Fiscal Regimes and Exchange Rates: A High-Frequency Identification

(Preliminary. Comments welcome.)

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Abstract

We study the behavior of the exchange rate in Ricardian vs. non-Ricardian regimes. In a non-Ricardian regime, the fiscal authority raises taxes insufficiently to offset an increase in debt. In such a regime, we show that a monetary tightening or higher government spending lead to a depreciation of the domestic currency. We use these theoretical predictions to uncover market participants’ expectation about future fiscal policy in Brazil by looking at daily movements of the BRL/USD exchange rate around policy announcements. We find unconventional signs of the effect of policy shocks on the exchange rate on certain occasions in the past, and in particular, when the fiscal stance tended to worsen.

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1 Introduction

Fiscal policy in the mainstream macroeconomics is assumed to behave in a Ricardian way. Fiscal expansions entailing debt increases today will be financed by fiscal actions in the future that increase the stream of net revenues to satisfy the intertemporal government budget constraint. However, the long history of defaults and hyperinflation suggests that not all governments behave in such way. When fiscal actions in the future do not assure fiscal solvency, the fiscal policy is considered to be non-Ricardian.\footnote{See Woodford (2001). Literature also refers to this regime as active fiscal regime, see Leeper (1991).} The aim of this paper is to explore the behavior of exchange rates under these different fiscal regimes.

We develop a small open economy model to study the reaction of exchange rate to fiscal and monetary policy shocks. In the Ricardian regime, the exchange rate appreciates in the face of contractionary monetary shocks and expansionary fiscal shocks, as future fiscal policy is subordinated to debt sustainability. In the non-Ricardian regime, fiscal policy does not increases taxes sufficiently to assure debt sustainability. Two equilibria arise under this regime, associated either with an outright default on debt or with a debasing of the debt value through inflation.

In both equilibria, we show that a contractionary monetary shock and an expansionary fiscal shock cause the exchange rate to depreciate. Both shocks increase the stock of debt of the government and, absent corrective fiscal measures in the future, raise the probability of a default or inflation expectations. In the former case, the currency risk premium must rise in order to compensate foreign investors for the increased risk of a default. Hence, the exchange rate depreciates on the spot to deliver an expected appreciation. In the latter case, higher inflation expectations reduce the real interest rate and cause a consumption boom that reduces the trade balance and depreciates the exchange rate. In such case, there is fiscal dominance over monetary policy as it is subordinated to the fiscal policy.

We bring this theoretical predictions to the data. The focus on the exchange rates allows us to carry out a high frequency identification\footnote{See Cochrane and Piazzesi (2002) and Bernanke and Kuttner (2005) among many others.} of the shocks (surprises) and analyze the exchange rate reaction on impact. We choose Brazil as an example country given the availability of data and the fact that some previous studies, most notably Blanchard (2004), argued that Brazil might have found itself in a situation of fiscal dominance in the past. Our
empirical strategy builds on the basic regression of the reaction of the exchange rate to fiscal and monetary shocks identified on the days of primary balance and monetary policy announcements. From here, we take two venues. First, fiscal regimes are identified using Markov regime switching. Second, the basic regression is interacted with fiscal variables to ascertain the impact of the fiscal situation on the exchange rate reactions.

We find a strong support of a second regime in the data using the quasi-likelihood ratio statistic of Cho and White (2007). In that regime, negative shocks to primary balance (fiscal expansion) and contractionary monetary policy shocks result in depreciation of real. We show that the estimated probability of that regime correlates with market expectations about primary balance and interest payments of the government. The higher the interest payments and the lower the primary balance, the higher the probability of being in that particular regime. Finally, we show in the interaction analysis that the effect of monetary policy shock changes sign from negative (conventional) to positive (unconventional) when government debt is sufficiently high.

To the best of our knowledge, this study is one of few that explore the implications of non-Ricardian regimes for exchange rates in the New Keynesian framework. Most previous studies focused on implications of those regimes on variables in the closed economy. The high frequency approach is also novel in this context and it is key to uncover the actual, exchange rate market reaction on impact to unanticipated shocks. Developing the theoretical model with testable implication and testing these implication provides a comprehensive view of the issue at hand.

The paper is organized as follows. Section 2 summarises the related literature. Section 3 introduces the model and devises the theoretical predictions we bring to the data. Section 3 explains our empirical strategy based on high-frequency identification. Section 4 illustrates the results for Brazil.

2 Literature review

We contribute and build upon the literature on the fiscal theory of the price level (FTPL). This literature argues that the fiscal authority can impose constraints on the central bank so that contractionary monetary policy can lead to high future and current inflation. Other papers call it fiscal dominance or passive monetary-active fiscal regime. In Sargent and Wallace

\footnote{See Leeper (1991) among many others.}
(1981) and Sargent (1982) the fiscal authority is unable to finance large fiscal deficits by issuing government debt and instead the central bank must use an inflation tax. In Leeper (1991), Sims (1994), and Woodford (1995) the real value if government debt is equal to the expected discounted value of future primary government surpluses, which implies under some assumptions that the price level is determined by the current nominal government debt. We follow Woodford (1995) to define two alternative policy regimes. In a Ricardian regime the primary deficit adjust passively to satisfy the government budget constraint. In a non-Ricardian regime, the fiscal authority sets the primary deficit independently of other policy variables.

In the first part of the paper, we develop a theoretical model where monetary and fiscal policies are linked through a consolidated government budget constraint. In a non-Ricardian regime, fiscal policy is not subordinated to debt sustainability and dominates monetary policy. We then analyse the behaviour of the exchange rate in the two regimes. Other theoretical models on the FTPL focus mostly on the response of inflation to policy shocks in the different regimes. Within this literature, Kim (2003) presents a New Keynesian sticky price model where in non-Ricardian regime a monetary contraction increases the inflation rate persistently. Andolfatto and Martin (2018) propose a model with a similar structure where monetary policy follows a Friedman rule that eliminates the liquidity premium on government debt. Bassetto and Cui (2018) and Berentsen and Waller (2018) also explore the implications of the FTPL when government debt has a liquidity premium. In the former study, their focus is on types of fiscal policy that generate unique equilibria when the real interest rate on bonds is negative. In the latter study, their focus is on how the dynamics of the liquidity premium affects the aggregate price level. By contrast, Williamson (2018) proposes a Fisherian model where the central bank can be set up as an institution with no fiscal constraints. The necessary condition is that the central bank can create money growth through central bank lending or through the purchase of private assets. Finally, Canzoneri et al (2018) show how the FTPL can solve part of the forward guidance puzzle pertaining to New Keynesian models when monetary policy is temporarily caught in a liquidity trap.

In the second part of the paper we show that the theoretical predictions of the model hold empirically for Brazil. We choose Brazil as our case study because of its history of fiscal profligacy and hyperinflation, suggestive of fiscal dominance in the past. Our paper is closely related to the work of Blanchard
He develops a model in which interest rate hikes can lead to currency depreciation under non-Ricardian regimes. The model is tested on daily data on exchange rate movements following monetary policy decisions by the central bank of Brazil. A practical advantage of analysing Brazil is the availability of high-frequency data to identify monetary and fiscal shocks or surprises. Daily surveys of interest rates, fiscal and other economic variables provide a rich, high frequency sample of data on policy expectations. Observing the reaction of fiscal and interest rate forecasts to monthly primary balance announcements and monetary policy announcements after COPOMs allows us to construct a populated series of monetary and fiscal policy unanticipated shocks or surprises. The strategy of identifying policy shocks by taking the difference in prices just before and just after policy actions has been applied by Cochrane and Piazzesi (2002), Bernanke and Kuttner (2005), and Gurkaynak et al (2005).

