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Estimating Fiscal Multipliers Under Alternative Exchange Rate Regimes

The Case of Bolivia

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ABSTRACT: Empirical (employing the Blanchard-Perotti framework) and modeling (using a country-specific DSGE model) approaches are used to estimate fiscal multipliers by policy instrument for Bolivia, to evaluate possible adjustments in a fiscal consolidation strategy. Multipliers are also estimated using alternative assumptions about the accompanying exchange rate regime and capital mobility, highlighting the importance of the policy mix in determining the impact of fiscal adjustments. The study exploits the DSGE modeling structure to assess this interaction of fiscal and monetary policy in a lower middle-income country under different exchange rate regimes. It finds that expenditure multipliers fall into the range of 1/3 to 2/3, with public investment multipliers slightly higher than government consumption multipliers over longer horizons, and multipliers generally higher under a peg than inflation targeting. Tax multipliers are shown to be about half of expenditure multipliers.

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Executive Summary

Developing countries often require clear, well-planned, fiscal consolidation to restore economic stability. Countries have an interest in minimizing the growth cost of this adjustment, which may vary depending on the fiscal instruments deployed and the choice of monetary/exchange rate policy. To assess the potential tradeoff between fiscal savings and growth, we use empirical (employing the Blanchard-Perotti framework) and DSGE modeling approaches to estimate fiscal multipliers by policy instrument for Bolivia, a lower middle income commodity exporter with a *de facto* pegged exchange rate regime. The study exploits the DSGE modeling structure to arrive at a preliminary assessment of this interaction of fiscal and monetary policy in a low middle income country under different exchange rate regimes.

Fiscal multipliers depend in part on the accompanying monetary/exchange rate policy. In the basic Mundell-Fleming framework, fiscal multipliers are normally higher under a peg than with a floating exchange rate. However, this ordering can be reversed if capital mobility is sufficiently low, because the current account gap resulting from a fiscal expansion under a fixed exchange rate requires a large interest rate increase to attract sufficient compensating capital inflows if mobility is low, slowing the economy. Low capital mobility could be due to a sudden stop, financial market restrictions or other factors, and may be quite common in practice.

Estimates of fiscal multipliers in the literature are typically lower for developing countries than for advanced economies, possibly reflecting greater capital mobility and higher policy credibility in the latter. While there is substantial variation, spending multipliers for emerging market economies average around 1/3 – 2/3, whereas estimates for advanced economies average around 1/2 - 1. To the extent that these are available, estimates for tax multipliers are typically lower for most economies, at about half of spending multipliers.

We find that multipliers in Bolivia are in line with ranges presented in the literature for developing countries. Within limits imposed by data availability and structural breaks, empirical analysis using the Blanchard-Perotti structural VAR approach over the period 1990-2022 indicates that spending multipliers are higher for public investment than for current spending, with public investment multipliers estimated at more than 0.5 on a cumulative basis and those for public consumption at about 0.3.[1]

DSGE modeling allows for more detailed differentiation of multipliers by fiscal instrument and monetary/exchange rate policy and also provides more intuition about underlying mechanisms driving the results. Using a full neo-Keynesian model calibrated to lower middle-income country and – wherever possible – Bolivian averages, we obtain fiscal multipliers within the range suggested by the literature and the empirical exercise. Multipliers for public investment and current spending are similar on impact, at about 0.65, although public investment multipliers are somewhat higher than current spending multipliers in the longer run, as output responds to the increase in the public capital stock from accumulated public investment. Tax multipliers are about half of spending multipliers, consistent with the literature. As in the basic Mundell-Fleming model, multipliers are higher under a peg than a float, given normally high capital mobility. Also as in the basic model, this ordering reverses under very low capital mobility.

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[1] The empirical analysis focuses on spending multipliers. Since tax revenues are highly dependent on commodity revenues, estimation of tax multipliers for commodity exporters such as Bolivia is subject to wide confidence intervals.

For developing countries facing fiscal challenges, there are some useful policy implications. Revenue enhancements have a role to play in fiscal consolidation, given low tax multipliers. On the spending side, subject to considerations such as legal commitments, spending cuts should fall more heavily on current spending than on public investment, and cuts to the latter should be determined in part by the productivity of specific type of investment under consideration. From the result that multipliers are generally lower with a float than a peg, it follows that to minimize the output cost associated with an adjustment program, there may be a benefit to matching spending cuts or tax increases with a transition towards a floating exchange rate regime, depending in part on the degree of capital mobility in the economy. In combining fiscal and monetary policy in this way, policymakers can make use of the exchange rate to absorb some of the negative growth impact of the fiscal consolidation.

1. Introduction

Fiscal adjustments in developing countries require difficult tradeoffs. Reductions in government spending (investment or consumption) or tax increases, while often necessary to restore macroeconomic sustainability, can dampen growth. For this reason, it is important to understand the fiscal multipliers associated with different fiscal instruments. Such multipliers cannot be treated as invariant, as they may depend on other policy settings, including monetary and exchange rate policies. They also depend on the degree of capital mobility, as well as other features of the economy such as regulatory structures, degree of openness, and import and export elasticities.

Recognizing that no single method is likely to provide definitive values for different multipliers, we take an eclectic approach to obtaining them. Accordingly, this study takes into account standard open economy macroeconomic theory, empirical time series approaches, and detailed dynamic stochastic general equilibrium (DSGE) modeling, and applies each of these to Bolivia, a lower middle income commodity exporter with a fixed exchange rate. The results are broadly consistent with each other and with other estimates in the literature, with some interesting variations.

The structural VAR approach used here avoids some potential pitfalls – notably the identification of different fiscal shocks (tax or spending) – by imposing a prior structure on fiscal shocks. It must still reckon, however, with undetected structural changes, a challenge in the case of Bolivia, which has undergone several major political and economic changes in the last four decades. Data reliability, particularly for the quarterly data used in this study, is also an issue in Bolivia as it is in many developing countries. Small sizes of some subsamples (e.g., those used to estimate multipliers under a floating exchange rate) may limit the reliability of those estimates.

DSGE models avoid some of these problems by allowing direct manipulation of policy variables. However, they do not fit the data as closely as empirical models and they require a number of structural assumptions. Although the model used here is calibrated for Bolivia, it also draws from developing country averages for certain parameters and, like all DSGE models, must converge to a steady state in the long run.

Previous work ("Fix vs. Float: Evaluating the Transition to a Sustainable Equilibrium in Bolivia, WP/22/43) has indicated that Bolivia requires a consolidation of its primary deficit from the present level of about 6 percent of GDP to 1-1½ percent of GDP, depending on the exchange rate regime. DSGE and empirical approaches suggest this can be done most efficiently through tax reform, reductions in current spending where possible, and by addressing the more inefficient areas of public investment. A more flexible exchange rate would soften the burden of these changes on activity and employment. Reform outcomes will still be dependent on initial conditions, the policy, i.e. the mix between different revenue and expenditure measures and the graduality of the adjustment, the political environment, and on external conditions.

2. Basic Model

In the basic open economy Mundell-Fleming framework under standard assumptions about capital mobility, fiscal multipliers are higher with a peg than with a float. Consider the textbook model, with IS and LM lines shown in RY (nominal interest rate, real output) space, starting at point A where the current account is in balance. The red (BOP(e_0, R,R*,Y)=0) line marks out those points in RY space where the nominal exchange rate is equal to e_0, given the foreign interest rate R* and no change in international reserves.[2] Points to the northwest (above and to the left) of the line correspond to an exchange rate appreciation.

A positive shock to government spending induces a shift from the solid green IS line to the dashed green IS' line, as the decline in the average savings rate from the fiscal expansion means that output must increase to keep savings equal to investment. The resulting equilibrium, under a flexible exchange rate where the monetary authority takes no action in response to the fiscal shock, is at point B, where output has expanded, the nominal interest rate is higher than before the shock (bringing in capital flows), and the nominal exchange rate has appreciated (inducing expenditure switching towards foreign goods). At this point, the balance of payments is again at zero, but with an appreciated exchange rate.

Under a pegged regime, the same fiscal expansion moves the economy to point C rather than B, because the monetary authority responds to the fiscal shock with a monetary expansion, shown by the shift from the solid blue LM line to the dashed blue LM' line, to keep the economy on the BOP(e_0, R*,R,Y)=0 line and prevent the exchange rate from appreciating.[3] Output is higher at point C than B, reflecting the combined impact of a joint fiscal and monetary stimulus. Consequently, the fiscal multiplier is higher under the peg than with the float.

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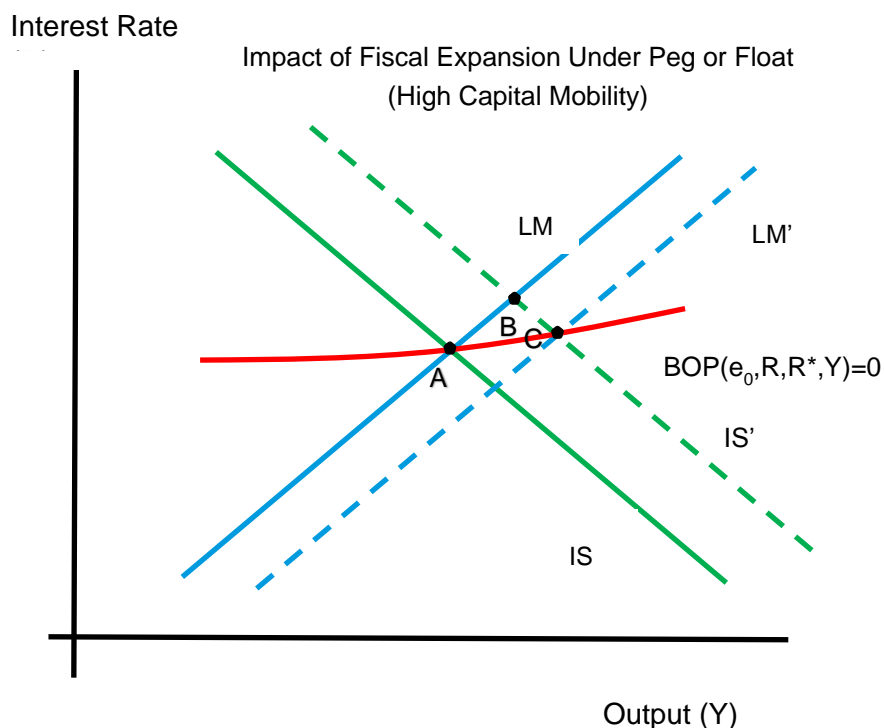
[2] This reflects CA = CA(Y,e) (where CA_Y<0 and CA_e>0), KA = b(R-R* - E(e)/e, and CA+KA=ΔR=0.

[3] This monetary adjustment entails an increase in the money supply which may be implemented by keeping international reserves fixed while expanding domestic assets, or by a combination of domestic asset accumulation and reserves accumulation. In the latter case, there would be an upward parallel shift in the (BOP=0) line, but not all the way to point B, implying the multiplier under a peg would still be larger than with a float.

