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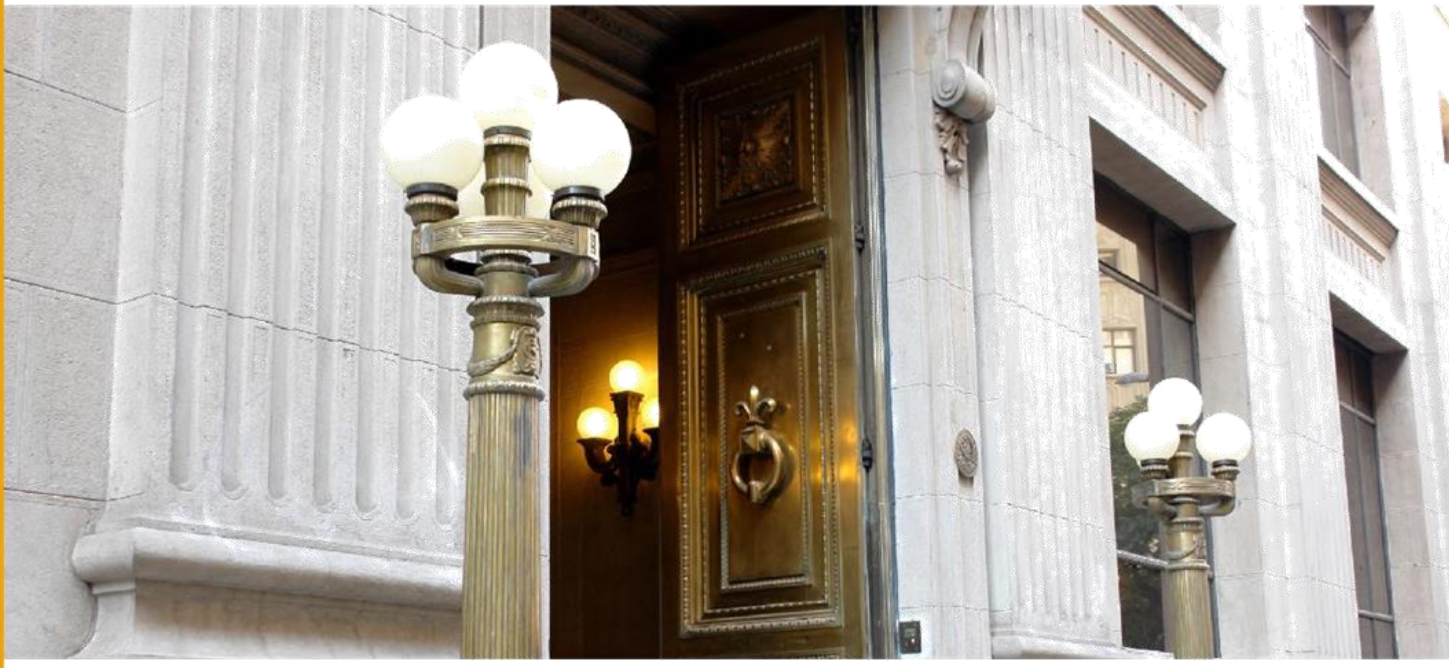

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Fiscal Consolidations in Commodity-Exporting Countries: A DSGE Perspective*

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Abstract

We build a small open economy DSGE model to evaluate the macroeconomic effects of fiscal consolidations in commodity-exporting countries. The fiscal block includes productive public capital, utility-augmenting government consumption, transfers to hand-to-mouth households, and taxes on labor and capital income as well as consumption. A country risk premium that depends on the level of foreign debt is crucial for the transmission of fiscal policy. This premium influences consumption and saving decisions of the financially unconstrained households, and the rest of the economy through general-equilibrium effects. We estimate the model with Bayesian methods using data from Ecuador, an economy with a high dependence on oil exports. We then study the macroeconomic effects of different tax and expenditure instruments. We consider a full consolidation program following the agreement between Ecuador and the IMF for the 2020-2025 period. The program reduces the country premium, which promotes private investment. Consumption of financially unconstrained households is adversely affected by higher labor income taxes, but consumption of hand-to-mouth households increases due to the expansion of government transfers under the program. In aggregate terms, GDP declines by about 1% relative to trend.

Resumen

En este artículo desarrollamos un modelo DSGE de economía pequeña y abierta para evaluar los efectos macroeconómicos de consolidaciones fiscales en economías exportadoras de materias primas. El bloque fiscal incluye inversión pública productiva, consumo de gobierno que aumenta la utilidad de los hogares, transferencias a hogares con restricciones financieras, e impuestos al consumo y a los ingresos laborales y de capital. Una prima por riesgo soberano, que depende del nivel de deuda externa, es crucial para la transmisión de la política fiscal. Esta prima afecta el consumo e inversión de los hogares que no enfrentan restricciones financieras, y al resto de la economía a través de efectos de equilibrio general. El modelo se estima con métodos Bayesianos y datos del Ecuador, un país con alta dependencia de exportaciones de petróleo. Estudiamos los efectos macroeconómicos de distintos impuestos y componentes del gasto público, y consideramos un programa de consolidación completo siguiendo el acuerdo entre el Ecuador y el FMI del periodo 2020-2025. El programa reduce la prima soberana, lo que promueve la inversión. El consumo de los hogares sin restricciones financieras cae por el mayor impuesto al ingreso laboral, pero el consumo de los hogares restringidos aumenta debido a la expansión de las transferencias de gobierno. En términos agregados, el PIB cae alrededor de 1% por debajo de su tendencia.

*The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or the Central Bank of Chile.

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1 Introduction

When the boom in commodity prices ended around 2014, several oil-exporting countries faced deteriorated fiscal sustainability prospects and higher risks of debt distress (see Richaud et al., 2019). The COVID-19 pandemic exacerbated these problems, with sovereign credit spreads such as the Emerging Market Bond Index Global (EMBIG) increasing by about 300 basis points (bps). Moreover, the turbulence caused by the global monetary tightening cycle and the Russian invasion of Ukraine also sent the spread up by more than 100 bps between December 2021 and July 2022. These tighter financial conditions have affected the fiscal situation of many countries to the point that they have needed to ask international organizations for extraordinary financing in order to face the challenges brought by the global pandemic and its aftermath.

Indeed, the IMF lists 90 countries currently receiving or having received about USD 170 billion in financial assistance and debt service relief from March 2020 to March 2022.[1] This type of funding is typically tied to the implementation of fiscal consolidation programs aimed at putting public finances on a sustainable trajectory. However, evaluating the macroeconomic effects of fiscal consolidations is challenging because the government has many different tools on the revenue and expenditure sides of the fiscal balance to achieve a given reduction in the deficit and public debt, with each of these tools having different effects on the macroeconomy, both directly and through general equilibrium effects.

In this paper, we specify and estimate a small open economy (SOE) dynamic stochastic general equilibrium (DSGE) model to evaluate the macroeconomic effects of fiscal consolidations in commodity-exporting countries. The model has a rich fiscal block that includes productive public capital, utility-augmenting government consumption, transfers to hand-to-mouth households, and taxes on labor and capital income, as well as consumption. A country risk premium that depends on the level of foreign debt is crucial for the transmission of fiscal policy. This premium influences consumption and saving decisions of the financially unconstrained households, who can invest in capital goods and issue non-state-contingent debt in foreign markets, and affects the rest of the economy through general equilibrium effects.[2] The model can be used to analyze alternative consolidation programs, e.g., comparing revenue-based with expenditure-based programs. One of the contributions of this paper is that the code that implements the model is freely available and, we hope, easy to use. It can be adapted to study consolidation scenarios for different countries. This

[1]See `https://www.imf.org/en/Topics/imf-and-covid19/COVID-Lending-Tracker`.

[2]The debt-elastic country premium serves as a methodological device to close the open economy model, as explained by Schmitt-Grohe and Uribe (2003), but it has also been found to be a key mechanism in the transmission of fiscal consolidations to the macroeconomy (see Guajardo, David and Yepez, 2019).

should be particularly useful for government agencies in developing countries, where building general-equilibrium models is challenging due to limited resources.

We estimate the model using data from Ecuador, a country with a high dependence on oil revenues. Since 2000, oil exports have accounted for 30%–60% of total exports, and, since 2012, for 20%–35% of fiscal revenues. Other commodity-exporting countries, especially in the developing world, are also dependent on revenue from commodity exports. This revenue is highly volatile because it inherits the volatility of commodity prices. Furthermore, many of these countries are prone to fiscal procyclicality—increasing spending and public debt during commodity price booms. When commodity prices decline, they find themselves experiencing fiscal crises and facing the need to consolidate, i.e., to adjust taxes and/or expenditure to rein in public debt and restore sustainability.[3]

Ecuador is a good example of a commodity-rich country with procyclical fiscal policy. In response to the commodity price boom of the 2000s, the government increased spending substantially on transfers, infrastructure, and public services. In addition to exhausting the oil revenue windfall to finance these expenses, the government issued foreign debt aggressively at high interest rates in the 2010s. High interest rates were a consequence of the decision to default on foreign debt, for political reasons, in 2008. When the oil price tumbled in 2014, public finances were squeezed by declining revenue and even higher country risk premia.[4] Moreover, in the aftermath of the Covid-19 pandemic, the country was close to default on its sovereign bonds, until an agreement to secure funds for $6.5 billion from the IMF under an Extended Fund Facility allowed the country to renegotiate its sovereign debt.[5]

To study the macroeconomic effects of consolidations, we proceed in three steps. First, we simulate consolidation scenarios in which the government adjusts, in turn, each one of its six fiscal instruments. By isolating the effect of each tax and expenditure instrument, these six simulations develop intuition on the transmission mechanisms of fiscal policy in the model economy. In the second step, we simulate a consolidation that uses all of the government's instruments. To discipline this exercise, we follow the program that the government of Ecuador agreed with the IMF for the 2020–2025 period. This program included a mix of permanent and transitory increases of various tax rates, as well as cuts to government consumption and investment. To cushion the impact of the contractionary policy on the most vulnerable households, transfers were allowed to increase. More specifically, we feed the DSGE model with the path of various fiscal instruments implied by the program and

[3]For classic references on fiscal procyclicality in emerging countries, see Gavin and Perotti (1997) and Kaminsky, Reinhart and Végh (2005).

[4]See Cueva, Díaz and Martin (2021); García-Albán, González-Astudillo and Vera-Avellán (2021) for a more detailed history of recent fiscal developments of the Ecuadorian economy.

[5]See International Monetary Fund (2020).

study their macroeconomic effects, following the technique proposed by Bańbura, Giannone and Lenza (2015). In the third and final step, we simulate revenue only- and expenditure only-based consolidations that provide the same level of fiscal adjustment as the IMF program to evaluate the desirability of each alternative.

For brevity, we discuss in this section the results of the full simulation. The IMF program generates a decline in the fiscal deficit of more than 5% of GDP, as intended by the program. The moderation of public debt, in turn, reduces the country risk premium, promoting private investment. Consumption of financially unconstrained households declines by about 1% relative to trend at the trough, mainly due to higher labor income taxes. Consumption of hand-to-mouth households, however, increases by up to 2% above trend, as a result of the expansion of government transfers under the program. Both financially unconstrained and hand-to-mouth households work fewer hours. In aggregate terms, the program induces a decline of GDP of about 1% relative to trend.

Despite featuring a rich fiscal block with key revenue and expenditure instruments, the model abstracts from sovereign default. This is, of course, an important issue that deserves attention, because it is not infrequent that developing, commodity-exporting countries default on their obligations. Introducing default, however, would add such substantial complexity to the model that, we believe, would defeat one of our main purposes—to offer a tractable model that can be put to use by policymakers. However, the model does consider the reduced-form relationship between foreign debt and the country premium, which intuitively reflects default risk, even though there is no default in the model.

The paper is structured as follows: Section 2 reviews the existing literature on SOE DSGE modeling and fiscal scenario analysis for commodity-exporting countries. In section 3, we present our SOE DSGE model for a commodity-exporting country with a rich fiscal block. Section 4 describes the parametrization strategy of the model, including its estimation. In turn, section 5 describes the performance of the model in matching key moments of the data and analyzes its dynamic behavior with the parametrization chosen. After showing that the model produces reasonable dynamics to oil price and risk premium shocks, we perform fiscal consolidation exercises in section 6, including the analysis of a program that follows Ecuador's agreement with the IMF. Finally, section 7 concludes.

2 Related Literature

Our paper is among the first to combine, in a tractable model, the necessary features for quantitative analyses of the macroeconomic effects of fiscal consolidations in commodity-exporting countries. These features include a government with various tax and expenditure tools, an open-economy perspective, a commodity that is exported and generates volatile fiscal revenue, and an estimation approach designed to fit a broad set of domestic and international aggregates, which is useful for quantitative analyses.

The evaluation of fiscal consolidations in developed countries is relatively well covered in the literature (see, for instance, Alesina, Favero and Giavazzi, 2015, and the references therein), but these countries are typically modeled as closed economies. Moreover, these papers ignore the role of commodity prices, because fiscal revenue in developed countries is not nearly as vulnerable to commodity price shocks as in emerging countries. A good example is Coenen, Straub and Trabandt (2013), who study the impact of the European Economic Recovery Plan on euro area GDP. The authors estimate an extended version of the ECB's New Area-Wide Model with a richly specified fiscal sector. The model features complementarity between private and government consumption, Ricardian and non-Ricardian households, public capital in the production function of domestic firms, and consumption, labor, dividend, and capital income taxes. This paper computes fiscal multipliers and the contribution of fiscal shocks to real GDP growth, estimating the trajectory of GDP growth in the absence of such shocks between 2008 and 2010.

González et al. (2014) build a SOE DSGE model to evaluate the effects of fiscal policy and oil price shocks, as well as the welfare effects of alternative structural fiscal rules, on the Colombian economy. The model incorporates non-Ricardian agents, price rigidities, and a fiscal authority that finances government spending and subsidies with taxes to consumption, labor income, and capital income, as well as oil revenue and public debt. However, the model ignores productive government investment, and is not estimated, but calibrated. Ojeda-Joya, Parra-Polanía and Vargas (2016) formulate a DSGE model for the welfare analysis of different degrees of fiscal policy pro-, a-, or counter-cyclicality. The model includes Ricardian and non-Ricardian agents, and three productive sectors—non-tradable, manufacturing, and commodities. The model is estimated to match data from Colombia. However, it does not feature SOE characteristics, distortionary taxation, or a role for government investment.

Medina and Soto (2016) propose a SOE DSGE model to analyze the macroeconomic effects of commodity price shocks under different fiscal rules. The model is calibrated to match data from Chile, a copper-exporting country. Taxation is lump-sum, and the main fiscal policy instrument is a rule for the government's structural balance, which is defined as the overall balance minus cyclical revenues. The model does not feature a role for government investment.

Fornero and Kirchner (2018) offer an in-depth analysis of the macroeconomic effects of commodity price shocks in a SOE DSGE model estimated to the Chilean economy, but the model largely abstracts from the role of fiscal policy. In their framework, agents learn if a commodity price shock is transitory or permanent. A persistent shock triggers an investment boom because of higher expected returns to capital, especially in the commodity sector. Since it takes time for agents to learn about the persistence of the shock, investment responds gradually. The commodity price shock thus generates an initial current account surplus that eventually turns into a deficit. The authors find that a significant fraction of investment and current account dynamics in the Chilean data are explained by commodity price movements through this mechanism.

Díaz-Kovalenko and Torres (2022) formulate a two-sector (oil and non oil) DSGE model with fiscal policy to evaluate the effects of alternative oil revenue fiscal rules on economic activity and welfare for Ecuador. The government finances lump-sum transfers and public investment with consumption, labor income, capital income, and profits taxes in addition to oil revenues and public debt. In the calibrated model, the authors find that a fiscal rule that links government investment to all government revenues and not only to oil revenues (as is implicit in Ecuadorian legislation) would reduce the volatility of the economy. However, this paper does not feature SOE characteristics.

A related paper in terms of the methodology we propose to evaluate fiscal policy scenarios in a SOE is due to Babajanyan et al. (2022). Their model features liquidity constrained and unconstrained households, consumption, labor income, and capital gains taxes, in addition to household transfers, government consumption, and government investment. The authors choose a calibration strategy to match key macroeconomic moments of the Armenian economy and then perform alternative scenario analysis with the model. However, this model does not feature a commodity-producing economy in which the government has commodity revenues to finance its expenses.

3 The DSGE Model

This section spells out a two-agent SOE model with real rigidities and a rich fiscal policy block. The economy is populated by optimizing households that have access to international financial assets, and rule-of-thumb households that consume their disposable income every period. There are three categories of government expenditure: (i) consumption of final goods, which contribute to household utility, (ii) investment in public capital, which enters the production function of the firms producing domestic goods, and (iii) transfers to households. The government finances its expenditures by levying three types of distortionary taxes—on consumption, labor income, and capital income—as well as by issuing foreign debt. Domestic goods, which are produced with private and public capital, and labor, are combined with imported goods to form final goods. Real rigidities include habit formation in private consumption and adjustment costs in private investment. In addition to trade in domestic and foreign goods, the economy exports an exogenous endowment of a commodity good. Finally, the economy is subject to shocks to preferences, technology (neutral and investment-specific), commodity production, the components of government expenditure, tax rates, foreign GDP, foreign interest rates, a risk premium on external debt, and the international price of the commodity good.

3.1 Households

There is a continuum of infinitely lived households of unit mass. A fraction $\omega \in (0,1)$ of households are restricted and do not have access to saving instruments, thus behaving in a "hand-to-mouth" fashion whereby they consume their disposable income every period; we refer to this group as rule-of-thumb households and use the superscript r to denote variables that correspond to them. The remaining fraction $(1-\omega)$ of households have access to financial assets and can accumulate physical capital, which they rent to firms; we refer to this group as optimizing households and denote variables related to them with the superscript o. Both types of households have preferences that depend on a consumption bundle, $\hat{C}_t^j$, and hours worked, h_t^j, for $j \in \{o,r\}$.[6]

Following Coenen, Straub and Trabandt (2013), the consumption bundle for households of type $j = \{o,r\}$ is a constant-elasticity-of-substitution (CES) aggregate of household purchases, denoted $\hat{C}_t^j$, of a final good, C_t^j, and government consumption, G_t^c, as follows:

$$\hat{C}_t^j \equiv \hat{C}^j(C_t^j, \breve{C}_{t-1}^j, G_t^c) = \left[(1-o_c)^{\frac{1}{\eta_c}} \left(C_t^j - \varsigma \breve{C}_{t-1}^j \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(G_t^c \right)^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}},$$

where $\breve{C}_t^j$ denotes average consumption purchases across households of type j, which each household takes as given (in equilibrium, $C_t^j = \breve{C}_t^j$). The parameter $\varsigma \in (0,1)$ governs consumption habits, whereas $\eta_c > 0$ governs the elasticity of substitution between consumption purchases by the household and the government.[7]

Expected discounted utility of a representative household of type j is given by

$$E_t \sum_{s=0}^{\infty} \beta^s \upsilon_{t+s} \left[\frac{1}{1-\sigma} \left(\hat{C}_{t+s}^j \right)^{1-\sigma} - \Theta_t^j A_{t+s-1}^{1-\sigma} \kappa_{t+s}^j \frac{\left(h_{t+s}^j \right)^{1+\phi}}{1+\phi} \right], \tag{1}$$

[6]Throughout, uppercase letters denote variables containing a unit root in equilibrium (due to technological progress), whereas lowercase letters indicate variables with no unit root. The imported good is the numeraire. Appendix A describes how each variable is transformed to achieve stationarity in equilibrium. Variables without a time subscript denote non-stochastic steady state values in the stationary model.

[7]$\eta_c \to 0$ implies perfect complementarity, $\eta_c \to \infty$ gives perfect substitutability, and $\eta_c \to 1$ yields the Cobb–Douglas case.

where υ_t and κ_t are exogenous preference shocks, $\beta \in (0,1)$ is the intertemporal discount factor, $\sigma > 0$ and $\phi \geq 0$ are the inverse elasticity of intertemporal substitution and the inverse Frisch elasticity of hours worked, respectively, whereas A_t is a non-stationary technology index. Following Galí, Smets and Wouters (2012), Θ_t^j is an endogenous preference shifter that regulates the strength of the wealth effect on labor supply and satisfies

$$\Theta_t^j = \widetilde{\chi}_t^j A_{t-1}^{\sigma} \left[\hat{C}^j(C_t^j, \check{C}_{t-1}^j, G^c) \right]^{-\sigma}, \qquad \widetilde{\chi}_t^j = \widetilde{\chi}_{t-1}^{j\,1-\nu} A_{t-1}^{-\sigma\nu} \left[\hat{C}^j(\check{C}_t^j, \check{C}_{t-1}^j, G^c) \right]^{\sigma\nu},$$

where $\nu \in [0,1]$ regulates the strength of the wealth effect: when $\nu = 1$, preferences are of the standard CRRA type; when $\nu = 0$, the wealth effect is shut down, as in the preferences by Greenwood, Hercowitz and Huffman (1988).[8]

Optimizing Households. Households receive a common hourly wage denoted W_t. Optimizing households save and borrow by trading non-state-contingent international bonds, F_t^{o*}, with foreign agents.[9] They also purchase an investment good, I_t^o, which determines next period's physical capital stock, K_t^o. Further, let r_t^* denote the gross return on F_{t-1}^{o*} and let r_t^k be the rental rate on capital K_{t-1}^o. Additionally, let Π_t^o denote the profits from the home good producing firm, which is owned by this type of household.

