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EXCHANGE RATE MOVEMENTS AND MONETARY POLICY IN BRAZIL: ECONOMETRIC AND SIMULATION EVIDENCE

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Abstract

The literature on monetary economy has aroused growing interest in macroeconomics. Due to computational advancements, models have been increasingly more complex and accurate, allowing for the in-depth analysis of the relationships between real economic variables and nominal variables. Therefore, using a dynamic stochastic general equilibrium (DSGE) model, based on Gali and Monacelli (2005), we propose and estimate a model for the Brazilian economy by employing Bayesian methods so as to assess whether the Central Bank of Brazil takes exchange rate fluctuations into account in the conduct of monetary policy. The most striking result of the present study is that the Central Bank of Brazil does not directly change the interest rate path due to exchange rate movements. A simulation exercise is also used. Our conclusion is that the economy quickly accommodates shocks induced separately on the exchange rate, on the terms of trade, on the interest rate, and on global inflation.

Keywords: Dynamic and stochastic general equilibrium (DSGE) models, monetary policy, exchange rate, Bayesian methods, simulation.

JEL Classification: E47, E52, F41.

1. Introduction

According to Walsh (2003), the study of monetary economics can be defined as the process of investigation into the relationships between real economic variables and nominal variables, i.e., relationships between real output, real interest rate, employment, real exchange rate, *etc*, with the inflation rate, nominal interest rate, nominal exchange rate, money supply, among others.

After Keynes (1923), the literature on monetary economy has aroused growing interest in macroeconomics which, with the advent of computational improvements, has encouraged the development of increasingly complex models to explain the dynamics of economies. The seminal works by Ramsey (1928) and Solow (1956), regarded as

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benchmark for current macroeconomic models, were the first ones to provide consistent explanations on the growth paths of different economies, determined solely by exogenous factors such as technological growth rate.

Thus, endogenous growth models, such as the *AK* models of Romer (1986, 1987), Lucas (1988), Rebelo (1987) and their variations in Romer (1990), Grossman and Helpman (1991a, 1991b) and Aghion and Howitt (1992) came into existence. These models, however, had serious shortcomings (e.g.: multiple equilibria). But the most serious problem is that they did not include money in their formulation, thus overlooking important impacts on the growth path, at least in the short run, and eventually affecting all neoclassical growth models.

A great deal of effort was put in and different methods that included money in the models of determination of economic relationships were developed to overcome this drawback, chiefly those devised by Sidrauski (1967), Baumol (1952), Tobin (1956), Kiyotaki and Wright (1989), Clower (1967) and Samuelson (1958). But none of the models commanded so much attention as the IS-LM model, shown in detail in Romer (2005).

The model obviously combines an IS curve with an LM curve, in which the monetary authority responds to economic shocks with increases in monetary aggregates. From the equilibrium between the IS and LM curves, it is possible to obtain an aggregate demand curve which, along with a Phillips curve – aggregate supply –, represents the dynamics of the economic equilibrium, given by the trade-off between output and inflation.

However, this type of model also contains some flaws, especially with regard to the explanation of mechanisms of monetary policy transmission to the economy. Several authors proposed solutions to these flaws, but none of the works considered the effects of expectations on economic equilibrium, something that is extremely important and that gave Lucas (1976) a Nobel prize. Lucas's criticism leads to the conclusion that monetary policy may have nontrivial effects on real variables, becoming a stabilization tool or an instrument that generates additional economic fluctuations.

As a result, numerous models were devised, in which expectations played a determining role in equilibrium relationships. The most successful models, albeit quite complex in terms of concept and implementation, were the dynamic and stochastic general equilibrium (DSGE) models, viewed as an improvement of the conventional IS-LM models.

In lieu of the LM curve, DSGE models use a Taylor rule, i.e., a monetary policy rule in which interests rather than monetary aggregates are the central bank's instruments for invigorating the economy. With the monetary policy rule and a dynamic IS curve, which includes expectations, one obtains the aggregate demand. Since the new Keynesian Phillips curve, which has this name for also considering the expectations of individuals, represents the aggregate demand, economic equilibrium is achieved by the relationship between aggregate supply and aggregate demand curves, rendering this type of model highly intuitive.