However, the above ordering of fiscal multipliers presupposes high capital mobility, meaning that capital flows respond sensitively to changes in relative interest rates. In some emerging economies (and at times of capital market stress) this may not be the case, possibly due to impediments to capital arbitrage or to investor uncertainty regarding future regulatory changes or economic developments. In such circumstances, very large increases in domestic interest rates may be needed to attract sufficient capital.
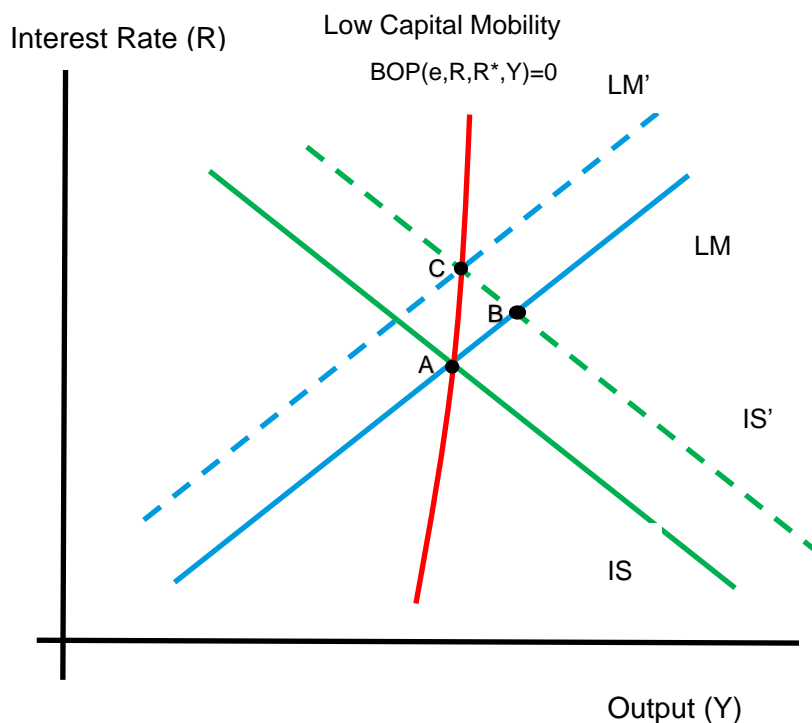
The case of low capital mobility is depicted in figure 2, similar to Figure 1 except for the slope of the (BOP=0) line, which is now very steep, to reflect that a very large increase in domestic interest rates is needed to attract enough capital to fill in the current account gap from a fiscal expansion. With the (BOP=0) line now steeper than the LM line, the shift from the IS to the IS' line puts the economy at point B, where the interest rate is higher, but the exchange rate is weaker than at the starting point A. In this case a monetary *tightening* is needed to maintain the exchange rate at e_0, as it is at point C, weakening the impact of the fiscal expansion on growth. This demonstrates that, in principle, fiscal multipliers may be higher with a float than a peg, if capital mobility is sufficiently low.

3. Recent Literature

Estimating fiscal multipliers is a difficult exercise because growth and fiscal policy can affect each other. Variations in economic activity affect both fiscal revenues and expenditures (e.g., income tax revenues, unemployment benefits). At the same time, fiscal policy affects aggregate demand through automatic stabilizers and discretionary measures. However, researchers have developed empirical techniques to achieve robust estimations. Below is a review of the main approaches developed, and a review of technical issues relevant to Bolivia.

The Main Approaches

The main technical approaches can be grouped into three main classes (Ramey, 2019): (1) aggregate country-level time series; (2) cross-sectional or panel estimates; and (3) New Keynesian dynamic stochastic general equilibrium (DSGE) models.

<u>Aggregate Estimates</u>. Following seminal work by Blanchard and Perotti (2002), empirical macro approaches use a mix of narrative and structural vector autoregression (sVAR) strategies to perform causal inference. Both strategies aim to identify an instrument that represents a credibly exogenous variation in policy, and to use it to measure multipliers. The narrative approach relies on official documents to create data series of exogenous changes in policies. Those are typically budget documents (Attinasi and Klemm, 2016), tax legislation (Romer and Romer, 2010), special budget items such as military expenditures (Ramey and Shapiro, 1998), or multi-year fiscal consolidation plans (Guajardo, Leigh, and Pescatori, 2014; Alesina, Favero, and Giavazzi, 2019). The sVARs identification strategy relies on high frequency (usually quarterly) data, to isolate shocks. Given that fiscal policy typically adjusts at a yearly frequency (i.e., via budgets and legislation), using quarterly data allows treatment of the reactions of GDP and fiscal aggregates as exogeneous in the first instance. The technique is a two-step approach: in the first step, fiscal variables (taxes and expenditures) and output are regressed on multiple quarterly lags. A fiscal shock is then obtained by exploiting lags in policy implementation under the assumption that controlling for lags of taxes, spending, and output eliminates endogenous variations. Alternatively, sign restrictions can be imposed on impulse responses functions (Mountford and Uhlig, 2009).[4]

<u>Panel Estimates</u>. The Bartik instruments (see Goldsmith-Pinkham, Sorkin, and Swift, 2020) allow researchers to exploit geographical variation to identify exogenous shifts in fiscal policy by removing any potential measurement biases in the multiplier, at the sub-national level. Using this approach, Nakamura and Steinsson (2014) argue that evidence on large regional multipliers provides validation to models in which output responds strongly to demand shocks. In these models, the aggregate multiplier is large when monetary policy is accommodative (for example, at the zero lower bound). Chodorow-Reich (2019) generalizes this approach and aggregates estimates of sub-national multipliers into a national one, thereby obtaining large spending multipliers at the national level. He argues that they represent a lower bound for national multipliers, as regional estimates suffer from downward bias due to spillover effects. Adopting the corrections suggested by Ramey (2019), however, national multipliers generally accord with previous studies. A point of caution is that cross-sectional estimates rely on the tacit assumption that the economy is closed, with a no-monetary-policy-response, deficit-financed expansion. Violations of this hypothesis would imply an upward bias.[5]

<u>DSGE Models</u>. Many scholars have used DSGE models to calibrate and estimate fiscal multipliers. In models with no or limited nominal frictions, fiscal multipliers tend to be generally smaller than in empirical studies, as real wages decrease and agents cut down on their consumption (e.g., Baxter and King (1993), Burnside, Eichenbaum and Fisher (2004)). However, multipliers are larger in standard new-Keynesian DSGE models with significant nominal frictions and are particularly large in liquidity traps where monetary policy is passive or constrained by the zero lower bound (e.g., Christiano, Eichenbaum and Rebelo (2011), Leeper, Traum, and Walker (2017)). Farhi and Werning (2017) complement the latter finding by suggesting that multipliers within a currency union or fixed exchange regime would tend to be larger when spending is externally financed rather

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[4] Chahrour, Schmitt-Grohe and Uribe (2012) evaluate the reasons behind the larger tax multipliers (3 percent) under the narrative approach relative to SVAR approach (1 percent). They find that it is not due to differences in the assumed reduced-form transmission mechanisms but rather to a failure to identify the same tax shock, or to small-sample uncertainty.

[5] Panel estimates also allow researchers to use annual data for smaller time periods, increasing the number of countries. This has allowed researchers to include countries at lower levels of developments, where high frequency fiscal data is scarce. Researchers, including Auerbach and Gorodnichenko (2013), use the forecast errors for the growth rate of government spending as reported in the IMF World Economic Outlook for the same year. These forecast errors are proxies to identify fiscal shocks since IMF staff based their forecasts on budget documents and discussions with country members' authorities. Those are sometimes further purged of predictable components available at the time of the forecast by regressing them on the lags of output and government spending and taking the residuals.

than self-financed. The use of heterogeneous agents in many new Keynesian studies underlines the importance of accounting for income and wealth inequality which is associated with larger fiscal multipliers (e.g., Kopiec (2022), Brinca et al. (2016)), while Ramey (2011) stresses the role of timing and anticipation in determining fiscal multipliers. Timing is particularly important when considering the composition of public spending or revenues in the study of fiscal multipliers. Kass-Hanna, Kpodar and Tessema (2020) illustrate how in times of consolidation, while cuts in current expenditures may be more contractionary in the short-run than reductions in public investment, such cuts are more efficient in boosting medium and long-term growth and hence more likely to lead to a sustained reduction in fiscal deficits. DSGE modeling finds lower tax multipliers than spending multipliers, while stressing that the modeling of timing and news aspects of taxes is key to getting realistic multipliers (e.g., Leeper, Walker and Yang (2013), Chahrour, Schmitt-Grohe, and Uribe (2012)).

Conditions Affecting Multiplier Estimates

Consistent with the basic model presented above, countries with flexible exchange rate regimes tend to have smaller multipliers, because exchange rate movements can offset the impact of discretionary fiscal policy on the economy (Corsetti and others, 2012; Born and others, 2013; Ilzetzki and others, 2013). Relatedly, fiscal multipliers can be larger when the transmission of monetary policy is impaired, e.g., at the zero interest lower bound (Erceg and Lindé, 2014; Woodford, 2011).

Multipliers are found to be larger during downturns than upswings and when there is slack in the economy (Auerbach and Gorodnichenko, 2012; and Baum, Ribeiro, and Weber, 2012). The rationale is that the proportion of credit-constrained households and firms increases during economic downturns and these agents are unable to offset the reduction in their disposable income and revenues by borrowing (Mineshima, Poplawski-Ribeiro, and Weber, 2014; and Canzoneri et al. 2016). Fiscal multipliers also vary with the business cycle: they increase if the initial spending shock occurs in a recession and decline if the shock happens in an expansion (Auerbach and Gorodnichenko, 2012). A recent study (Kinda, Lengyel, and Chahande, 2022) found that during health crises social distancing and uncertainty may lower multipliers which then increase in magnitude as economies re-open and pent-up demand is unleashed.

While multipliers might be expected to be higher in developing economies where structural constraints are more prevalent and public capital stocks are lower (Baxter and King, 1993), empirical evidence on this conjecture is mixed, as structural weaknesses in public finances in developing economies lead to more inefficiencies and leakages that weaken the impact of fiscal policy. Multipliers in low-income countries could also be reduced by larger precautionary savings stemming from a more uncertain environment; low efficiency of public expenditure; difficulty in unwinding expenditure; low revenue levels; and lower fiscal policy credibility (Miyamoto et al., 2020; and Ilzetzki, Mendoza, and Végh, 2013). On the other hand, consumption smoothing behavior is less prevalent when: (i) liquidity constraints arise in less developed financial markets; and (ii) agents are less forward looking if there is too much instability. Finally, automatic stabilizers are also found to be less important in developing countries (see below).

Significant spending leakage through imports as well as a large informal economy may also result in lower multipliers (Colombo et al., 2022; and Dime, Ginting and Zhuang, 2021). Supported by an empirical analysis across 141 countries using the local projections method and a two-sector new-Keynesian DSGE model, Colombo et al. (2022) show that a higher degree of informality is associated with weaker fiscal multipliers. Some studies (IMF, 2019) highlighted the role of corruption in enabling tax evasion and thus undermining tax collection efforts, which may lead the government to adopt policy changes that are larger than would otherwise be necessary in order to achieve the required consolidation.

Commodity exporters are typically studied solely from the spending angle, since most of their fiscal revenues are dependent on international prices, and therefore vary exogenously. Indeed, studies focusing on MENA and GCC countries for example (Espinoza and Senhadji, 2011; Cerisola and others, 2015) do not estimate tax multipliers. Spending multipliers are found to be in the same order of magnitude of non-commodity exporters countries. Countries with a lower propensity to import (i.e., large countries and/or countries only partially open to trade) tend to have higher fiscal multipliers because the demand leakage through imports is less pronounced (Barrell and others, 2012; Ilzetzki and others, 2013; IMF, 2008). Countries with more rigid labor markets (i.e., with stronger unions, and/or with stronger labor market regulation) have larger fiscal multipliers if such rigidity implies reduced wage flexibility, since rigid wages tend to amplify the response of output to demand shocks (Cole and Ohanian, 2004; Gorodnichenko and others, 2012), implying that the output loss from a fiscal consolidation would be greater with rigid than with flexible wages.

Larger automatic stabilizers reduce fiscal multipliers, since mechanically the automatic response of transfers and taxes offsets part of the initial fiscal shock, thus lowering its effect on GDP (Dolls and others, 2012). High-debt countries generally have lower multipliers, as fiscal consolidation has positive credibility and confidence effects on private demand and lowers the sovereign risk premium (Ilzetzki and others, 2013, Kirchner and others, 2010).

Different Types of Fiscal Multipliers

The simplest form of the fiscal multiplier is the impact multiplier measuring the contemporaneous effect of a fiscal policy shock, or the effect at some future horizon (Spilimbergo, Symansky, and Schindler, 2009). The literature also presents the peak multiplier, which measures the largest response over any horizon, and the cumulative multiplier, which captures the cumulative change in output over the cumulative change in fiscal policy over a period. For expenditure multipliers, there is also the present value (PV) multiplier, which measures the discounted cumulative value of the output response over time divided by the discounted cumulative value of the fiscal shock (Mountford and Uhlig, 2009).

Understanding the shape and persistence of fiscal multipliers is crucial for computing the effects of fiscal policy beyond the first year. The persistence of multipliers should be distinguished, conceptually and empirically, from the persistence of the fiscal shock. In general, model-based, and econometric studies find that the output effect of an exogenous fiscal shock vanishes within five years—even if fiscal measures are permanent. The effect does not decline linearly but usually has an inverted U shape, with the maximum impact occurring in the second year (Batini and others, 2014; Baum and others, 2012; Coenen and others, 2012). Based on the literature review by Mineshima and others (2014), the second-year multiplier is, on average, 10–30 percent higher than in the first year.