These households have labor income, consumption, and capital income (after deducting depreciation costs) taxed at rates, τ_t^n, τ_t^c, and τ_t^k, respectively. They also receive government transfers, TR_t^o. Hence, the period-by-period budget constraint of the representative optimizing household is given by

$$(1+\tau_t^c)p_t C_t^o + p_t I_t^o + r_t^* F_{t-1}^{o*} + T^o = (1-\tau_t^n)W_t h_t^o + F_t^{o*} + \left[(1-\tau_t^k)r_t^K + \tau_t^k \delta\right] K_{t-1}^o + TR_t^o + \Pi_t^o, \tag{2}$$

where p_t denotes the price of the final good relative to the price of the imported good, which is the numeraire. Note that consumption, C_t^o, and investment, I_t^o, are bundles of the final good, so to express them in terms of the foreign good, they must be multiplied by p_t; the other terms in the budget constraint are expressed in terms of the foreign good. T^o is a constant lump-sum tax that is needed to facilitate the calibration of the model to match elements of its budget constraint to the data.

The physical capital stock evolves according to the following law of motion:

[8]Because the consumption bundle that determines household utility includes government consumption, the preference shifter Θ_t^j includes government consumption in steady state G^c. This is a slight abuse of notation, because, to be precise, government consumption has a unit root, so it does not have a steady state; it is the transformed variable $\frac{G_t^c}{A_{t-1}}$ which does.

[9]Foreign variables are denoted with an asterisk.

$$K_t^o = (1-\delta)K_{t-1}^o + [1 - \Gamma\left(I_t^o/I_{t-1}^o\right)]u_t I_t^o, \qquad \delta \in [0,1], \tag{3}$$

where I_t^o denotes investment expenditures and

$$\Gamma\left(\frac{I_t^o}{I_{t-1}^o}\right) = \frac{\gamma_k}{2}\left(\frac{I_t^o}{I_{t-1}^o} - \bar{a}\right)^2, \qquad \gamma \geq 0, \qquad \bar{a} \geq 1,$$

are convex investment adjustment costs. The variable u_t is an investment shock that captures changes in the efficiency of the investment process (see Justiniano, Primiceri and Tambalotti, 2010) and $\bar{a}$ is the steady-state trend growth rate of the economy. The household chooses C_t^o, h_t^o, I_t^o, K_t^o, and F_t^{o*} to maximize (1) subject to (2)-(3), taking W_t, r_t^*, r_t^K, TR_t^o, G_t^c, Π_t^o, F_{t-1}^{o*}, K_{t-1}^o, and T^o as given.

The gross return on foreign bonds is given by:

$$r_t^* = R_{t-1}^* \xi_{t-1},$$

where R_{t-1}^* is the gross foreign real interest rate, which evolves exogenously, and ξ_{t-1} denotes a country premium given by (see Schmitt-Grohe and Uribe, 2003; Adolfson et al., 2008):

$$\xi_t = \bar{\xi}\exp\left[\psi\frac{(F_t^* + B_t^*)/Y_t - (\bar{f}^* + \bar{b}^*)}{\bar{f}^* + \bar{b}^*} + \frac{\zeta_t - \bar{\zeta}}{\bar{\zeta}}\right], \qquad \psi > 0, \qquad \bar{\xi} \geq 1, \tag{4}$$

where F_t^* is the aggregate stock of private foreign debt, B_t^* is foreign government debt, Y_t is GDP (to be defined below), ζ_t is an exogenous idiosyncratic component of the country premium, and $(\bar{f}^* + \bar{b}^*)$ is an exogenous target for the ratio of foreign debt to GDP. The steady-state level of the country risk premium is determined by $\bar{\xi}$.

Rule-of-Thumb Households. The subset of households that do not have access to financial assets or investment receive only labor income at the same hourly wage as the optimizing households, and government transfers, TR_t^r, which they use to consume and pay the consumption tax. Note that these households do not pay labor income taxes. Hence, they face the following simpler budget constraint:

$$(1+\tau_t^c)p_t C_t^r = W_t h_t^r + TR_t^r. \tag{5}$$

They solve a static optimization problem, choosing C_t^r and h_t^r, subject to (5).

3.2 Firms

The supply side of the economy is composed of four types of competitive firms. There is a set of firms that produce a domestic good using labor and capital, a set of firms that import a homogeneous foreign good, and a set of firms that combine the domestic and foreign goods into a final good. This final good is purchased by households and the government for consumption and investment. In addition, there is a set of competitive firms producing a homogeneous commodity good that is exported. A proportion of those commodity-exporting firms is owned by the government and the remaining proportion is owned by foreign agents. The total mass of firms in each sector is normalized to one.

Home Goods. Home goods are produced according to the following technology:

$$Y_t^H = z_t \left(K_{t-1}^g\right)^\gamma K_{t-1}^\alpha [A_t h_t]^{1-\alpha-\gamma}, \qquad \alpha \in [0,1), \qquad \gamma \in [0,1), \tag{6}$$

where z_t is an exogenous stationary technology shock, A_t (with $a_t \equiv A_t/A_{t-1}$) is a non-stationary technology index, K_{t-1} is the aggregate stock of private capital available for production in period t, and K_{t-1}^g is the stock of public capital.

The firm takes the stock of public capital as given, and hires labor and rents private capital to maximize profits subject to the technology constraint (6).[10]

Foreign Goods. A representative importing firm buys an amount Y_t^F of a homogeneous foreign good to meet the demand of the final good producers, X_t^F. This representative importing firm makes zero profits.

Final Goods. A representative final goods firm demands home and foreign goods in the amounts X_t^H and X_t^F, respectively, and combines them according to the following technology:

$$Y_t^C = \left[(1-o)^{\frac{1}{\eta}} \left(X_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}} \left(X_t^F\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \qquad o \in (0,1), \qquad \eta > 0. \tag{7}$$

Let p_t and p_t^H denote the relative prices of Y_t^C and X_t^H in terms of the imported good. Subject to the technology constraint (7), the firm maximizes its profits $\Pi_t^C = p_t Y_t^C - p_t^H X_t^H - X_t^F$ over the input demands X_t^H and X_t^F, taking p_t and p_t^H as given. This firm makes zero profits in equilibrium.

[10]The firm makes positive profits in equilibrium because the presence of public capital in its production function implies decreasing returns to scale in private capital and labor.

Commodities. A representative commodity producing firm produces a quantity of a commodity good Y_t^P in each period, which evolves exogenously. The entire production is sold abroad at a given international price p_t^{P*}, which also evolves exogenously. The income generated in the commodity sector is therefore equal to $p_t^{P*} Y_t^P$. The government receives a share $\chi \in [0, 1]$ of this income and the remaining share goes to foreign agents.

3.3 Fiscal Policy

The government demands the final good for consumption, G_t^c, and investment purposes, G_t^i, makes transfers to households, TR_t, levies taxes on consumption, labor income, and capital income, issues foreign debt, and receives a share $\chi \in (0, 1)$ of the income generated in the commodity sector. Hence, the government satisfies the following period-by-period constraint:

$$p_t G_t^c + p_t G_t^i + TR_t + r_t^* B_{t-1}^* = B_t^* + \tau_t^c p_t C_t + (1-\omega)\tau_t^n W_t h_t^o + \tau_t^k (r_t^k - \delta) K_{t-1} + \chi p_t^{P*} Y_t^P + (1-\omega) T^o. \tag{8}$$

The tax rates τ_t^c, τ_t^n and τ_t^k are fixed at their steady state values when we estimate the model, but in the simulation of fiscal consolidations that include increases in tax rates, we allow them to follow an exogenous AR(1) process, as follows:

$$\tau_t^x = \rho_{\tau x} \tau_{t-1}^x + (1 - \rho_{\tau x}) \tilde{\tau}^x + \varepsilon_t^{\tau x} \quad \rho_{\tau x} \in [0, 1), \tag{9}$$

where $x \in \{c, n, k\}$, $\varepsilon_t^{\tau x}$ are i.i.d. shocks to tax rates, and the parameters $\tilde{\tau}^x$ determine the value of tax rates at steady state.

The components of government expenditure respond to deviations of output from steady state (the output gap) and to deviations of the public debt-to-GDP ratio from target, according to the following rules:

$$G_t^c = (a_{t-1} G_{t-1}^c)^{\rho_{gc}} \left(G^c \left(\frac{Y_t}{Y} \right)^{\alpha_{gc}} \left(\frac{B_{t-1}^* / Y_{t-1}}{\bar{b}^*} \right)^{\gamma_{gc}} \right)^{1-\rho_{gc}} \exp(e_t^{gc}), \tag{10}$$

$$G_t^i = (a_{t-1} G_{t-1}^i)^{\rho_{gi}} \left(G^i \left(\frac{Y_t}{Y} \right)^{\alpha_{gi}} \left(\frac{B_{t-1}^* / Y_{t-1}}{\bar{b}^*} \right)^{\gamma_{gi}} \right)^{1-\rho_{gi}} \exp(e_t^{gi}), \tag{11}$$

$$TR_t = (a_{t-1} TR_{t-1})^{\rho_{TR}} \left(TR \left(\frac{Y_t}{Y} \right)^{\alpha_{TR}} \left(\frac{B_{t-1}^* / Y_{t-1}}{\bar{b}^*} \right)^{\gamma_{TR}} \right)^{1-\rho_{TR}} \exp(e_t^{TR}), \tag{12}$$

where ρ_{gc}, ρ_{gi} and ρ_{TR} lie in the $[0, 1)$ interval and govern the persistence of the components of expenditure. The parameters α_{gc}, α_{gi}, and α_{TR} govern the strength of the response of each expenditure component to the business cycle, with positive values indicating procyclical behavior and negative values indicating countercyclical behavior. The parameters γ_{gc}, γ_{gi}, and γ_{TR} govern the strength of the response of each expenditure component to deviations of the public debt-to-GDP ratio from its target, $\bar{b}^*$, with negative values indicating a debt-stabilizing behavior. The components of government expenditure are also subject to exogenous i.i.d. shocks, e_t^{gc}, e_t^{gi}, and e_t^{TR}.[11]

Government investment augments the stock of public capital, which is an input in the production of home goods, according to the following law of motion:

$$K_t^g = (1-\delta_g)K_{t-1}^g + G_t^i, \quad \delta_g \in [0,1], \tag{13}$$

where δ_g is the depreciation rate of public capital.

The government distributes shares ω^G and $(1-\omega^G)$ of total transfers to rule-of-thumb and optimizing households, respectively. Total transfers received by rule-of-thumb households satisfy $\omega TR_t^r = \omega^G TR_t$, whereas transfers received by optimizing households satisfy $(1-\omega)TR_t^o = (1-\omega^G)TR_t$.

3.4 The Rest of the World

Foreign demand for the home good, X_t^{H*}, is given by the schedule

$$X_t^{H*} = o^* \left(p_t^H\right)^{-\eta*} Y_t^*, \qquad o^* \in (0,1), \qquad \eta* > 0, \tag{14}$$

where Y_t^* denotes foreign aggregate demand or GDP, which evolves exogenously.

3.5 Aggregation and Market Clearing

To aggregate private consumption, hours worked, and transfers, consider that both types of households, optimizing and rule-of-thumb, consume and work, and receive transfers. Hence, the following conditions hold: $C_t = (1-\omega)C_t^o + \omega C_t^r$; $h_t = (1-\omega)h_t^o + \omega h_t^r$; and $TR_t = (1-\omega)TR_t^o + \omega TR_t^r$.

As only optimizing households own firms and hold financial assets and physical capital, we have the following conditions for aggregate profits, private asset holdings, the aggregate

[11] Once again, we are slightly abusing notation in the expenditure rules by denoting the steady state value of each component as G^c, G^i and TR. The components of expenditure have a unit root, so they do not have a steady state. It is the transformed variables, $\frac{G_t^c}{A_{t-1}}$, $\frac{G_t^i}{A_{t-1}}$, and $\frac{TR_t}{A_{t-1}}$ that have a steady state.

capital stock and aggregate investment, respectively: $\Pi_t = \Pi_t^H = (1-\omega)\Pi_t^o$; $F_t^* = (1-\omega)F_t^{o*}$; $K_t = (1-\omega)K_t^o$; and $I_t = (1-\omega)I_t^o$.

In the market for final goods, the clearing condition is $Y_t^C = C_t + I_t + G_t^c + G_t^i$, while in the markets for home and foreign goods we have $Y_t^H = X_t^H + X_t^{H*}$, and $Y_t^F = X_t^F$.

Aggregate demand or GDP, Y_t, is defined as the sum of domestic absorption Y_t^C and the trade balance, TB_t. Expressed in terms of foreign goods (the numeraire), GDP is given by:[12]

$$Y_t = p_t Y_t^C + TB_t = \underbrace{p_t(C_t + I_t + G_t^c + G_t^i)}_{\text{Domestic absorption}} + \underbrace{p_t^H X_t^{H*} + p_t^{P*} Y_t^P - Y_t^F}_{\text{Trade balance}}.$$

The net foreign asset position of this economy results from combining the period-by-period budget constraints of the households and government. The aggregate household budget constraint is the weighted sum of the optimizing and rule-of-thumb households' budget constraints, where the weights are their shares in the population, $(1-\omega)$ and ω, respectively, which results in:

$$\begin{aligned}(1+\tau_t^c)p_t C_t + p_t I_t + r_t^* F_{t-1}^* + (1-\omega)T^o =& W_t h_t - (1-\omega)\tau_t^n W_t h_t^o + F_t^* + \\ &+ \left[(1-\tau_t^k) r_t^K + \tau_t^k \delta\right] K_{t-1} + TR_t + \Pi_t.\end{aligned}$$

Combining the previous expression with the period-by-period budget constraint of the government in (8) results in the balance-of-payments identity:

$$F_t^* + B_t^* = r_t^*(F_{t-1}^* + B_{t-1}^*) - TB_t + (1-\chi)p_t^{P*} Y_t^P,$$

which states that the change in the net foreign asset position is equal to the current account balance (the trade balance plus net interest income).

3.6 Driving Forces

In addition to the previously described i.i.d. shocks to tax rates and government expenditure, several variables in the model follow an exogenous AR(1) process of the form

$$log(x_t/\bar{x}) = \rho_x log(x_{t-1}/\bar{x}) + \varepsilon_t^x, \qquad \rho_x \in [0,1),$$

where ε_t^x are i.i.d. shocks and $\bar{x}$ is their steady-state counterpart, for $x = \{v, \kappa, u, z, a, \zeta, R^*, p^P, y^P, y^*\}$. The economy is, therefore, buffeted by shocks to consumption preferences (v), labor supply preferences (κ), investment technology (u), transitory (z)

[12]Alternatively, real GDP can be expressed as domestic supply: $Y_t = p_t^H Y_t^H + p_t^{P*} Y_t^P$.

and permanent technology (a), the country premium (ζ), foreign interest rates (R^*), the commodity price (p^{P*}), commodity production (y^P), and foreign demand (y^*).[13]

4 Parametrization Strategy

Our strategy for taking the model to the data combines the estimation of most of the parameters and the calibration of the rest. Some of the calibrated parameters take values from the related literature, whereas others are endogenously determined in steady state to target first moments in the data from Ecuador.[14]

4.1 Calibrated Parameters

Table 1 presents the calibrated parameters and targeted steady state values. Following Medina and Soto (2016), we use logarithmic preferences, setting the inverse elasticity of intertemporal substitution, $\sigma = 1$. We follow Coenen, Straub and Trabandt (2013) and set the share of private consumption in the aggregate consumption bundle, $1 - o_c$, equal to 0.75. The depreciation rates of private and public capital, δ and δ_g, are set to 6% annually, following Medina and Soto (2016) for the former and Coenen, Straub and Trabandt (2013) for the latter. The parameter characterizing home bias in domestic demand, o, is set to 0.27, which is the average contribution of imports over domestic demand in the 2000–2019 period. In our Cobb-Douglas specification for the production of home goods, the output elasticity of labor, $1 - \alpha - \gamma$, is 0.66, following Medina and Soto (2016). The share of public capital is set to 0.034. This value corresponds to 10% of the share of total capital (private plus public, $\alpha + \gamma = 0.34$), and is motivated by Coenen, Straub and Trabandt (2013), who use a share of 0.1 for public capital in their CES aggregator of private and public capital.

We set the price elasticity of foreign demand for home goods, η^*, to 0.25 (see the estimates in Crespo and Gómez, 2004; Peláez et al., 2020). The government's share of the income generated in the commodity sector, χ, is set to 0.74, considering that the average share of total oil output produced by the public oil company during 2000–2019 is 60%, and a general tax on foreign firms is 35%.[15] The share of hand-to-mouth households, ω, is set to 0.7, following estimates by the Central Bank of Ecuador that suggest that about 30% of the population has an outstanding loan in the financial system (see Banco Central del Ecuador, 2023). We assume that all government transfers go to the hand-to-mouth households, setting

[13]The full set of stationary equilibrium conditions appears in appendix A.

[14]See Appendix B for details on the parameters that are solved endogenously.

[15]Note that $\chi = c + (1 - c) * t$, where c is the share of production owned by the government and t is the average tax rate on foreign oil producers.

$\omega_G = 1$. Finally, normalizing the time endowment of households to unity and using the historical average of hours worked per week adjusted by the average employment rate, we set $h^o = h^r = 0.3$.

Regarding the targeted first moments, most values are drawn from the 2022-2027 projections in the July 2022 IMF Staff Report for Ecuador (see Oner et al., 2022). This is the case for the ratios of government consumption and transfers to GDP, s^g and s^{tr}, the ratios of private and public external debt to GDP, $\bar{f}$ and $\bar{b}$, and the share of oil production in GDP, s^P. Other targeted moments are sample averages or drawn from other sources. This is the case for the ratio of public to total investment, i_r, the annualized quarterly growth rate of labor productivity, $\bar{a}$, the annualized quarterly gross real 3-month T-bill rate, R^*, the country risk premium, $\bar{\xi}$, and the consumption, corporate, and labor income tax rates, $\bar{\tau}_c$, $\bar{\tau}_k$, $\bar{\tau}_n$.

We also calibrate the parameters associated with the exogenous processes for which we have a data counterpart—oil production, the international interest rate, world GDP, and the price of oil. In all cases, we remove trends from these variables using the Hodrick and Prescott (1997) filter and estimate univariate AR(1) processes for the same sample period we use to estimate the rest of the parameters of the model.

4.2 Estimated Parameters

The rest of the parameters of the model are estimated using Bayesian techniques, solving the model with a linear approximation around the non-stochastic steady state. For the observable variables, we use quarterly information from Ecuador for the period 2004–2019. Ecuador adopted the U.S. dollar as its official currency in January 2000. Our sample begins in 2004 because inflation took about 4 years to stabilize after a banking crisis in 1999 and the introduction of the U.S. dollar. We use the following 13 observable variables: Non-oil GDP, private aggregate consumption, aggregate investment, government consumption, government investment, government transfers, the trade balance, hours worked, the country risk premium as measured by the Emerging Markets Bond Index (EMBI) for Ecuador, the West Texas Intermediate (WTI) oil price, oil production, the foreign interest rate, and foreign GDP. Because the foreign good is the numeraire in the model, we deflate all the variables, which are expressed in current U.S. dollars, using the U.S. GDP deflator. In addition, we express all the flow variables as quarter-over-quarter growth rates, except hours worked and foreign output, which are expressed as percent deviations from a Hodrick and Prescott (1997) filtered trend. We do the same for the foreign interest rate, the (log real) oil price, and oil production. As we previously mentioned, we calibrate the parameters of

Table 1: Calibrated Parameters and Targeted Steady State Values

Parameter	Description	Value	Source
σ	Inverse elast. intert. subst.	1	Medina and Soto (2016)
$(1-o_c)$	Share of private consumption in $\hat{C}$	0.75	Coenen, Straub and Trabandt (2013)
δ	Annualized depreciation rate (K)	6%	Medina and Soto (2016)
δ_g	Annualized depreciation rate (K^g)	6%	Coenen, Straub and Trabandt (2013)
o	Home bias in domestic demand	0.27	Avg. share of imports (2000–2019)
$1-\alpha-\gamma$	Output elasticity of labor	0.66	Medina and Soto (2016)
γ	Output elasticity of public capital	0.034	Coenen, Straub and Trabandt (2013)
η^*	Price elasticity of foreign demand	0.25	Peláez et al. (2020)
χ	Government share in commodity sector	0.74	Average (2000–2019)
ω	Share of hand-to-mouth households	0.7	Central Bank of Ecuador estimates
h^o, h^r	Hours worked	0.3	Assumption and INEC statistics
s^g	Government consumption to GDP ratio	0.11	Oner et al. (2022)
s^{tr}	Government transfers to GDP ratio	0.05	Oner et al. (2022)
$\bar{f}$	Private external debt to quarterly GDP ratio	0.26	Oner et al. (2022)
$\bar{b}$	Total external debt to quarterly GDP ratio	1.42	Oner et al. (2022)
s^P	Oil production to total GDP ratio	0.08	Oner et al. (2022)
i_r	Public to total investment ratio	0.16	OECD average (2007-2020)
$\bar{a}$	Annualized balanced growth path	2%	González-Astudillo (2016)
R^*	Quarterly gross real foreign int. rate	1.001	Congressional Budget Office (2021)
$\bar{\xi}$	Quarterly gross country premium	1.013	Latin America avg. (1997-2020)
$\bar{\tau}_c$	Consumption tax rate	12%	Current rate
$\bar{\tau}_k$	Corporate tax rate	25%	Current rate
$\bar{\tau}_n$	Labor income tax rate	4%	Avg. labor income tax rate

the exogenous processes for which we have a data counterpart, but we also include these variables as observables in the Bayesian estimation.[16] Our estimation strategy also includes i.i.d. measurement errors for all observables. The variance of the measurement errors are set to 10% of the variance of the corresponding observables. Appendix C contains the sources of the data and offers details on the construction of the observable variables.