3 A small open economy model

Consider a small open economy model with infinite horizon. The world economy is composed of a continuum of countries, indexed by \( i \in [0, 1] \), each inhabited by a measure one of identical households. In each country there is also a measure one of monopolistically competitive firms that produce a continuum of differentiated trainable goods. The public sector of each country is composed of a monetary authority, which we call central bank, that sets the interest rate on the domestic-currency riskless bond and a fiscal authority, which we call government, that borrows, spends, and levies taxes on domestic households.

The focus of this paper is on the policy of a single economy which we call “Home” and can be thought of as a particular value of \( H \in [0, 1] \). To simplify the analysis, we assume that all foreign countries are identical at all points in time\(^4\) and we treat them as a unique country which we call “Foreign”. Foreign variables are denoted with a star superscript. For analytical tractability, the model is developed in continuous time and described in its deterministic form. We will then log-linearize its equilibrium conditions and study the effects of time-zero unanticipated shocks to the domestic policy rate and government expenditures under different policy scenarios.

\(^4\)This assumption allows us to keep track of only one set of international prices rather than a continuum of bilateral prices.
Households

Home is inhabited by a continuum of measure one of identical households. The representative household maximizes

$$\int_0^\infty e^{-\rho t} \left( \ln C(t) - \frac{L(t)^{1+\varphi}}{1+\varphi} \right) dt \tag{1}$$

where $C$ is consumption and $L$ is the amount of labor supplied. The parameter $\rho > 0$ is the time discount factor, and $\varphi$ the inverse of the Frisch elasticity of labor supply. The consumption index $C$ is a composite of Home and imported goods, given by

$$C'(t) \equiv \frac{C_H(t)^{1-\alpha} C_F(t)^\alpha}{(1-\alpha)^{1-\alpha} \alpha^\alpha}$$

where $\alpha \in [0, 1]$ is the degree of Home bias in consumption and measures the degree of openness of the Home economy. The imported goods index $C_F$ is itself an aggregator of goods produced in different countries and it is defined by $C_F(t) \equiv \exp \int_0^1 \ln C_i(t) \, di$. Each country produces a continuum of varieties of the domestic good. Therefore each $C_i$ is an index of consumption of all varieties defined by

$$C_i(t) \equiv \left[ \int_0^1 C_{i,j}(t)^{\frac{1}{\epsilon}} \, dj \right]^{\frac{1}{\epsilon}} \quad i \in [0, 1]$$

where the parameter $\epsilon > 1$ measures the elasticity of substitution across different varieties produced in a single country.

We assume that international financial markets are segmented. Home households save in domestic government bonds but have no access to foreign bonds. Their dynamic budget constraint is

$$dD(t) = [D(t) i(t) + W(t) L(t) + \Gamma(t) - P(t) C(t) - P_H(t) T(t)] \, dt \tag{2}$$

where $D$ denotes the amount of domestic bonds held by Home households, $i$ is the domestic nominal interest rate, $P$ is the domestic Consumer Price Index (CPI), $T$ are real lump-sum taxes (in units of the domestic tradable good, $W$ is the nominal wage, and $\Gamma$ represents nominal profits received from domestic firms.

Define the Home terms of trade as the Home price of imported goods divided by the price of Home goods, $S \equiv P_F/P_H$, such that an increase in $S$ represents a deterioration in the Home terms of trade. Let $\mathcal{E}$ be the nominal exchange
rate between the Home country and the rest of the world, defined as the 
Home currency price of one unit of any foreign currency, such that a decrease 
in \( E \) is an appreciation of the domestic currency. The optimal allocation of 
expenditure across different goods yields the following demand functions 

\[
C_H(t) = (1 - \alpha) \left( \frac{P_H(t)}{P(t)} \right)^{-1} C(t) \quad C_F(t) = \alpha \left( \frac{P_F(t)}{P(t)} \right)^{-1} C(t) \\
C_i(t) = \left( \frac{P_i(t)}{P_F(t)} \right)^{-1} C_F(t) \quad C_{i,j}(t) = \left( \frac{P_{i,j}(t)}{P_i(t)} \right)^{-\epsilon} C_i(t)
\]

\( \forall i \in [0, 1] \) and \( \forall j \in [0, 1] \), where the Home’s CPI is defined as 
\( P \equiv P^1 - \alpha P_F = P_H S^\alpha \), the price of imported goods is given by 
\( P_F \equiv \exp \int_0^1 \ln P_i(t) \, dj \), and the 
price of the good produced in country \( i \) is 
\( P_i \equiv \left( \int_0^1 P^1_{i,j} \, dj \right)^{1/\alpha} \).

The problem of the representative household is to choose consumption, savings, 
and labor to maximize (1) subject to the budget constraint (2). The optimal 
consumption/saving policy is described by the Euler equation 

\[
\frac{dC(t)}{C(t)} = (i(t) - \pi(t) - \rho) \, dt
\]

where \( \pi(t) \equiv dP(t)/P(t) \). Finally, the labor supply schedule is 
\( L(t) \equiv C(t) = W(t)/P(t) \).

Foreign households have identical preferences and solve a symmetric problem. 
Hence, their demand function for Home goods is 
\( C^*_H(t) = \alpha (P^*(t)/P^*_H(t)) C^*(t) \), 
where \( C^* \) satisfies the Euler equation 
\( \frac{dC^*(t)}{C^*(t)} = (i^*(t) - \pi^*(t) - \rho) \, dt \).

**Firms**

A continuum of monopolistically competitive firms, indexed by \( j \in [0, 1] \), 
produce different varieties of the domestic good. All firms use the same technology, 
described by the production function 

\[
Y_j(t) = L_j(t)
\]

for \( j \in [0, 1] \). The profits generated by a generic firm \( j \) are given by 

\[
\Gamma_j(t) = P_{H,j}(t) C_{H,j}(t) + \mathcal{E}(t) P^*_H(t) C^*_H(t) - W(t) L_j(t)
\]

where \( P_{H,j} \) is the Home-currency price of good \( j \) when it is sold in the Home country 
while \( P^*_H \) is the foreign-currency price of the good when it is sold.
abroad. $C_{H,j}$ represents sales of the good in the Home country while $C^*_{H,j}$ represents its export. Aggregate profits are given by $\Gamma = \int_0^1 \Gamma_j \, dj$.

Firms face an identical isoelastic demand schedule for their own good and set prices infrequently a la ?. Each firm is allowed to reset its prices only at stochastic dates determined by a Poisson process with intensity $\theta$. I assume that firms set their prices in domestic currency and the law of one price holds:

$$P^*_{H,j} (t) \equiv \frac{P_{H,j} (t)}{E(t)}$$

Under this assumption there is perfect exchange rate pass-through as exchange rate shocks are transmitted one-to-one to import prices. The firm’s objective is to maximize the present discounted value of its stream of profits, subject to the sequence of domestic and foreign demand schedules. A firm that is allowed to reset its prices at time $t$ solves the following problem

$$\max_{P_{H,j}(t)} \int_t^{\infty} e^{-(\rho+\theta)(k-t)} \frac{C(t)}{C(k)} \frac{P(t)}{P(k)} \Gamma_j (k|t) \, dk$$

where $\Gamma_j (k|t) = \left[ \frac{\hat{P}_{H,j} (t)}{P_H (k)} - (1 - \tau) W (k) \right] Y_j (k|t)$ and $Y_j (k|t) = \left( \frac{\hat{P}_{H,j} (t)}{P_H (k)} \right)^{-\epsilon} Y (k)$. The firms optimal price-setting behavior implies that producer prices inflation is given by $\pi_H (t) = \frac{\theta}{\epsilon - 1} \left[ 1 - \left( \frac{U(t)}{V(t)} \right)^{1-\epsilon} \right]$, where $U$ and $V$ evolve as

$$\frac{dU(t)}{U(t)} = \left[ \rho + \theta - \epsilon \pi_H (t) - \mathcal{M} (1 - \tau (t)) \frac{W (t) Y (t)}{P (t) C (t) U (t)} \right] dt 
\frac{dV(t)}{V(t)} = \left[ \rho + \theta - (\epsilon - 1) \pi_H (t) - \frac{P_H (t) Y (t)}{P (t) C (t) V (t)} \right] dt$$

where $\tau$ is a labor subsidy which is chosen to maximize welfare under flexible prices.