However, the duration of these effects varies depending on several factors examined in the following paragraphs: (i) the persistence of the fiscal shock; (ii) the type of fiscal instrument; and (iii) conjunctural factors such as the cyclical position and whether monetary policy responds to the fiscal shock. The persistence of the effect of discretionary fiscal policy on output may to some extent depend on the fiscal instruments used. The model-based literature shows that a permanent discretionary change in indirect taxes, government consumption, and transfers has only short-term output effects, typically vanishing within five years (Anderson and others, 2013; Coenen and others, 2012; European Commission, 2010). In contrast, the effect of a permanent discretionary change in public investment or corporate taxes is longer, and may even be permanent, with multipliers steadily increasing after the first year towards their long-term values (Coenen and others, 2012). This is because corporate income taxes have distortionary effects on investment, leading to a

long-run decrease in the capital stock, and hence the productive capacity of the economy. Similarly, cuts in government investment in infrastructure could reduce the productivity of the economy and therefore have durable negative effects on output.

Summary of Estimates

There is consensus in the literature that spending multipliers are positive and hover around a range of 0.5-1 at peak and are lower around the range of 0.3-0.5 during the first year (Guajardo, Leigh, and Pescatori, 2014; Ilzetzki, Mendoza, and Végh, 2013; IMF, 2010; and Blanchard and Perotti, 2002). There is also some consensus that public investment multipliers are higher than consumption multipliers (Izquierdo et al., 2019; and Ilzetzki, Mendoza, and Végh, 2013). Our literature review focuses on spending multipliers, given that Bolivia is a commodity exporter, and on Latin America and the Caribbean (LAC). The results, in Table 1 Column 1, show that spending multipliers are about 0.5 on average in the region. Looking at large country samples, Table 1 Column 2, shows that spending multiplier a closer to 0.4 on average. Restrepo (2020) which is the closest to our empirical strategy, in that he replicates the Blanchard and Perotti methodology for eight LAC countries, found a peak spending multiplier of 0.8 on average.

Table 1.

Authors	Sample	Spending	Authors	Sample	Spending
Anós-Casero et al (2010)	Argentina	0.0	Mineshima et al. (2014)	Survey 41 studies	0.75
Valdivia (2016)	**Bolivia**	**0.3**	Colombo et al (2022) - high informality	141 countries	0
Restrepo (2020)	Brazil	0.8	Geli and Moura (2023)	177 countries	0.7
Matheson and Pereira (2016)	Brazil	0.5	Kinda et al. (2022)	91 countries	0.4
Narita (2014)	Caribbean	0.5	IMF (2013)	US/EU	0.7
Restrepo (2020)	Chile	1.2	Geli and Moura (2023)	EME	1
Fornero, Guerra-Salas, Perez (2017)	Chile	0.6	Ilzetzki and others (2013)	EMEs	0
Restrepo (2020)	Colombia	1.9	Ducanes et al. (2006)	EMEs	1
Estevão and Samake (2013)	Costa Rica	0.2	Ilzetzki and Vegh (2008)	EMEs	0.4
Estevão and Samake (2013)	Dominican Rep.	0.1	IMF (2008)	EMEs	0.2
Restrepo (2020)	Dominican Rep.	0.5	Ilzetzki, Mendoza, and Végh (2013)	EMEs	-0.03
Gonzales-Garcia et al (2013)	ECCU	0.2	Ilzetzki (2011)	EMEs	0.2
Estevão and Samake (2013)	El Salvador	0.2	Gonzales-Garcia, Lemu, and Mrkaic (2013)	EMEs	0.4
Estevão and Samake (2013)	Guatemala	0.3	Honda, Miyamoto, and Taniguchi (2020)	EMEs	0.1
Estevão and Samake (2013)	Honduras	0.3	Espinoza and Senhadji (2011)	GCC	0.7
OECD (2009)	Mexico	0.7	Cerisola (2015)	MENAP	0.7
Restrepo (2020)	Mexico	0.7	Geli and Moura (2023)	LIC	0
Valencia (2016)	Mexico	0.7			
Estevão and Samake (2013)	Nicaragua	0.1			
Estevão and Samake (2013)	Panama	0.5			
Restrepo (2020)	Paraguay	1.1			
David (2017)	Paraguay	0.8			
Anós-Casero et al (2010)	Peru	0			
Restrepo (2020)	Peru	1.1			
Vtyurina and Leal (2016)	Peru	0.3			
Restrepo (2020)	Uruguay	0.5			
Average	*All LAC*	*0.5*			
Average Restrepo		*0.8*			

4. Empirical Analysis

We follow the Blanchard and Perotti (2002) specification of the VAR, as in Restrepo (2020):

$$Y_t = A(L, q)Y_{t-1} + U_t$$

where $Y_t \equiv [T_t, G_t, X_t]'$ is a three-dimensional vector in logarithms of the quarterly taxes, spending –
differentiating by current vs. capital spending, and GDP. All variables are in real and per capita terms.[6] $U_t \equiv [t_t, g_t, x_t]'$ is the corresponding vector of reduced-form residuals. $A(L, q)$ is a four-quarter distributed lag
polynomial that allows for the coefficients at each lag to depend on the quarter q that indexes the dependent
variable. The reason for allowing for quarter-dependence of the coefficients is the presence of seasonal
patterns.

The identification strategy is as follows, where e_t^t, e_t^g, and e_t^x are the mutually uncorrelated structural shocks to
be recovered:

$$t_t = a_1 x_t + a_2 e_t^g + e_t^t$$

$$g_t = b_1 x_t + b_2 e_t^t + e_t^g$$

$$x_t = c_1 t_t + c_2 g_t + e_t^x$$

The first equation states that unexpected movements in taxes within a quarter, t_t can be due to one of three
factors: the response to unexpected movements in GDP, captured by $a_1 x_t$, the response to structural shocks to
spending, captured by $a_2 e_t^g$, and to structural shocks to taxes, captured by e_t^t. A similar interpretation applies to
unexpected movements in spending, e_t^g, in the second equation. The third equation states that unexpected
movements in output, e_t^x, can be due to unexpected movements in taxes, unexpected movements in spending,
or to other unexpected shocks. More details are provided in Restrepo (2020).

Empirically, we construct the logarithms of quarterly taxes, spending, and GDP, all in real and per capita terms
- over 1990-2022. We use data from the national accounts provided by the Ministry of Economy and Finance
for fiscal data ("*Cuadro N°59*"). Fiscal data is smoothed using the X12 technique given that it comes in monthly
frequency and shows high seasonality. As for population, the deflator and GDP data, we use data from the
National Statistical Institute (www.ine.gob.bo). Population is extrapolated linearly from annual to quarterly
frequency.

In line with the narrative approach of Blanchard and Perotti (2002), dummies are added for the years 1995,
2004, and 2005, following David and Leigh (2018). They found that in 1995, fiscal consolidation amounted to
0.9 percent of GDP, with a tax increase of 1.2 percent of GDP, offset by a spending increase of 0.3 percent of
GDP. The tax increase was part of a tax reform presented to Congress in November 1994 with an expected
revenue yield of 1.2 percent of GDP in 1995 (0.9 percent of GDP considering offsetting expenditure increases),
motivated by the need to cover the costs of structural reforms. In 2004, tax hikes amounted to 2 percent of
GDP. The tax hikes were part of the program supported by an IMF stand-by arrangement that aimed at
reducing the fiscal deficit. Finally, in 2005, tax hikes amounted to 4.1 percent of GDP. The tax increases were

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[6] See the next section for a definition of the variables, including dummies.

motivated by the desire to reduce the deficit and for long run considerations (greater role of the state in hydrocarbons sector).

The main results for Bolivia are presented in the next two charts. We disentangle between current and capital spending. Chart X plots the impulse-response function (IRF) for current spending and shows that a 1 percentage increase in current spending leads to a cumulative multiplier of 0.15 after 8 quarters. The peak multiplier is in the order of 0.2. Chart Y plots the impulse-response function (IRF) for capital spending and show that a 1 percentage increase in capital spending leads to a cumulative multiplier of 0.75 after 8 quarters. The peak multiplier is in the order of 0.6.

The results are generally consistent with the figures in the literature presented in Table 1. They are quite close to those presented by Restrepo (2020) for spending multipliers for Latin American countries. On average, Restrepo shows peak spending multipliers of 0.8, whereas for Bolivia the capital expenditure multiplier is estimated at 0.6. In terms of the behavior of the spending multiplier over time, Bolivia shows similarities with Dominican Republic, Mexico, and Uruguay, with relatively low and stable multipliers.

An interesting feature of the estimation is the relatively low level of the current spending multiplier, given the high level of current spending in Bolivia. Indeed, at 25-30 percent of GDP, current spending in Bolivia is among the highest in the region. The gap between the current spending and public investment multipliers appears to bear out claims for the importance of public investment as a driver of productivity in Bolivia. Public investment typically accounts for more than 40 percent of total investment in Bolivia, but some studies (e.g. Endegnanew and Tessema, 2019) have noted difficulties with public investment efficiency, as indicated by a relatively high incremental capital-output ratio (ICOR) of more than 5.

Chart X. Impulse-Response Function (IRF) for Current Spending.

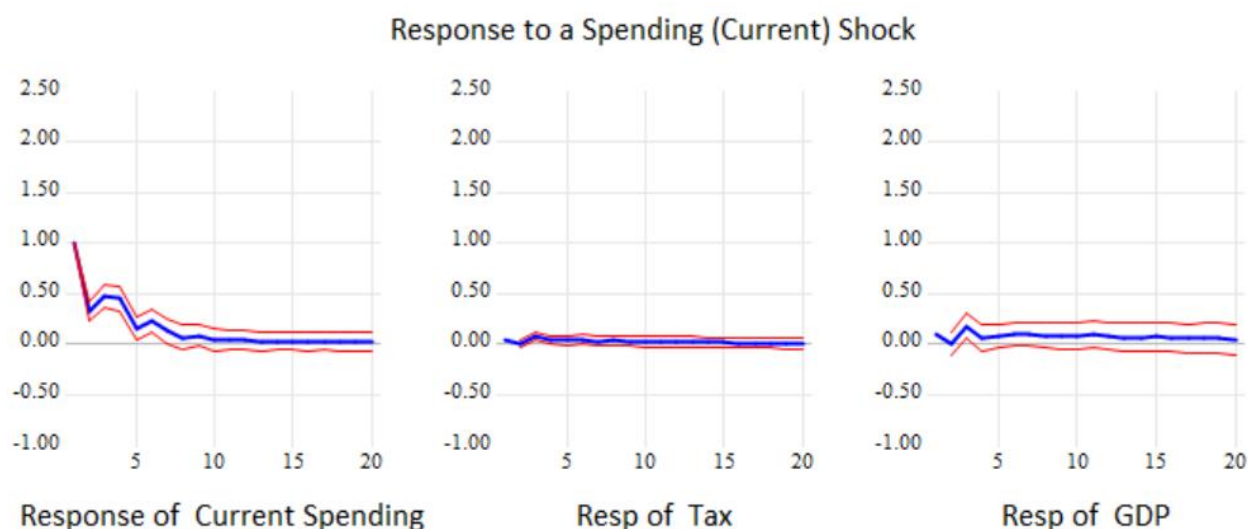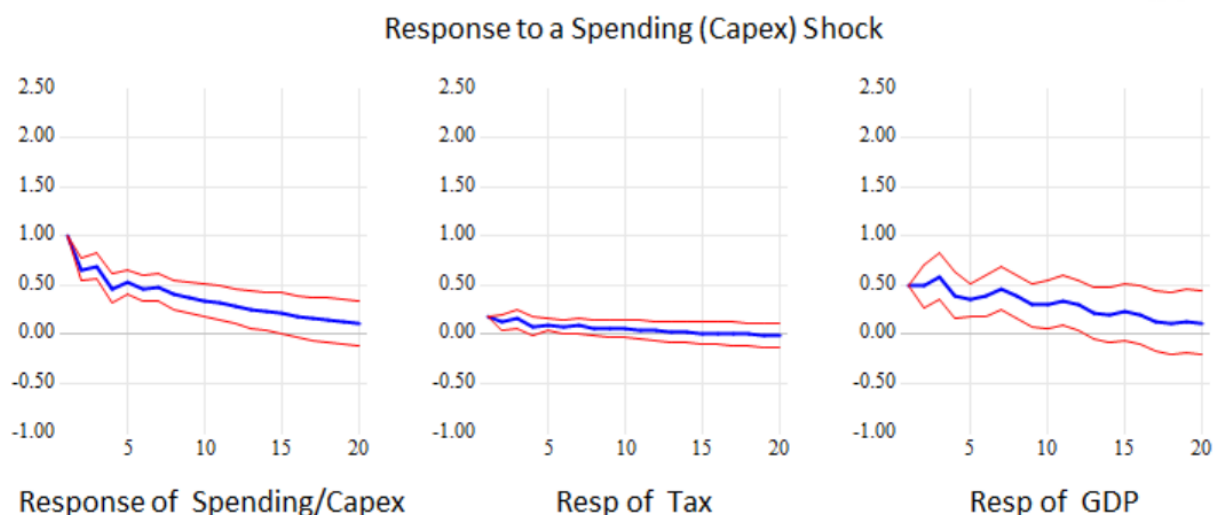Response to a Spending (Current) Shock

Chart Y. Impulse-Response Function (IRF) for Capital Spending.