Table 2 shows the prior and posterior distributions of the estimated parameters. The prior distributions are fairly loose. For the parameters of the fiscal expenditure rules ($\rho_x, \alpha_x, \gamma_x$ for $x = gc, gi, TR$), we center their prior distributions at the values we obtain from an external estimation in which the HP-filtered log deviation of each expenditure component is regressed on the log deviation of the government debt-to-GDP ratio and output, in addition to a lagged expenditure term. The prior distributions of the persistence coefficients of the structural shocks (ρ_x for $x = \upsilon, \kappa, u, z, a, \zeta$) are centered at 0.75, following the DSGE model estimated by Guerra-Salas, Kirchner and Tranamil-Vidal (2021) for Chile. We follow the same paper to inform the prior mean of the elasticity of the country risk premium to the aggregate debt-to-GDP ratio, ψ, which is centered at 0.005. The coefficient of investment adjustment costs, γ_k, is centered at the value obtained by Smets and Wouters (2007), close to 6. The rest of the parameters, including the variances of the shocks, were chosen to loosely match the sample standard deviation of the observed variables with their model counterparts under the prior means of the other coefficients, but the standard deviations of the prior distributions are wide enough to allow the data to inform the estimated posterior distributions.

We now discuss the results of the Bayesian estimation. The posterior mean estimates of the parameters associated with the fiscal expenditure rules suggest all three components (government consumption, investment, and transfers) are procyclical, because the parameters α_{gc}, α_{gi} and α_{TR} are all greater than zero. Fiscal transfers are the most procyclical component, whereas government investment is the least procyclical. Regarding the debt-stabilization parameters of the fiscal expenditure rules, we find that government investment is the most active expenditure instrument in debt stabilization. The negative values of these parameters indicate that when the public debt-to-GDP ratio deviates from target, expenditure moves in the opposite direction.[17]

The second set of results concerns preference parameters. The estimated value of ϕ, at 3.4, suggests a low elasticity of labor supply. The wealth effect on labor supply, ν, at 0.7, is estimated to be closer to CRRA formulations (the case when $\nu = 1$), than formulations

[16]While the parameters of these exogenous processes were calibrated, including these variables in the data set is informative for the inference of the innovations associated with the other exogenous processes.

[17]Note that the prior distributions of the debt-stabilization parameters are truncated to avoid destabilizing values.

Table 2: Estimated Parameters

Parameter	Description	Prior Distribution	Post. Mean	Post. SD
ϕ	Inv. Frisch elast. of h	$N^{(0,\infty)}\,(0.1, 2)$	3.42	1.00
ς	Habit formation	$N^{(0,1)}\,(0.9, 0.2)$	0.74	0.09
η_c	Elast. of subst. (C, G^c)	$N^{(0,\infty)}\,(1.5, 2)$	0.79	0.71
ν	Wealth effect	$N^{(0,1)}\,(0.5, 0.5)$	0.70	0.20
η	Elast. subst. home-foreign	$N^{(0,\infty)}\,(3, 2)$	6.08	1.06
γ_k	Inv. adj. cost	$N^{(0,\infty)}\,(6, 10)$	8.85	4.44
100ψ	Country prem. debt elast.	$N^{(0,\infty)}\,(0.5, 10)$	2.21	1.40
ρ_{gc}	Gov. cons. persistence	$N^{(0,1)}\,(0.70, 1)$	0.88	0.07
ρ_{gi}	Gov. inv. persistence	$N^{(0,1)}\,(0.48, 1)$	0.77	0.08
ρ_{TR}	Transfers persistence	$N^{(0,1)}\,(0.37, 1)$	0.47	0.12
α_{gc}	Gov. cons. cyclicality	$N\,(0.13, 2)$	0.59	0.92
α_{gi}	Gov. inv. cyclicality	$N\,(1.77, 2)$	2.58	1.57
α_{TR}	Transfers cyclicality	$N\,(3.52, 2)$	5.46	0.96
γ_{gc}	Gov. cons. debt stabilization	$N^{(-\infty,0)}\,(-0.01, 2)$	-0.50	0.41
γ_{gi}	Gov. inv. debt stabilization	$N^{(-\infty,0)}\,(-0.13, 2)$	-1.82	0.67
γ_{TR}	Transfers debt stabilization	$N^{(-\infty,0)}\,(-0.35, 2)$	-0.26	0.21
ρ_{υ}	AC cons. pref. sh.	$\text{Beta}(0.75, 0.15)$	0.41	0.12
ρ_{κ}	AC labor pref. sh.	$\text{Beta}(0.75, 0.15)$	0.74	0.10
ρ_u	AC invest. sh.	$\text{Beta}(0.75, 0.15)$	0.35	0.11
ρ_z	AC stationary tech. sh.	$\text{Beta}(0.75, 0.15)$	0.86	0.09
ρ_a	AC non-stationary tech. sh.	$\text{Beta}(0.75, 0.15)$	0.79	0.13
ρ_{ζ}	AC country prem. sh.	$\text{Beta}(0.75, 0.15)$	0.65	0.06
$\sigma_{e^{gc}}$	SD gov. cons. sh.	$\text{IG}(0.03, \infty)$	0.03	0.00
$\sigma_{e^{gi}}$	SD gov. inv. sh.	$\text{IG}(0.15, \infty)$	0.17	0.02
$\sigma_{e^{TR}}$	SD transfers sh.	$\text{IG}(0.10, \infty)$	0.11	0.01
$100\sigma_{\upsilon}$	SD cons. pref. sh.	$\text{IG}(1, \infty)$	10.23	2.63
$100\sigma_{\kappa}$	SD labor pref. sh.	$\text{IG}(4, \infty)$	7.56	1.91
$100\sigma_u$	SD invest. sh.	$\text{IG}(1, \infty)$	27.24	13.09
$100\sigma_z$	SD stationary tech. sh.	$\text{IG}(0.1, \infty)$	2.08	0.30
$100\sigma_a$	SD non-stationary tech. sh.	$\text{IG}(0.1, \infty)$	0.62	0.39
$100\sigma_{\zeta}$	SD country prem. sh.	$\text{IG}(0.9, \infty)$	0.89	0.08

Note: $N^{(l,u)}\,(a, b)$ denotes a normal distribution with mean a and standard deviation b that was restricted to take values between l and u during mode finding, but not during posterior distribution sampling. Beta(a, b) denotes a beta distribution with mean a and standard deviation b. $IG(a, b)$ denotes an inverse gamma distribution for the variance of the shocks where a is the mean of the standard deviation and b is its variance. Results are based on two Metropolis-Hastings chains of 500,000 draws each from the posterior distribution, after dropping 500,000 draws for each chain, using an acceptance rate of 0.3, and starting the chains around the posterior mode obtained with Dynare's Monte-Carlo–based optimization routine.

that shut down the wealth effect (the case when $\nu = 0$). Additionally, the habit persistence parameter, ς, at 0.7, is estimated in the vicinity of the results in the literature. The parameter that governs the elasticity of substitution between private and government-provided goods, η_c, at 0.8, is estimated to be relatively low, pointing to complementarity between these two types of goods. Finally, the consumption preference shock, υ is estimated to be less persistent than the labor preference shock, κ, although it is also more volatile.

A third set of parameters is related to production and investment technologies. For instance, the estimation points to a high degree of substitutability between home and foreign goods, as indicated by the posterior mean of the parameter η. The investment adjustment cost parameter, γ_k, is in the upper bound of the results in the literature for developing economies (see, for example Sheen and Wang, 2016; Fornero and Kirchner, 2018; Guerra-Salas, Kirchner and Tranamil-Vidal, 2021), reflecting the higher investment adjustment costs faced by countries dependent on commodities with volatile prices, as argued by Devlin and Titman (2004). Among technology shocks, the investment efficiency shock, u_t, is estimated to have the lowest persistence and highest variance. The shock to the non-stationary technological index, a_t, is estimated to be highly persistent for a shock that generates permanent effects on the level of variables in the economy. As we explain below, this is a reasonable inference given the performance of the Ecuadorian economy in the sample period.

The last set of coefficients is related to the country risk premium, ξ. The posterior mean of parameter ψ suggests that a 1 percentage point increase in the total foreign debt-to-GDP ratio is estimated to increase the premium by about 23 basis points.[18] The idiosyncratic risk premium shock, ζ, displays moderate levels of persistence and volatility, relative to the other shocks.

5 Model Performance and Dynamics

In this section, we examine the performance of the model by comparing moments such as co-movement, volatility, and persistence, with their data counterparts. We also study how different shocks affect aggregate fluctuations.

[18] To gain intuition on this interpretation, note that linearizing the expression for the country premium, (4), around $\bar{f}^* + \bar{b}^*$, and ignoring the idiosyncratic risk shock, we get $\xi_t = \bar{\xi} + \frac{\psi}{\bar{f}^*+\bar{b}^*}((F_t^* + B_t^*)/Y_t - (\bar{f}^* + \bar{b}^*))$. Hence, the effect of a marginal increase in the quarterly debt-to-GDP ratio implies an increase in the quarterly risk premium equal to $\frac{\psi}{\bar{f}^*+\bar{b}^*}$. Consequently, a 1 pp increase in the annualized debt-to-GDP ratio is equivalent to an increase of 0.04 in $(F_t^* + B_t^*)/Y_t$, which is the quarterly counterpart. Then, the effect on the quarterly country premium is $0.04 \times \frac{\psi}{\bar{f}^*+\bar{b}^*}$, where $\bar{f}^* + \bar{b}^* = 1.55$. As a consequence, the effect is $0.04 \times 0.0221/1.55 = 0.00057$. Annualizing this effect results in $1.00057^4 - 1 = 0.0023$, i.e., 23 basis points. Interestingly, a linear regression of the EMBI spread against the total foreign debt-to-GDP ratio results in a coefficient equal to 19.

Table 3: Co-Movement, Volatility and Persistence

	Corr. with GDP		SD		1st order AC	
	Data	Model	Data	Model	Data	Model
Non-Oil GDP Growth	1	1	1.65	1.54	0.46	0.41
Private Consumption Growth	0.76	0.63	1.90	2.39	0.21	0.26
Total Investment Growth	0.64	0.51	3.45	5.18	0.53	0.27
Trade Balance to GDP	0.12	0.02	1.97	3.97	0.67	0.77
Hours Worked	−0.03	−0.15	1.97	0.81	0.36	0.74
Government Consumption Growth	0.67	0.29	3.30	3.66	0.15	0.15
Government Investment Growth	0.33	0.30	19.39	19.42	−0.08	−0.01
Government Transfers Growth	0.49	0.36	15.77	15.91	0.26	−0.01
Country Premium	−0.14	−0.16	1.30	1.26	0.73	0.70

Note: GDP is non-oil real GDP, SD denotes standard deviation, AC denotes autocorrelation.

To assess how the model fits the data, table 3 reports, for nine selected variables, the correlation with GDP, standard deviation, and first-order autocorrelation coefficient implied by the posterior mean of the parameters, and compares these statistics with empirical moments. The model does a good job of matching the co-movement of most of these variables with GDP, both qualitatively and quantitatively. In terms of standard deviations, the model does a good job of matching the relative volatility of most variables. For example, investment is more volatile than consumption, which in turn is more volatile than output; government investment is the most volatile component of public expenditure, followed by transfers and government consumption. Quantitatively, however, the model overstates the volatility of consumption and investment. Finally, the model fits the persistence of the data very well, because the first-order autocorrelation coefficients are quantitatively close to their data counterparts.

We also analyze how the model interprets the data through its structural shocks. To this end, table 4 shows the unconditional variance decomposition of selected variables. We comment on the role of commodity, risk, and fiscal policy shocks, which are key aspects of our analysis. Commodity and risk premium shocks are not important drivers of fluctuations in output growth, but are important drivers of the trade balance-to-GDP ratio due to their direct influence on oil exports and the external cost of financing. Commodity shocks drive 25% of the fluctuations in government transfers, most likely due to the substantial gasoline subsidies offered to households in Ecuador. We now turn to fiscal policy shocks. These shocks explain a significant fraction of fluctuations in private consumption, likely due to the complementarity with private consumption goods in households' consumption basket. Fiscal policy shocks are also important drivers of investment growth, due to the role of public capital in the demand for private capital of the home goods-producing firm. Finally, as is usually the case in real business cycle models, the most important drivers of aggregate fluctuations

Table 4: Variance Decomposition

	Commodity	Risk	FP	Technology	Foreign	Preferences
Non-Oil GDP Growth	3.1	1.4	6.3	73.8	0.6	14.8
Private Consumption Growth	10.7	5.0	14.4	19.7	0.8	49.3
Total Investment Growth	3.7	2.8	27.5	63.4	0.4	2.2
Trade Balance-to-GDP Ratio	33.8	11.8	6.4	31.1	1.7	15.3
Hours Worked	4.4	1.2	2.3	9.8	0.2	82.2
Government Consumption Growth	5.9	1.1	70.9	18.0	0.2	4.0
Government Investment Growth	4.9	0.8	91.5	2.3	0.1	0.4
Government Transfers Growth	25.7	0.4	66.8	5.5	0.1	1.5
Country Premium	2.8	92.7	0.3	3.2	0.0	0.3

Note: Fraction of the unconditional theoretical variances at the posterior mean (in percent) explained by the shocks, excluding measurement error. Commodity shocks include oil price (p^{P*}) and oil output (Y^P) shocks. The risk shock affects the country premium (ζ). Fiscal policy (FP) shocks include those to government consumption, government investment, and transfers (e^{gc}, e^{gi}, and e^{TR}). Technology shocks include transitory (z) and permanent (a) productivity shocks, and investment efficiency (u) shocks. Foreign shocks include shocks to the foreign interest rate (R^*) and foreign demand (y^*). Preference shocks include consumption (v) and labor supply (κ) shocks. Columns may not add to their exact percentages due to rounding.

are technology shocks, especially for output and investment growth, and preference shocks, especially or consumption growth and hours worked.

It is also instructive to study the role of different shocks at specific points of the business cycle. Figure 1 shows the historical shock decomposition of the annual growth rate of non-oil GDP. Shocks are grouped as in the variance decomposition analysis above.[19] Ecuador displays a cycle marked by a substantial expansion since the mid 2000s, which, as in other Latin American countries, coincided with the boom in international commodity prices. This boom was briefly interrupted in 2008–2009 by the Global Financial Crisis (GFC), and later brought to a sudden halt in 2014, when international commodity prices collapsed. The last five years of the sample are marked by a seemingly permanent decline in the growth rate of non-oil GDP.

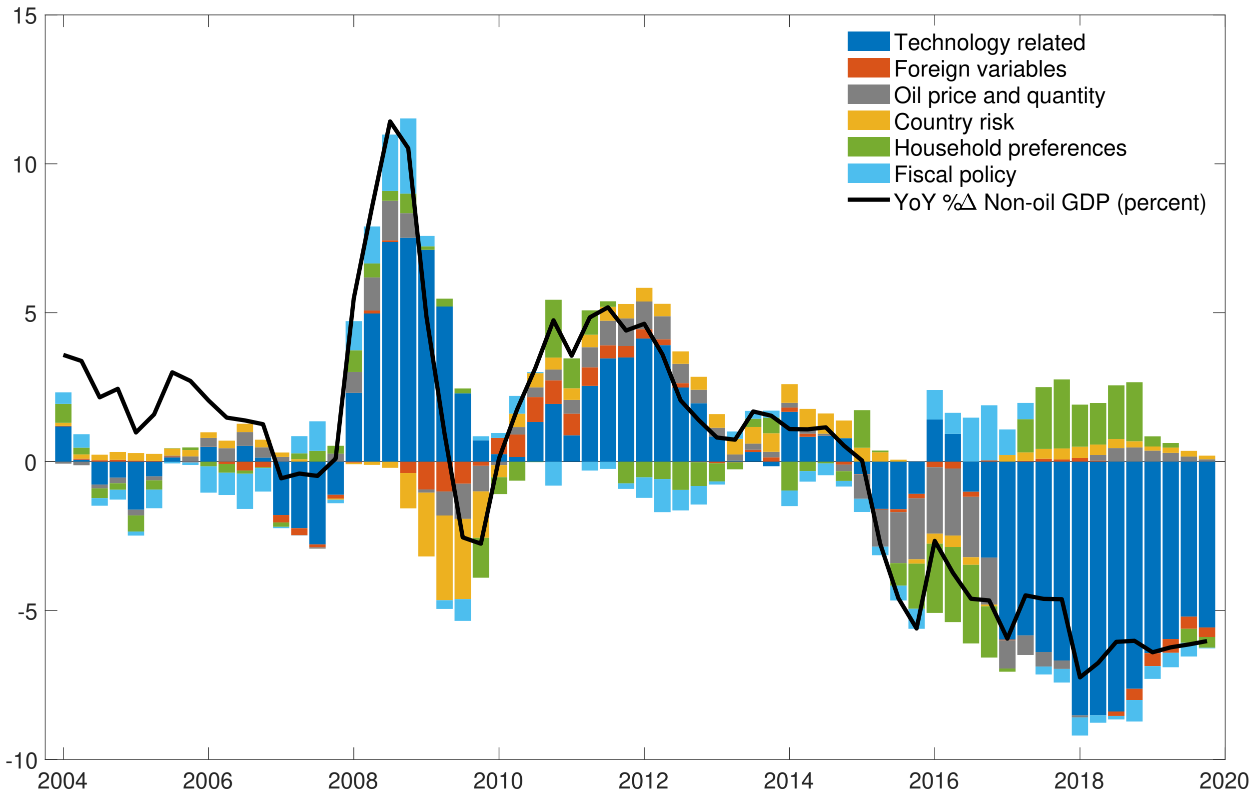
As we previously mentioned, looking at the cycle through the lens of the model points to technology shocks (dark blue bars) as the most important drivers. This is particularly relevant in the last part of the sample, in which permanent productivity shocks (a_t) are the only way for the model to rationalize the permanent decline in output growth. A deep understanding of this phenomenon is beyond the scope of this paper, but one possible explanation is that growth patterns featuring weak (strong) demand induce a slowdown (rise) in productivity, as argued by Stadler (1990), Anzoategui et al. (2019), Jordà, Singh and Taylor (2020), and Furlanetto et al. (forthcoming), among others.

Oil shocks (gray bars) are relevant drivers of output growth during episodes of oil price swings, such as the high prices observed from the mid 2000s to 2013, which exert upward

[19] We ignore the role of initial conditions and measurement error, so the bars do not add up exactly to the solid line. Appendix D contains the shock decomposition of the other observable variables of the model.

pressure, in general. Oil shocks contribute negatively during the GFC, when the oil price declined, and especially during 2014–2017, a period of low oil prices that exerted substantial negative pressure on output growth.

Figure 1: Historical Shock Decomposition of Annual Non-Oil GDP Growth



Note: The solid black line denotes the four-quarter moving sum of the observable variable—the demeaned quarter-on-quarter log difference of non-oil GDP, which approximates its annual growth rate. The bars are four-quarter moving sums of shocks obtained from the historical shock decomposition of the observable variable. The shock groupings are the same as for the variance decomposition; see the note to table 4.

Country risk premium shocks (yellow bars) exert downward pressure on output growth around the GFC of 2008 for two reasons, one global and one idiosyncratic. First, the global turmoil increased international investors' risk perception of emerging markets. The second and surely more important reason is that Ecuador decided to default on its sovereign debt for political considerations in December of 2008. These forces sent the Ecuadorian EMBI spread above 4,000 points (a 40 percentage-point premium above the equivalent risk-free bond). As time progressed and Ecuador regained access to financial markets, the downward trend in the country risk premium generated a positive effect of these shocks on output growth through

2014. Between 2015 and 2016, risk shocks put downward pressure on growth, again due to global and idiosyncratic factors. In this period, country premiums increased in developing countries (especially in Latin America) due to the decline in commodity prices. The idiosyncratic factor was a severe earthquake that affected two coastal provinces in Ecuador. Towards the end of the sample, with the country risk premium mostly declining, the effect of these shocks on GDP growth is small but positive.

Fiscal policy shocks (light blue bars) contribute positively to output growth during 2007–2008, a period of highly expansionary fiscal policy. Fiscal policy shocks are also expansionary during 2016–2017, likely due to the severe earthquake and its effect on the Ecuadorian economy, which required a fiscal expansion in full force to restore physical infrastructure.[20] Additionally, the presidential elections of 2017 might have also played a role in the expansionary fiscal policy, as the sitting president was trying to promote a candidate of his own party.