**Public sector**

The Home public sector is composed of a fiscal authority and a monetary authority. The fiscal authority, or government, finances and exogenous stream of

\[\tau (t) = 1 - \frac{1}{\mathcal{M}} \left( 1 + \frac{\alpha}{1 - \alpha} \frac{1}{\Lambda (t)} \right)\]

For simplicity, we assume that the tax needed to finance the labor subsidy is levied lump-sum directly from firms.
expenditures by raising lump-sum taxes from domestic households and issuing
nominal bonds denominated in domestic currency. Some of these bonds are
held domestically while some are held by foreign households. Let $B$ denote
the outstanding amount of government debt, then

$$B(t) = D(t) + F(t)$$

where $D$ denotes the amount of government debt held by domestic households
and $F$ the amount of debt held by foreigners. Since Home households cannot
hold foreign assets, $F$ is also the net foreign debt of the Home country.

The fiscal authority has two policy instruments to reduce its debt burden. It
can either raise taxes, $T$, or it can default on its foreign debt. Since the goal of
the paper is to characterize the behavior of the exchange rate under different
policy scenarios and not to characterize optimal policies, we assume that the
fiscal authority follows two simple rules for its instruments. More specifically,
we assume that the government set taxes according to the fiscal rule

$$T(t) = T + \phi_T \tilde{B}(t)$$

where $\phi_T \geq 0$, $\tilde{B}(t) = B(t)/P_H(t)$ is real debt, and variables without a time
argument denote their steady-state value. If $\phi_T > 0$, the government increases
taxes whenever debt rises while if $\phi_T = 0$ the fiscal policy is passive and
the government maintain a constant level of taxation regardless of the level
of debt. Similarly, we assume that default follows a Poisson process whose
intensity $\nu(t)$ is set by the government according to the following rule

$$\nu(t) = \begin{cases} 
\phi_D \left( \frac{\tilde{B}(t)}{\tilde{B}} - 1 \right) & \text{if } \tilde{B}(t) \geq \tilde{B} \\
0 & \text{otherwise}
\end{cases} \quad (6)$$

where $\phi_D \geq 0$. When $\phi_D = 0$ the government never defaults on its foreign
debt while if $\phi_D > 0$, and total debt is above its steady-state level, then the
government defaults at the time-dependent rate of $\nu(t) = \phi_D \left( \tilde{B}(t) - \tilde{B} \right)/\tilde{F}$.
That is, the probability of default over the interval $(t, t + dt)$, for $dt \downarrow 0$, is
$\nu(t) dt$. Hence, the law of motion of the expected value of real debt is

$$d\tilde{B}(t) = \left[ (i(t) - \pi_H(t)) \tilde{B}(t) - \nu(t) \tilde{F}(t) + G(t) - T(t) \right] dt \quad (7)$$

This is the government budget constraint. The government is solvent if the
following no-Ponzi condition holds: $\lim_{T \to \infty} e^{-\rho T} \tilde{B}(T) = 0$. 

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Finally, the monetary authority sets the interest rate on the domestic-currency riskless bond. As for the fiscal authority, we assume that the central bank follows a simple policy described by the following Taylor rule

\[ i(t) = \rho + (1 + \phi_\pi) \pi_H(t) + m(t) \]

where \( m \) is an exogenous component in the Taylor rule and represents monetary policy shocks.

We close the model by characterizing the behavior of foreign investors and the no-arbitrage condition between domestic and foreign bonds. We assume that foreign investors are risk-neutral. Thus their indifference condition between domestic and foreign bonds give rise to the following modified Uncovered Interest rate Parity (UIP) equation:

\[ \frac{dE(t)}{E(t)} = (i(t) - \nu(t) - i^*) \, dt \quad (8) \]

In the model, the path of the exchange rate is determined not only by the interest rate differential between the small open economy and the rest of the world, but also by the probability of default of the government on its external debt. As the probability of default increases, so does the expected appreciation of the domestic currency, that is \( dE(t) / E(t) \) falls. The expected appreciation increases the foreign-currency expected return of Home bonds which compensate foreign investors for the increase risk of a default. Notice that the UIP equation only describe the dynamics of the exchange rate while its level is determined in equilibrium.

**Equilibrium**

Let \( \Lambda \) be the consumption wedge, defined as \( \Lambda (t) = (C(t)/C^*) / Q(t) \) where \( Q(t) \equiv E(t) P^*/P(t) = S(t)^{1-\alpha} \) is the real exchange rate, defined as the relative price of one unit of foreign consumption in terms of domestic consumption. Using the households’ Euler equations we can derive its law of motion

\[ d\Lambda(t) = \nu(t) \Lambda(t) \, dt \]

Let \( Y(t) \equiv \int_0^1 Y_j(t) \, \epsilon^{-1} \, dj \) be aggregate domestic output. Market clearing in the goods markets requires \( Y(t) = C_H(t) + C_H^*(t) + G(t) = [\alpha + (1 - \alpha) \Lambda(t)] S(t) C^* + G(t) \). Therefore, output evolves as

\[ dY(t) = (1 - \alpha) S(t) C^* d\Lambda(t) + dG(t) + (Y(t) - G(t)) \frac{dS(t)}{S(t)} \]
where \( d \frac{S(t)}{S(t)} = [\phi \pi_H(t) + m(t) - v(t)] dt \). The labor market clearing condition is \( L(t) = \int_0^1 L_j(t) dj = v(t) Y(t) \), where \( v(t) \equiv \int_0^1 \left( \frac{P_{H,j}(t)}{P_H(t)} \right)^{-1} dj \) is an index of price dispersion. The firm's optimal price-setting behavior implies that producer prices inflation follows the law of motion

\[
\frac{d\pi_H(t)}{dt} = \left[ \theta - (\epsilon - 1) \pi_H(t) \right] \left[ \frac{Y(t)}{S(t) \alpha C(t) V(t)} - \left( 1 + \frac{\alpha}{1 - \alpha \Lambda(t)} \right) \frac{v(t)^\varphi Y(t)^{1+\varphi}}{U(t)} - \pi_H(t) \right] dt
\]

where \( U \) and \( V \) evolve according to \[4\] and \[5\]. Finally, the dynamic budget constraint of the government is given by equation \[7\] while foreign debt evolves as

\[
\frac{d\tilde{F}(t)}{dt} = \left[ (\rho + \phi \pi_H(t) + m(t) - v(t)) \tilde{F}(t) + G(t) - Y(t) + S(t) \alpha C(t) \right] dt
\]

This is the country's dynamic budget constraint and must satisfy the transversality condition \( \lim_{T \to \infty} e^{-\rho T} \tilde{F}(T) = 0 \).

### 3.1 The Log-Linearized Model

As common in the New Keynesian small open economy literature, we approximate the equilibrium dynamics of the model using a log-linear approximation around its steady state.\[7\] We use the log-linear approximation to study the impulse response of the model to an unexpected increase in government spending and an unexpected rise in the monetary policy rate, under different policy scenarios.\[8\] Let lowercase letters denote percentage deviations from steady state values. The log-linear equilibrium dynamics around the steady state are

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\(^6\) Its law of motion is \( dv(t) = \left[ \theta \left( 1 - \frac{\epsilon - 1}{\theta} \pi_H(t) \right) \right]^{\frac{-1}{\epsilon - 1}} + v(t) (\epsilon \pi_H(t) - \theta) \) \( dt \).