5. DSGE Modeling

DSGE modeling permits targeted analysis of specific fiscal instruments and scenarios, while presupposing substantial economic structure. The neo-Keynesian model used in this study is calibrated to match Bolivian values over the past 30 years, but with some parameters based on developing country averages and others (e.g., trade elasticities) set to ensure overall coherence (as, for example, compliance with the Marshall-Lerner condition).

Overview of the model[7] Similar to other DSGE models, this model incorporates a standard upward-sloping Phillips curve, reflecting price and wage rigidities. The final domestic consumption good is produced by a perfectly competitive domestic firm that sources inputs from a continuum of monopolistically competitive domestic intermediate producers who in turn employ domestic labor and public and private capital. Price stickiness arises from Rotemburg adjustment costs faced by the intermediate producers. Wage stickiness stems from the inclusion of labor unions, which negotiate wages in advance each period to maximize expected worker utility.

Demand for home goods comes from government consumption, private consumption, public and private investment, and exports. Supply (GDP) is the total of home good production and commodities production. Home good production is a function of private and public investment, and labor. The economy imports foreign goods for domestic private investment and consumption, and exports commodities, which are a stochastic endowment. There are two types of households: non-Ricardian ("hand-to-mouth") households do not have access to financial markets and are constrained to spend their entire income in each period, while Ricardian households are able to borrow and save. Both types of households have the same utility function, deriving

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[7] The DSGE model, developed by Andres Gonzalez and Diego Rodriguez of ICD, was used in analysis of "Fix vs float: Evaluating the Transition to a Sustainable Equilibrium in Bolivia" (WP/22/43). A detailed description of the model structure is provided in Annex I. The model is run using the Dynare software in Matlab.

utility from leisure, money, and the consumption of domestic and foreign goods (which are imperfect substitutes).

Fiscal expenditures are for public consumption, public investment, transfers, and interest payments to service government debt, while revenues are obtained from taxes on consumption, capital, and labor, royalties from the commodity sector and quasi-fiscal balance in the form of seignorage gains from the central bank. Financing is obtained through net domestic bond issuance (bG – bG(-1)). Public investment plays a productive role in the economy, as it helps accumulate public capital that in turn enters—with a lag—into the intermediate good production function. The model specification hence assumes that the investment process takes time to be implemented and to materialize in public capital creation.

The central bank chooses between a currency peg and an inflation targeting regime. In the baseline calibration, the central bank adjusts the money supply and reserves to maintain its currency peg. In an alternative calibration, the exchange rate is allowed to float, and the central bank follows an inflation target without F/X intervention.

Parameterization. The economy is assumed to begin in a steady state, which is estimated for the Bolivian economy using 40-year averages for Bolivia and for lower middle-income developing economies. The exchange rate is pegged in the steady state, but monetary policy may be set to follow an inflation target in response to fiscal or other shocks, as described above. Selected parameters and long-term values used for the policy simulation are illustrated in table 2. Specifically, the parameterization sets the share of non-Ricardian households (hand-to-mouth consumers) to 20 percent and captures a steady state debt-to-GDP ratio of 40 percent, a potential growth rate of 3.7 percent, and a trade surplus of 0.1 percent, *inter alia*.

Table *2*. Parametrization

Description	Value
Frisch elasticity	1.0
Trade elasticity of substitution	0.25
Share of hand-to-mouth consumers	0.2
Capital share	0.38
Public capital share	0.05
Government spending to GDP	0.25
Public investment to Government spending	0.4
Private investment to GDP	0.08
Private consumption to GDP	0.669
Net exports to GDP	0.001
Depreciation rate of private capital	0.05
Depreciation rate of public capital	0.05
Import composition of investment	0.35
Import composition of consumption	0.35
Government debt to GDP	0.4
Persistence of fiscal shocks	0.15
Long-term Inflation	2%
Foreign inflation	2%
Potential growth	3.7%

Two caveats are important for the interpretation of simulation results. First, this calibration does not take account of the larger reserve adequacy levels that would be needed under a fixed vs a flexible exchange regime, which limits the divergence of scenario results. Second, Bolivian macroeconomic indicators at end-2022 are some distance from the sustainable steady state levels used as initial conditions, and as such results should be interpreted as an indication of the channels and magnitudes through which fiscal policy affects other macroeconomic variables in Bolivia and not as characterizing a transition path to a sustainable equilibrium.

6. Responses to Fiscal Shocks

Impulse responses show the impact of increases in public consumption, public investment, transfers, or consumption taxes under either the peg or inflation target, given high capital mobility. The shocks are imposed in the steady state of the model and standardized to 1 percent of GDP, with a low persistence of 0.15. Responses of the endogenous variables are also shown as percentages of GDP, with the exception of the interest rate and the nominal exchange rate, which are presented as percentage variations from the baseline. Values for each variable are presented as variations from the steady state, implying that the steady state is shown at zero in each sub-chart.

Figure 1: Impact of 1 Percent of GDP Shock to Govt Cons
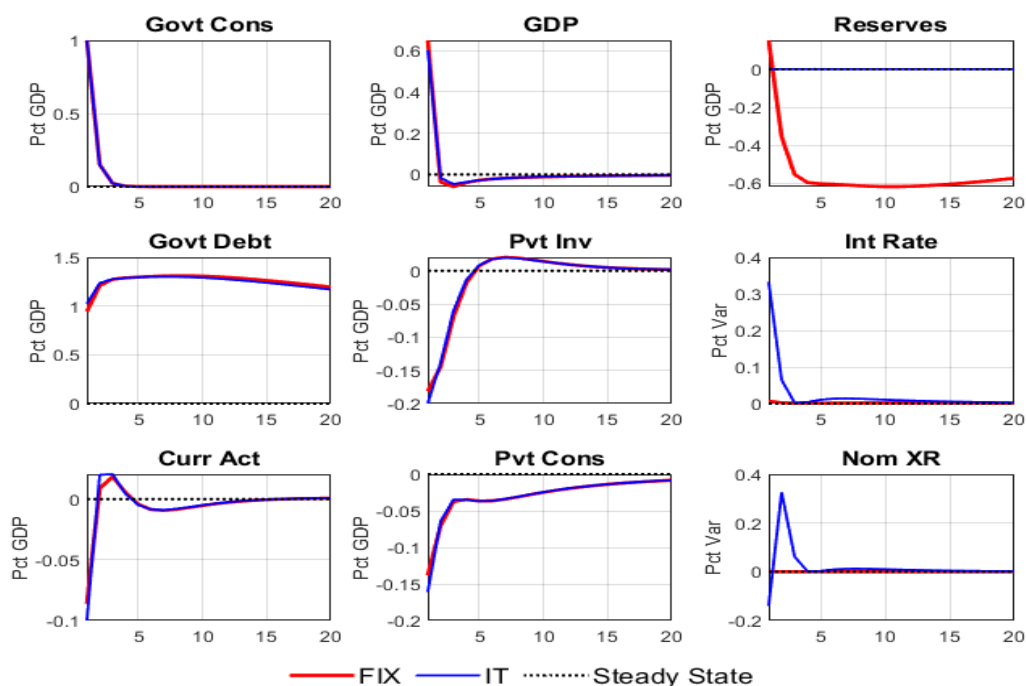

Responses to a 1 percent of GDP increase[8] in government consumption (Figure 1) are generally consistent with the pegged exchange rate (red line in the diagram), GDP rises by 0.65 percent in the

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[8] Impulse responses are linear in the vicinity of the steady state, implying that the response to a spending reduction is the additive inverse of the response to an increase.

initial period as domestic output responds to increased demand from the government. Government debt rises by the amount of the government spending increase, and private consumption and investment demand fall slightly as domestic prices rise.[9] Given the commitment to the peg, the central bank initially accumulates reserves to keep the domestic currency from appreciating, thereby limiting the increase in domestic interest rates, but then switches to selling reserves in period 2 as the fiscal shock subsides. The current account slips into deficit on impact from higher government demand.

Under inflation targeting (blue line in the diagram), reserves are maintained at the steady state by assumption. The domestic interest rate increases as the central bank sells bonds to reduce demand and limit inflation. The exchange rate appreciates on impact from the fiscal shock but then depreciates as the shock subsides. Responses of GDP, private demand, and the fiscal deficit are similar to those under the peg, but multipliers are slightly lower, due to the exchange rate appreciation. Impulse responses to an increase in public investment (not shown) are similar to that of public consumption, under both a peg and IT, with some differences over the longer term.

Figure 2: Impact of 1 Percent of GDP Shock to Cons Tax
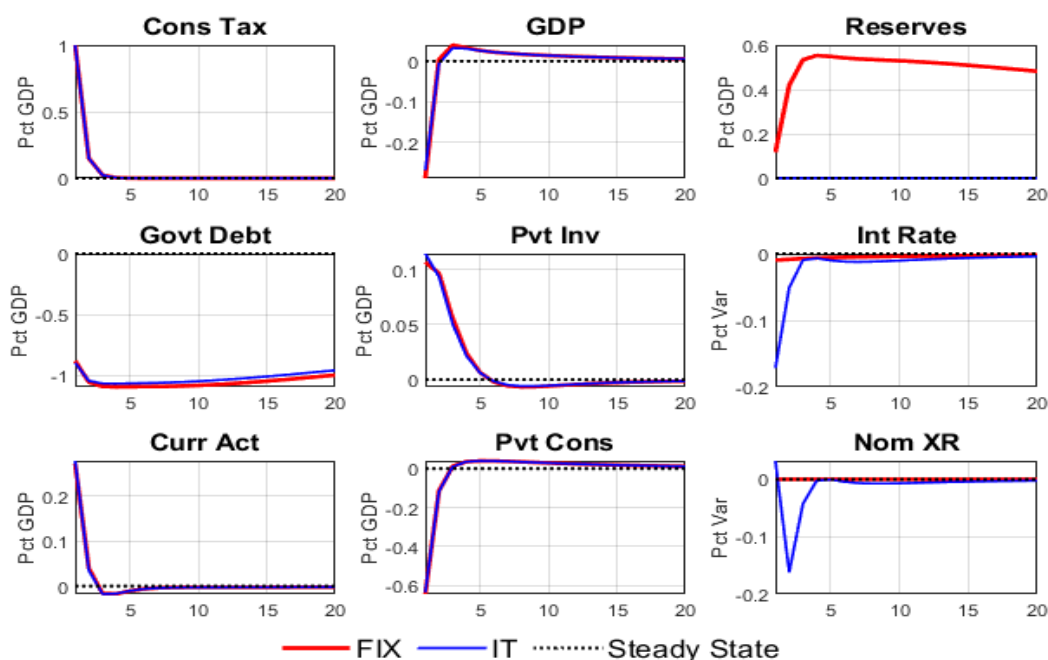
A 1 percent of GDP increase in the consumption tax (Figure 2) reduces GDP on impact as private consumption declines, under both a peg and inflation targeting, although the impact is less than that of a spending reduction. Under the peg, reserves accumulate slowly in the first period, then more rapidly, as the central bank sells domestic currency to counter the drop in demand. Under IT, the interest rate drops, as the central bank compensates for the decline in consumption demand by expanding its balance sheet. After depreciating slightly

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[9] Note that Valdivia (2017) found a crowding-in effect using a DGSE model.

on impact, due to the interest rate drop, the nominal exchange rate appreciates as domestic demand and the interest rate recover.