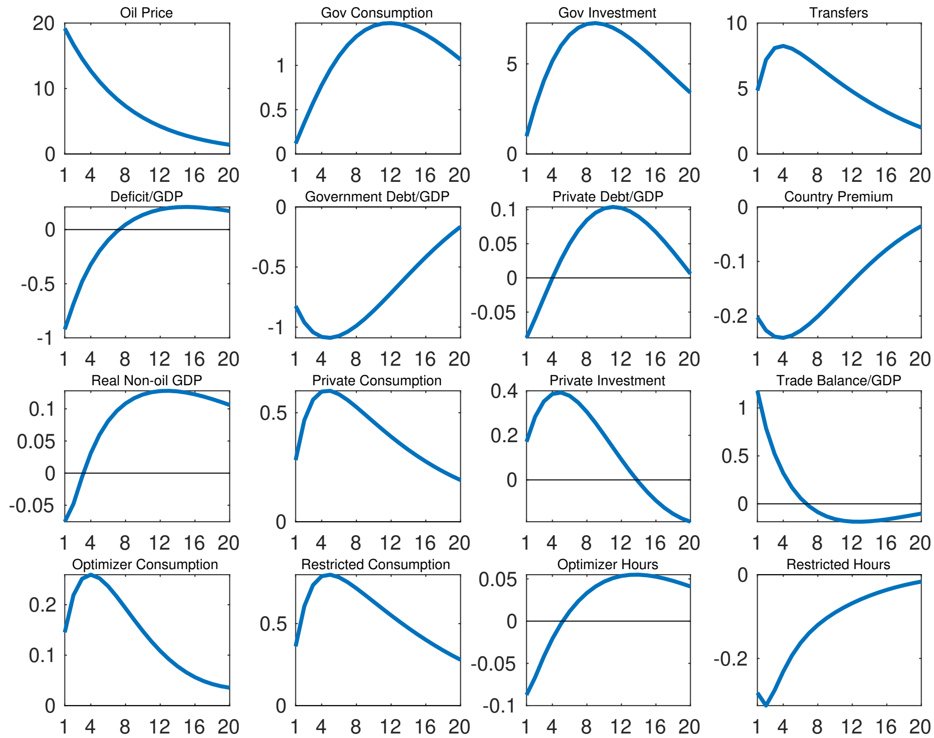
To conclude this section, we illustrate how shocks of interest for this paper propagate through the model economy. We study impulse responses to shocks to the international oil price and to the country risk premium. These shocks are of particular interest because they are intrinsically linked to the financial situation of the government. In the next section, we discuss the effects of changes to various fiscal instruments in the context of fiscal consolidation scenarios.

Effects of an oil price shock. A one-standard-deviation shock to the price of oil causes the price to increase by 19% on impact, as shown in figure 2 (top-left panel). The government receives an oil revenue windfall that reduces the deficit (panel 2-1) and, accordingly, public debt (panel 2-2). The decline in the model economy's debt-to-GDP ratio leads to a decline of more than 200 bps in the country premium (panel 2-4). Following the estimated reaction functions of government expenditure, all three components —government consumption, government investment, and transfers—increase gradually, reaching peaks four to twelve quarters after the shock hits the economy (panels 1-2, 1-3, and 1-4). The increase in government expenditure is driven by two forces—a lower public debt-to-GDP ratio, and the procyclical response to a positive output gap.

Because public and private consumption are complementary for household utility, both the optimizing and restricted rule-of-thumb households increase consumption on impact (panels 4-1, 4-2, and 3-2). The increase in transfers also contributes to the increase in

[20]Governmental and international institutions report the cost of reconstruction and economic recovery was close to $3 billion. See https://www.worldbank.org/en/news/feature/2021/04/27/a-cinco-a-os-del-terremoto-ecuador-sigue-trabajando-en-su-resiliencia-frente-a-desastres and https://ecuadorchequea.com/moreno-ley-de-solidaridad-1500-millones/.

Figure 2: Impulse Responses to an Oil Price Shock



Note: Impulse responses to a one-standard-deviation shock to the international oil price. X axes denote quarters. Y axes denote percent deviations from steady state, except for variables expressed as ratios to GDP and the country premium, which are expressed as percentage point deviations from steady state. Public and private debt, and the country premium, are annualized.

consumption of hand-to-mouth households, who also reduce hours worked (panel 4-4) due to the income effect. The decline in the country premium increases the present value of investment—i.e., increases Tobin's q—so the optimizing households increase private investment (panel 3-3). The overall effect on non-oil GDP is slightly negative on impact (panel 3-1) because hours worked reach their trough almost immediately, whereas public and private demand for consumption and investment, as well as government transfers, take several quarters to reach their peak. Non-oil GDP starts a persistent expansion about a year after the shock hits the economy.

Effects of a country premium shock. We now describe the response of the model economy to a shock to the country risk premium, which is shown in figure 3. A one-standard-deviation shock to the idiosyncratic component of the country premium (the top-left panel) drives up the premium by over 300 basis points (panel 2-4). This increase in the country premium drives down the present value of investment, which leads the optimizing households to decrease investment (panel 3-3). The higher country premium also exerts downward pressure on the consumption of optimizing households (panel 4-1) due to the intertemporal substitution effect. Furthermore, because optimizing households are debtors in steady state, the higher country premium makes them relatively poorer, which also drives down their consumption, as well as their leisure (panel 4-3), due to the negative income effect.

The higher country premium also increases the government's interest payments and, thus, the deficit (panel 2-1) and debt (panel 2-2). The components of government expenditure (panels 1-2, 1-3 and 1-4) decline for two reasons—to stabilize a rising public debt-to-GDP ratio and due to their procyclical response to a contractionary shock. The decline in government transfers depresses consumption of the hand-to-mouth households (panel 4-2) and leads them to work more (panel 4-4) due to the negative income effect. Overall, GDP rises slightly on impact due to the expansion of hours worked, but declines persistently shortly after the shock hits the economy.

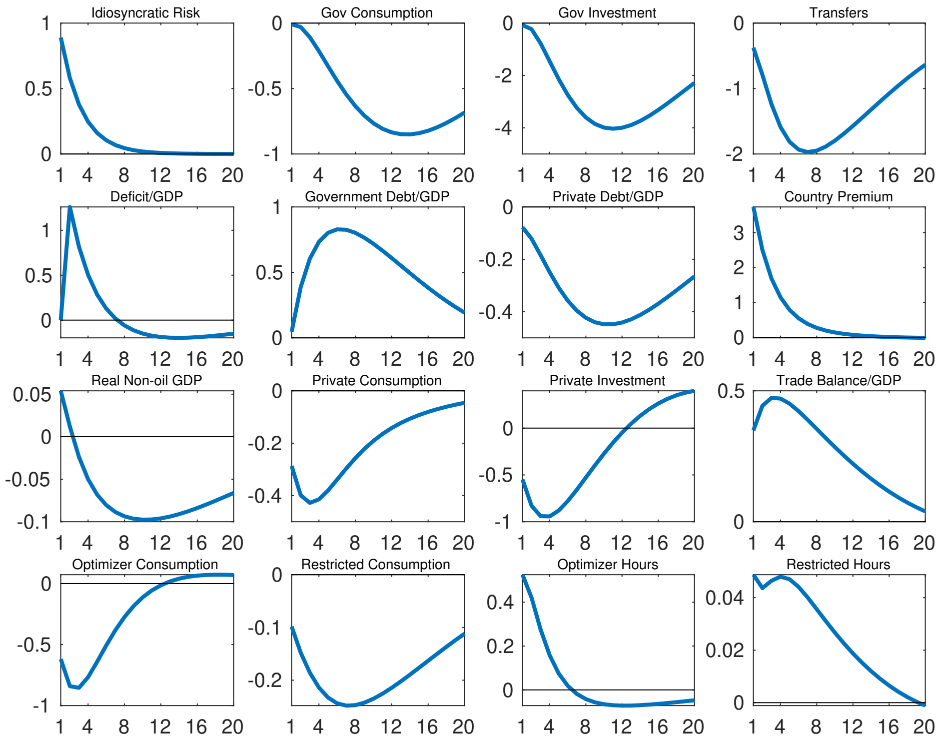
Eventually, the decline in government expenditure pushes the deficit-to-GDP ratio below steady state (panel 2-1), containing the increase in public debt. Forward-looking, optimizing households anticipate that this fiscal contraction will induce the country premium to fall below steady state, which ultimately pushes their consumption and investment above steady state.

6 Fiscal Consolidations

This section discusses the macroeconomic effects of fiscal consolidations, i.e., adjustments in government expenditure and/or tax rates with the objective of reducing the fiscal deficit. We proceed in three steps. First, we simulate consolidation scenarios in which the government adjusts, in turn, only one of its six fiscal instruments. By isolating the effect of each tax or expenditure instrument, these six simulations develop intuition on the transmission mechanisms of fiscal policy in the model economy. In a second step, we simulate a fiscal consolidation that uses all of the government's fiscal instruments. To discipline this exercise, we follow the fiscal program that the government of Ecuador agreed with the IMF for the 2020–2025 period. In the third and final step, we simulate revenue- and expenditure-based consolidation scenarios. In the revenue-based scenario, fiscal adjustment is achieved by an increase in all three tax rates—on consumption, labor income, and capital income. In the expenditure-based scenario, adjustment results from a reduction in all three components of government expenditure—consumption, investment and transfers.

To simulate increases in tax rates, we depart from our assumption during estimation that

Figure 3: Impulse Responses to an Idiosyncratic Country Risk Shock



Note: Impulse responses to a one-standard-deviation shock to the idiosyncratic component of country risk. Y axes denote percent deviations from steady state, except for variables expressed as ratios to GDP and the country premium, which are expressed as percentage point deviations from steady state. Public and private debt, and the country premium, are annualized.

all tax rates remain at their steady state, and instead allow them to evolve according to an AR(1) process with very high persistence, to capture the fact that agents understand tax changes to be long lasting.[21]

To generate the simulations, we work with a version of the linear state-space form of the solution to our model in which the state variables are all the model variables, and the "observable" variables are the six fiscal instruments. A simulation of a consolidation based on the adjustment of one or more fiscal instruments is a conditional forecast from the steady state of this state-space system in which we condition on a change to the set of instruments in question, holding all other fiscal instruments constant. We set the change in the fiscal instruments to last 20 quarters (5 years).[22]

[21]In the model, we assume that tax rates evolve as follows: $\tau_t^x = .999\tau_{t-1}^x + (1 - .999)\tilde{\tau}^x + e_{\tau^x}$, for $x \in \{c, n, k\}$ where $\tilde{\tau}^x$ is the steady-state tax rate.

[22]We implement this conditional forecast with the Kalman smoother. In effect, we hit the model with a sequence of unexpected shocks to the fiscal instruments that deliver the desired paths. For example, in a

The first six subsections present simulations in which each of the six fiscal instruments is adjusted to achieve a reduction in the fiscal deficit-to-GDP ratio of 1 percentage point on impact.

6.1 An Increase in the Consumption Tax Rate

Figure 4 presents a fiscal consolidation based on an increase in the consumption tax rate (plotted in the second row and first column of the figure; panel 2-1). The size of the tax rate increase, 1.6 pp above steady state, is designed to reduce the fiscal deficit-to-GDP ratio by 1 pp on impact (top-left panel).[23] Again, the simulation is a 5-year forecast, conditioning on the consumption tax rate lying 1.6 pp above its steady state and all other fiscal instruments remaining at their steady state for 20 quarters.

The decline in the fiscal deficit-to-GDP ratio generates a decline in the (annualized) government debt-to-GDP ratio (panel 1-2). Aggregate private consumption declines in response to the higher consumption tax rate (panel 2-4). The decline in consumption is more immediate for the hand-to-mouth households (panel 4-2) and more gradual for the optimizing households (panel 4-1), who can smooth consumption by increasing debt (panel 1-3). The increase in private debt is not sufficient to compensate the decline in public debt, so the aggregate foreign debt-to-GDP ratio declines (panel 1-4), generating downward pressure on the country risk premium (panel 2-2).

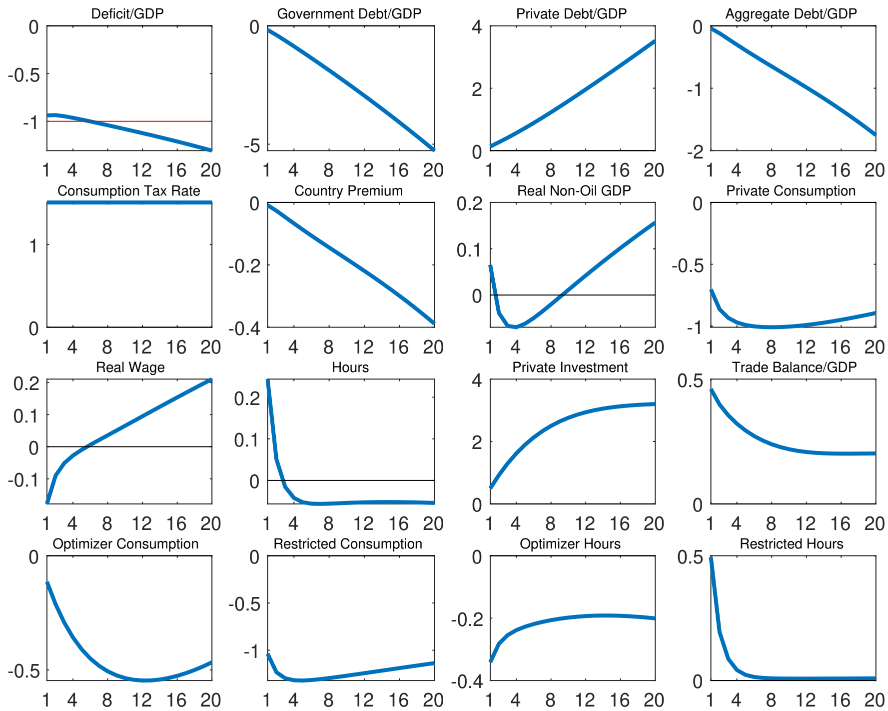
Forward-looking, optimizing households anticipate the decline in the country premium due to the fall in government debt, which increases the present value of investment (higher Tobin's q), leading to higher private investment throughout the simulation horizon (panel 3-3). During the first couple of years, as the model economy adjusts to the higher consumption tax rate, non-oil GDP declines (panel 2-3). However, as private investment gradually expands

simulation in which the government increases only one of the tax rates for 20 quarters, we use a sequence of shocks to that tax rate, and a sequence of shocks to keep the components of government expenditure unchanged. This is necessary because expenditure would otherwise fluctuate according to the reaction functions described in equations (10)-(12). The macroeconomic effect of this simulation is then the expected value of the model variables given the sequence of shocks to the fiscal instruments. Furthermore, in the simulation, we shut down all but the fiscal policy shocks, so the Kalman smoother cannot infer other shocks to accommodate the given paths of the fiscal instruments. A limitation of our methodology is that, by using sequences of unexpected shocks to generate the simulations, anticipatory responses are limited, especially to adjustments in government expenditure. Adjustments in tax rates do generate substantial anticipatory responses, because they are simulated as quasi-permanent changes.

[23] We calibrate the consumption tax rate change using the government budget constraint in steady state. Explicitly, we solve the following equation for x: $(pg^c + pg^i + tr + \xi R^* b^* - b^* - \chi p^{Co*} y^{Co*} - \tau^n w(1-\omega)h^o - \tau^k (r^k - \delta)\frac{k}{a} - (\tau^c + x)pc)/y = (pg^c + pg^i + tr + \xi R^* b^* - b^* - \chi p^{Co*} y^{Co*} - \tau^n w(1-\omega)h^o - \tau^k (r^k - \delta)\frac{k}{a} - \tau^c pc)/y - .01 \implies x = \frac{.01y}{pc}$. The deficit-to-GDP ratio does not fall by exactly 1 pp on impact because the calibration of the consumption tax rate assumed all other variables remained at steady state and thus did not account for the endogenous response of the economy to the tax change.

in response to the lower country risk premium, output eventually increases above trend.

Figure 4: Consolidation: An Increase in the Consumption Tax Rate



Note: Fiscal consolidation designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 percentage point on impact through an increase in the consumption tax rate, holding all other fiscal instruments constant. X axes denote quarters. Y axes denote percent deviations from steady state, except for variables expressed as ratios to GDP and the country premium, which are expressed as percentage point deviation from steady state. Public and private debt, and the country premium, are annualized.

6.2 An Increase in the Labor Income Tax Rate

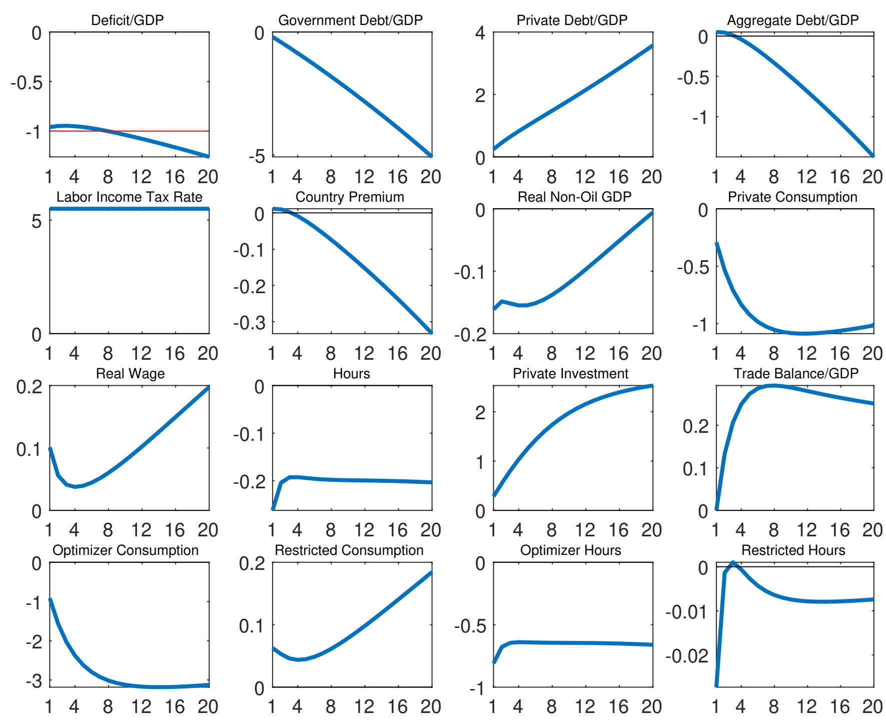
Figure 5 presents a fiscal consolidation based on an increase in the labor income tax rate (plotted in the second row and first column; panel 2-1). Again, the increase in the tax rate, of 5.6 pp above steady state, is calibrated to generate a decline in the fiscal deficit-to-GDP ratio of approximately 1 pp on impact (top-left panel).[24] The fall in the fiscal deficit leads to a decline in the (annualized) government debt-to-GDP ratio (panel 1-2).

[24]We calibrate the labor tax rate change using the government budget constraint in steady state. Explicitly, we solve the following equation for x: $(pg^c + pg^i + tr + \xi R^* b^* - b^* - \chi p^{Co*} y^{Co*} - (\tau^n + x) w(1-\omega) h^o - \tau^k (r^k - \delta) \frac{k}{a} - \tau^c pc)/y = (pg^c + pg^i + tr + \xi R^* b^* - b^* - \chi p^{Co*} y^{Co*} - \tau^n w(1-\omega) h^o - \tau^k (r^k - \delta) \frac{k}{a} - \tau^c pc)/y - .01 \implies x = \frac{.01y}{w(1-\omega)h^o}$.

The higher labor income tax rate generates a decline in hours worked (panel 3-2) and an increase in the real wage due to its contractionary effect on labor supply (panel 3-1). The labor income tax is only levied on optimizing households, so the decline in hours is driven by this group (panel 4-3). On the one hand, optimizing households also reduce consumption gradually but substantially in response to the intratemporal substitution effect induced by lower labor supply (panel 4-1). The group of hand-to-mouth households, on the other hand, increases consumption slightly in response to the rise in their disposable income due to the higher wage (panel 4-2).

Aggregate private consumption declines (panel 2-4), driven by the behavior of optimizing households, despite them issuing private foreign debt (panel 1-3) in order to reduce consumption gradually. The aggregate foreign debt-to-GDP ratio, however, declines (panel 1-4), driven by public debt, so the country risk premium also falls (panel 2-2). The lower premium induces an increase in private investment (panel 3-3). All in all, non-oil GDP falls below steady state (plot 2-3), driven by the decline in consumption demand and hours worked.

Figure 5: Consolidation: An Increase in the Labor Income Tax Rate



Note: Fiscal consolidation designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 percentage point on impact through an increase in the labor income tax rate, holding all other fiscal instruments constant. For more details, see the note to figure 4.

6.3 An Increase in the Capital Income Tax Rate

Figure 6 presents a fiscal consolidation based on an increase in the capital income tax rate (panel 2-1) designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 pp on impact (top-left panel). To achieve this, the capital income tax rate, which is levied only on the group of optimizing households, has to increase by 6.5 pp above steady state.[25].The decline in the fiscal deficit leads to a decline in the (annualized) government debt-to-GDP ratio (panel 1-2).

The country risk premium falls in response to lower aggregate debt (panel 2-2) which should lead to an increase in investment projects. However, private investment declines substantially (panel 3-3) because the force of the higher capital income tax dominates the decline in the premium. The lower risk premium generates an intertemporal substitution effect that leads optimizing households to increase consumption (panel 4-1), which drives a slight increase in aggregate private consumption (panel 2-4). The decline in investment affects the capital stock, which lowers the marginal product of labor and thus the real wage (panel 3-1), lowering consumption by hand-to-mouth households. Overall, the higher capital income tax generates a persistent decline in non-oil GDP (panel 2-3).