Note that DSGE models allow studying several aspects of the economy and have inspired many authors to put their efforts in developing them. In this regard, the work by Gali and Monacelli (2005) is noteworthy, as a dynamic and stochastic general equilibrium model for a small open economy is developed therein, based on Calvo's (1983) sticky price model. The authors also use the developed model to test three different monetary policy rules for the economy, using simulation methods: Taylor rule for domestic inflation, Taylor rule for the consumer price index and a pegged exchange rate regime.[4]

Other authors decided to apply models developed from real data to assess, for instance, the conduct of monetary policy by the central bank. This is the case of Lubik and Schorfheide (2007), who use a simplified version of the model developed by Gali and Monacelli (2005) to assess the conduct of monetary policy in Australia, Canada, New Zealand and the United Kingdom. The authors consider general Taylor rules in which the monetary authority reacts to movements in output, inflation and exchange rate, to test whether the central banks of these countries change the conduct of their monetary policy due to exchange rate fluctuations. The conclusion is that only the central banks of Canada and of the United Kingdom change their interest rates due to exchange rate movements.

Nevertheless, Lubik and Schorfheide (2007) are not the only ones to carry out this type of work. Clarida and Gertler (1997) provide estimates that lead to the conclusion that

[4] Other important works, which preceded the model of Gali and Monacelli (2005) and that should be cited, are those of Obstfeld and Rogoff (1995, 1999), Bacchetta and van Wincoop (2000), Betts and Devereux (2000) and Corsetti and Pesenti (2001), handsomely contributing to the development of this type of study.

the central bank of Germany responds to real exchange rate devaluation by increasing short-term interest rates. While adjusting a model for the Australian economy, Brischetto and Voss (1999) and Dungey and Pagan (2000) found evidence that the central bank of Australia also reacts to exchange rate movements by increasing short-term interest rates.

Clarida, Gali and Gertler (1998) show reaction of nominal interest rates at the central banks of Germany, Japan and England to real exchange rate movements. Gerlach and Smets (2000) estimate a monetary policy rule for the central banks of New Zealand, Canada and Australia, concluding that the former two respond to nominal exchange rate movements with short-term interest rate increases, whereas the latter refrains from doing that.

Quite recently, Hüfner (2006), by investigating the behavior of the central banks of Australia, Canada, New Zealand, Sweden and the United Kingdom, found significant terms regarding the exchange rates of the United Kingdom and New Zealand. For emerging economies, the works by Ades, Buscaglia and Masih (2002) are of note, as they analyzed the behavior of the central banks of Chile, Israel, South Africa, Czech Republic and Mexico, and found significant coefficients for the exchange rate of these countries.

Wollmershäuser (2006) assesses the impact of uncertainty on exchange rate for the conduct of monetary policy with the aim of elucidating the rationale of central banks for changing the conduct of monetary policy due to exchange rate movements. The results suggest that monetary policy rules that also consider exchange rate are superior to simple monetary policy rules, which only take inflation and output into account.

Thus, the present study uses a dynamic and stochastic general equilibrium model to assess the conduct of monetary policy by the central bank of Brazil (CBB). More specifically, the main goal is to test whether the CBB directly changes its conduct of monetary policy due to exchange rate movements, later on performing simulation exercises to assess how the economy accommodates induced shocks, contributing to an unparalleled application to the Brazilian economy. The importance of deeply understanding the characteristics of the Brazilian monetary authority is evident, especially for financial market agents, for whom this clearer understanding allows substantially increasing potential gains in the future interest rate market.

Besides the introduction, this paper is organized as follows: Section 2 presents the theoretical model used, alongside the simplifications that are necessary for econometric estimation, which is carried out in Section 3. Section 4 deals with the simulation exercises, performed to assess the behavior of the economy through induced shocks and the time elapsed until the variables return to their respective steady states. Section 5 provides the final comments and suggestions for future research.

2. The Dynamic and Stochastic General Equilibrium Model

The model used in the present paper belongs to the class of dynamic and stochastic general equilibrium (DSGE) models, a simplified version of the model developed by Gali and Monacelli (2005). The authors model the world economy based upon numerous open economies represented on the interval $[0,1]$, which means that each economy is extremely small and that its domestic policy decisions have no impact on other world economies. Economies are liable to different productivity shocks, but they share the same preferences, technology, and market structure.