Figure 3: Impact of 1 Pct of GDP Shock to Transfers
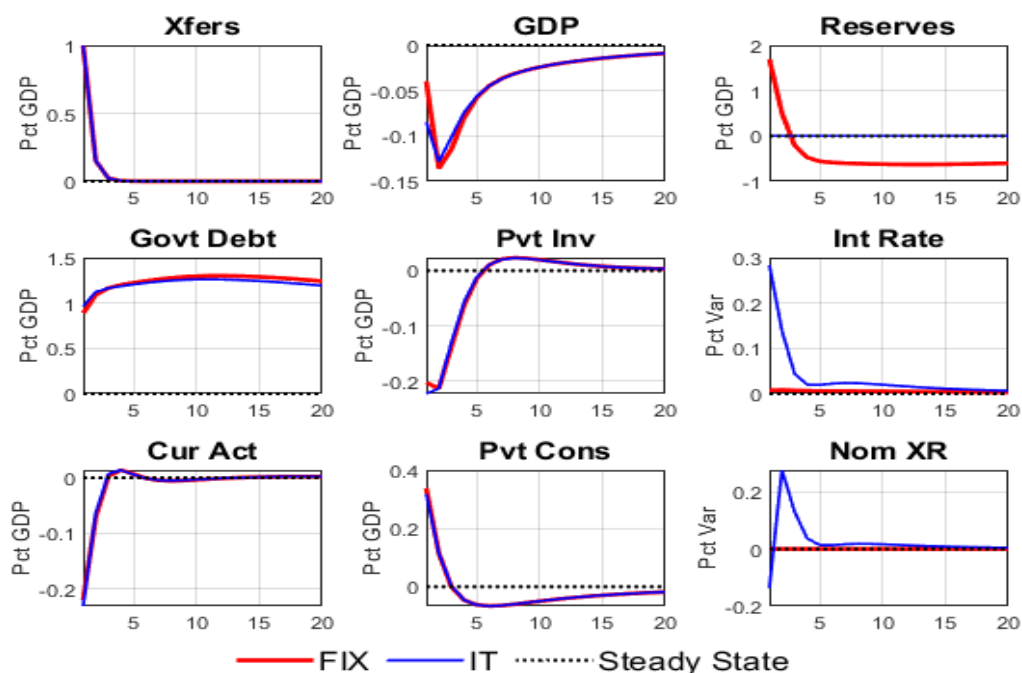
A 1 percent of GDP increase in transfers to non-Ricardian households (Figure 3) is shown to *reduce* GDP despite the positive effect on demand, under either the peg or inflation targeting. The explanation for this effect is found on the supply side, as an increase in government transfers shifts households' relative preferences between leisure and consumption, reducing hours worked and therefore output. However, while GDP declines slightly with an increase in transfers, consumption rises substantially, entailing that a reduction in transfers would have significant negative welfare effects.

7. Multipliers Estimated from DSGE Model

Multipliers summarize the effects of fiscal instruments on GDP (and, secondarily, on consumption) over different horizons, under both a peg and inflation targeting, and under different assumptions about capital mobility. On impact (Figure 4), under high capital mobility, spending multipliers for both government consumption and public investment are 0.65 under the peg and 0.60 under IT, consistent with the basic model, and implying that a reduction of 1 percent of GDP government consumption or public investment will result in a 2/3 of 1 percent
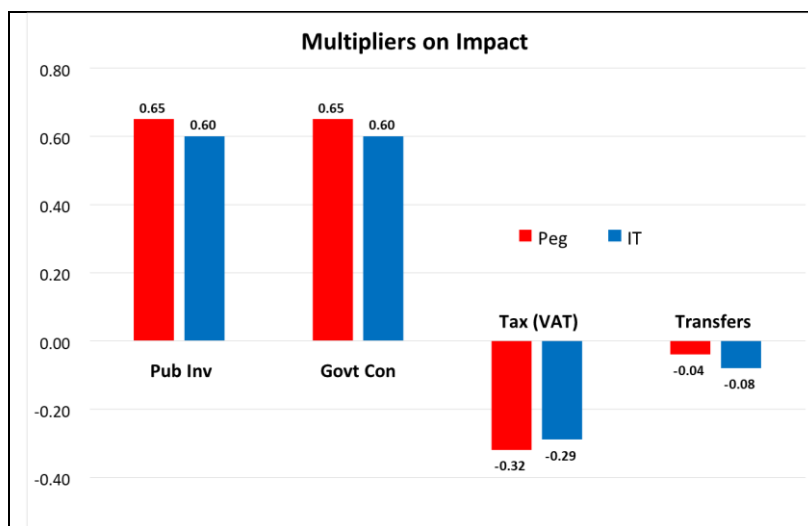
drop in GDP in the short term. The multiplier associated with a consumption tax increase is about half that of a spending reduction, while the GDP multiplier of an increase in transfers to non-Ricardian households is close to zero. As detailed in the previous section, the negligible effect of transfers on GDP, which may be seen as somewhat counterintuitive, is attributable in the model to the negative impact on labor supply that arises from a positive consumption shock, which counterbalances the boost to demand from higher household purchasing power.

Cumulatively (Figure 5) over the longer term, the spending multipliers, computed as the sum of GDP variations over 8 quarters divided by the corresponding sum of spending variations, are somewhat lower than on impact, with multipliers under the peg still slightly higher than under IT. Public investment multipliers diverge from government

Cumulative Multipliers after 8 Quarters

	Peg	IT
Pub Inv	0.45	0.44
Govt Con	0.38	0.37
Tax (VAT)	-0.13	-0.13
Transfers	-0.43	-0.44

Impact of Capital Mobility (CM)

	Peg High CM	IT High CM	Peg Low CM	IT Low CM
Public Investment	0.65	0.60	0.51	0.58
Tax	-0.32	-0.29	-0.11	-0.23

consumption multipliers over this horizon, reflecting the benefit of public investment in increasing the public capital stock, raising the productivity of other factors as capital accumulates.

Under low capital mobility (Figure 6) the ordering of spending multipliers reverses, as in the basic model. On impact, the public investment multiplier is 0.51 under the peg, well below the 0.58 multiplier under inflation targeting, reflecting the benefit of an exchange rate depreciation in maintaining private sector demand in this scenario (similar results obtain with an increase in government consumption). While it is normally assumed (as in the baseline Bolivia model) that capital mobility is high, capital mobility may vary substantially, not only from country to country, but also over time, depending on shifts in risk aversion and government regulation, among other factors.

Consumption multipliers (Figure 7), showing the ratio of the change in consumption to each fiscal measure, are provided as a gauge of the welfare impact of each policy. As demonstrated in the previous section, fiscal shocks that have large effects on GDP may have small effects on consumption, or the effects may even be in
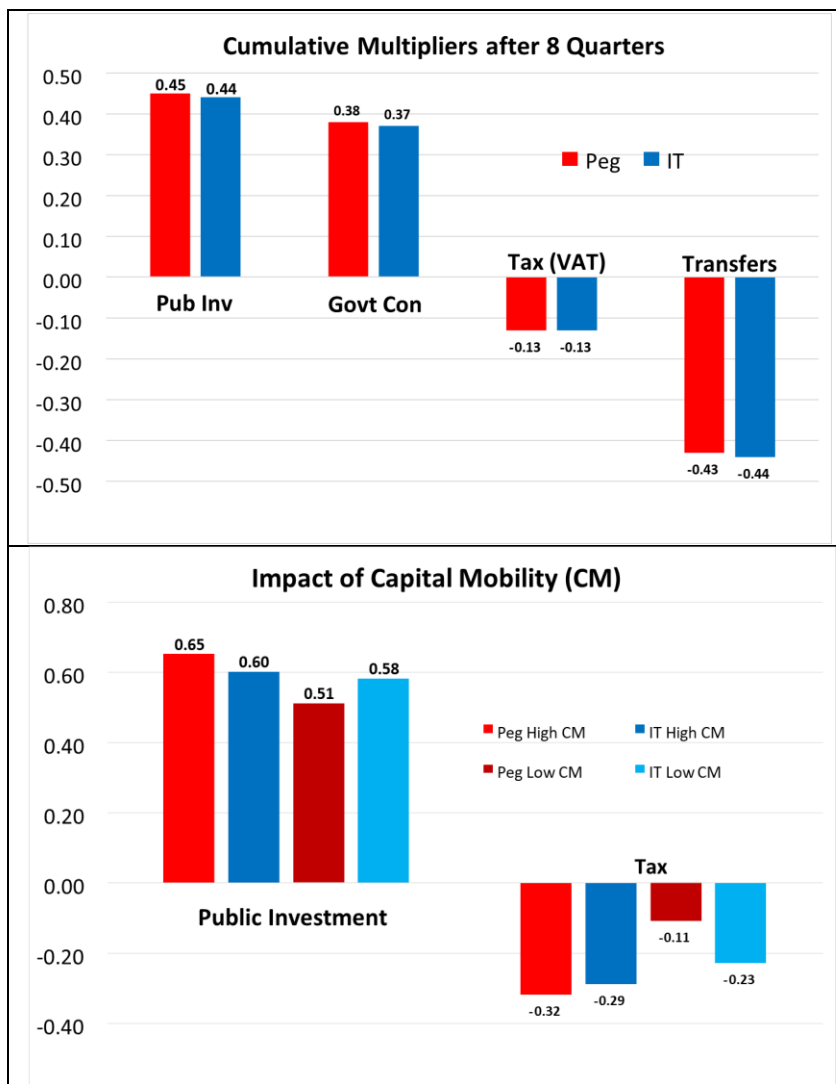
opposing directions. This is notably the case with respect to transfers, which have little impact on GDP but substantial and opposite effects on consumption and, in particular, on the consumption of non-Ricardian ("hand-to-mouth") households.

To verify that the tradeoffs between fiscal consolidation and GDP indicated by the fiscal multipliers would obtain, the ratio of the change in GDP to the change in government debt (Figure 8) is also computed for each fiscal instrument, over an 8-quarter horizon[10]. This takes into account secondary fiscal effects of the different policy instruments, as, for example, when an increase in government spending leads to higher interest rates, thereby increase capital tax receipts. Results from this exercise track the cumulative multipliers closely but are slightly higher for both government consumption and public investment.
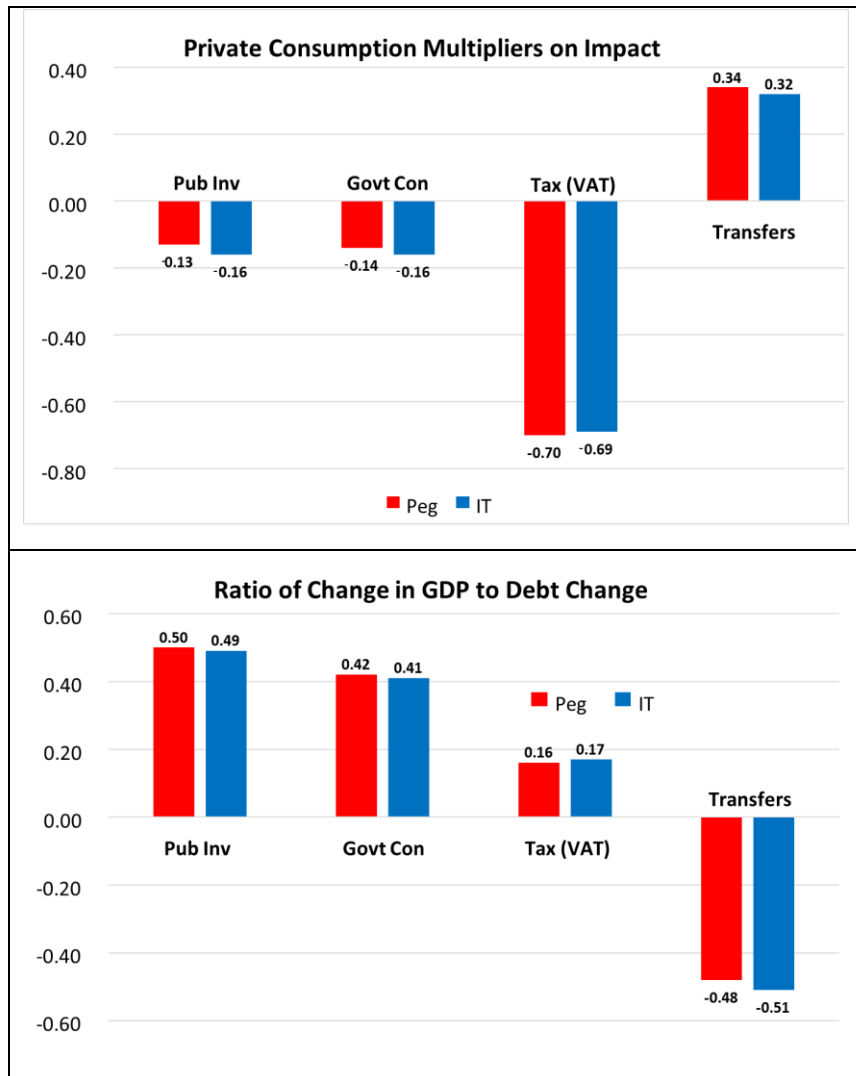
8. Conclusion

Assessing the impact of fiscal policy on GDP and other macroeconomic variables, in either a fiscal expansion or contraction, is a challenging task. Endogeneity complicates empirical estimation. The wide range of external environments, initial conditions, and complementary monetary and structural policies makes it difficult to control for all relevant factors. Nevertheless, there is broad agreement about the order of magnitude of fiscal multipliers, the main channels by which they operate, and the fact that multipliers for advanced economies tend to be different (and higher) than those for developing economies. This agreement is reflected in the empirical and modeling work presented here on Bolivia, a lower middle income commodity exporter with a currency peg.