6.4 A Reduction in Government Consumption

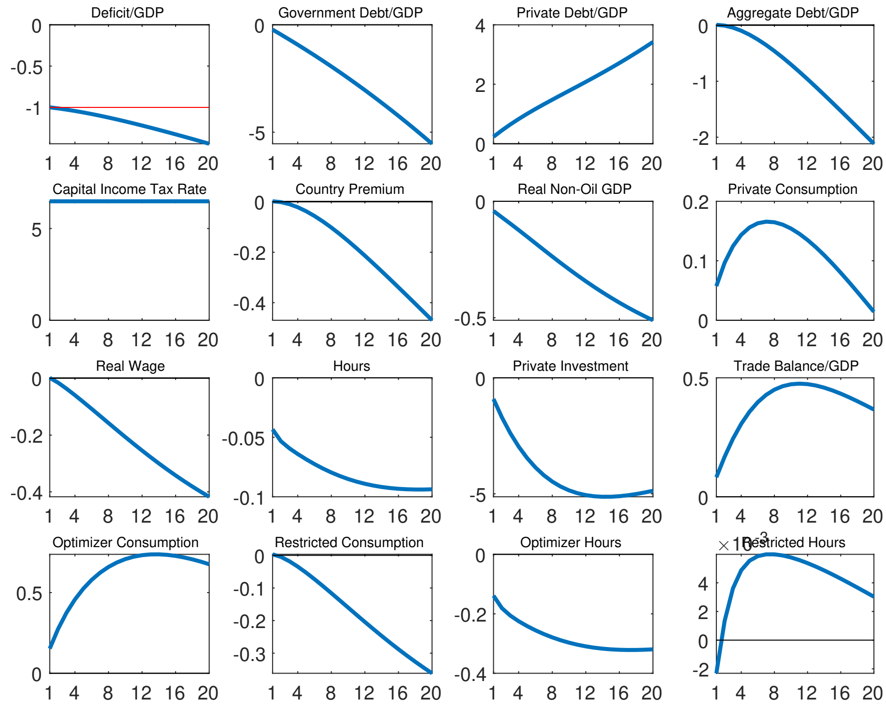
We now turn to fiscal consolidation scenarios based on adjustments of the components of government expenditure. Figure 7 presents a fiscal consolidation based on a reduction in government consumption. Again, we calibrate the size of the adjustment so that it generates a 1 pp decline, on impact, in the fiscal deficit-to-GDP ratio (top-left panel in the figure). We find that a 9% reduction in the level of government consumption generates the required adjustment (panel 2-1).[26]

The contraction in government consumption reduces the government debt-to-GDP ratio (panel 1-2), which in turn leads to a substantial decline in the country risk premium (more than 60 basis points after five years; panel 2-2). The intertemporal substitution effect induced by the lower country premium leads the optimizing households to increase consumption (panel 4-1). The decline in the country premium also induces an increase in investment

[25]We calibrate the capital tax rate change using the government budget constraint in steady state. Explicitly, we solve the following equation for x: $(pg^c+pg^i+tr+\xi R^*b^*-b^*-\chi p^{Co*}y^{Co*}-\tau^n w(1-\omega)h^o-(\tau^k+x)(r^k-\delta)\frac{k}{a}-\tau^c pc)/y = (pg^c+pg^i+tr+\xi R^*b^*-b^*-\chi p^{Co*}y^{Co*}-\tau^n w(1-\omega)h^o-\tau^k(r^k-\delta)\frac{k}{a}-\tau^c pc)/y-.01 \implies x = \frac{.01y}{(r^k-\delta)\frac{k}{a}}$.

[26]We calibrate the government consumption change using the government budget constraint in steady state. Explicitly, we solve the following equation for x: $(p(1-x)g^c+pg^i+tr+\xi R^*b^*-b^*-\chi p^{Co*}y^{Co*}-\tau^n w(1-\omega)h^o-\tau^k(r^k-\delta)\frac{k}{a}-\tau^c pc)/y = (pg^c+pg^i+tr+\xi R^*b^*-b^*-\chi p^{Co*}y^{Co*}-\tau^n w(1-\omega)h^o-\tau^k(r^k-\delta)\frac{k}{a}-\tau^c pc)/y-.01 \implies x = \frac{.01y}{pg^c}$.

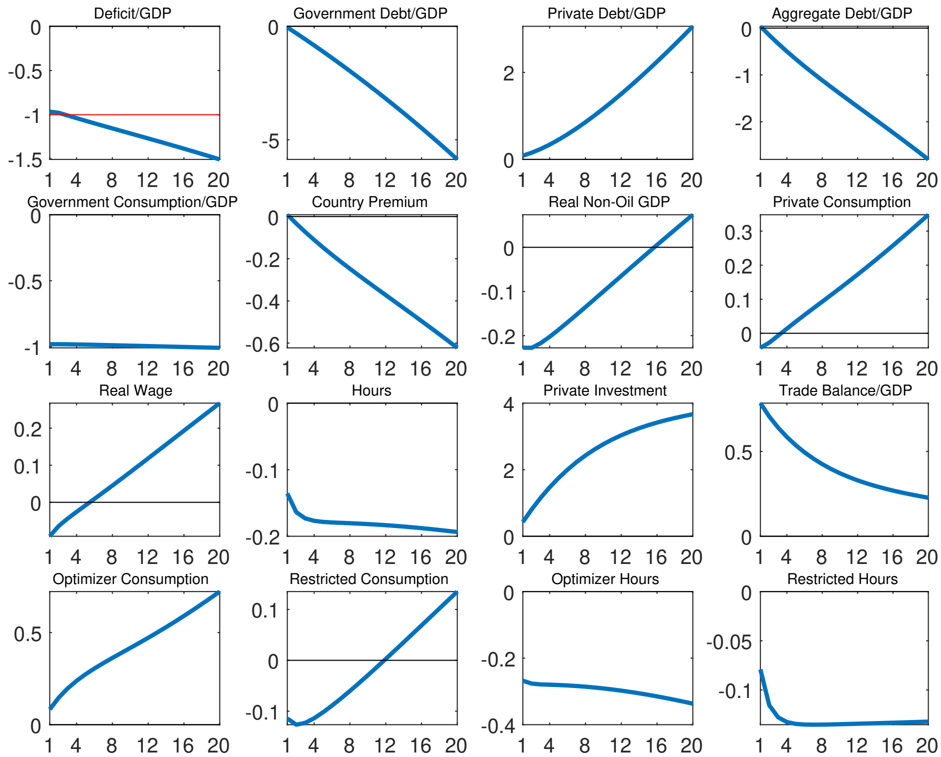
Figure 6: Consolidation: An Increase in the Capital Income Tax Rate



Note: Fiscal consolidation designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 percentage point on impact through an increase in the capital income tax rate, holding all other fiscal instruments constant. For more details, see the note to figure 4.

(panel 3-3) due to the increase in its present value. The group of restricted, hand-to-mouth households reduces consumption initially (panel 4-2), because of the complementarity between public and private consumption and their inability to smooth the adjustment by issuing foreign debt, which is what the optimizing households do (panel 1-3). Eventually, however, the higher stock of private capital pushes the marginal product of labor and the real wage upwards (panel 3-1), which allows the hand-to-mouth households to increase consumption. Hours worked by both groups decline (panels 4-3 and 4-4). This is another consequence of the complementarity between public and private consumption—the decline in government consumption puts downward pressure on the marginal utility of private consumption, which leads to an intratemporal substitution towards leisure. Overall, the lower government consumption (panel 2-1) and hours worked (panel 3-2) generate an initial contraction in non-oil GDP (panel 2-3), but the subsequent expansion in aggregate demand eventually pulls it above trend.

Figure 7: Consolidation: A Reduction in Government Consumption



Note: Fiscal consolidation designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 percentage point on impact through a reduction in government consumption, holding all other fiscal instruments constant. For more details, see the note to figure 4.

6.5 A Reduction in Government Investment

Figure 8 presents a consolidation scenario based on a reduction in government investment. To generate a 1 pp decline in the fiscal deficit-to-GDP ratio (top-left panel), the level of government investment has to decline 37% (panel 2-1).[27]

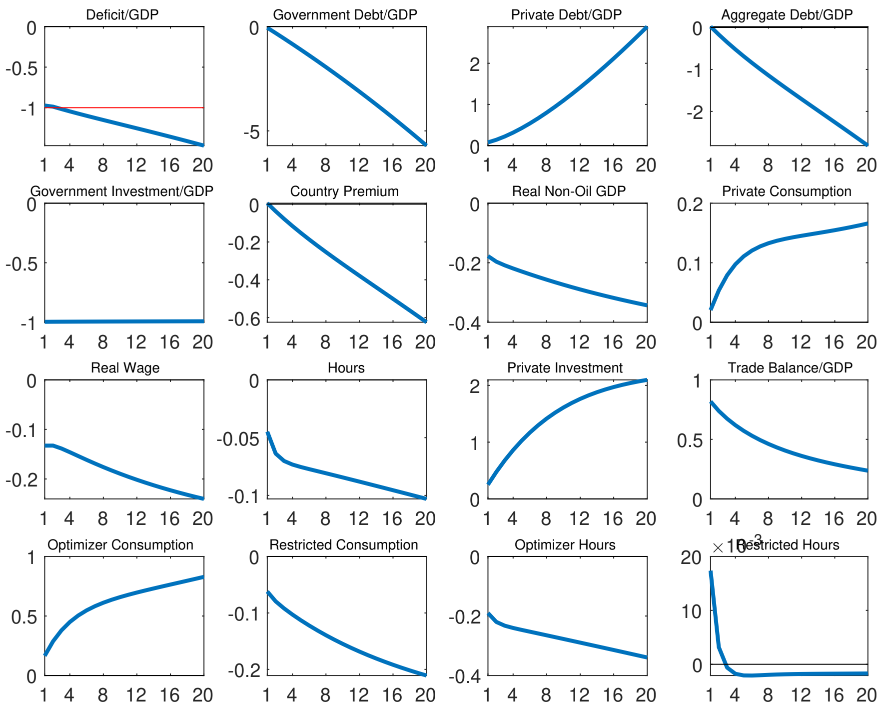
The reduction in government investment leads to a substantial decline in the country risk premium (panel 2-2) through its effect on the government debt-to-GDP ratio (panel 1-2), which generates an intertemporal substitution effect for the households. The optimizing households increase consumption (panel 4-1) and leisure (panel 4-3). The decline in the premium also induces an increase in private investment (panel 3-3). The decline in the stock of public capital is larger, however, so the marginal product of labor and the real wage decline

[27] We calibrate the government investment change using the government budget constraint in steady state. Explicitly, we solve the following equation for x: $(pg^c+p(1-x)g^i+tr+\xi R^*b^*-b^*-\chi p^{Co*}y^{Co*}-\tau^n w(1-\omega)h^o-\tau^k(r^k-\delta)\frac{k}{a}-\tau^c pc)/y = (pg^c+pg^i+tr+\xi R^*b^*-b^*-\chi p^{Co*}y^{Co*}-\tau^n w(1-\omega)h^o-\tau^k(r^k-\delta)\frac{k}{a}-\tau^c pc)/y-.01 \implies x = \frac{.01y}{pg^i}$.

persistently (panel 3-1). Due to the reduction in the real wage, the restricted, hand-to-mouth households have no alternative but to reduce consumption.

Despite the expansion in aggregate private demand, the decline in government investment (panel 2-1) and hours worked (panel 3-2) weigh on non-oil GDP, which remains below trend throughout the five-year horizon (panel 2-3).

Figure 8: Consolidation: A Reduction in Government Investment



Note: Fiscal consolidation designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 percentage point on impact through a reduction in government investment, holding all other fiscal instruments constant. For more details, see the note to figure 4.

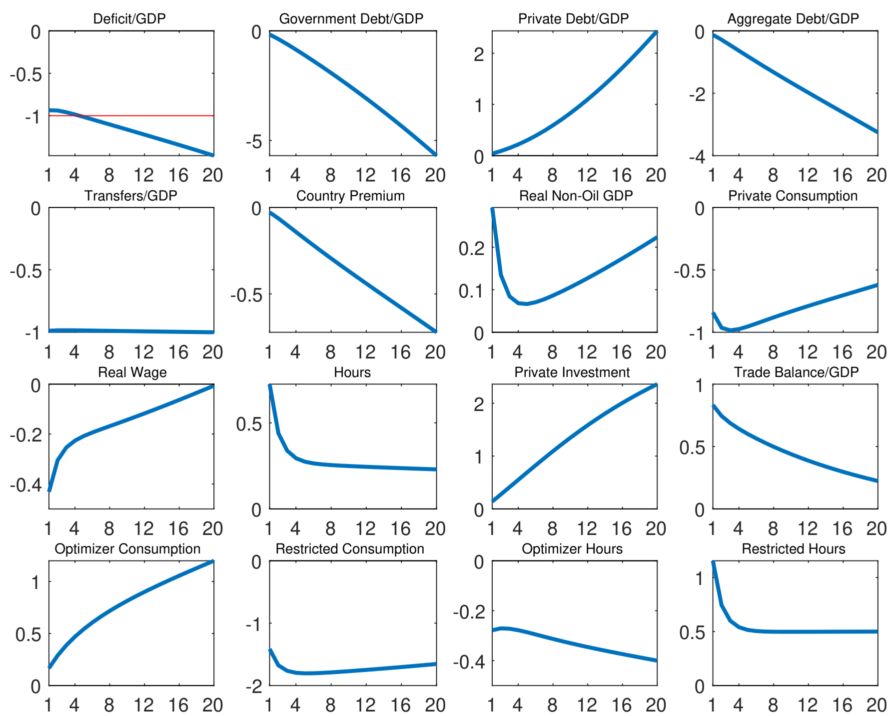
6.6 A Reduction in Government Transfers

We now discuss a fiscal consolidation scenario based on a reduction of the final component of government expenditure, namely transfers, which we assume are only paid to the restricted, hand-to-mouth households. The results are shown in figure 9. To generate a 1-pp reduction in the fiscal deficit-to-GDP ratio on impact (plot 1-1), the level of transfers must decline 20%, which is equivalent to 1 pp of GDP (plot 2-1).[28]

[28] We calibrate the transfer change using the government budget constraint in steady state. Explicitly, we solve the following equation for x: $(pg^c+pg^i+(1-x)tr+\xi R^* b^* - b^* - \chi p^{Co*} y^{Co*} - \tau^n w(1-\omega)h^o - \tau^k (r^k-\delta)\frac{k}{a} -$

The reduction in transfers is a substantial income shock to the restricted households, who reduce consumption and leisure drastically in response (panels 4-2 and 4-4). The improvement in the fiscal deficit lowers the government debt-to-GDP ratio (panel 1-2), which generates a substantial decline in the country risk premium (panel 2-2). The optimizing households, who are not directly affected by the reduction in transfers, increase consumption and leisure because of the intertemporal substitution effect caused by the lower interest rate (panels 4-1 and 4-3). The decline in the premium also generates an increase in private investment (panel 3-3). The aggregate increase in labor supply (panel 3-2) puts downward pressure on the real wage (panel 3-1). The overall expansion in hours worked and private demand induce a modest expansion in non-oil GDP (panel 2-3).

Figure 9: Consolidation: A Reduction in Government Transfers



Note: Fiscal consolidation designed to reduce the fiscal deficit-to-GDP ratio by approximately 1 percentage point on impact through a reduction in government transfers, holding all other fiscal instruments constant. For more details, see the note to figure 4.

$\tau^c pc)/y = (pg^c + pg^i + tr + \xi R^* b^* - b^* - \chi p^{Co*} y^{Co*} - \tau^n w(1-\omega)h^o - \tau^k (r^k - \delta)\frac{k}{a} - \tau^c pc)/y - .01 \implies x = \frac{.01y}{tr}$.

6.7 Full Fiscal Consolidation

We now simulate a fiscal consolidation that combines multiple revenue and expenditure instruments. To discipline this exercise, we roughly follow the fiscal consolidation under the agreement between the government of Ecuador and the IMF for the 2020–2025 period, which included adjustments in personal income and corporate taxes, as well as government purchases and transfers. These fiscal adjustments are far more complex than our stylized DSGE model, so we approximate the agreement to the fiscal instruments in our model. The trajectory of tax rates and government expenditure that we consider in our simulation are shown in tables 5 and 6, respectively.[29] Our fiscal consolidation scenario is a forecast of the model conditioned on six-year trajectories for tax rates and government expenditure. Without loss of generality, we assume the economy is at steady state prior to the consolidation.[30]

Table 5: Full Fiscal Consolidation: Tax Rate Changes

Year	Consumption Tax	Labor Income Tax	Capital Income Tax
2020	+0	+0	+0
2021	+0	+0	+0
2022	+0	+3	+0.5
2023	+0	+0	−0.5
2024	+0	+0	+0
2025	+0	+0	+0

Note: Entries denote percentage point changes from tax rates in the previous year.

Figure 10 shows the results of the simulation. We first comment on the trajectories of the fiscal instruments and then on their macroeconomic effects. The labor income tax rate permanently increases by 3 pp from the third year (quarter 9, panel 2-1). The capital income tax rate increases by 0.5 pp during the third year (panel 2-2). The consumption

[29]The personal income tax reform implied a more progressive scheme and a reduction of deductions for high-income earners. Because the model has a single labor income tax rate for all agents, we assume an average tax rate change across the board as a way to implement this reform, taking into account that the Ecuadorian government estimated that 3.4% of the labor force would have been affected by the reform (see the proposal of the law for economic development and fiscal sustainability sent by the executive branch to Congress: https://www.comunicacion.gob.ec/wp-content/uploads/2021/11/LeyParaElDesarrolloEconomico.pdf). Similarly, the program considered a temporary contribution in 2022 by persons whose net worth was above $1 million (a 1% to 1.5% tax rate) and firms whose net worth was above $5 million (0.8% tax rate). To include these measures in our model, we assume a transitory increase in the capital income tax rate. For the components of government expenditure as a share of GDP, we use the trajectories in item 18 of IMF Country Report No. 22/225 (https://www.elibrary.imf.org/view/journals/002/2022/225/article-A000-en.xml).

[30]We could also run a conditional forecast from 2019 values. However, because we are working with a linearized solution to the model, there is no state dependence and the forecasts would be equivalent.

Table 6: Full Fiscal Consolidation: Expenditure Changes (% of GDP)

Year	Government Consumption	Government Investment	Transfers
2020	+0.2	−0.9	+0.1
2021	−1.1	+0.3	+0.9
2022	−1.2	−0.3	+0.2
2023	−0.4	+0	−0.5
2024	−0.3	+0	−0.6
2025	−0.2	−0.1	−0.4

Note: Entries denote percent changes in spending with respect to the previous year's GDP.

tax rate remains at steady state over the entire simulation (panel 1-4). The annual paths of the components of government spending experience more variability, as shown in table 6. To get sequences of quarterly percentage point deviations from steady state, we apply a quadratic interpolation to the annual sequences, ensuring that each year's four-quarter average is equal to the corresponding annual value.[31] Government consumption declines gradually over the 24-quarter horizon, reaching 3 pp of GDP below steady state by the end of the simulation (top-left panel). The adjustment of government investment, of 1 pp of GDP, is swifter, since it is nearly completed by the third year of the consolidation (panel 1-2). The transfers-to-GDP ratio lies above steady state for the first five years, reaching 1.3 pp of GDP by the third year (panel 1-3). The increase in the transfers-to-GDP ratio is designed to provide vulnerable households with support after the pandemic and to protect them from the contractionary effects of the consolidation.

The fiscal consolidation gradually reduces the deficit-to-GDP ratio, which reaches 6.1 pp below steady state by the end of the six-year horizon (panel 2-3).[32] The decline in the deficit contains public debt, leading to a gradual but substantial decline in the country risk premium, which reaches 160 basis points below steady state on an annual basis by the end of the simulation (panel 2-4). The lower country risk premium leads to higher private investment (panel 3-3).