The proposed simplifications are targeted at adjusting the model for estimation, since its original form produces some problems at this stage, such as identification problems. The hypotheses of intertemporal elasticity of substitution equal to one and the perfectly elastic labor supply[5] were added to the original model proposed by Gali and Monacelli (2005). Therefore, the dynamic IS curve can be written as:

$$y_t = E_t\{y_{t+1}\} - \left[\frac{1-\alpha(2-\alpha)(1-\sigma)}{\sigma}\right](r_t - E_t\{\pi_{t+1}\}) + \left[\frac{1-\alpha(2-\alpha)(1-\sigma)}{\sigma}\right]\left(\frac{1}{\beta}-1\right) - \\ -\alpha\left[\frac{1-\alpha(2-\alpha)(1-\sigma)}{\sigma}\right]E_t\{\Delta s_{t+1}\} - [\alpha(2-\alpha)(1-\sigma)]E_t\{\Delta y^*_{t+1}\} \quad (3.1)$$

Where y_t is the output at time *t*, α is a parameter inversely related to the level of preference for domestic products, σ represents the intertemporal elasticity of substitution,

5 Such hypotheses are supported in the literature, as in the work conducted by Lubik and Schofheide (2007).

r_t is the nominal interest rate, π_t is the rate of inflation at *t*, β is an intertemporal discount factor, s_t are the terms of trade at *t* and, finally, y_t^* is the world output at time *t*.

The new Keynesian Phillips curve is as follows:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \alpha\beta E_t\{\Delta s_{t+1}\} - \alpha\Delta s_t + \frac{\lambda\sigma}{1-\alpha(2-\alpha)(1-\sigma)}(y_t - \bar{y}_t) \tag{3.2}$$

Where, $\lambda > 0$ is a constant that captures the level of price stickiness and $\bar{y}_t$ is the potential output at *t*. To close the model it is necessary to introduce a monetary policy rule for the central bank. A Taylor rule, in which the central bank reacts to movements in inflation, output and exchange rate, is used. Formally we have:

$$r_t = \rho_R r_{t-1} + (1-\rho_R)[\psi_1\pi_t + \psi_2 y_t + \psi_3\Delta e_t] + \varepsilon_t^R \tag{3.3}$$

Where, $0 < \rho_R < 1$ introduces some persistence to the nominal interest rate, $\psi_1, \psi_2, \psi_3 \geq 0$, e_t is the nominal exchange rate at *t*, and ε_t^R is a non-systematic component of monetary policy, that is, an exogenous shock, with variance σ_R^2. As the main purpose of the present study is to verify whether the central bank changes the conduct of monetary policy due to exchange rate movements, one should estimate the model and test the significance of ψ_3.

However, ρ_R may impose a very strong restriction on the central bank's reaction function, making it inappropriate for reliably representing its behavior. So, an alternative reaction function is proposed, which does not impose such restriction and is estimated simultaneously with the equation of the original model:[6]

$$r_t = \rho_R r_{t-1} + \psi_1\pi_t + \psi_2 y_t + \psi_3\Delta e_t + \varepsilon_t^R \tag{3.4}$$

Where all parameters have the same interpretation and are restricted to the same spaces of equation (3.3). One should also consider that purchasing power parity (PPC) holds and therefore:

[6] Also, as a third option, another reaction function was proposed, in which the central bank responds, with interest rates, to movements in the difference between current inflation and inflation target, output gap and exchange rate fluctuations. However, Bayesian algorithms showed difficulty converging to a stationary distribution and therefore this reaction function was ruled out.