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[10] This is equivalent to accounting for the endogenous response of other fiscal variables, as discussed in the empirical section.

Fiscal multiplier estimates for Bolivia are generally consistent across a range of approaches, while fitting in well with the bulk of estimates for developing countries presented in the literature. Spending (public consumption and public investment) multipliers generally range from one-third to two-thirds, with multipliers for public investment somewhat higher than those for consumption, reflecting the productivity benefits over longer horizons of expanding the public capital stock. Tax multipliers are lower, around half of spending multipliers. The multipliers associated with transfers to households are lower still, and difficult to distinguish from zero. However, the impact of transfers on consumption – particularly of poorer households – is substantial.

This study provides support for the basic theory of the role of monetary policy and capital market mobility in determining fiscal multipliers. Multipliers under a peg are normally higher than under inflation targeting, since with a sufficient degree of capital mobility, exchange rate movements in response to a fiscal expansion or contraction tend to dampen the impact of the fiscal change on aggregate demand. However, this ordering reverses under low capital mobility, when the exchange rate response to a fiscal expansion switches sign (e.g., when a fiscal expansion prompts a depreciation). Empirical and modeling results in the present study support the general conclusion under high capital mobility, while DSGE modeling demonstrates the possibility of reversing this conclusion under low capital mobility.

Some policy recommendations for Bolivia, and for other developing countries encountering the need for fiscal consolidation, are suggested by this work. While there is some indication that public investment multipliers are higher than government consumption multipliers at longer terms, the difference is not large (larger in empirical estimates than in the model), and both should be included in fiscal strategy. Low tax multipliers indicate that tax reforms should play a role in a fiscal consolidation strategy, although structural and political impediments may constrain the possibilities for increasing tax revenues, particularly over the short- or medium-term. Adjustments to transfers have little impact on GDP but large effects on consumption of non-Ricardian households. Accordingly, reducing transfers, while efficient with respect to GDP, is likely to have significant negative repercussions for overall welfare and distributive equity.

One insight of the study concerns the role of monetary policy in a fiscal tightening cycle. Although the estimated differences are moderate, a shift away from a peg to a float can reduce fiscal multipliers if capital is mobile, implying that transitioning to a float could ease the pain of fiscal adjustment under certain conditions. When weighed against clearer benefits of floating exchange rates, including resilience to external shocks, preservation of reserves, and real exchange rate realignment, this effect is likely to be of secondary importance. At the same time, it highlights the need for coordination between fiscal and monetary policy in a transition to long-run sustainability.

Annex I. Model Structure[1]

The model described in this Appendix incorporates features from the canonical Pillar IV DSGE macroeconomic model of the financial programming initiative of the 2.0 of ICD.

Households

There is a continuum of households indexed by $i \in [0,1]$. As in   households in the interval $[0, \omega)$ cannot access financial markets and do not have an initial capital endowment. Therefore, these households consume their disposable income in each period. The other households, in the interval $(\omega, 1]$, have access to the financial market and own physical capital. The utility function is common across agents and has the following functional form:

$$u_t(C_t, N_t) = z_{u,t}\ln(C_t - \text{hab}C_{t-1}) - \gamma_N \frac{N_t^{1+\sigma_L}}{1+\sigma_L} + \gamma_m + \frac{1}{1-\sigma_M}\left(\frac{M_t}{P_t}\right)^{1-\sigma_M}$$

where C_t denotes consumption, N_t labor, and $\frac{M_t}{P_t}$ the stock of real money balances. The parameters in the utility function are the inverse of Frisch elasticity, σ_L, the elasticity of money demand σ_M, and two scale parameters γ_N and γ_m. This utility function allows for slowly changing consumer habits, where hab is the parameter that controls the speed of habit adjustment. $z_{u,t}$ is the preference shock and follows and ARMA process.

There is a non-competitive labor market implying that there is a wedge between the marginal rate of substitution and the real wage. To incorporate the non-competitive labor market, we follow Schmitt-Grohé and Uribe (2005)

Non-Ricardian Households

Non-Ricardian households maximize their utility with respect to the following budget constraint:

$$\left(1 + \tau_{c,t}\right)P_{c,t}C_{r,t} + M_{r,t} = \left(1 - \tau_{w,t}\right)\int W_{jt}N_{r,t}^j dj + M_{r,t-1} + P_{c,t}T_{r,t}$$

where $\int W_{jt}N_{r,t}^j dj$ denotes labor income, $C_{r,t}$ per-capita non-Ricardian consumption, $P_{c,t}$ the consumer price index, and $\tau_{c,t}$ and $\tau_{w,t}$ the marginal tax rates on consumption expenditure and labor income. $T_{r,t}$ are transfers from the government.

The first-order conditions with respect to consumption and money demand are:

$$\left(1 + \tau_{c,t}\right)\Lambda_{r,t}P_{c,t} = \frac{z_{u,t}}{C_{r,t} - \text{hab}C_{r,t-1}} - \beta\, \text{hab}\, E_t\left(\frac{z_{u,t+1}}{C_{r,t+1} - \text{hab}C_{r,t}}\right)$$

$$\frac{\gamma_m}{\left(M_{r,t}\right)^{\sigma_M}} + \beta\, E_t\left(\Lambda_{r,t+1}\right) - \Lambda_{r,t} = 0$$

where $\Lambda_{r,t}$ is the Lagrange multiplier.

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[1] This Annex is adapted from the annex to "Fix vs float: Evaluating the Transition to a Sustainable Equilibrium in Bolivia" (WP/22/43), prepared by Andres Gonzalez and Diego Rodriquez. It is provided here for ease of reference.

Ricardian Households

The resource constraint of these households is given by the following equation:

$$(1 + \tau_{c,t})P_{c,t}C_{o,t} + P_{x,t}X_{o,t} + M_{o,t} + B_{o,t} + S_t B_{o,t}^* =$$
$$R_{t-1}B_{o,t-1} + S_t R_{t-1}^* B_{o,t-1}^* + (1 - \tau_{w,t})\int W_{jt}N_{o,t}^j dj + [(1 - \tau_t^k)R_t^k + \tau_t^k \delta Q_{t-1}]K_{o,t-1}$$
$$+ \frac{\gamma_{com}}{(1 - \omega)}S_t \bar{Co}\, P_{co,t}^* + T_{o,t} + \xi_{o,t} + M_{o,t-1}$$

where, $C_{o,t}$ denotes per-capital consumption by the Ricardian household, $X_{o,t}$ investment, $P_{x,t}$ nominal price of the investment good, $B_{o,t}$ a nominal government bond that pays a risk-free nominal interest rate R_t, S_t the nominal exchange rate defined as domestic currency per unit of foreign currency, and $B_{o,t}^*$ nominal bond denominated in foreign currency.[2] $[(1 - \tau_{k,t})R_t^k + \tau_{k,t}\delta Q_{t-1}]$ is the after tax capital income, where R_t^k is the nominal rate of return of capital, Q_t is the nominal price of a unit of installed capital, and $\tau_{k,t}$ is the marginal tax rate on capital income. $\frac{\gamma_{com}}{(1-\omega)}S_t \bar{Co}P_{co,t}^*$ is the per-capital revenue coming from the commodity export sector[3]. $P_{co,t}^*$ is the external nominal price of the commodity goods, and $\bar{Co}$ is a constant flow of commodity exports. Finally, $T_{o,t}$ are government transfers, and $\xi_{o,t}$ are benefits from the production firms.

We assume that rapid changes in investment are costly, and the cost is modeled through the quadratic function given by:

$$f\left(\frac{X_{o,t}}{X_{o,t-1}}\right) = \frac{a}{2}\left(\frac{X_{o,t}}{X_{o,t-1}} - 1\right)^2$$

Parameter a controls the speed of the adjustment of investment.

The household's stock of capital evolves based on the following equation:

$$K_{o,t} = (1 - \delta)K_{o,t-1} + z_{x,t}X_{o,t}\left(1 - f\left(\frac{X_{o,t}}{X_{o,t-1}}\right)\right)$$

where $K_{o,t-1}$ is per-capital the stock of capital available at time t, and δ is the depreciation rate. $z_{x,t}$ is an investment-specific exogenous shock and follows an ARMA process.

The first-order conditions with respect to consumption, government bonds, foreign bonds, investment, capital, and money are as follow:

$$(1 + \tau_{c,t})\Lambda_{o,t}P_{c,t} = \frac{z_{u,t}}{C_{o,t} - \mathsf{hab}C_{o,t-1}} - \beta\,\mathsf{hab}\,\mathsf{E}_t\left(\frac{z_{u,t+1}}{C_{o,t+1} - \mathsf{hab}C_{o,t}}\right)$$

$$-\Lambda_{o,t} + \beta\mathsf{E}_t\Lambda_{o,t+1}R_t = 0$$

$$-\Lambda_{o,t}S_t + \beta\mathsf{E}_t\Lambda_{o,t+1}S_{t+1}R_t^* = 0$$

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[2] In this notation, a negative number implies a debt.

[3] $(1 - \gamma_{com})S_t \bar{Co}P_{co,t}^*$ is the share of the commodity revenue accrued to the government.

$$-\Lambda_{o,t}P_{x,t} + \mu_t z_{x,t}\left(1 - f\left(\frac{X_{o,t}}{X_{o,t-1}}\right) - f'\left(\frac{X_{o,t}}{X_{o,t-1}}\right)X_{o,t}\right) + \beta\,\mathsf{E}_t\left(\mu_{t+1}z_{x,t+1}f'\left(\frac{X_{o,t+1}}{X_{o,t}}\right)X_{o,t+1}^2\right) = 0$$

$$-\mu_t + \beta\mu_{t+1}(1-\delta) + \beta\,\mathsf{E}_t\left(\Lambda_{o,t+1}\left((1-\tau_{t+1}^k)R_{t+1}^k + \tau_{t+1}^k\delta Q_t\right)\right) = 0$$

$$\frac{\gamma_m}{(M_{o,t})^{\sigma_M}} + \beta\,\mathsf{E}_t\left(\Lambda_{o,t+1}\right) - \Lambda_{o,t} = 0$$

where $f'\left(\frac{X_{o,t}}{X_{o,t-1}}\right) = a\left(\frac{X_{o,t}}{X_{o,t-1}} - 1\right)\frac{1}{X_{o,t-1}}$ and $f'\left(\frac{X_{o,t+1}}{X_{o,t}}\right) = a\left(\frac{X_{o,t+1}}{X_{o,t}} - 1\right)\frac{1}{X_{o,t}^2}$.