Higher taxes, especially on labor income, reduce the consumption of optimizing households (panel 4-1), whereas the expansion of government transfers supports the consumption of restricted, hand-to-mouth households (panel 4-2). Overall, aggregate private consumption increases, because the expansion of hand-to-mouth households dominates. In addition, both

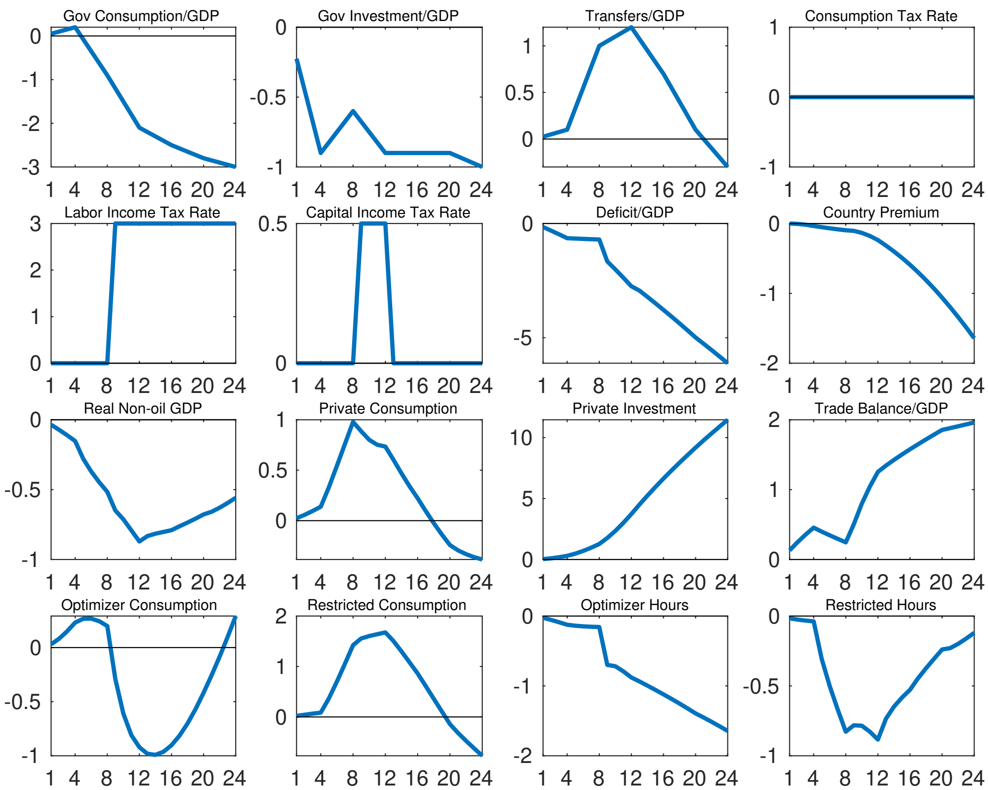
[31]We do a quadratic interpolation as opposed to a linear one so that the spending transitions from quarter to quarter within a year are smooth.

[32]In our model, the effect of the consolidation on the fiscal balance is larger than estimates by the IMF, whose Country Report No. 22/225 shows that the primary balance of the non financial public sector would improve by 4.5% of GDP between 2020 and 2025 with the program.

groups of households reduce hours worked. In the case of optimizing households (panel 4-3), this is mainly due to the effect of the higher labor income tax. In the case of hand-to-mouth households (panel 4-4), this is due to the income effect of higher transfers.

The contraction in public demand and hours worked induce a steady decline in non-oil GDP for the first three years, reaching nearly 1% below steady state (panel 3-1). From the fourth year, the expansion in private investment due to the lower country risk premium and an improvement in the trade balance (panel 3-4) contribute to a partial recovery of GDP, which ends the six-year simulation about 0.5% below trend.

Figure 10: Full Fiscal Consolidation



Note: Fiscal consolidation combining adjustments of multiple revenue and expenditure instruments designed to approximate the agreement between the government of Ecuador and the IMF for the 2020–2025 period, as shown in tables 5 and 6. X axes denote quarters. Y axes denote percent deviations from steady state, except for variables expressed as ratios to GDP and the country premium, which are expressed as percentage point deviation from steady state. The country premium is annualized.

6.8 Revenue- and Expenditure-Based Consolidations

The final step of our analysis compares a fiscal consolidation based on adjustments to tax rates (a revenue-based consolidation), with a consolidation based on adjustments to the components of government spending (expenditure-based). Specifically, we run counterfactual simulations that achieve the same level of deficit reduction as the full fiscal consolidation described in the previous subsection, but through adjustments in either tax rates or the components of government expenditure.

To implement the revenue-based consolidation, we assume that adjustments to each of the three tax rates in the model are responsible for achieving one third of the improvement in the primary balance-to-GDP ratio that is achieved under the full fiscal consolidation.[33] The revenue-based consolidation is a forecast conditioned on trajectories for the revenue from each tax as a share of GDP that deliver the desired improvement to the deficit, leaving the components of expenditure unchanged.[34] In every quarter of the six-year simulation horizon, the increase in each of the three tax revenue-to-GDP ratios equals one third of the improvement in the primary balance-to-GDP ratio in the corresponding quarter under the full fiscal consolidation. The adjustment is achieved by a sequence of shocks to the six fiscal instruments in the model.

Figure 11 presents the results of the revenue-based consolidation in solid blue lines, and compares them to the results of the full consolidation (dashed red lines). To achieve the desired improvement in the fiscal deficit-to-GDP ratio (panel 2-3), the consumption tax rate must increase by up to 2.8 pp (panel 1-4), the labor income tax rate, by up to 8.9 pp (panel 2-1), and the capital income tax rate, by up to 10.7 pp (panel 2-2).

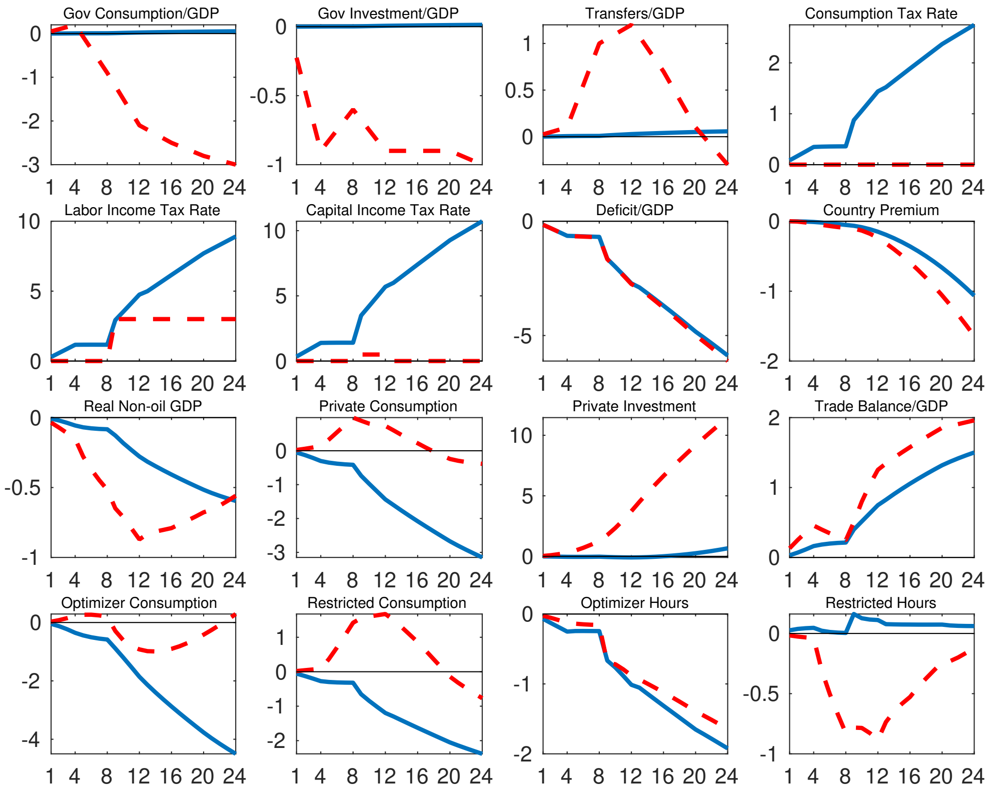
The revenue-based consolidation generates a more adverse effect on the consumption of both optimizing and hand-to-mouth households than the full fiscal consolidation (described in the previous subsection) due to the higher labor income and consumption tax rates, as well as the absence of support from transfers (panels 4-1 and 4-2). The country risk premium declines by up to 100 bps (panel 2-4), less than the 160 bps in the full simulation, because of a larger expansion in private foreign debt (not shown in the figure) that optimizing households use to smooth consumption. Private investment remains nearly unchanged for the first four years, and only increases slightly in fifth and sixth years (panel 3-3), due to the adverse effects of a higher capital income tax rate. However, hours worked decline less than in the full fiscal consolidation simulation because the restricted households do not reduce their hours (panel 4-4); they do so in the full simulation due to the income effect of higher transfers. The lower decline in aggregate labor and the fact that government purchases do not decline cushion the impact of the tax rate increases on non-oil GDP, which declines slightly less than in the

[33]The primary fiscal balance is defined as revenue minus expenditure, excluding interest payments. We match changes in the primary balance rather than the overall balance because it affords more precision in reproducing the path of the fiscal deficit-to-GDP ratio.

[34]Although the levels of government spending are unchanged, they can fluctuate slightly when expressed as a share of GDP.

full simulation (panel 3-1).

Figure 11: Revenue-Based Fiscal Consolidation



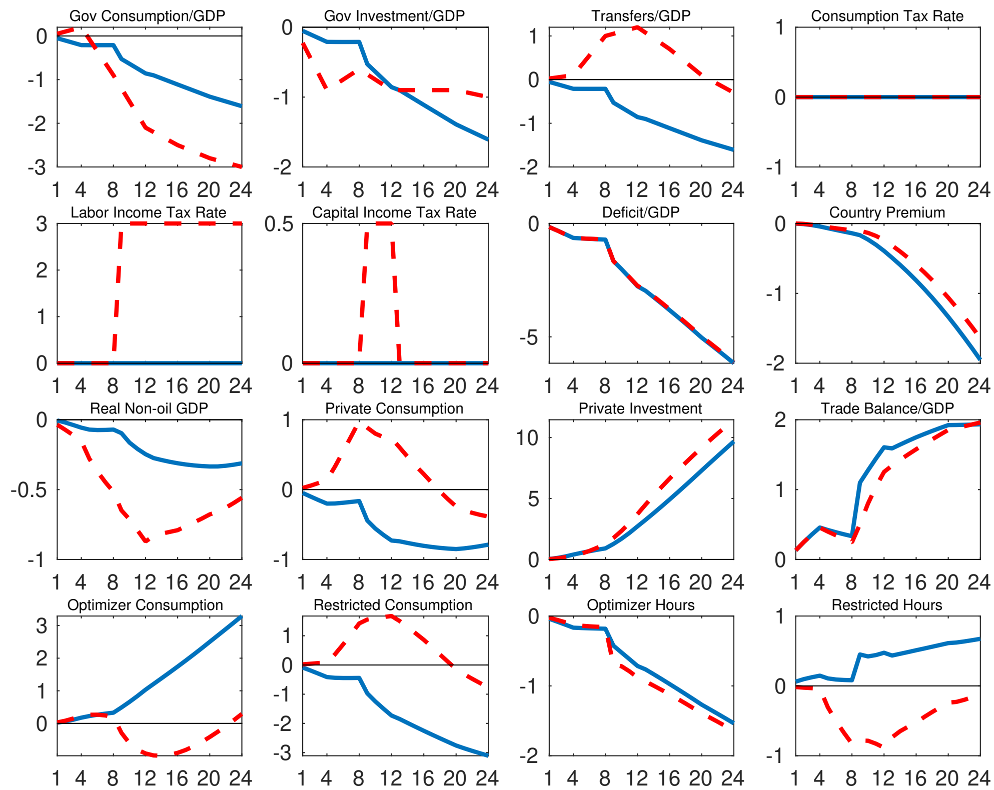
Note: Fiscal consolidation based on adjustments to labor income, capital income, and consumption tax rates (solid blue lines). The adjustment of each tax rate is designed to deliver one third of the improvement in the fiscal deficit achieved under the full fiscal consolidation, described in subsection 6.7, and shown in dashed red lines. X axes denote quarters. Y axes denote percent deviations from steady state, except for variables expressed as ratios to GDP and the country premium, which are expressed as percentage point deviation from steady state. The country premium is annualized.

We now describe our final experiment—an expenditure-based fiscal consolidation. For this exercise, each of the three components of government expenditure declines by a magnitude that achieves one third of the improvement in the primary deficit-to-GDP ratio that occurs under the full fiscal consolidation. The expenditure-based consolidation is a forecast conditioned on trajectories for the three components of government spending, expressed as ratios to GDP, leaving tax rates unchanged. As in the previous simulations, the conditional forecast represents the response of the model economy to a sequence of structural shocks to the fiscal instruments that delivers the desired trajectories.

Figure 12 depicts the results of the expenditure-based consolidation in solid blue lines, and compares them to the effects of the full consolidation, shown in dashed red lines. The plots in the first three columns of the first row show the evolution of the components of government spending (panels 1-1, 1-2, and 1-3). The decline in transfers generates a substantial negative income effect on the restricted, hand-to-mouth households, who reduce consumption (panel 4-2) and increase hours worked (panel 4-4) by more than in the revenue-based consolidation. In the full fiscal consolidation, transfers *increase* to cushion the impact on hand-to-mouth households, so the opposite occurs in that scenario.

The adjustment of government expenditure reduces foreign debt, which leads to a decline of up to 200 bps in the country risk premium (panel 2-4). The lower premium contributes to a substantial expansion in private investment (panel 3-3), which is slightly larger than that under the full consolidation. Such an expansion does not occur under the revenue-based consolidation due to the adverse effects of a higher capital income tax rate in that scenario. The lower country premium also generates an intertemporal substitution effect on optimizing households, who increase consumption (panel 4-1) and reduce hours worked (panel 4-3). However, aggregate private consumption declines (panel 3-2), driven by the behavior of hand-to-mouth households, in contrast to the expansion of aggregate private consumption under the full consolidation. The decline of private consumption under the expenditure-based consolidation is lower than that under the revenue-based consolidation due to the compensating force of higher consumption of optimizing households. Despite the differences with the revenue-based consolidation, the performance of non-oil GDP is similar (panel 3-1) because lower public demand is compensated by the better performance of private demand.

Figure 12: Expenditure-Based Fiscal Consolidation



Alone

Fiscal consolidation based on adjustments to the components of government expenditure—consumption, investment and transfers (solid blue lines). The adjustment of each component is designed to deliver one third of the improvement in the fiscal deficit achieved under the full fiscal consolidation described in subsection 6.7, and shown in dashed red lines. For more details, see the note to figure 11.

7 Conclusion

We provide a rich but tractable DSGE approach to evaluate the macroeconomic effects of fiscal consolidations in small open commodity-exporting countries. The model includes financially constrained and unconstrained households, and the response of the country risk premium to foreign debt is a key transmission mechanism of fiscal adjustment.

The model features six fiscal instruments—three tax rates and three components of government expenditure, which allows us to study alternative strategies to achieve a given improvement in the fiscal balance. To illustrate this potential, we simulated the fiscal adjustment stipulated in an agreement between the government of Ecuador and the IMF, which included tax rate increases and cuts to government consumption and investment, as well as an expansion of government transfers to vulnerable households. We also simulated adjustments based exclusively on higher tax rates (revenue-based consolidation) and on lower government expenditure (expenditure-based consolidation).

The model could be easily calibrated and estimated to match the cyclical dynamics of other commodity-exporting countries in need of evaluating fiscal consolidations. It could also prove useful to study the effect of shocks to commodity prices or other variables that can be amplified or dampened by the response of fiscal policy.

Additional avenues for future research include a more formal treatment of the possibility of sovereign default, and an analysis of the anticipatory effects of fiscal announcements.

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Appendix

A Stationary Equilibrium Conditions

The variables in uppercase contain a unit root in equilibrium due to the presence of the non-stationary productivity index A_t. We need to transform these variables to have a stationary version of the model. To do this, lowercase variables denote the uppercase variable divided by A_{t-1} (e.g. $c_t \equiv \frac{C_t}{A_{t-1}}$). The only exception is the Lagrange multiplier Λ_t, which is multiplied by A_{t-1}^{σ} (i.e. $\lambda_t \equiv \Lambda_t A_{t-1}^{\sigma}$), for it decreases along the balanced growth path.

The rational expectations equilibrium of the stationary version of the model model is the set of 45 sequences

$$\{\lambda_t^o, \hat{c}_t^o, c_t^o, h_t^o, i_t^o, k_t^o, f_t^{*o}, \Theta_t^o, \widetilde{\chi}_t^o, \lambda_t^r, \hat{c}_t^r, c_t^r, h_t^r, \Theta_t^r, \widetilde{\chi}_t^r, c_t, h_t, i_t, k_t, f_t^*, q_t, w_t, r_t^K, y_t, y_t^C, y_t^F\}$$

$$\{y_t^H, x_t^F, x_t^H, x_t^{H*}, \pi_t, p_t^H, p_t, tb_t, \xi_t, b_t^*, \tau_t^k, \tau_t^n, \tau_t^c, k_t^g, g_t^c, g_t^i, tr_t, tr_t^o, tr_t^r\},$$

such that for given initial values and 11 exogenous sequences

$$\{\upsilon_t, \kappa_t^o, \kappa_t^r, u_t, z_t, a_t, \zeta_t, R_t^*, p_t^{Co*}, y_t^{Co}, y_t^*\}$$

the following conditions are satisfied:
Optimizer consumption first order condition:

$$\lambda_t^o(1+\tau_t^c)p_t = \hat{c}_t^{o^{-\sigma}} \left(\frac{(1-o_c)\hat{c}_t^o}{c_t^o - \varsigma \frac{c_{t-1}^o}{a_{t-1}}} \right)^{\frac{1}{\eta_c}} \tag{E.1}$$

Restricted consumption first order condition:

$$\lambda_t^r(1+\tau_t^c)p_t = \hat{c}_t^{r^{-\sigma}} \left(\frac{(1-o_c)\hat{c}_t^r}{c_t^r - \varsigma \frac{c_{t-1}^r}{a_{t-1}}} \right)^{\frac{1}{\eta_c}} \tag{E.2}$$

Consumption aggregation:

$$c_t = (1-\omega)c_t^o + \omega c_t^r \tag{E.3}$$

Optimizer hours first order condition:

$$(1-\tau_t^n)w_t = \Theta_t^o \kappa_t^o \frac{h_t^{o^{\phi}}}{\lambda_t^o} \tag{E.4}$$

Restricted hours first order condition:

$$w_t = \Theta_t^r \kappa_t^r \frac{h_t^{r^{\phi}}}{\lambda_t^r} \tag{E.5}$$

Hours aggregation:

$$h_t = (1-\omega)h_t^o + \omega h_t^r \tag{E.6}$$

Optimizer debt first order condition:

$$\lambda_t^o = \frac{\beta}{a_t^\sigma} R_t^* \xi_t E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \lambda_{t+1}^o \right\}, \tag{E.7}$$

Final good production function:

$$y_t^C = \left[(1-o)^{\frac{1}{\eta}} \left(x_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}} \left(x_t^F\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{E.8}$$

Foreign good first order condition:

$$x_t^F = o \left(\frac{1}{p_t} \right)^{-\eta} y_t^C, \tag{E.9}$$

Home good first order condition:

$$x_t^H = (1-o) \left(\frac{p_t^H}{p_t} \right)^{-\eta} y_t^C, \tag{E.10}$$

Foreign demand for home goods:

$$x_t^{H*} = o^* \left(p_t^H\right)^{-\eta^*} y_t^*, \tag{E.11}$$

Home good production function:

$$y_t^H = z_t \left(\frac{k_{gt-1}}{a_{t-1}} \right)^\gamma \left(\frac{k_{t-1}}{a_{t-1}} \right)^\alpha (a_t h_t)^{1-\alpha-\gamma}, \tag{E.12}$$

Home good market clearing:

$$y_t^H = x_t^H + x_t^{H*}, \tag{E.13}$$

Final good market clearing:

$$y_t^C = c_t + i_t + g_t^c + g_t^i, \tag{E.14}$$

Defenition of GDP:

$$y_t = p_t \left(c_t + i_t + g_t^c + g_t^i \right) + tb_t = p_t^H y_t^H + p_t^{Co*} y_t^{Co}, \tag{E.15}$$

Defenition of trade balance:

$$tb_t = p_t^H x_t^{H*} + p_t^{Co*} y_t^{Co} - y_t^F, \tag{E.16}$$

Private debt aggregation:

$$f_t^* = (1-\omega) f_t^{o*} \tag{E.17}$$

Balance of payments:

$$(f_t^* + b_t^*) = \frac{(f_{t-1}^* + b_{t-1}^*)}{a_{t-1}} R_{t-1}^* \xi_{t-1} - tb_t + (1-\chi) p_t^{Co*} y_t^{Co}, \tag{E.18}$$

Country premium:

$$\xi_t = \bar{\xi} \exp\left[\psi \frac{(f_t^* + b_t^*)/y - (\bar{f}^* + \bar{b}^*)}{\bar{f}^* + \bar{b}^*} + \frac{\zeta_t - \bar{\zeta}}{\bar{\zeta}}\right], \tag{E.19}$$

Evolution of private capital:

$$k_t^o = (1-\delta)\frac{k_{t-1}^o}{a_{t-1}} + \left[1 - \frac{\gamma_k}{2}\left(\frac{i_t^o}{i_{t-1}^o} a_{t-1} - \bar{a}\right)^2\right] u_t i_t^o, \tag{E.20}$$

Private capital aggregation:

$$k_t = (1-\omega) k_t^o \tag{E.21}$$

Private investment aggregation:

$$i_t = (1-\omega) i_t^o \tag{E.22}$$

Optimizer capital first order condition:

$$q_t = \frac{\beta}{a_t^\sigma} E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}^o}{\lambda_t^o} \left[(1-\tau_{t+1}^k) r_{t+1}^K + \tau_{t+1}^k \delta + q_{t+1}(1-\delta) \right] \right\}, \tag{E.23}$$

