tax rate, P_t^{ICo} is the price of commodity investment, and P_t^{Co} is the

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

$$\Gamma\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}}\right) = \frac{\phi_k^{Co}}{2}\left(\frac{\hat{I}_t^{Co}}{\hat{I}_{t-1}^{Co}} - a\right)^2. \tag{26}$$

where ϕ_k^{Co} is the elasticity parameter.

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

$$\Phi(u_t^{Co}) = \frac{\tilde{r}^{Co}}{\phi_u^{Co}}\left(e^{\phi_u^{Co}(u_t^{Co}-1)} - 1\right) \tag{27}$$

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

domestic-currency price of the commodity good. By the law of one price, $P_t^{Co} = S_t P_t^{Co*}$, where P_t^{Co*} is the foreign-currency price following an exogenous AR(1) process.

E.6 Price and Wage Settings

Price Setting. 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 their nominal price $\tilde{P}_t^J(i)$ to maximize expected profits, taking the demand for their variety and marginal costs as given. With probability θ^J firms cannot choose prices optimally and use a passive price updater which depends on a weighted average of lagged CPI inflation and the Central Bank's inflation target π, with weights ζ^J: $\left[(\pi_{t-1})^{\zeta^J} (\pi)^{1-\zeta^J}\right]$. This standard setup gives rise to traditional New Keynesian Phillips curves describing the relationship between current inflation and marginal costs, adjusted by past and expected future inflation.

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:

$$h_t^d(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\epsilon_w} h_t^d \tag{29}$$

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

$$W_t \equiv \left[\int_0^1 (W_t(j))^{1-\epsilon_w} dj\right]^{\frac{1}{1-\epsilon_w}} \tag{30}$$

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: $h_t = (1-\omega)h_t^R + \omega h_t^{NR} = h_t^d$.

E.7 Fiscal Policy

The government follows a fiscal rule intended to isolate fiscal spending from cyclical fluctuations in government income. Total government spending G_t includes consumption of final goods C_t^G, government investment I_t^G, and lump-sum transfers to households TR_t^G. Fiscal income includes tax revenues Π_t^τ and a share $\gamma^{Co} \in [0,1]$ of the commodity sector cash flow F_t^{Co} in (12). Defining the fiscal surplus as $s_t^G = \Pi_t^\tau + \gamma^{Co} F_t^{Co} - G_t$, the government budget can be written as follows:

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

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.[31] 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:

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

where $\tilde{\Pi}_t^\tau$ and $\tilde{F}_t^{Co}$ are fiscal revenues in "normal" times,[32], 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**.[33] In turn, values of $\kappa < 1$ imply **procyclical** rules.[34] 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 revenue gap (κ^{Co}), as follows:

$$\begin{aligned}\tilde{G}_t = {} & S_t(r_{t-1}^* - 1)B_{t-1}^{G*} + (\Pi_t^\tau + \gamma^{Co}F_t^{Co}) \\ & + \kappa^\tau(\tilde{\Pi}_t^\tau - \Pi_t^\tau) + \kappa^{Co}\gamma^{Co}(\tilde{CF}_t^{Co} - F_t^{Co}) + \kappa^B(B_{t-1}^{GT} - B^{GT}).\end{aligned} \tag{33}$$

The expenditure components C_t^G, I_t^G and TR_t^G 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_t^{CG}, ξ_t^{IG} and ξ_t^{TR} 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 tech-

[31]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.

[32]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 (28) evaluated at the long-run commodity price, which is defined as the expected 10-year average of the effective commodity price.

[33]To see this, note that if $\kappa = 1$ (and $\kappa^B = 0$), equation (22) becomes: $\tilde{G}_t = S_t(r_{t-1}^* - 1)B_{t-1}^{G*} + \tilde{\Pi}_t^\tau + \gamma^{Co}\tilde{F}_t^{Co}$, that is, the government should spend only its *long-run* or structural revenues (plus interests).

[34]For instance, in the illustrative case when $\kappa = 0$ (and $\kappa^B = 0$), equation (22) now becomes: $\tilde{G}_t = S_t(r_{t-1}^* - 1)B_{t-1}^{G*} + \Pi_t^\tau + \gamma^{Co}F_t^{Co}$, 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)."

nologies combining nontradable and exportable goods:

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

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

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_t^G are assumed to be a constant share α^T of nominal GDP, that is, $T_t^G = \alpha^T P_t^Y Y_t$. 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_t^G are assigned to households in constant proportions ω^{TR} and $(1-\omega^{TR})$.

E.8 Monetary Policy

Monetary policy follows a standard Taylor rule of the form:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r} \right)^{\rho_R} \left[\left(\frac{\pi_t^Z}{\pi} \right)^{\alpha_\pi} \left(\frac{Y_t}{aY_{t-1}} \right)^{\alpha_y} \right]^{(1-\rho_R)} \xi_t^m \tag{36}$$

with $\rho_R \in (0,1)$, $\alpha_y \geq 0$, $\alpha_\pi > 1$, and where $\pi_t^Z = \frac{P_t^Z}{P_{t-1}^Z}$ 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_t^m is a random AR(1) shock.

E.9 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_t^{X*} depends on the relative foreign-currency price set by domestic producers $\left(\frac{P_t^{X*}}{P_t^*} \right)$, the rest of the world economic output (Y_t^*), and an i.i.d. demand shock for local exportable goods ξ_t^{X*}, as follows:

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

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 AR(1) as well.

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 $\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}$.

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):

$$spr_t = \overline{spr} \cdot \exp\left[-\phi_b \left(\frac{S_t B_t^*}{P_t^Y Y_t} - \bar{b}\right) + \frac{\xi_t^{S*} - \xi^{S*}}{\xi^{S*}} + \frac{\xi_t^{U*} - \xi^{U*}}{\xi^{U*}}\right] \tag{38}$$

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.

E.10 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:

$$S_t B_t^* = S_t r_{t-1}^* B_{t-1}^* + TB_t + REN_t \tag{39}$$

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

$$TB_t = P_t^X C_t^{X*} + P_t^{Co} Y_t^{Co} - P_{m,t} M_t \tag{40}$$

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

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

E.11 Exogenous Processes

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

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

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

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

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