Labor Markets and Wage Setting

Households forgo labor and wage decisions and instead allow labor unions to make decisions for them. This introduces some rigidity into the labor market, allowing for the possibility of underemployment. We assume that there is a continuum of labor unions one for each labor type, and that labor types, i, are uniformly distributed across household. Labor unions will maximize profits, considering that their decision affects both Ricardian and non-Ricardian utilities. For each labor union j, the maximization is subject to two restrictions: A resource constraint

$$N_{j,t} = \int_0^1 N_t\,(j,i)di \qquad\qquad \text{Eq1}$$

that limits the total available labor for union j, and to the demand for labor type j given by

$$N_{j,t} \quad = \quad \left(\frac{W_{j,t}}{W_t}\right)^{-\epsilon_w} N_t^d \qquad\qquad \text{Eq2}$$

where ϵ_w denotes elasticity of substitution across labor type varieties, N_t^d the aggregate labor demand, W_t the aggregate nominal wage index, and $W_{j,t}$ the wage fixed by union j.[4]

When selecting the optimal wage, unions take into account that they cannot adjust wages freely and that there is an exogenous probability of not being able to adjust wages each period. In fact, each period there is a $1 - \theta_w$ probability of setting wages optimally. When a union is able to adjust wages, it does it by maximizing a weighted average of lifetime utility functions

$$\max_{W_{j,t}}\mathsf{E}_t \sum_{s=0}^{\infty}(\theta_w\beta)^s\left\{\left[\left((1-\omega)\ln\left(C_{o,t+s} - \mathsf{hab}C_{o,t+s-1}\right) + \omega\ln\left(C_{r,t+s} - \mathsf{hab}C_{r,t+s-1}\right)\right) - U(N_{t+s})\right]\right\}$$

subject to Eq1 and Eq2. In the above specification we have used the fact that labor types are uniformly distributed across household types. Hence, aggregate demand for labor type j is spread uniformly across the households. When the union is not able to adjust wages optimally, it adjusts them accordingly to the indexation rule

$$W_t = W_{t-1}g_z\pi_{t-1}^{\chi_w}\bar{\pi}^{(1-\chi_w)}$$

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[4] The section on firms contains the formal derivation of this demand equation.

where π_t denotes the consumer price inflation and $\bar{\pi}$ the inflation target. This indexation rule implies that nominal wages are indexed to a weighted average of past inflation and the inflation target and to the long run productivity growth, g_z. χ_w is the wage indexation parameter. If $\chi_w = 1$, there is full indexation to past inflation.

To find the optimality condition for the unions that can adjust wages, it is useful to find the value of the nominal wage s periods after the last re-optimization. Using the indexation rule, we can show that the value of nominal wage after s periods is

$$W_{j,t+s} = W_t^* \prod_{k=1}^{s} \left(g_z \bar{\pi}^{(1-\chi_w)} \pi_{t+k-1}^{\chi_w} \right)$$

and, in real terms, it is

$$w_{j,t+s} = w_t^* X_{t,s}^w$$

where

$$X_{t,s}^w = \prod_{k=1}^{s} \left(\frac{g_z \bar{\pi}^{(1-\chi_w)} \pi_{t+k-1}^{\chi_w}}{\pi_{t+k}} \right)$$

where $w_t = \frac{W_t}{P_{c,t}}$ is the real wage.

In every period, a union chooses the optimal level of labor $N_t(j)$, employing a weighted average of utilities of Ricardian and non-Ricardian households to obtain the following optimality condition:

$$U_N(N_{j,t}) = (1 - \tau_{w,t}) w_t \left(\omega \lambda_{r,t} + (1 - \omega) \lambda_{o,t} \right) mct_t^w$$

where mct_{t+s}^w is the co-state variable of the restriction Eq2. Unions that are able to select wages will select it such that w_t^* is

$$E_t \sum_{s=0}^{\infty} (\theta_w \beta)^s U_N(N_{t+s}) (X_{t,s}^w)^{-\epsilon_w} w_{t+s}^{\epsilon_w} h_{t+s}^d \left\{ \left[(1 - \omega) \frac{1}{MRS_{t+s}^o} + \omega \frac{1}{MRS_{t+s}^r} \right] X_{t,s}^w w_t^* - \frac{\epsilon_w}{(\epsilon_w - 1)} \right\} = 0$$

where

$$MRS_{t+s}^o = \frac{(1 + \tau_{c,t+s})}{(1 - \tau_{w,t+s})} \frac{U_{N,t+s}}{U_{c,t+s}^o}$$

$$MRS_{t+s}^r = \frac{(1 + \tau_{c,t+s})}{(1 - \tau_{w,t+s})} \frac{U_{N,t+s}}{U_{c,t+s}^r}$$

are the marginal rates of substitution (MRS) between consumption and labor. $U_{c,t}^j$ is the marginal utility of consumption of Ricardian and non-Ricardian agents.

Note that, if wages are flexible, the first order condition simplifies to

$$\left[(1 - \omega) \frac{1}{MRS_{t+s}^o} + \omega \frac{1}{MRS_{t+s}^r} \right] w_t^* = \frac{\epsilon_w}{(\epsilon_w - 1)}$$

This implies that there is a constant mark-up between the MRS and the real wage. Hence households of both types will always be willing to supply more labor when real wage increases (see Gali, Lopes and Valles, 2007, for more details).

The negotiated wage in all unions are identical, and $(1 - \theta_w)$ of unions are able to negotiate wages in every period. Then, we have the following equilibrium condition

$$N_t = \nu_{w,t} N_t^d$$

where ν_t^w is a number bonded above one and measures the inefficiency created by the wage dispersion. Since, it is larger than one, it implies that the labor supply is larger than what the firms use effectively in production, N_t^d. ν_t^w may be expressed recursively as follows:

$$\nu_{w,t} = \theta_w \left(\frac{w_{t-1}}{w_t} g_z \frac{\pi_{t-1}^{\chi_w} \bar{\pi}^{1-\chi_w}}{\pi_t} \right)^{-\epsilon_w} \nu_{w,t-1} + (1 - \theta_w) \left(\frac{w_t^*}{w_t} \right)^{-\epsilon_w}$$

Note that when wages are fully flexible, the wage dispersion disappears, that is $\nu_{w,t} = 1$.

The aggregate real wage index evolves as in the following equation:

$$w_t = \left(\theta_w \left(w_{t-1} g_z \frac{\pi_{t-1}^{\chi_w} \bar{\pi}^{1-\chi_w}}{\pi_t} \right)^{1-\epsilon_w} + (1 - \theta_w)(w_t^*)^{1-\epsilon_w} \right)^{\frac{1}{1-\epsilon_w}}$$

Firms

There are three types of goods producers in the economy: producers of final goods, producers of intermediate goods, and producers of domestic goods. Final goods are for consumption and investment. These goods are produced by combining imported and domestic inputs. Intermediate goods producers use labor and capital to produce inputs for the domestic producer. The domestic producer produces a homogenous good used as input in the production of the final goods and it is also exported.

Producers of Final Goods

Consumption Goods

The final consumption good is produced using domestic, $C_{H,t}$, and foreign goods, $C_{F,t}$ as inputs. The producer of this good minimizes cost subject to the production technology

$$C_t = \left[(1 - \alpha_c)^{\frac{1}{\eta_c}} \left(C_{H,t} \right)^{\frac{\eta_c - 1}{\eta_c}} + (\alpha_c)^{\frac{1}{\eta_x}} \left(C_{F,t} \right)^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}$$

where η_c is the elasticity of substitution between home and foreign goods and α_c is the share of foreign goods.

The optimality conditions for this problem are:

$$C_{H,t} = (1 - \alpha_c)(p_{H,t})^{-\eta_c} C_t$$

$$C_{F,t} = (\alpha_c)(p_{F,t})^{-\eta_c} C_t$$

These conditions represent the demand for domestic and foreign goods and depend negatively on domestic relative prices $p_{H,t} = \frac{P_{H,t}}{P_{c,t}}$, and foreign relative prices $p_{F,t} = \frac{P_{F,t}}{P_{c,t}} = rer_t$ and positively on aggregate consumption, C_t.

Investment Good

The producer of the investment good solves a similar problem. That is, it minimizes costs subject to the following production technology:

$$X_t = \left[(1 - \alpha_x)^{\frac{1}{\eta_x}} (X_{H,t})^{\frac{\eta_x - 1}{\eta_x}} + (\alpha_x)^{\frac{1}{\eta_x}} (X_{F,t})^{\frac{\eta_x - 1}{\eta_x}} \right]^{\frac{\eta_x}{\eta_x - 1}}$$

where η_x is the elasticity of substitution between home and foreign investment goods and α_x is the share of foreign investment in the production technology. The first-order conditions are

$$X_{H,t} = (1 - \alpha_x) \left(\frac{p_{H,t}}{p_{x,t}} \right)^{-\eta_i} X_t$$

$$X_{F,t} = (\alpha_x) \left(\frac{p_{F,t}}{p_{x,t}} \right)^{-\eta_x} X_t$$

where $p_{x,t} = \frac{P_{x,t}}{P_{c,t}}$ is the relative price of investment. This relative price is function of the domestic good price and the price of the imported good.

Producers of Domestic Good

In each period t, a the domestic good $Y_{H,t}$ is produced by a perfectly competitive firm combining intermediate goods according to the following production function

$$Y_{H,t} = \left(\int_0^1 Y_{j,t}^{1 - \frac{1}{\epsilon_H}} dj \right)^{\frac{\epsilon_H}{\epsilon_H - 1}}$$

where ϵ_H is the elasticity of substitution between goods varieties, j. Producers of the domestic good takes prices as given and choose the quantities of intermediate goods that maximize their profits. This generates the demand for the intermediate good j and the price of the domestic good as represented below:

$$Y_{H,j,t} = \left(\frac{P_{H,j,t}}{P_{H,t}} \right)^{-\epsilon_H} Y_{H,t}^d$$

and $P_{H,t} = \left(\int_0^1 P_{H,j,t}^{1 - \epsilon_H} dj \right)^{\frac{1}{1 - \epsilon_H}}$. The demand for the final domestic goods is

$$Y_{H,t}^d = C_{H,t}^* + C_{g,t} + X_{g,t} + C_{H,t} + X_{H,t}$$

where $C_{H,t}^*$ is the foreign demand for domestic output (exports) and $X_{g,t}$ is public investment.

Intermediate Goods

Intermediate goods are produced by a continuum of monopolistic firms indexed by l. These firms use capital and labor to produce $y_{H,l,t}$. The production function is

$$Y_{H,l,t} = z_{y,t} K_{l,t-1}^\alpha Z_t^{1-\alpha-\alpha_g} \left(N_{l,t}\right)^{1-\alpha} \left(K_{t-1}^g\right)^{\alpha_g}$$

where $\alpha \in (0,1)$ is the capital share of total output, Z_t is a permanent productivity shock such that

$$\frac{Z_{t+1}}{Z_t} = g_{z,t}$$

$$g_{z,t} = \left(1 - \rho_{gz}\right)g_z + \rho_{gz}g_{zt-1} + \epsilon_{z,t}$$

and $z_{y,t}$ is an exogenous transitory productivity shock, $g_{z,t}$ is a transitory shock to the growth rate of productivity and K_{t-1}^g is public capital. Note that each intermediate-good firm l has access to the same public capital stock and that the latter grows along the balanced growth path.

Following Schmitt-Grohe and Uribe, 2017, we assume that the labor input used by firm l is a composite made of a continuum of differentiated labor services. Formally, the labor input is provided as follows:

$$N_{l,t} = \left[\int_o^1 N_{j,t}^{\frac{\epsilon_w-1}{\epsilon_w}} dj\right]^{\frac{\epsilon_w}{\epsilon_w-1}} \qquad \text{Eq3}$$

Firms select the optimal combination of labor varieties by $\min \int_0^1 W_{j,t} N_{jt} dj$ subject to Eq3. The optimal demand for labor services j by firm l is

$$N_{l,j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\epsilon_w} N_{l,t}^d$$

where W_t is the nominal wage index $W_t = \left(\int_0^1 W_{j,t}^{1-\epsilon_w}\right)^{\frac{1}{1-\epsilon_w}} dj$. The total demand for labor services j is, $N_{j,t} = \int_0^1 N_{l,j,t} \, dl$ and equals

$$N_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\epsilon_w} N_t^d$$

where $N_t^d = \int_0^1 N_{lt} \, dl$. This last expression is the labor demand used in the household optimization problem.

The optimality conditions of the cost minimization problems are

$$W_t = (1-\alpha)MC_{H,t} \frac{Y_{lt}}{N_{lt}}$$

$$R_t^k = \alpha MC_{H,t} \frac{Y_{lt}}{K_{lt-1}}$$

where MC_t^H is the marginal cost, which is determined as follows:

$$MC_{H,t} = \frac{1}{Z_t^{1-\alpha-\alpha_G} K_{g,t-1}^{\alpha_G}} \left(\frac{R_{k,t}}{\alpha}\right)^\alpha \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}$$

Note that, we dropped the index l since $MC_{H,l,t} = MC_{H,t}$ for l.