\(^7\) In steady state we have \( T = \rho \tilde{B} + G \) and \( \Lambda = \left( 1 + \frac{\rho \tilde{F}/\alpha}{Y - G - \rho \tilde{F}} \right)^{-1} \). We focus on a steady state in which \( \tilde{B} > \tilde{F} > 0 \) such that part of the government debt is held domestically, \( \tilde{D} > 0 \), and \( G \in (0, Y - \rho \tilde{B}) \) such that domestic consumption is strictly positive. These assumption also imply that \( \Lambda < 1 \).

\(^8\) Note that both shocks increase the government debt, thus the default rate, equation \( \[6\] \), takes the simple form \( v(t) = \phi_D \tilde{b}(t) \).
described by the following system of differential equations:

\[
\begin{align*}
  d\lambda(t) &= \phi_D \tilde{b}(t) \, dt \\
  dy(t) &= (1 - \gamma) \left( \phi_\pi \pi_H(t) + m(t) - \iota \phi_D \tilde{b}(t) \right) \, dt + \gamma dg(t) \\
  d\pi_H(t) &= \left( \rho \pi_H(t) + \frac{\kappa \gamma}{1 - \gamma} g(t) - \frac{\kappa \omega}{1 - \gamma} y(t) \right) \, dt \\
  d\tilde{b}(t) &= \left[ (\rho - \phi_T - \chi \phi_D) \tilde{b}(t) + \phi_\pi \pi_H(t) + m(t) + \beta g(t) \right] \, dt \\
  d\tilde{f}(t) &= \left[ \rho \tilde{f}(t) + \phi_\pi \pi_H(t) + m(t) - \phi_D \tilde{b}(t) - \frac{\rho}{1 - \gamma} y(t) + \frac{\rho \gamma}{1 - \gamma} g(t) + \sigma \lambda(t) \right] \, dt
\end{align*}
\]

with \( \iota = \frac{\alpha}{\alpha + (1 - \alpha) \Lambda} \), \( \kappa = \theta (\rho + \theta) \), \( \omega = 1 + \varphi (1 - \gamma) \), \( \chi = \tilde{F}/\tilde{B} \), \( \beta = G/\tilde{B} \), and \( \sigma = \frac{\alpha}{\alpha + (1 - \alpha) \Lambda} \), subject to the initial conditions \( \tilde{b}(0) = \tilde{f}(0) = 0 \). The exogenous variables, \( g \) and \( m \), evolve according to the laws of motion

\[
\begin{align*}
  dg(t) &= -\varrho_g g(t) \, dt \\
  dm(t) &= -\varrho_m m(t) \, dt
\end{align*}
\]

subject to the initial shocks \( g(0) = \varrho_g \xi_g \), and \( m(0) = \varrho_m \xi_m \), where \( \xi_g \) and \( \xi_m \) represents the overall size of each shock.\(^9\)

The key equation in (9) is the law of motion for government debt. Positive shocks to \( m \) and \( g \) increase debt as they tilt its path upward. Without any policy intervention, debt would increase at rate \( \rho \) violating the government budget constraint. The policymaker has three tools to reduce the real value of debt. She can raise taxes to repay the debt, she can choose to run the risk of defaulting, or she can use monetary policy to inflate debt away. The next proposition derives the condition for the existence of a unique equilibrium and characterize the policy space available to the policymaker.

**Proposition 3.1.** The system of differential equations (9) is exactly determined if and only if \(^{10}\)

\[
\phi_\pi \left[ \rho - \phi_T - (\chi - \iota) \phi_D \right] < 0
\]

Proposition 3.1 shows that, if \( \chi > \iota \), there are three policy scenarios that guarantees that the equilibrium of the model is determined. In the first scenario, which we call Ricardian Equilibrium (RE), the central bank stabilizes

\(^9\)That is, \( \xi_g = \int_0^\infty g(t) \, dt \) and \( \xi_m = \int_0^\infty m(t) \, dt \)

\(^{10}\)We also assume \( \phi_\pi < \rho^2/4\kappa \omega \) such that the roots of the system of differential equations are real. This also guarantees that the determinacy region of the parameter space is not empty.
inflation by raising the interest rate more than one-for-one in response to an increase in the PPI index, \( \phi_\pi > 0 \), while the fiscal authority prevents default by committing to increase taxes when debt rises, that is \( \phi_T > \rho \) and \( \phi_D = 0 \). If the government is not willing to raise taxes enough to offset the increase in debt, that is \( \phi_T < \rho \), then two scenarios can arise. If the central bank maintains its commitment to stabilize inflation, then the government runs the risk of defaulting at rate \( \phi_D > (\rho - \phi_T) / (\chi - \iota) > 0 \). We call this scenario the Default Equilibrium (DE). The central bank can prevent a government default by letting inflation rise to reduce the real value of its debt, that is if \( \phi_\pi < 0 \) then \( \phi_D = 0 \). We call this scenario Non-Ricardian Equilibrium (NRE).\(^{11}\)

We are mainly interested in the reaction of the exchange rate to fiscal and monetary shocks in the three different policy scenarios. We are going to use the theoretical predictions of the model to infer market participants’ expectations about future policies from the high-frequency behavior of the exchange rate. The next proposition proves the main theoretical point of the paper. To derive close form solutions we consider limit cases of the policy scenarios described above. This is just for analytical convenience and the results proved in Proposition 3.2 hold on a larger subset of the state space as shown numerically in the appendix (TBA).

**Proposition 3.2.** In a Ricardian Equilibrium (RE) with \( \phi_\pi \downarrow 0 \), \( \phi_T > \rho \), and \( \phi_D = 0 \), the response of the exchange rate to a government spending shock \( \xi_g > 0 \) and a monetary policy shock \( \xi_m > 0 \) is given by

\[
e^{RE}(0) = -\frac{\alpha}{\iota} \xi_m
\]

In a Default Equilibrium (DE) with \( \phi_\pi \downarrow 0 \), \( \phi_T \in [0, \rho) \), and \( \phi_D \downarrow (\rho - \phi_T) / (\chi - \iota) \), the response of the exchange rate to a government spending shock \( \xi_g > 0 \) and a monetary policy shock \( \xi_m > 0 \) is given by

\[
e^{DE}(0) = \alpha \beta \frac{\rho (\chi - \iota) + (\rho - \phi_T) \frac{\varrho_g + \rho}{\varrho_g + \rho} \xi_g}{\iota (\chi \rho - \iota \phi_T)} + \frac{\alpha (\rho - \phi_T) (1 - \iota) \varrho_m}{\iota (\varrho_m + \rho) (\chi \rho - \iota \phi_T)} \xi_m
\]

In a Non-Ricardian Equilibrium (NRE) with \( \phi_\pi < 0 \), \( \phi_T \in [0, \rho) \), and \( \phi_D = 0 \), the response of the exchange rate to a government spending shock \( \xi_g > 0 \) and

\(^{11}\)Since \( \phi_D \geq 0 \), if \( \chi < \iota \) then there cannot be an equilibrium with default in which monetary policy is active. Note that the sign of \( \chi - \iota \) is given by

\[
\chi - \iota = (1 - \alpha) \frac{S^\alpha C}{Y - G} - \frac{\tilde{B} - \tilde{F}}{\tilde{B}}
\]

Thus, \( \chi > \iota \) if the steady state level of foreign debt is sufficiently high.
a monetary policy shock $\xi_m > 0$ is given by

$$
e^{NRE}(0) = \alpha g \frac{\beta (\mu + \rho - \phi_T) + \frac{1-\omega}{\omega} \frac{\psi \mu (\mu + \rho)(\rho - \phi_T)}{\mu + \rho + \rho}}{\omega (\mu + \rho - \phi_T)} \xi_m + \alpha g \frac{\mu (\mu + \rho - \phi_T)}{\mu + \omega + \rho} \xi_m
$$

where $\mu > 0$.