Marginal product of capital:

$$r_t^K = p_t^H \alpha \frac{y_t^H}{k_{t-1}} a_{t-1}, \tag{E.24}$$

Marginal product of labor:

$$w_t = p_t^H (1-\alpha-\gamma) \frac{y_t^H}{h_t}, \tag{E.25}$$

Optimizer investment first order condition:

$$\begin{aligned} \frac{p_t}{q_t} \;=\; & \left[1 - \frac{\gamma_k}{2}\left(\frac{i_t^o}{i_{t-1}^o} a_{t-1} - \bar{a}\right)^2 - \gamma_k \left(\frac{i_t^o}{i_{t-1}^o} a_{t-1} - \bar{a}\right) \frac{i_t^o}{i_{t-1}^o} a_{t-1}\right] u_t \\ & + \frac{\beta}{a_t^\sigma} \gamma_k E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \frac{q_{t+1}}{q_t} \left(\frac{i_{t+1}^o}{i_t^o} a_t - \bar{a}\right) \left(\frac{i_{t+1}^o}{i_t^o} a_t\right)^2 u_{t+1} \right\}, \end{aligned} \tag{E.26}$$

Foreign good market clearing:

$$y_t^F = x_t^F. \tag{E.27}$$

Defenition of optimizer consumption bundle:

$$\hat{c}_t^o = \left[(1-o_c)^{\frac{1}{\eta_c}} \left(c_t^o - \varsigma \frac{c_{t-1}^o}{a_{t-1}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(g_t^c\right)^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}} \tag{E.28}$$

Defenition of restricted consumption bundle:

$$\hat{c}_t^r = \left[(1-o_c)^{\frac{1}{\eta_c}} \left(c_t^r - \varsigma \frac{c_{t-1}^r}{a_{t-1}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(g_t^c \right)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}} \tag{E.29}$$

Optimizer wealth effect parameter 1:

$$\Theta_t^o = \widetilde{\chi}_t^o \left(\left[(1-o_c)^{\frac{1}{\eta_c}} \left(c_t^o - \varsigma \frac{c_{t-1}^o}{a_{t-1}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(\bar{g}^c \right)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}} \right)^{-\sigma}. \tag{E.30}$$

Optimizer wealth effect parameter 2:

$$\widetilde{\chi}_t^o = \widetilde{\chi}_{t-1}^{o\,1-\upsilon} \left(\left[(1-o_c)^{\frac{1}{\eta_c}} \left(c_t^o - \varsigma \frac{c_{t-1}^o}{a_{t-1}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(\bar{g}^c \right)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}} \right)^{\sigma\upsilon} \tag{E.31}$$

Restricted wealth effect parameter 1:

$$\Theta_t^r = \widetilde{\chi}_t^o \left(\left[(1-o_c)^{\frac{1}{\eta_c}} \left(c_t^r - \varsigma \frac{c_{t-1}^r}{a_{t-1}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(\bar{g}^c \right)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}} \right)^{-\sigma}. \tag{E.32}$$

Restricted wealth effect parameter 2:

$$\widetilde{\chi}_t^r = \widetilde{\chi}_{t-1}^{r\,1-\upsilon} \left(\left[(1-o_c)^{\frac{1}{\eta_c}} \left(c_t^r - \varsigma \frac{c_{t-1}^r}{a_{t-1}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} \left(\bar{g}^c \right)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}} \right)^{\sigma\upsilon} \tag{E.33}$$

Government budget constraint:

$$p_t g_t^c + p_t g_t^i + R_{t-1}^* \xi_{t-1} \frac{b_{t-1}^*}{a_{t-1}} + tr_t = \chi p_t^{Co*} y_t^{Co} + b_t^* + \tau_t^n w_t (1-\omega) h_t^o + \tau_t^k (r_t^k - \delta) \frac{k_{t-1}}{a_{t-1}} + \tau_t^c p_t c_t + (1-\omega) T \tag{E.34}$$

Transfers to optimizer households:

$$tr_t^o = \frac{1-\omega^G}{1-\omega} tr_t \tag{E.35}$$

Transfers to restricted households:

$$tr_t^r = \frac{\omega^G}{\omega} tr_t \tag{E.36}$$

Home good producer profits

$$\pi_t = \pi_t^H = p_t^H \gamma y_t^H \tag{E.37}$$

Government capital evolution:

$$k_t^g = (1-\delta_g)\frac{k_{t-1}^g}{a_{t-1}} + g_t^i \tag{E.38}$$

Consumption tax:

$$\tau_t^c = \tilde{\tau}^c \tag{E.39}$$

Labor income tax:

$$\tau_t^n = \tilde{\tau}^n \tag{E.40}$$

Capital income tax:

$$\tau_t^k = \tilde{\tau}^k \tag{E.41}$$

Government investment spending rule:

$$g_t^i = \left(g_{t-1}^i\right)^{\rho_{gA}} \left(\bar{g}^i \left(\frac{y_t}{y}\right)^{\alpha_{gi}} \left(\frac{b_{t-1}^*/y_{t-1}}{\bar{b}}\right)^{-\gamma_{gi}}\right)^{1-\rho_{gi}} \exp(e_t^{gi}) \tag{E.42}$$

Consumption spending investment rule:

$$g_t^c = \left(g_{t-1}^c\right)^{\rho_{gc}} \left(\bar{g}^c \left(\frac{y_t}{y}\right)^{\alpha_{gc}} \left(\frac{b_{t-1}^*/y_{t-1}}{\bar{b}}\right)^{-\gamma_{gc}}\right)^{1-\rho_{gc}} \exp(e_t^{gc}) \tag{E.43}$$

Transfers spending rule:

$$tr_t = \left(tr_{t-1}\right)^{\rho_{tr}} \left(\bar{tr} \left(\frac{y_t}{y}\right)^{\alpha_{tr}} \left(\frac{b_{t-1}^*/y_{t-1}}{\bar{b}}\right)^{-\gamma_{tr}}\right)^{1-\rho_{tr}} \exp(e_t^{tr}) \tag{E.44}$$

Restricted budget constraint:

$$(1+\tau_t^c)p_t c_t^r = w_t h_t^r + tr_t^r \tag{E.45}$$

The exogenous processes are

$$\log\left(x_t/\bar{x}\right) = \rho_x \log\left(x_{t-1}/\bar{x}\right) + \varepsilon_t^x, \qquad \rho_x \in [0,1), \qquad \bar{x} > 0,$$

for each exogenous sequence x_t, where the ε_t^x are i.i.d. shocks.

B Steady State

We show how to compute the steady state for given values of h^o, h^r, p, $i_r = g^i/i$, $s^f = f^*/y$, $s^g = pg^c/y$, $s^P = p^{Co*}y^{Co}/y$, $\bar{b} = b^*/y$,$s^{tr} = tr/y$, and $\xi = \bar{\xi}$. The parameters β, $\bar{\kappa}^o$,$\bar{\kappa}^r$, o^*, $\bar{g}^c$, $\bar{g}^A$, $(\bar{f}^* + \bar{b}^*)$,T, $\bar{tr}$, and $\bar{y}^{Co}$ are determined endogenously while the values of the remaining parameters are exogenous. All exogenous variables are equal to their "bar" values in steady state.

From (E.7),

$$\beta = \bar{a}^{\sigma}/(\bar{R}^{*}\bar{\xi}).$$

From (E.6)

$$h = (1-\omega)h^{o} + \omega h^{r}.$$

From (E.26) and the fact that we calibrate $\bar{u}$ to 1,

$$q = p.$$

From (E.39) - (E.41)

$$\tau^{k} = \bar{\tau}^{k}$$
$$\tau^{n} = \bar{\tau}^{n}$$
$$\tau^{c} = \bar{\tau}^{c}$$

From (E.23),

$$r^{K} = \frac{q\left(\frac{\bar{a}^{\sigma}}{\beta} - 1 + \delta\right) - \tau^{k}\delta}{1-\tau^{k}}.$$

Plugging (E.9) and (E.10) in (E.8),

$$p^{H} = p\left[\frac{1}{1-o}\left(1 - o\left(\frac{1}{p}\right)^{1-\eta}\right)\right]^{\frac{1}{1-\eta}}.$$

We now perform the following steps to derive $y^{H}, k, k^{g}, i, g^{i}, i^{o}$,and k^{o}.
From (E.38)

$$k^{g} = \frac{g^{i}}{1 - \frac{(1-\delta_{g})}{\bar{a}}}.$$

From (E.20) and $\bar{u} = 1$,

$$k^{o} = \frac{i^{o}}{1 - \frac{1-\delta}{\bar{a}}}.$$

From (E.21),

$$k = k^{o}(1-\omega).$$

From (E.22),

$$i^{o} = i/(1-\omega)$$

Combining these results yields

$$k_{r} \equiv \frac{k^{g}}{k} = i_{r}\frac{1 - \frac{1-\delta}{\bar{a}}}{1 - \frac{1-\delta_{g}}{\bar{a}}}.$$

This result along with equations (E.12) and (E.24) form a system in y^{H}, k, and k^{g} which gives

$$y^H = \left(\bar{z}\left(k_r \frac{p^H \alpha}{r^k}\right)^\gamma \left(\frac{p^H \alpha}{r^K}\right)^\alpha (\bar{a}h)^{1-\alpha-\gamma}\right)^{\frac{1}{1-\alpha-\gamma}}$$

$$k = p^H \alpha \frac{y^H}{r^K}\bar{a},$$

$$k^g = k_r k.$$

Then substituting in these results yields

$$g^i = \left(1 - \frac{1-\delta_g}{\bar{a}}\right) k^g$$

$$k^o = k/(1-\omega),$$

$$i^o = \left(1 - \frac{1-\delta}{a}\right) k^o,$$

$$i = (1-\omega) i^o.$$

From (E.25),

$$w = p^H (1-\alpha-\gamma)\frac{y^H}{h}.$$

Equations (E.15) and the definition of the share of commodity output in GDP, $s^P = (p^{Co*}y^{Co})/y$, form a system in y and $\bar{y}^{Co}$, which gives

$$y = \frac{p^H y^H}{1 - s^{Co}}$$

$$\bar{y}^{Co} = \frac{s^{Co} y}{p^{Co*}}.$$

From $s^g = pg^c/y$,

$$g^c = s^g y/p.$$

From (E.42) and the assumption $\bar{b} = b^*/y$,

$$\bar{g}^i = g^i.$$

From (E.43) and the assumption $\bar{b} = b^*/y$,

$$\bar{g}^c = g^c.$$

From $\bar{b} = b^*/y$

$$b^* = \bar{b}y$$

From $\bar{f} = f^*/y$,

$$f^* = \bar{f}y.$$

From (E.17),

$$f^{o*} = \frac{f^*}{1-\omega}$$

From (E.18),

$$tb = (1-\chi) * p^{Co\star} y^{Co} - \left(1 - \frac{\bar{R}^* \bar{\xi}}{\bar{a}}\right)(f^* + b^*).$$

From (E.19) and $\xi = \bar{\xi}$,

$$(\bar{f}^* + \bar{b}^*) = \frac{f^* + b^*}{y}.$$

From the definition of GDP as the sum of domestic absorption and the trade balance (E.15),

$$c = \frac{y - tb}{p} - i - g^c - g^i.$$

From (E.14),

$$y^C = c + i + g^c + g^i$$

From (E.9),

$$x^F = o\left(\frac{1}{p}\right)^{-\eta} y^C.$$

From (E.10),

$$x^H = (1-o)\left(\frac{p^H}{p}\right)^{-\eta} y^C.$$

From (E.27),

$$y^F = x^F.$$

From (E.16),

$$x^{H*} = \frac{tb - \bar{p}^{Co*} y^{Co} + y^F}{p^H}.$$

From (E.11),

$$o^* = \frac{x^{H*}}{(p^H)^{-\eta*}\, \bar{y}^*}.$$

From (E.37),

$$\pi = p^H \gamma Y^H.$$

From the defenition of s^{tr},

$$tr = s^{tr} y$$

From (E.34),

$$T = \frac{\chi p^{Co*} y^{Co} - R^* \bar{\xi} \frac{b^*}{\bar{a}} + \tau^n W(1-\omega)h^0 + \tau^k (r^k - \delta)\frac{k}{\bar{a}} + \tau^c pc + \tau^\pi \pi - pg^c - pg^i + b^* - tr}{1-\omega}.$$

From (E.44),

$$\bar{tr} = tr.$$

From (E.35)-(E.36),

$$tr^o = \frac{1-\omega^G}{1-\omega} tr$$

$$tr^r = \frac{\omega^G}{\omega} tr.$$

From (E.45)

$$c^r = \frac{wh^r + tr^r}{(1+\tau^c)p}.$$

From (E.3),

$$c^o = \frac{c - \omega c^r}{1-\omega}.$$

From (E.28),

$$\hat{c}^o = \left[(1-o_c)^{\frac{1}{\eta_c}} \left(c^o - \varsigma \frac{c^o}{\bar{a}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} (g^c)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}.$$

From (E.29),

$$\hat{c}^r = \left[(1-o_c)^{\frac{1}{\eta_c}} \left(c^r - \varsigma \frac{c^r}{\bar{a}} \right)^{\frac{\eta_c - 1}{\eta_c}} + o_c^{\frac{1}{\eta_c}} (g^c)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}.$$

From (E.31),

$$\widetilde{\chi}^o = \hat{c}^{o^\sigma}.$$

From (E.33),

$$\widetilde{\chi}^r = \hat{c}^{r^\sigma}.$$

From (E.30),

$$\Theta^o = 1.$$

From (E.32),

$$\Theta^r = 1.$$

From (E.1),

$$\lambda^o = \frac{\hat{c}^{o^{-\sigma}}}{(1+\tau^c)p} \left(\frac{(1-o_c)\hat{c}^o}{c^o - \varsigma \frac{c^o}{\bar{a}}} \right)^{\frac{1}{\eta_c}}.$$

From (E.2),

$$\lambda^r = \frac{\hat{c}^{r^{-\sigma}}}{(1+\tau^c)p} \left(\frac{(1-o_c)\hat{c}^r}{c^r - \varsigma \frac{c^r}{\bar{a}}} \right)^{\frac{1}{\eta_c}}.$$

From (E.4)

$$\bar{\kappa}^o = \frac{\lambda^o (1-\tilde{\tau}^n) w}{h^{o^\phi}}.$$

From (E.5)

$$\bar{\kappa}^r = \frac{\lambda^r w}{h^{r^\phi}}.$$

C Data Details

This section describes the data used, their sources, and the transformations we performed in order to estimate the model. The variables are as follows:

- Non oil GDP in current dollars: From the Central Bank of Ecuador's (CBE) national accounts bulletin. We deflate the data with the U.S. GDP price deflator and obtain quarter-over-quarter percent growth rates.

- Household consumption in current dollars: From the CBE's national accounts bulletin. We deflate the data with the U.S. GDP price deflator and obtain quarter-over-quarter percent growth rates.

- Total investment in current dollars: From the CBE's national accounts bulletin. We deflate the data with the U.S. GDP price deflator and obtain quarter-over-quarter percent growth rates.

- Oil production in current dollars: From the CBE's national accounts bulletin. We divide the oil GDP by the quarterly average oil price and apply the Hodrick and Prescott filter with $\lambda = 1600$ to obtain the cycle of that series in logs.

- Hours worked in current dollars: From the National Institute of Statistics and Censuses (NISC). We adjust the quarterly average weekly hours by the employment rate and divide by 120 hours, which is the total number of hours a week a person could work Monday through Friday. We then apply the Hodrick and Prescott filter with $\lambda = 1600$ to obtain the cycle of that series in logs.

- Government consumption spending in current dollars: From the CBE's national accounts bulletin. We deflate the data with the U.S. GDP price deflator and obtain quarter-over-quarter percent growth rates.

- Government investment spending in current dollars: From the CBE's monthly statistical information. We aggregate the monthly data to quarterly and then deflate the data with the U.S. GDP price deflator and obtain quarter-over-quarter percent growth rates.

- Government transfers in current dollars: From the CBE's monthly statistical information. We aggregate the monthly data to quarterly and then deflate the data with the U.S. GDP price deflator and obtain quarter-over-quarter percent growth rates.

- Trade balance in current dollars: From the CBE's national accounts bulletin. We divide by nominal GDP.

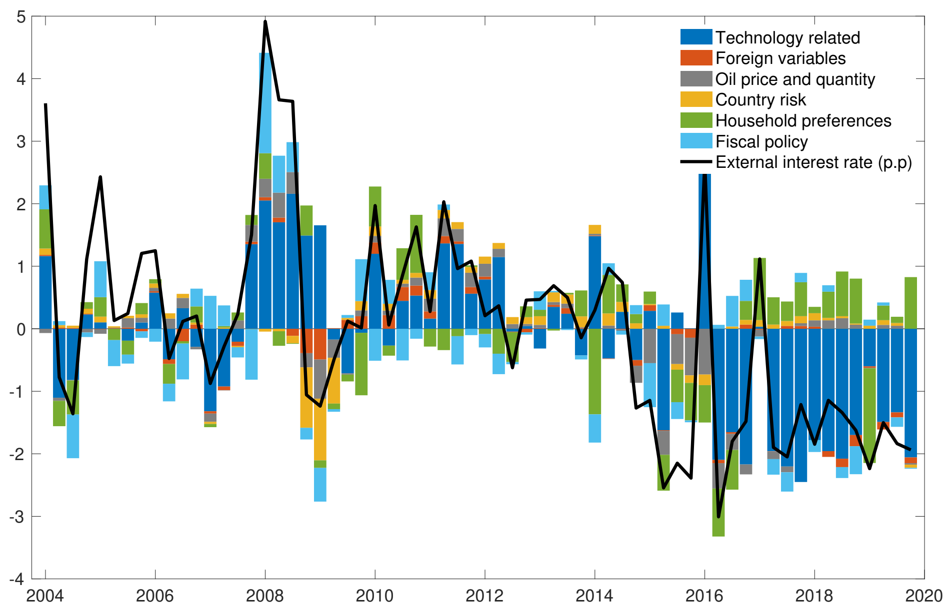
- 3-month Treasury bill rate: From the Federal Reserve Economic Database (FRED). We aggregate the monthly data to quarterly and obtain the equivalent quarterly gross rate. We then subtract the quarter-over-quarter U.S. inflation gross rate from the U.S. GDP price deflator.

- World GDP: From the OECD Statistics. We take the quarter-over-quarter growth rate of the G20 real GDP, compound the rate to obtain a level series, and then apply the Hodrick and Prescott filter with $\lambda = 1600$ to obtain the cycle of that series in logs.
- Oil price in current dollars: From the CBE's monthly statistical information. We aggregate the monthly data to quarterly, deflate the data with the U.S. GDP price deflator, and then apply the Hodrick and Prescott filter with $\lambda = 1600$ to obtain the cycle of that series in logs.
- EMBI: From the CBE's monthly statistical information. We aggregate the monthly data to quarterly, divide by 10,000 and add one to make it gross, and then obtain the equivalent quarterly gross rate.
- U.S. GDP price deflator: From the FRED database.

We demean all the series.