As in the tradition of Calvo pricing, firms will not adjust prices frequently. Instead, in each period $(1 - \theta_H)$ firms will adjust prices optimally and the remaining θ_H firms will adjust their prices following a simple rule. Consequently, when choosing its optimal price, a firm will maximize the expected profit taking into account that there is a probability that it won't be able to adjust prices in the future. Formally, the profit maximization problem, in nominal terms, can be written as follows:

$$\max_{P_{H,l,t}} \sum_{s=0}^\infty (\beta\theta_H)^s E_t \left[\frac{\lambda_{o,t+s} P_{c,t} Z_t}{\lambda_{o,t} P_{c,t+s} Z_{t+s}} \left[P_{H,l,t+s} Y_{H,l,t+s} - MC_{H,t+s} Y_{H,l,t+s}\right]\right]$$

subject to $Y_{l,t} = \left(\frac{P_{H,l,t}}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t}^d$. Here, $MC_{H,t}$ denotes the nominal marginal cost, and $P_{H,t}$ the nominal price of the domestic goods.

We allow for price indexation. That is, firms that cannot adjust prices optimally change their prices following the indexation rule: $\pi_t^{rH} = \pi_t^{\iota_H} \bar\pi_t^{1-\iota_H}$. Hence, when a price at time t is not adjusted optimally, the price next period nominal price is determined as follows:

$$P_{H,l,t} = P_{H,l,t-1} \pi_{t-1}^{\iota_H} \bar\pi^{1-\iota_H}$$

where ι_H is a parameter that controls the degree of price indexation. When $\iota_H = 1$, there is full indexation to past inflation. If $\iota_H = 0$, price changes follow the inflation target.

The first order condition of this problem is:

$$\sum (\beta\theta_H)^s E_t \left[\frac{\lambda_{o,t+s}}{\lambda_{o,t}} \frac{P_{H,t+s}}{P_{c,t+s}} X_{H,t,s}^{-\epsilon_H} \left[X_{H,t,s} \frac{P_{H,t}^*}{P_{H,t}} + \frac{\epsilon_H}{(1-\epsilon_H)} \frac{MC_{H,t+s}}{P_{H,t+s}}\right] \frac{Y_{H,t+s}}{Z_{t+s}}\right] = 0$$

where P_t^{H*} denotes the optimal price in period t, and

$$X_{H,t,s} = \prod_{k=1}^s \frac{\pi_{t+k-1}^{rH}}{\pi_{t+k}^H}$$

Writing the first order condition in stationary variables, we get

$$\sum_{s=0}^\infty (\beta\theta_H)^s E_t \left[\frac{\lambda_{o,t+s}}{\lambda_{o,t}} p_{H,t+s} X_{H,t,s}^{1-\epsilon_H} \frac{p_{H,t}^*}{p_{H,t}} y_{H,t+s}\right] = \sum_{s=0}^\infty (\beta\theta_H)^s E_t \left[\frac{\lambda_{o,t+s}}{\lambda_{o,t}} p_{H,t+s} (X_{H,t,s})^{-\epsilon_H} \frac{\epsilon_H}{(\epsilon_H - 1)} \frac{mc_{H,t+s}}{p_{H,t+s}} y_{H,t+s}\right]$$

Denoting the sum on the left-hand side and on the right-hand side f_t^H the optimality condition can be written in a recursive form by the two equations

$$f_t^H = p_{H,t}^* y_{H,t} + \theta_H E_t \left[\frac{g_{t+1}^Z \pi_{c,t+1}}{\mathcal{R}_t} \left(\frac{\pi_t^{rH}}{\pi_{t+1}^H} \right)^{1-\epsilon_H} \frac{\pi_{t+1}^H}{\pi_{t+1}^{H*}} f_{t+1}^H \right]$$

$$f_t^H = \frac{\epsilon_H}{\epsilon_H - 1} mc_{H,t} y_{H,t} + \theta_H E_t \left[\frac{g_{t+1}^Z \pi_{c,t+1}}{\mathcal{R}_t} \left(\frac{\pi_t^{rH}}{\pi_{t+1}^H} \right)^{-\epsilon_H} f_{t+1}^H \right]$$

To complete the model, we need the nominal price index

$$P_{H,t} = \left[\int_0^1 P_{H,l,t}^{1-\epsilon_H} \, dl \right]^{\frac{1}{1-\epsilon_H}}$$

which can be written as

$$\pi_t^H = \left[\theta_H \left(\pi_{t-1}^{\iota_H} \bar{\pi}^{1-\iota_H} \right)^{1-\epsilon_H} + (1 - \theta_H) \left(p_{H,t}^* \pi_t^H \right)^{1-\iota_H} \right]^{\frac{1}{1-\epsilon_H}}$$

While we have found the optimality conditions at the firm level, we need to aggregate them. Under the current assumptions, aggregation is straightforward since the production technology is the same across firms, and the marginal cost is the same. The main difficulty is the price dispersion that creates a wedge between the output demanded and its supply. Formally,

$$\int_0^1 Y_{H,l,t} \, dl = \int_0^1 \left(\frac{P_{H,l,t}}{P_{H,t}} \right)^{-\epsilon_H} Y_{H,t} dl$$

which we write as

$$Y_{H,t} = \nu_{H,t} Y_{H,t}^d$$

where $\nu_{H,t} = \int_0^1 \left(\frac{P_{H,l,t}}{P_{H,t}} \right)^{-\epsilon_H} dl$. $\nu_{H,t}$ captures the price distortion, which is related to the welfare costs of inflation. $\nu_{H,t}^p$ can also be written recursively as

$$\nu_{H,t} = \theta_H \left(\frac{\pi_{t-1}^{rH}}{\pi_t^H} \right)^{-\epsilon_H} \nu_{H,t-1} + (1 - \theta_H) \left(P_{H,t}^* \right)^{-\epsilon_H}$$

Monetary Policy

We model two monetary policy regimes. An inflation targeting regime with flexible exchange rates and a peg regime. In the inflation targeting regime, the central bank controls the short-term nominal interest rate and sets it following a rule that responds to deviations of inflation from the target. In particular, the monetary policy rule is

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left(\left(\frac{\pi_t}{\bar{\pi}} \right)^{\varphi_\pi} \right)^{1-\rho_R} \exp(z_t^m)$$

where ρ_R is the smoothing parameter, φ_π measure the sensibility of the policy rule to deviations of inflation from the target, and z_t^m is the monetary policy shock. This shock is exogenous and follows an ARMA model.

In the peg regime, the nominal devaluation rate is constant

$$d_t = \frac{S_t}{S_{t-1}} = \bar{d}$$

To completely characterize the policy regime, we write down the balance sheet of the central bank. The bank issues money, M_t, holds foreign reserves, $B^*_{cb,t}$, and net domestic assets comprising government and central bank bonds, $B_{cb,t}$. Hence, the balance sheet of the central bank is

$$M_t = B_{cb,t} + S_t B^*_{cb,t}$$

The central bank flow of funds is

$$M_t - M_{t-1} + R_{t-1}B_{cb,t-1} + R^*_{t-1}S_t B^*_{cb,t-1} = B_{cb,t} + S_t B^*_{cb,t} + P_{c,t} qfb_t$$

Accordingly, the quasi-fiscal balance (qfb_t) is a function of the return on external and domestic assets, the domestic inflation rate, and the real exchange rate.

The adjustment of the balance sheet of the central bank depends on the policy regime. In the inflation targeting regime, the central bank adjusts the money supply is such that the short-term interest rate aligns with the policy rate. The holding of external assets is constant, and net domestic assets adjust endogenously. In the pegged regime, the central bank adjusts external asset holdings to maintain the exchange rate aligned with the target. The bank accommodates the changes in the holdings of external assets with changes in the supply of money. In the peg regime, changes in the government assets at the central bank led to changes in holdings of foreign assets.

Fiscal Policy

The government collects taxes on consumption, capital, and labor, receives the quasi-fiscal balance from the central bank and revenues from the commodity sector. It issues public debt to finance its overall balance. The central bank holds a fraction α_g of the government debt and households the remaining part. The government spends on consumption, investment, transfers to households, and interest payments on its debt.

In real terms, the government budget constraint is

$$rer_t p^*_{co,t}(1 - \gamma_{com})\bar{C}o + Tax^c_t + Tax^l_t + Tax^k_t + b_t + qfb_t = p_{H,t}(C_{gt} + X_{gt}) + \frac{R_{t-1}}{\pi_t}b_{t-1} + Tr_t$$

where $Tax^k_t = \tau^k_t \left[r^k_t - \delta\frac{q_{t-1}}{\pi_t}\right]K_{t-1}$, $Tax^l_t = \tau^l_t w_t N_t$ and $Tax^c_t = \tau^c_t C_t$, $p_{H,t}C_{gt}$ and $p_{H,t}X_{gt}$ are government expenditures on consumption and investment goods. In the current setup, marginal tax rates, government consumption, and government investment are constant. An alternative to this assumption is to include a fiscal rule for each instrument.

Transfers to households are set optimally and the government maximizes the following objective function:

$$U_{p,t} = U(C_t, N_t, m_t) + \omega_1\left(b^g_t - \bar{b}^g\right)^2 + \omega_2(Tr_t - \overline{Tr})^2$$

where $U(C_t, N_t, m_t)$ is a weighted average of Ricardian and non-Ricardian utilities. The term $\omega_2(Tr_t - \overline{Tr})^2$ captures the cost of adjusting the fiscal instrument. This term reflects the inability (or unwillingness) of the government to change the fiscal instrument abruptly. We added the public debt deviations with respect to the steady-state to the planner's objective function to capture the welfare effects of macroeconomic stability, and

as a means of encouraging time consistency in fiscal policy. When ω_1 is small, the impact of the public debt level on the planner's objective function is low, allowing the government to run larger deficits and deviations from the long-run debt level target.

Public investment is used to build public capital that enters with a lag in the production function of the intermediate good producers. Public capital is accumulated according to the following equation:

$$K_{gt} = (1-\delta)K_{gt-1} + z_{xg,t} A_{gt-L}$$

where a_{gt-l} denotes authorized budget for government investment in period $t - L$. Government investment implemented at t is

$$X_{gt} = \sum_{n=0}^{L-1} b_n A_{gt-n}$$

with $\sum_{n=0}^{L-1} b_n = 1$. This specification of the investment process assumes that it takes time to build public investment and that there are lags between the announcement of public investment and its implementation. $z_{xg,t}$ is a productivity shock in public investment.

External Sector and Current Account

The external interest rate is the sum of an external risk-free rate $\bar{R}_t^*$ and an endogenous risk premium. That is,

$$R_t^* = \bar{R}_t^* - \Omega_u \left(\exp\left(\frac{rer_t \; nfa_t}{GDP_t} - \frac{\overline{rer} \; \overline{nfa}}{\overline{GDP}} \right) - 1 \right) \quad \text{Eq 4}$$

The country risk premium is a negative function of the ratio of NFA to GDP and Ω_u is the elasticity of the country risk to the NFA-to-GDP ratio[5]. With this parametrization, the risk premium reacts to domestic productivity and commodity price shocks. Accordingly, GDP in the model equals

$$GDP_t = p_t^H Y_t^H + rer_t \; \bar{C}o \; P_{co,t}^*$$

where y_t^H is domestic output.

Non-commodity exports are modeled as

$$C_t^{h*} = \left(\frac{p_t^H}{rer_t} \right)^{-\epsilon_e} C_t^*$$

where C_t^* is proportional to the external output and ϵ_e is the elasticity of exports to the exchange rate. The balance of payments equation is found by aggregating the household budget constraint, the government budget constraint, and the balance sheet of the central bank.

$$rer_t(nfa_t - nfa_{t-1}) = \left[(p_t^H C_t^{H*} + \bar{C}o \; rer_t \; P_{co,t}^*) - rer_t(C_t^m + X_t^m) \right] + \left(\frac{R_{t-1}^*}{\pi_t^*} - 1 \right) rer_t nfa_{t-1}^*$$

where the net foreign asset position in domestic currency is $nfa_t = b_t^* + b_{cb,t}^*$.

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[5] Real net foreign assets are defined as $nfa_t = b_{cb,t-1}^* - b_{o,t-1}^*$

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PUBLICATIONS

Estimating Fiscal Multipliers Under Alternative Exchange Rate Regimes: The Case of Bolivia