Proposition 3.2 shows how the nominal exchange rate reacts to fiscal and monetary shocks differently in different policy scenarios. To understand the immediate reaction of the exchange rate it is helpful to study its law of motion, given by equation (8). By iterating it forward, and using the terminal condition $\lim_{t \to \infty} s(t) = 0$, we obtain

$$
e(0) = \int_0^\infty (v(t) - \phi_n \pi_H(t) - m(t)) \, dt \tag{11}
$$

The immediate reaction of the exchange rate to a shock depends on three elements: the expectation about future defaults, the expectation about the reaction of the policy rate to inflation, and finally the expectations about future monetary shocks. Consider a fiscal shock first. An unexpected increase in government spending increases output, inflation, and government debt in all three scenarios. However, the reaction of the exchange rate, both nominal and real, depends crucially on expected future policies. If the government is expected to raise taxes to stabilize debt, and the central bank raises the policy rate one-for-one with domestic inflation, i.e. $\phi_n \downarrow 0$, the exchange rate does not move. Domestic households fully expect higher taxes in the future and save the additional income to finance public debt. Since the central bank maintains the real interest rate constant, domestic private consumption does not change. Thus, the terms of trade and the real exchange rate remain constant. Since $s(t) = e(t) - p_H(t) = 0 \forall t$, then $e(0) = p_H(0) = 0$.\footnote{If $\phi_n > 0$, then the exchange rate would appreciate on the spot as can be seen from the second term in equation (11). Since the interest rate reacts more than one-for-one to inflation, the real interest rate rises and consumption falls. The terms of trade and the real exchange rate must appreciate, since $\lambda(0) = e(0) - q(0) = 0$.}

If the government is not expected to raise taxes sufficiently to stabilize the debt dynamic, then the probability of a default must rise. In order to compensate foreign investors for the risk of a default, the exchange rate must be expected to appreciate in the future, thus it depreciates on the spot. Hence, when $v$ increases, the exchange rate depreciates as can be seen from the first term in equation (11). Similarly, if agents expect the central bank to let inflation rise to prevent a default, the exchange rate depreciates in response to an expansionary
fiscal shock. This is captured by the second term in equation (11). When the interest rate rises less than one-for-one with inflation, the real interest rate falls and consumption increases, and the exchange rate appreciates. This is the well known expenditure-switching effect of the exchange rate. To stabilize the trade balance, the terms of trade depreciate in response to an increase in domestic consumption.

Similar logic applies to the case of a monetary shock. In a Ricardian Equilibrium, the fall in consumption caused by the unexpected tightening cause the exchange rate to appreciate. In a Default Equilibrium, the increase in the default probability cause the exchange rate to depreciate on the spot. Finally, in the Inflation Equilibrium, despite the sudden increase in the nominal rate, the persistence of future inflation cause the real interest rate to actually fall. As consumption rises, the exchange rate depreciates.

In the empirical part of the paper we use these theoretical predictions to uncover market perceptions of future policies in Brazil by looking at daily movements of the BRL/USD exchange rate around policy announcements.

4 High-frequency identification

In efficient markets, asset prices reflect all available public information at each point in time.\footnote{See Cochrane and Piazzesi (2002).} Some asset prices reflect expectations about future policies such as e.g. the Fed funds futures that embed expectations about future monetary policy in the US. The differences in these prices just before and just after policy actions should reflect the unexpected or “surprise” change in Fed’s policy and should therefore can be understood as monetary policy shocks.\footnote{See Cochrane and Piazzesi (2002), Bernanke and Kuttner (2005) and Gürkaynak et al. (2005) among many others} In this section, we first illustrate the basic regression used previously in the literature to assess the effect of policy shocks on asset prices, and in particular the exchange rates. Then, we explain how we depart from the basic regression to allow for variation in the estimated coefficients.

4.1 Basic regression

Following the seminal paper of Bernanke and Kuttner (2005), the changes in exchange rates around policy announcements are related to policy shocks as

\footnote{See Cochrane and Piazzesi (2002).}
follows

\[ e_d - e_{d-1} = \delta_0 + \delta_1 \xi_{v,d} + \varepsilon_d \]  

where \( d \) is the announcement day, \( e_d \) is the exchange rate, \( \xi_{v,d} \) is a policy shock (e.g. \( v \) is the key policy rate) and \( \varepsilon_d \sim N(0, \sigma^2) \). The estimated coefficient \( \delta_1 \) is then considered as the effect of the policy shock on the exchange rate. We add a vector of control variables \( X_t \) to the basic regression

\[ e_d - e_{d-1} = \delta_0 + \delta_1 \xi_{v,d} + \delta_x' X_d + \varepsilon_d \]  

First, we control for news about economic growth given that \( \xi_{v,d} \) could contain both news about the monetary or fiscal policy as well as the news about the underlying economy.\(^{15}\) Second, we suggest controlling for changes in global risk appetite toward the emerging markets, if the country in question is an emerging market country.\(^{16}\) Finally, other macroeconomic data such as Gross Domestic Product, unemployment or Consumer Price Index might have been released on the days of policy announcements. We control for these news by merging them to one time-series, since we are only interested in picking up reactions of the exchange rate to these news, rather than estimating the effect of each of the news separately. Therefore, the sign and the magnitude of the last element of the vector \( \delta_x \) have no interpretation.

4.2 Markov regime-switching

The first natural way to introduce time-variation in the coefficients of interest is to allow for Markov regime-switching. Similarly to Davig and Gerlach (2006), we estimate

\[ e_d - e_{d-1} = \delta_0(s_d) + \delta_1(s_d) \xi_{v,d} + \delta_x' X_d + \varepsilon_d \]  

where there are two regimes \( s_d = \{1, 2\} \) and \( \varepsilon_d \sim N(0, \sigma^2) \). We let both the intercept\(^{17}\) and the slope coefficient be regime-dependent, but we are primarily

\(^{15}\)See for example Cieslak and Schrimpf (2018).

\(^{16}\)Such risk appetite can be proxied with e.g. the global JPMorgan Emerging Market Bond Index (EMBI) spread.

\(^{17}\)Average daily price change of financial instruments in a random sample is almost always zero. However, the average change might be non-zero across the regimes and therefore we let the intercept be regime-dependent to minimize the omitted-variable bias in the slope coefficient.
interested in the sign of $\delta_1(s_d)$ across the two regimes. According to the model, the coefficient should have the following signs in case of a monetary policy shock

- a negative sign, when market reactions are consistent with a Ricardian regime i.e. a monetary tightening should result in appreciation of the domestic currency and therefore a lower exchange rate
- a positive sign, when market reactions are consistent with a non-Ricardian regime i.e. a monetary tightening should result in depreciation of the domestic currency and therefore a higher exchange rate.

In a regression of fiscal spending shock on the changes in the exchange rate, the coefficient $\delta_1(s_d)$ should

- be insignificant in case of market perception of a Ricardian regime i.e. a fiscal expansion/contraction should have no effect on the exchange rate
- have a positive sign in case of market perception of a non-Ricardian regime i.e. a fiscal expansion should result in depreciation of the domestic currency and therefore a higher exchange rate.

We estimate the regression (14) by maximizing the full log-likelihood function as explained in Hamilton (1994). We also test the presence of the second regime in the data by calculating the quasi-likelihood ratio statistic of Cho and White (2007).

4.3 Time-varying parameter regression

Along the lines of Kim and Nelson (1999)

$$e_d - e_{d-1} = \delta_{0,d} + \delta_{1,d} \xi_{v,d} + \delta'_X X_d + \varepsilon_d$$  

(15)

where $\delta_{*,d}$ follow a random walk without drift and $\varepsilon_d \sim N(0, \sigma^2)$. Again, we are interested in the changes of the slope coefficient $\delta_{1,d}$ and the signs we expect to observe are equivalent to those described above. We estimate this state-space model using the Gibbs sampler.
5 Evidence from Brazil

5.1 Data

For the dependent variable we use daily data on the exchange rate of Brazilian real against the US dollar obtained from the BIS statistics. The frequency of our data depends on the dates of announcements of monetary and fiscal policy decisions. For the central bank of Brazil policy actions, we consider all the decisions made by the Monetary Policy Committee including those where the Selic target rate was left unchanged. The reason to look at all the decisions is that we are also considering cases where the market was expecting a tightening or easing but the target rate was left unchanged, which is also considered a monetary policy shock.