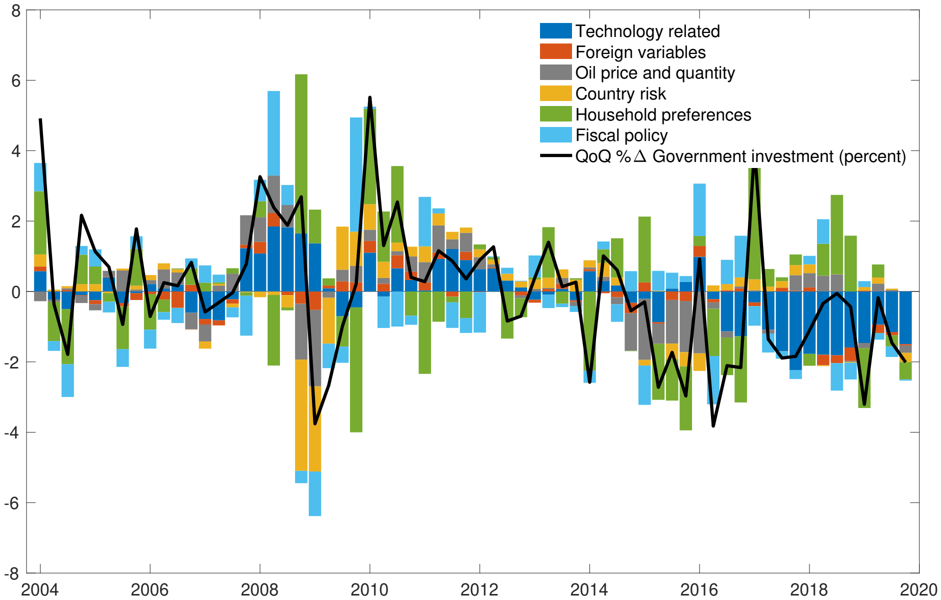
D Shock Decomposition for Observables

Figure D.1: Historical Shock Decomposition for Non-Oil GDP Growth Rate



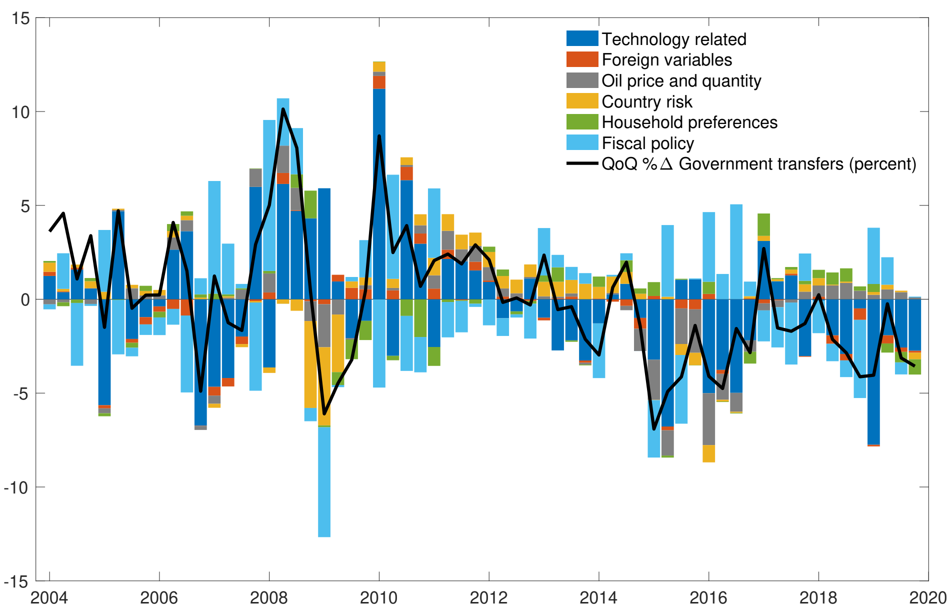
The black line is the observed variable. The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.2: Historical Shock Decomposition for Private Consumtpion Growth Rate



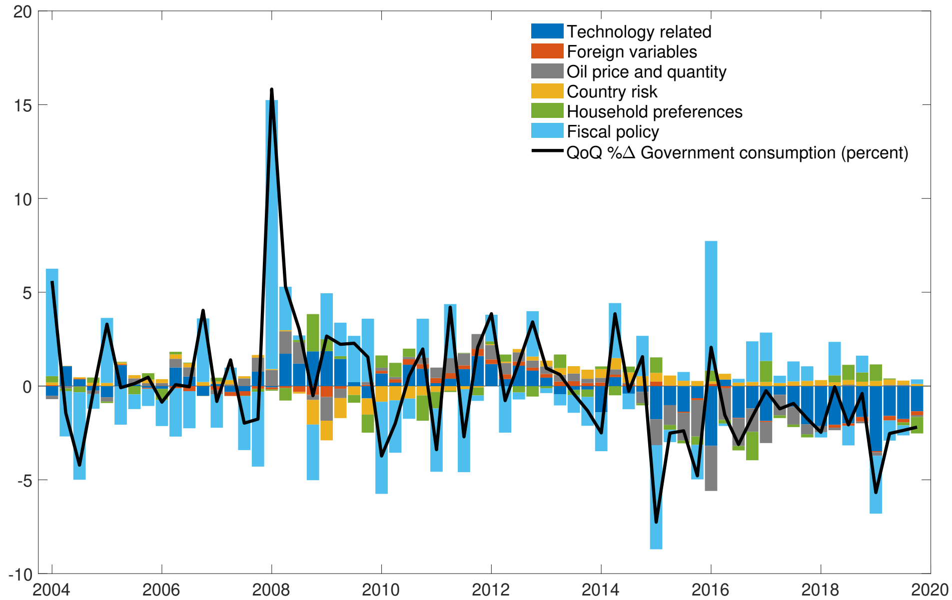
The black line is the observed variable. The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.3: Historical Shock Decomposition for Total Investment Growth Rate



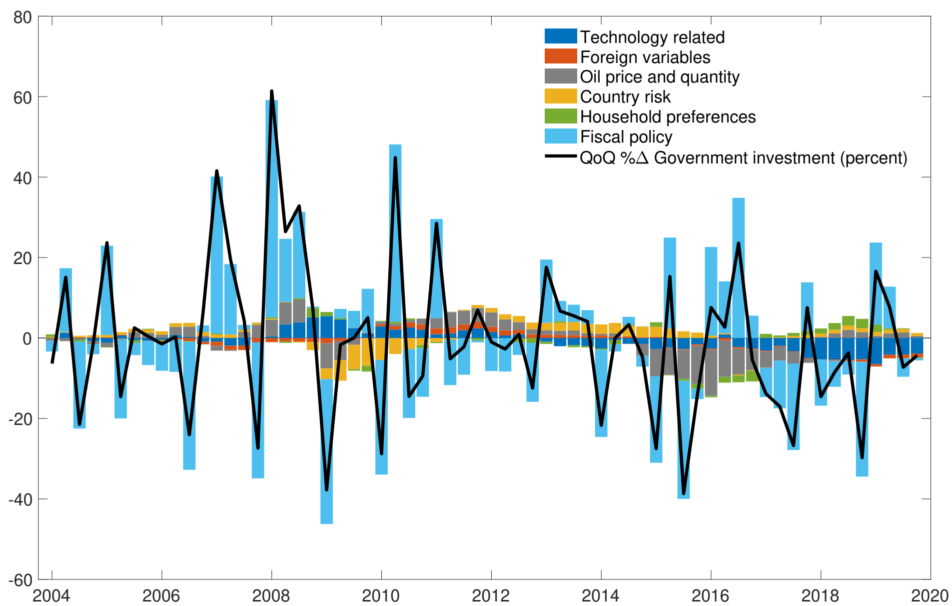
The black line is the observed variable. The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.4: Historical Shock Decomposition for Government Consumption Growth Rate



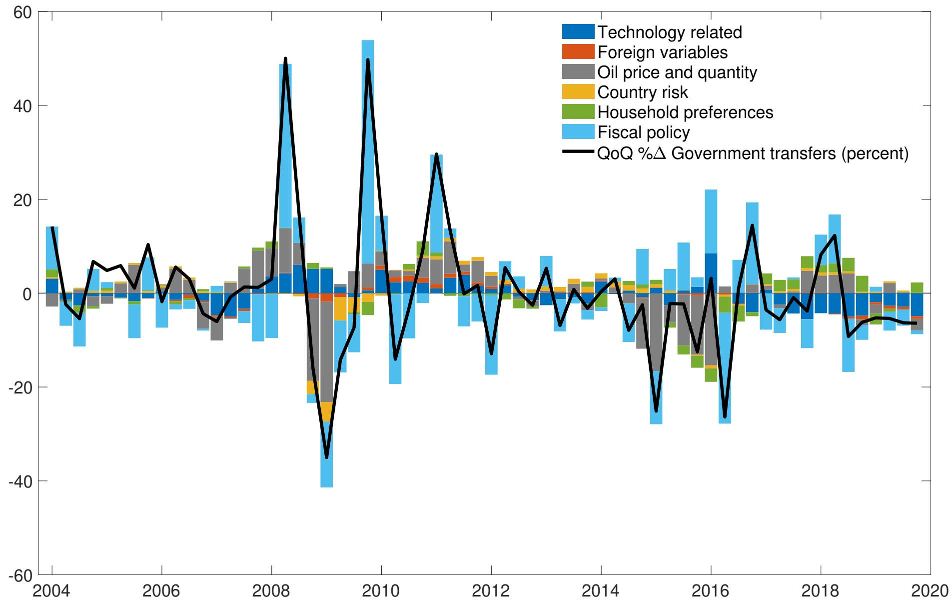
The black line is the observed variable. The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.5: Historical Shock Decomposition for Government Investment Growth Rate



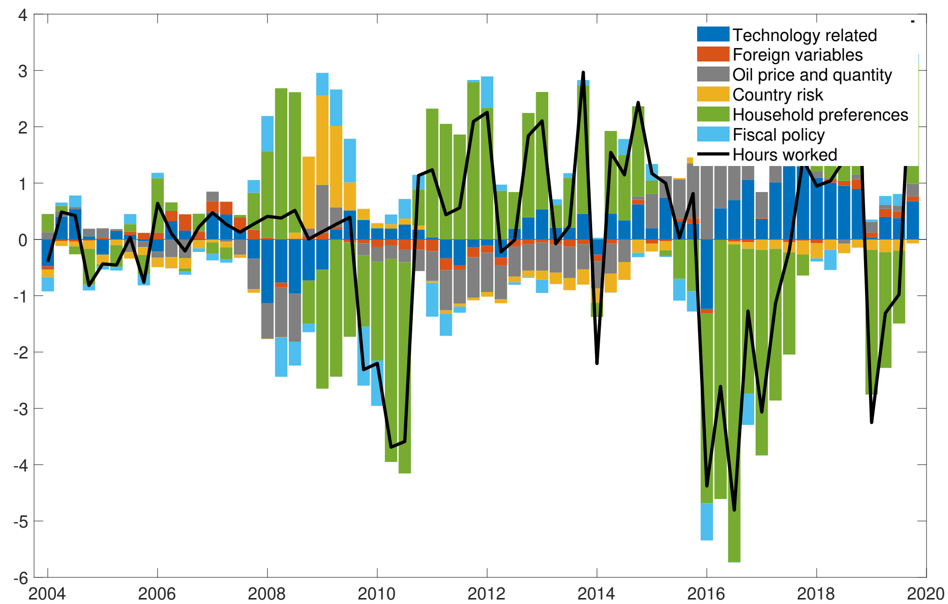
The black line is the observed variable.The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.6: Historical Shock Decomposition for Transfers Growth Rate



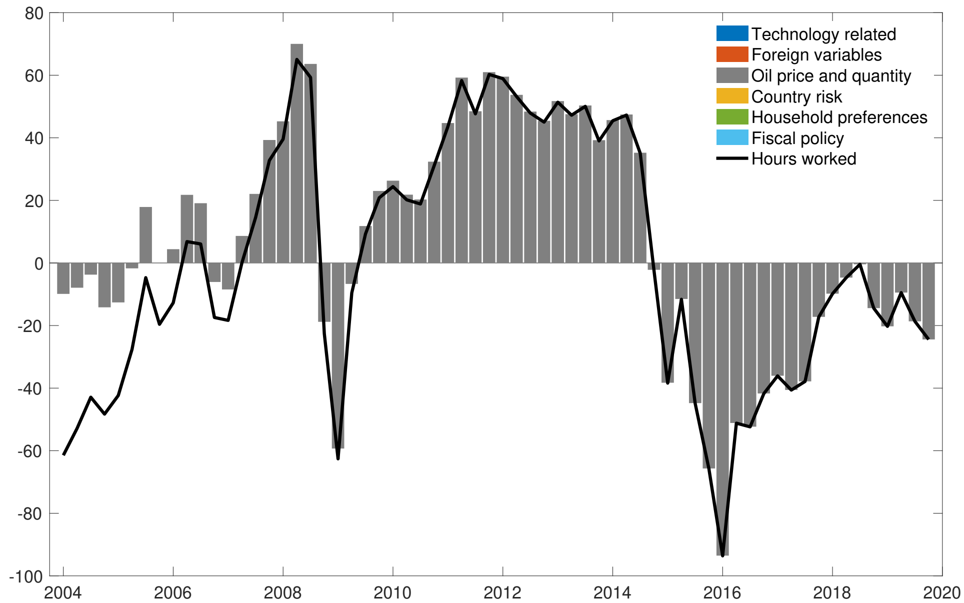
The black line is the observed variable. The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.7: Historical Shock Decomposition for Hours



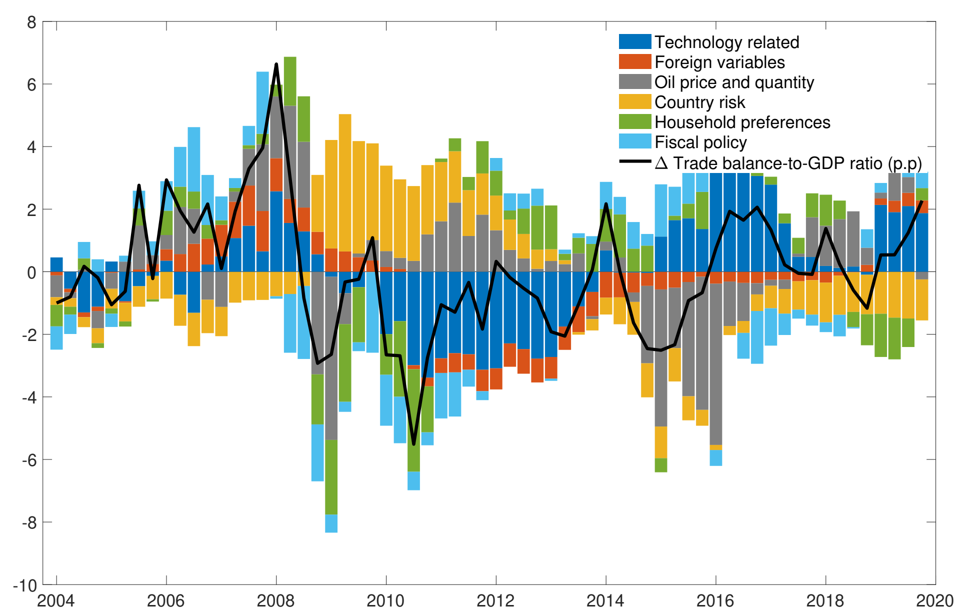
The black line is the observed variable. The y-axis is percent deviation from steady state and the x-axis is quarters.

Figure D.8: Historical Shock Decomposition for Oil Price



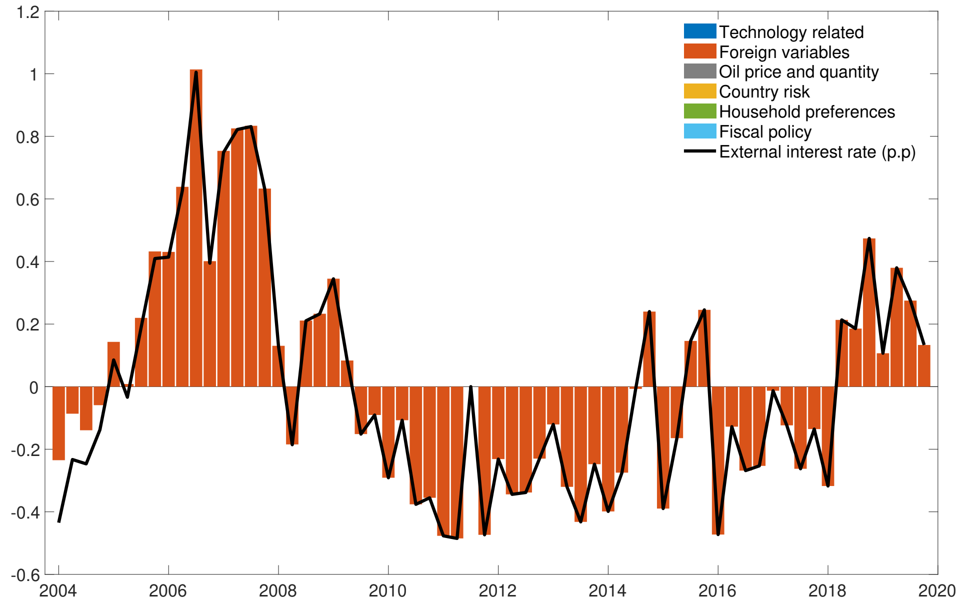
The black line is the observed variable.The y-axis is percent deviation from steady state and the x-axis is quarters.

Figure D.9: Historical Shock Decomposition for Trade Balance to GDP Ratio



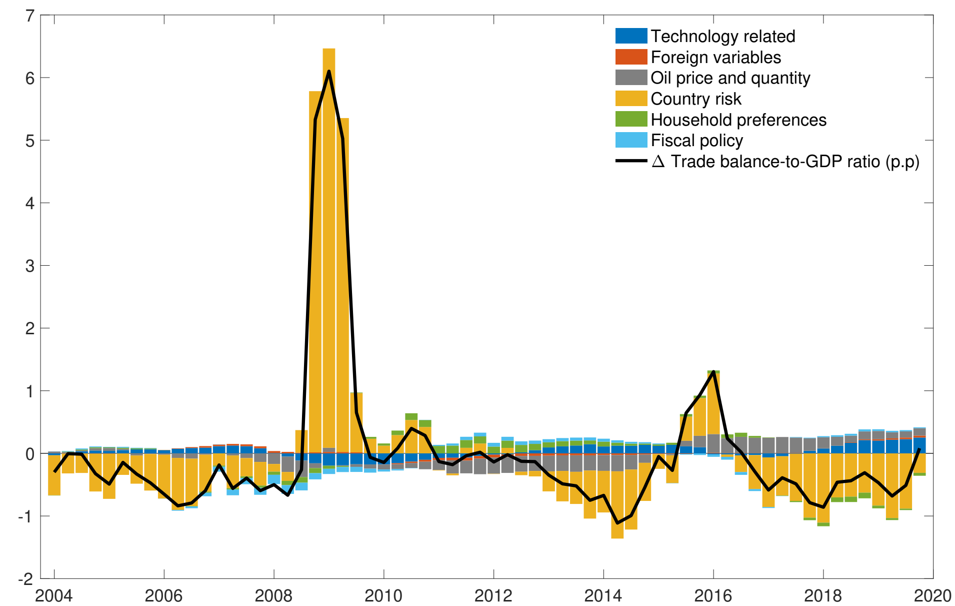
The black line is the observed variable. The y-axis is percentage point deviation from steady state and the x-axis is quarters.

Figure D.10: Historical Shock Decomposition for Foreign Interest Rate



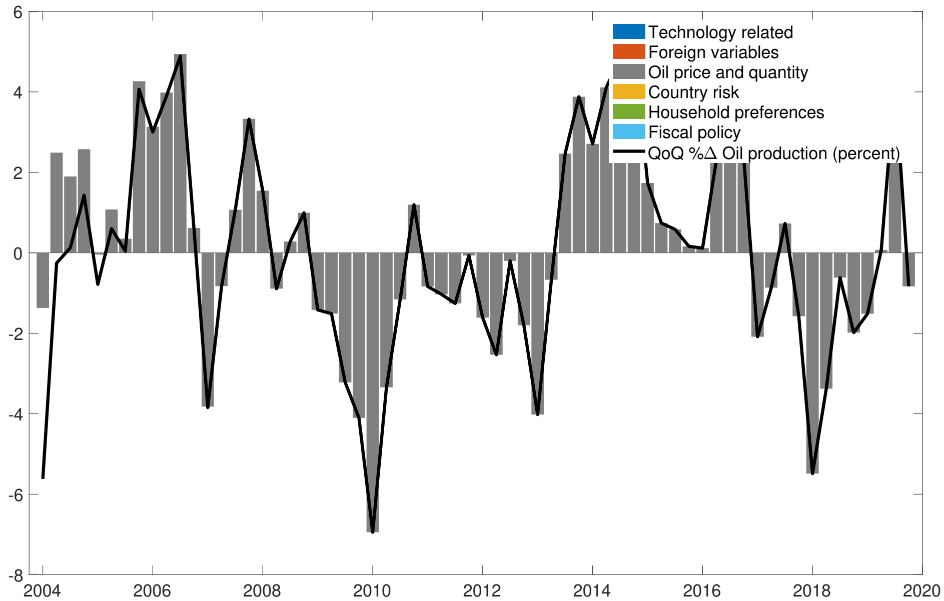
The black line is the observed variable. The y-axis is percent deviation from steady state and the x-axis is quarters.

Figure D.11: Historical Shock Decomposition for Country Premium



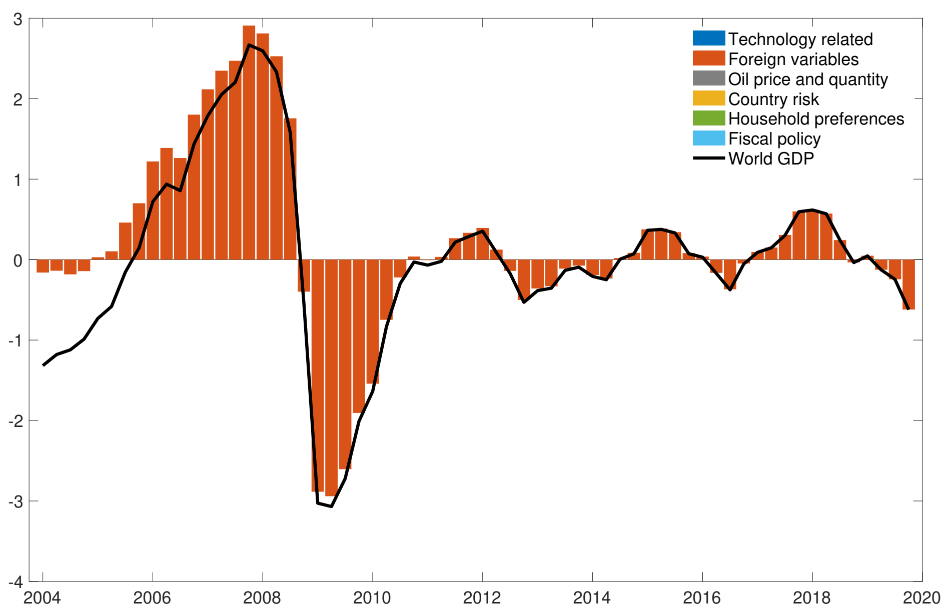
The black line is the observed variable. The y-axis is percent deviation from steady state and the x-axis is quarters.

Figure D.12: Historical Shock Decomposition for Oil Quantity



The black line is the observed variable. The y-axis is percent deviation from steady state and the x-axis is quarters.

Figure D.13: Historical Shock Decomposition for Foreign GDP



The black line is the observed variable. The y-axis is percent deviation from steady state and the x-axis is quarters.

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