$$\pi_t = \Delta e_t + (1-\alpha)\Delta s_t + \pi_t^* \tag{3.5}$$

Where π_t^* is a shock on global inflation, which captures deviations in purchasing power parity, with variance σ_π^2. The behavior of the exchange rate is represented by:

$$\Delta e_t = \rho_E \Delta e_{t-1} + \varepsilon_t^E \tag{3.6}$$

Where $0 < \rho_E < 1$ and ε_t^E is an exogenous shock, with variance σ_E^2. In turn, the behavior of the terms of trade is given by the following equation:

$$\Delta s_t = \rho_S \Delta s_{t-1} + \varepsilon_t^S \tag{3.7}$$

Where, $0 < \rho_S < 1$ and ε_t^S, just as in (3.6), is an exogenous shock, with variance σ_S^2. Then one can write:

$$\left[\frac{1-\alpha(2-\alpha)(1-\sigma)}{\sigma}\right]\Delta s_t = \Delta y_t^* - \Delta y_t \tag{3.8}$$

The interpretation of (3.8) is straightforward: an increase in world output, *ceteris paribus*, increases the demand for domestic goods and, consequently, the terms of trade.

Thus, the set of equations (3.1)-(3.8) constitutes the system to be estimated which will lead to the conclusion about the conduct of monetary policy by the central bank of Brazil (CBB). Given the use of a restricted sample, with a small number of observations, Bayesian econometric methods offer advantages over traditional methods in that they allow using *a priori* information. The use of these methods for estimating dynamic and stochastic general equilibrium models has other advantages, since, according to Canova (2007), DSGE models are problematic in at least two ways.

First because this type of model allows only an approximation to the actual data generating process, as the vector of structural parameters often has a small size and thus strong restrictions are imposed in the short and long run. Secondly, the number of exogenous variables is usually smaller than that of endogenous variables, rendering the covariance matrix of endogenous variables singular. These features make estimation and DSGE model tests by way of traditional methods (e.g.: maximum likelihood or GMM) too complex, as the singularity mentioned above prevents numerical Hessian-based routines from working properly, consequently preventing the objective function from reaching its maximum.

On the other hand, Bayesian methods are appropriate for circumventing these problems. The inference of the *a posteriori* distribution does not rely on whether the model is the actual data generating model and it is still possible even when the covariance matrix of the vector of endogenous variables is singular, since the Hessian is not necessary for obtaining the *a posteriori* distribution. Canova (2007) also mentions another advantage of using Bayesian methods for estimating DSGE models: the *a posteriori* distribution includes uncertainty over the parameters and over the specification of the model, making them more attractive to macroeconomists.

3. Econometric estimation

The sample used for the estimation includes log-linearized quarterly observations of the gross domestic product (GDP), inflation, nominal interests, nominal exchange rate and terms of trade, from the first quarter of 2000 to the third quarter of 2007, with 31 observations for each variable. The post-2000 period was chosen because the central bank of Brazil previously followed a pegged exchange rate regime and therefore it would make no sense to estimate a monetary policy rule to test whether the CBB considered exchange rate movements in its conduct of the monetary policy.

The chain-linked series of quarterly GDP with seasonal adjustment and the monthly IPCA (broad consumer price index), whose fluctuation was accumulated during three months in order to obtain the quarterly data, was provided by the Brazilian Institute of Geography and Statistics (IBGE). The monthly Selic rate, provided by the central bank of Brazil, was used for nominal interest rates, and also changed to the quarterly regime. The nominal exchange R$/US$ rate was obtained from the same source, using the Ptax sale value at the end of the period. Export and import data, necessary for the calculation of the terms of trade were obtained from the Brazilian Foreign Trade Research Foundation (FUNCEX).

In addition, another two series were built: potential GDP and world GDP. The former was obtained by applying the Hodrick-Prescott (HP) filter to the GDP series. It should be underscored that other measurements of potential GDP yielded similar estimation results, such as the Christiano-Fitzgerald filter, linear trend and the use of the Kalman filter. The quarterly world GDP was calculated using data from the International Monetary Fund (IMF).

The estimation was made using Dynare for Matlab, as this program contained predefined routines and thus allowed reducing the computational cost of implementation. Therefore, the first stage consisted in choosing independent *a priori* distributions for each parameter. For these choices, parameter restrictions, such as non-negativity, belonging to a certain domain, etc, were considered.

Since the information set to center parameters around some given values of certain distributions is limited, the natural choice was to use diffuse *a priori* distributions, in which only one interval is chosen for parameter variation. All the values belonging to this interval have the same probability of occurrence, whereas values outside the interval have zero probability.