Our period of study starts with the implementation of inflation-targeting in July 1999 and ends March 2018. In total, we consider 179 monetary policy decisions: 47 decisions to hike the Selic rate, 65 decisions to lower the rate and 67 where the rate was left unchanged. Turning to fiscal decisions we consider the monthly announcements of primary balance from April 2003 to March 2018. In total, we consider 180 policy decisions.

The monetary policy shock is identified using two time-series. First, we use daily differences around policy announcements of Deposito Interbancario (DI) futures prices. The DI futures are written on an overnight interbank borrowing rate in Brazil, which are the most popular market-based forecasts for the Selic rate. Second, we use the difference between realized and expected (average across surveyed economists) Selic target rate from the Bloomberg survey. For the fiscal policy shock, we also rely on Bloomberg survey and use the difference between realized and expected primary balance. Graph 1 plots the two time-series used to extract the monetary policy shock (left panel) and the fiscal policy shock (right panel).

Finally, we control for a variety of macro and external shocks in the regressions.

\[^{18}\text{We take the first principal component of the two series and use it as the monetary policy shock. The reason is that the monetary policy shock from futures only display almost no variability in the second part of the sample, while using monetary policy shock from the Bloomberg survey only does not allow the estimation of the Markov-switching regression to converge.}\]
In order to control for changes in expectations regarding economic growth, we use daily survey of the Brazilian central bank of GDP growth in the current calendar year. We proxy the risk appetite toward emerging markets with the JPMorgan global Emerging Market Bond Index (EMBI) spread. To control for other macro shocks, we consider the difference between realized and surveyed values around policy decisions of: 30-day unemployment rate, year-on-year growth of GDP, year-on-year growth of retail sales, and year-on-year growth in economic activity in Brazil, and change in non-farm payrolls, quarter-on-quarter annualized growth in GDP, year-on-year change in inflation and the FOMC rate in the US.\footnote{All of the data was obtained from Bloomberg.} Finally, for fiscal situation variables, we use the current year expectations for primary balance, interest payments, and net debt, all as a percentage of GDP\footnote{Data is obtained from the central bank of Brazil’s survey on market expectations.}.

If there are two macro news on the same date, we choose the one from Brazil since it likely had a higher effect than the US news. Regarding the Copom announcement dates, US CPI inflation came out on the same day as Retail sales and IBC-Br Index in Brazil on three occasions.\footnote{In particular on 17th November 2004, 19th April 2006 and 16th January 2013} Also, there were two instances when the FOMC Statement and US GDP were published on the same day.\footnote{On 29th April 2009 and 29th April 2015.} We choose the FOMC news. Regarding the primary balance announcement dates, there are overlaps of Brazilian and US macro news on 10 occasions, each involving the news about US GDP.\footnote{On 29th May 2003, 27th February 2004, 31st January 2007, 28th February 2007, 30th January 2008, 30th April 2008, 30th January 2013, 30th April 2014 and 29th May 2015.} On these dates, we choose the domestic macro news over the US GDP news. All these choices have a negligible effect on our main results.

### 5.2 Results

This section is structured as follows. We first report the results of the basic regression in equation 13 using the full-sample. Then we show the results of two alternative ways of allowing for time-variation in the slope coefficient, namely the Markov Regime-Switching and the time-varying parameter regression. Finally, we report the results from the interaction analysis.
5.2.1 Basic regression

The full-sample estimate of the regression when policy shock is the extracted fiscal policy shock from primary balance announcements in Brazil reads

\[ e_d - e_{d-1} = .283(.18) - .268(.19)\xi_{m,d} + [-.353(.65) 6.56(.03) 47.97(.57)] X_d \]

(16)

where p-values are reported in brackets. The estimated regression for the monetary policy shock reads

\[ e_d - e_{d-1} = .104(.54) - .720(.27)\xi_{m,d} + [-5.72(.03) 7.96(.01) -.001(.94)] X_d \]

(17)

As it can be seen, the estimated slope coefficients of the policy shocks are statistically insignificant. Changes in expectations regarding economic growth seem to explain the variation in the exchange rate around monetary policy decisions, but not around the announcements of the primary balance. Our proxy for risk appetite toward emerging markets seem to be an important driver of the variation in the exchange real vs. US dollar on both days of budget announcements as well as monetary policy decisions. The higher the proxy, the lower the value of the Brazilian real relative to the dollar.

5.2.2 Markov regime-switching

We find a strong support for the second regime in the data, see Table[1]. The calculated quasi-likelihood ratio statistics are much higher than the simulated critical value at the level of significance of 0.05. Therefore, there seem to be a second regime in the way how the BRL/USD exchange rate reacts to policy shocks and Table[2] provides more details.

In particular, the estimated slope coefficients in state 2 are consistent with the model-predicted reactions of the exchange rate to policy shocks under the non-Ricardian regime. A positive primary balance shock (contractionary fiscal policy) appreciates the domestic currency and reduces the exchange rate and a positive monetary policy shock depreciates the exchange rate (unfortunately, the coefficient is not statistically significant). Also, this state is much less persistent than the state 1 with the transition probability of staying in that state of 0.82 and 0.15 according to FP and MP regression, respectively.
On the other hand, the state 1 is much more persistent and the signs of the effect of the shocks are conventional and in line with the theoretical predictions: a positive fiscal policy shock has no effect on the exchange rate and a positive monetary policy shock appreciates the exchange rate.

Let us now examine more closely the probabilities of being in perceived non-Ricardian regime, see Figure 2. Although rather short-lived, they cluster in 2002/03 and 2015, exactly around the times when Blanchard (2004) and de Bolle (2015) argue that Brazil found itself in a fiscal dominance (non-Ricardian) regime. More specifically, Blanchard (2004) argues that interest rate increases in Brazil in 2002/03 would have spurred inflation rather than containing it, because higher interest rates would have resulted in higher probability of Brazilian government defaulting on its debt, an exchange rate depreciation, and in turn, higher inflation. de Bolle (2015) points to the fact that real depreciated significantly against the dollar over the course of 2015 despite the Central Bank hiking interest rates. Combined with a doubling of debt-servicing costs from 2013 to 2015, that has led to the diagnosis of fiscal dominance.

We further substantiate our results by relating the estimated probabilities to the fiscal stance, i.e. to the three variables shown in Figure 4 in a probit regression. We find a statistically significant and economically meaningful relationship between our estimated probabilities and interest payments of the Brazilian government, see Table 3. Also, we find from the MP regression that the higher the primary balance the lower the estimated probability. Finally, we find a negative relation between net debt and the probability of the non-Ricardian regime, which is somewhat confusing. Figures 5 and 6 illustrate the fit of the probabilities of the state 2 and show that significant portions of variation of probabilities from the two regressions can be explained by interest rate payments.

5.2.3 Time-varying parameter regression

We find that the estimated coefficients $\delta_1$ are on average insignificant over the sample period, see Figure 3. They exhibit some movement around the episodes we identified in the Markov regime-switching regressions, i.e. around 2002 and around 2014/2015, becoming more negative in case of FP regression

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24Since the market prices are forward looking, we use expectations of the fiscal variables rather than observed variables as explained in the data section.

25This result does not change, if we univariate regressions of each explanatory variable on the probabilities instead of one multivariate regression.
and changing the sign in the case of MP regression.

Nevertheless, the credible interval around the coefficient estimates is relatively large.