Parameter α, inversely related to the level of preference for domestic products, i.e., a kind of trade liberalization index, belongs to interval $[0;1)$. Therefore, one chooses the restricted uniform distribution on this interval. The intertemporal elasticity of substitution, σ, also has $[0;1)$ as domain and, consequently, a restricted uniform distribution was also chosen for this interval.

A uniform distribution with the same parameters and domain was chosen for β, as β is an intertemporal discount factor. In turn, λ, present in the new Keynesian Phillips curve as a constant that captures some price stickiness, should be positive. Thus, the uniform distribution between 0 and 2 is chosen, since the literature on the topic shows coefficients belonging to this interval, as in Lubik and Schorfheide (2007).

From the Taylor rule, in order to induce stationarity, ρ_R is restricted to interval $[0;1)$, with a uniform *a priori* distribution restricted to this interval. From the same equation, we have restriction $\psi_1, \psi_2, \psi_3 \geq 0$, where these parameters are responsible for the uniform distribution between 0 and 10. Both ρ_S and ρ_E are two parameters restricted to the interval $[0;1)$, to induce stationarity in the variables to which they are related, and therefore, they are restricted to this interval, with uniform distribution. Finally, the standard deviations of the shocks have an inverse gamma distribution. Table 3.1, below, summarizes the choices of *a priori* distributions:

Table 3.1 –*a Priori* Distributions

Parameter	Domain	Density	Mean	Variance
α	[0;1)	Uniform	0.5000	0.0833
σ	[0;1)	Uniform	0.5000	0.0833
β	[0;1)	Uniform	0.5000	0.0833
λ	[0;2]	Uniform	1.0000	0.3333
ρ_R	[0;1)	Uniform	0.5000	0.0833
ψ_1	[0;10]	Uniform	5.0000	8.3333
ψ_2	[0;10]	Uniform	5.0000	8.3333
ψ_3	[0;10]	Uniform	5.0000	8.3333
ρ_S	[0;1)	Uniform	0.5000	0.0833
ρ_E	[0;1)	Uniform	0.5000	0.0833
σ_R	$\Re_+$	InvGamma	0.2000	Inf.
σ_π	$\Re_+$	InvGamma	0.2000	Inf.
σ_S	$\Re_+$	InvGamma	0.2000	Inf.
σ_E	$\Re_+$	InvGamma	0.2000	Inf.

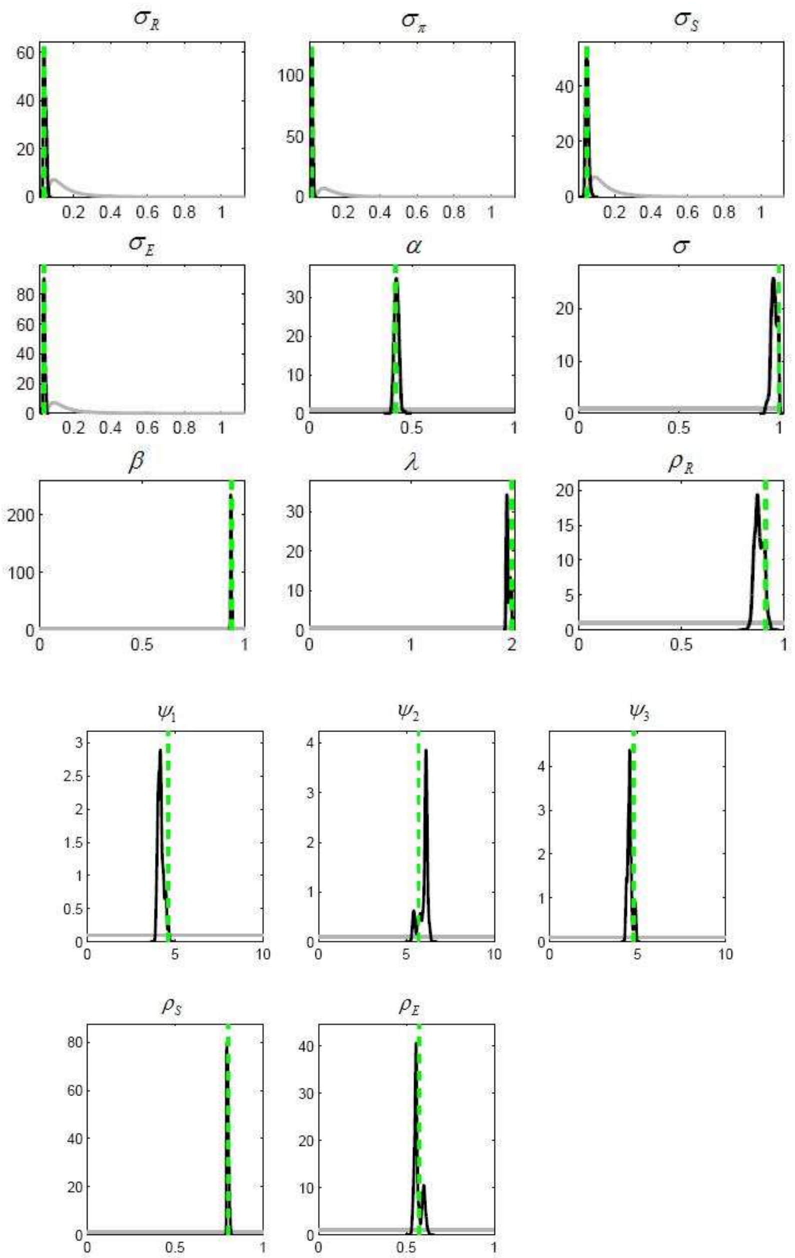
Source: Elaborated by the Authors.