6 Conclusion

In this paper, we study the behavior of the exchange rate in Ricardian vs. non-Ricardian regimes. In a non-Ricardian regime, the fiscal authority raises taxes insufficiently to offset the increase in government debt. In such a regime, our closed form solution of a standard small open economy model shows that the exchange rate depreciates after a positive government spending shock or after a contractionary monetary policy shock.

We then propose an empirical strategy based on high-frequency identification for testing this theoretical prediction and choose Brazil as an example country. We find a strong support of a second regime in the Brazilian data characterized by unconventional signs of reaction of Brazilian real to fiscal and monetary shocks around 2002/2003 and 2015. We show that the estimated probability of that regime is associated with rising interest payments on government debt and falling primary budget balance.

To the best of our knowledge, this study is one of few that explore the implications of non-Ricardian regimes for exchange rates in the New Keynesian framework. Most previous studies focused on implications of those regimes on variables in the closed economy. The high frequency approach is also novel in this context and it is key to uncover the actual, exchange rate market reaction on impact to unanticipated shocks. Our empirical strategy can be applied to any country that regularly announces its policies and there are readily available survey or market data that anticipates these announcements.
References


Appendix A  Proofs

Proof of Proposition 3.1  The system of differential equations that describes the log-linear dynamics around the steady state is, in matrix form, is

\[
\begin{bmatrix}
\frac{d\lambda(t)}{dt} \\
\frac{df(t)}{dt} \\
\frac{db(t)}{dt} \\
\frac{dy(t)}{dt} \\
\frac{d\pi_H(t)}{dt} \\
\frac{dg(t)}{dt} \\
\frac{dm(t)}{dt}
\end{bmatrix}
= \begin{bmatrix}
0 & 0 & \phi_D & 0 & 0 & 0 & 0 \\
\sigma & \rho & -\phi_D & -\frac{\rho}{1-\gamma} & \phi_\pi & \frac{\rho}{1-\gamma} & 1 \\
0 & 0 & \rho - \phi_T - \chi\phi_D & 0 & \phi_\pi & \beta & 1 \\
0 & 0 & -1 & (1 - \gamma)\phi_D & 0 & (1 - \gamma)\phi_\pi & -\gamma\varrho_g & 1 - \gamma \\
0 & 0 & 0 & -\frac{\kappa\omega}{1-\gamma} & \rho & \frac{\kappa\gamma}{1-\gamma} & 0 \\
0 & 0 & 0 & 0 & 0 & -\varrho_g & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -\varrho_m
\end{bmatrix}
\begin{bmatrix}
\lambda(t) \\
f(t) \\
b(t) \\
y(t) \\
\pi_H(t) \\
g(t) \\
m(t)
\end{bmatrix}
\]

dt

The eigenvalues of the system are

\[
\begin{bmatrix}
0 & \rho & \mu_1 & \mu_2 & \mu_3 & -\varrho_g & -\varrho_m
\end{bmatrix}
\]

where \(\mu\)s are the roots of

\[f(\mu) = -\mu^3 + (2\rho - \phi_T - \chi\phi_D)\mu^2 - [\kappa\omega\phi_\pi + \rho(\rho - \phi_T - \chi\phi_D)]\mu + \kappa\omega\phi_\pi[\rho - \phi_T - (\chi - \iota)\phi_D]
\]

Since we have 4 initial conditions, the system is determined if there are 3 (strictly) positive roots. Thus, the system is determined if the polynomial \(f(\mu)\) has two positive roots and one negative root. Using Descartes’ rule of sign, \(f(\mu)\) has exactly one negative roots if and only if there is exactly one change of sign in the coefficients of the polynomial \(f(-\mu)\). This happens if

\[\phi_\pi[\rho - \phi_T - (\chi - \iota)\phi_D] < 0
\]

and \(\rho - \phi_T - \chi\phi_D \notin \left(-\frac{\kappa\omega\phi_\pi}{\rho}, -\rho\right)\).

Proof of proposition 3.2  In a Ricardian equilibrium without default, \(\phi_\pi > 0\), \(\phi_T > \rho\), and \(\phi_D = 0\). To solve analytically, consider the limit for \(\phi_\pi \downarrow 0\). Then the solution is

\[
\begin{bmatrix}
\lambda(t) \\
f(t) \\
b(t) \\
y(t) \\
\pi_H(t) \\
g(t) \\
m(t)
\end{bmatrix}
= \begin{bmatrix}
\xi_m \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
+ \begin{bmatrix}
0 \\
-\frac{\beta}{\rho + \varrho_\phi - \phi_T} \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\xi_\varrho_\phi e^{-\varrho_\phi t} + \begin{bmatrix}
-\frac{\rho + \varrho_\phi - \phi_T}{\rho + \varrho_\phi} \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\xi_m \varrho_m e^{-\varrho_m t} + \begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\frac{\beta\xi_\varrho_\phi}{\varrho_\phi + \phi_T + \varrho_\phi} + \begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\frac{\beta\xi_m \varrho_m}{\varrho_\phi + \phi_T + \varrho_\phi}
\]
Thus we obtain

\[ e(0) = y(0) - (1 - \iota) (1 - \gamma) \lambda(0) - \gamma g(0) \]

\[ = - (1 - \gamma) \frac{\alpha}{\iota} \epsilon_m \]

In a default equilibrium we have \( \varphi_\pi > 0, \varphi_T = 0, \) and \( \phi_D > \frac{\rho}{\chi - \iota} \). To solve analytically, consider the limit for \( \varphi_\pi \downarrow 0 \). Then the solution is

\[
\begin{bmatrix}
\lambda(t) \\
\tilde{f}(t) \\
\tilde{b}(t) \\
y(t) \\
\pi_H(t) \\
g(t) \\
m(t)
\end{bmatrix} =
\begin{bmatrix}
-\frac{\beta \epsilon}{\sigma} \\
\frac{\beta \epsilon (\varphi_m + \rho)(\chi \phi_D (\varphi_m + \rho) + \varphi_D (\varphi_m + \rho)) + \xi_m (\varphi_m + \rho)(\chi \phi_D (\varphi_m + \rho) + \varphi_D (\varphi_m + \rho))}{\chi (\varphi_m + \rho)(\varphi_m + \rho)(\rho - \chi \phi_D)} \\
\frac{\beta \epsilon (\varphi_m + \rho)(\chi \phi_D (\varphi_m + \rho) + \varphi_D (\varphi_m + \rho)) + \xi_m (\varphi_m + \rho)(\chi \phi_D (\varphi_m + \rho) + \varphi_D (\varphi_m + \rho))}{\chi (\varphi_m + \rho)(\varphi_m + \rho)(\rho - \chi \phi_D)} \\
\frac{\beta \epsilon (\varphi_m + \rho)(\chi \phi_D (\varphi_m + \rho) + \varphi_D (\varphi_m + \rho)) + \xi_m (\varphi_m + \rho)(\chi \phi_D (\varphi_m + \rho) + \varphi_D (\varphi_m + \rho))}{\chi (\varphi_m + \rho)(\varphi_m + \rho)(\rho - \chi \phi_D)} \\
0 \\
0 \\
0 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\phi_D \\
\frac{\phi_D}{\varphi_m + \rho - \chi \phi_D} \\
\frac{\phi_D}{\varphi_m + \rho - \chi \phi_D} \\
\frac{\phi_D}{\varphi_m + \rho - \chi \phi_D} \\
\frac{\phi_D}{\varphi_m + \rho - \chi \phi_D} \\
\frac{\phi_D}{\varphi_m + \rho - \chi \phi_D} \\
\frac{\phi_D}{\varphi_m + \rho - \chi \phi_D}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\xi_\varphi \varphi e^{-\varphi t} + \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\]

Thus we obtain

\[ e(0) = y(0) - (1 - \iota) (1 - \gamma) \lambda(0) - \gamma g(0) \]

\[ = \alpha \beta (1 - \gamma) \frac{\varphi_\varphi + \iota \rho \chi \phi_D + \varphi_D}{\chi \phi_D - \rho} \xi_g + \alpha (1 - \gamma) \frac{\varphi_m (1 - \chi) - \rho \chi + \rho \frac{\chi \phi_D + \varphi_D}{\chi \phi_D - \rho} \xi_m}{\iota \chi (\varphi_m + \rho)} \]

26
In a non-Ricardian equilibrium, \( \phi_B = \phi_D = 0 \) and \( \phi_\pi < 0 \). Then the solution is

\[
\begin{bmatrix}
\lambda(t) \\
\bar{f}(t) \\
\bar{b}(t) \\
y(t) \\
\pi_H(t) \\
g(t) \\
m(t)
\end{bmatrix} = \begin{bmatrix}
0 \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
0 \\
0 \\
0
\end{bmatrix}
+ \begin{bmatrix}
0 \\
\xi_g \omega_g (\rho-\mu_\pi)(\gamma-1)(\omega_g+\rho) \mu_\pi + \mu_\omega + \rho \omega \\
\xi_g \omega_g (\rho-\mu_\pi)(\gamma-1)(\omega_g+\rho) \mu_\pi + \mu_\omega + \rho \omega \\
\xi_g \omega_g (\rho-\mu_\pi)(\gamma-1)(\omega_g+\rho) \mu_\pi + \mu_\omega + \rho \omega \\
\xi_g \omega_g (\rho-\mu_\pi)(\gamma-1)(\omega_g+\rho) \mu_\pi + \mu_\omega + \rho \omega \\
0 \\
0 \\
0 \end{bmatrix} \xi_g \omega_g (\rho-\mu_\pi)(\gamma-1)(\omega_g+\rho) \mu_\pi + \mu_\omega + \rho \omega \\
+ \begin{bmatrix}
0 \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
\frac{\rho+m_\pi}{(\rho-\mu_\pi+\omega_m)(\mu_\pi+\omega_m)} \\
0 \\
0 \\
0
\end{bmatrix} \frac{\kappa \omega}{\mu_\pi} \left( \frac{\xi_g \omega_g (\gamma-1)(\omega_g+\rho) \mu_\pi (\rho-\mu_\pi)}{(\gamma-1)(\omega_g+\rho) \mu_\pi + \mu_\omega + \rho \omega} - \beta \right) \\
- \frac{\xi_g \omega_g^2}{(\mu_\pi + \omega_m)(-\mu_\pi + \omega_m + \rho)}
\end{bmatrix}
\]

with \( \mu_\pi = \frac{-\rho^2 - 4\omega \kappa \phi_\pi}{2} > 0 \). Thus we obtain

\[
e(0) = y(0) - (1 - \iota)(1 - \gamma) \lambda(0) - \gamma g(0) \\
= \alpha (\rho + \mu_\pi) \frac{\beta \omega_{\pi-1,\gamma} \mu_\pi + \gamma \rho_{\omega_g+\rho+\mu_\pi}}{\iota \omega (\omega_g + \rho)} \omega_g \xi_g + \frac{\alpha \rho (1 - \gamma)}{\mu_\pi (\omega_m + \rho + \mu_\pi)} \omega_m \xi_m
\]
Appendix B  Figures
Figure 1: **Fiscal and Monetary policy shocks.** The figure shows differences in standard deviations between realized and expected primary balance from the Bloomberg Survey used to proxy the fiscal policy shock (upper panel) and differences in percentage points of *Deposito Interbancario* futures prices and between realized and expected Selic target rate from Bloomberg survey around monetary policy announcements (lower panel).
Figure 2: **Probabilities of non-Ricardian regime.** The figure illustrates the probabilities of being in the state 2 estimated from the regression with fiscal policy shocks (upper panel) and with monetary policy shocks (lower panel).
Figure 3: **Time-varying \( \delta_1 \) and 90% credible interval.** The figure plots the posterior mean of the slope coefficient from the regression with fiscal policy shocks (upper panel) and with monetary policy shocks (lower panel) together with a 90% credible interval.
Figure 4: **Current year expectations of fiscal variables (in % of GDP).** The figure shows the current year expectations for primary balance (solid blue), interest payments (dashed blue) and net debt (solid red line) in terms of % of GDP from the BCB’s Survey of market expectations on the days of monetary policy announcements.
Figure 5: **Fitted probabilities of non-Ricardian regime: FP regression.** The figure illustrates the fitted probabilities of being in the state 2 estimated from the regression with the fiscal policy shocks (left panel) and the decomposition of the fitted value (right panel).
Figure 6: Fitted probabilities of non-Ricardian regime: MP regression. The figure illustrates the fitted probabilities of being in the state 2 estimated from the regression with the monetary policy shocks (left panel) and the decomposition of the fitted value (right panel).
Appendix C  Tables

Table 1: Quasi-likelihood ratio statistic. The table reports the QLR statistic of Cho and White (2007) against the simulated critical value at the level of significance 0.05 of 7.0. The critical values are obtained using $H=(-5,5)$, grid mesh = 0.01 with 100,000 replications.

<table>
<thead>
<tr>
<th>MP regression</th>
<th>FP regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>105.26</td>
<td>42.1</td>
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</table>
Table 2: **Markov regime-switching.** The left panel reports the results from the regression with monetary policy shocks (MP regression) and the right panel the results with fiscal policy shocks (FP regression). Each panel shows the matrix of transition probabilities $P$, estimated coefficients with p-values (in brackets) and the number of observations (nObs).

<table>
<thead>
<tr>
<th></th>
<th>MP Regression</th>
<th></th>
<th>FP Regression</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>States</td>
<td>States</td>
<td>States</td>
<td>States</td>
</tr>
<tr>
<td>$P$</td>
<td>1</td>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>0.15</td>
<td>0.01</td>
<td>0.82</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2.90</td>
<td>(0.00)</td>
<td>5.36</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\delta_0$</td>
<td>-0.24</td>
<td>(0.24)</td>
<td>5.40</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\delta_1$</td>
<td>-1.61</td>
<td>(0.01)</td>
<td>2.42</td>
<td>(0.14)</td>
</tr>
<tr>
<td>$\delta_{GDP}$</td>
<td>-5.42</td>
<td>(0.01)</td>
<td>-0.10</td>
<td>(0.88)</td>
</tr>
<tr>
<td>$\delta_{EMBI}$</td>
<td>8.51</td>
<td>(0.00)</td>
<td>7.07</td>
<td>(0.01)</td>
</tr>
<tr>
<td>$\delta_{macro}$</td>
<td>0.00</td>
<td>(0.81)</td>
<td>65.86</td>
<td>(0.35)</td>
</tr>
<tr>
<td>nObs</td>
<td>179</td>
<td>180</td>
<td></td>
<td></td>
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</tbody>
</table>
Table 3: Relating non-Ricardian probabilities to fiscal stance. The table reports coefficients estimated from a regression of fiscal variables on the non-Ricardian probabilities from the regression with monetary policy shocks (column MP) and with fiscal policy shocks (column FP) together with p-values (in parenthesis) and the number of observations (nObs).

<table>
<thead>
<tr>
<th></th>
<th>FP</th>
<th>MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest payments</td>
<td><strong>-1.11</strong></td>
<td><strong>-0.34</strong></td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.06)</td>
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<tr>
<td>Primary result</td>
<td><strong>-0.17</strong></td>
<td><strong>-0.14</strong></td>
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<td></td>
<td>(0.08)</td>
<td>(0.05)</td>
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<tr>
<td>Net debt</td>
<td><strong>-0.18</strong></td>
<td>-0.01</td>
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<tr>
<td></td>
<td>(0.01)</td>
<td>(0.85)</td>
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<tr>
<td>Intercept</td>
<td>-1.55</td>
<td><strong>-3.24</strong></td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>nObs</td>
<td>180</td>
<td>149</td>
</tr>
</tbody>
</table>