The next step was then to use the data to change initial beliefs, given by *a priori* distributions. First, in subsection 3.1, the model with the original (restricted) reaction function is estimated, given by equation (3.3), and then later in subsection 3.2, the model with the alternative (unrestricted) reaction function is estimated, given by equation (3.4).

3.1. Restricted Reaction Function

In this subsection, the model with the original (restricted) reaction function is estimated, given by equation (3.3). By the program and methods mentioned in the previous section, Bayesian estimates can be summarized in Figure 3.1, which shows the *a priori* and *a posteriori* distributions, and in Table 3.2:

Figure 3.1 – A Priori and a Posteriori distributions



Source: Elaborated by the Authors.

Table 3.2 – Parameter Estimation

	A Priori Distribution	A Posteriori Distribution	
Parameter	**Mean**	**Mean**	**Confidence interval (95%)**
α	0.5000	0.4265	[0.4087;0.4440]
σ	0.5000	0.9775	[0.9570;0.9998]
β	0.5000	0.9331	[0.9302;0.9376]
λ	1.0000	1.9739	[1.9382;1.9924]
ρ_R	0.5000	0.8704	[0.8459;0.9112]
ψ_1	5.0000	4.1842	[3.9259;4.4536]
ψ_2	5.0000	5.8727	[5.4023;6.2165]
ψ_3	5.0000	4.5722	[4.3340;4.8313]
ρ_S	0.5000	0.8064	[0.7922;0.8085]
ρ_E	0.5000	0.5781	[0.5389;0.6046]
σ_R	0.2000	0.0453	[0.0334;0.0553]
σ_π	0.2000	0.0323	[0.0254;0.0376]
σ_S	0.2000	0.0490	[0.0377;0.0627]
σ_E	0.2000	0.0400	[0.0315;0.0474]

Source: Elaborated by the Authors.

Table 3.2 presents the means for the *a priori* and *a posteriori* distributions, in addition to the 95% confidence interval for the estimated coefficients. Results were consistent with the literature, as in Lubik and Schorfheide (2007). It is possible to conclude that the central bank of Brazil follows an anti-inflationary policy, since $\psi_1 = 4{,}1842$, an expected result for the central bank that conducts monetary policy using an inflation targeting system. This result is coherent with the idea of a stronger response of nominal interest rates to current inflation movements to induce an increase in real interest rate and the desired effects on the economy.

The CBB also shows a strong reaction to output, shown by the value estimated for ψ_2. Yet, for the purpose of the present paper, the value of 4,5722 obtained for ψ_3 is more important and seems to indicate that the CBB reacts to exchange rate movements to define the interest rate path. However, to guarantee the validity of this conclusion, it is necessary to compute statistical tests, performed later. To eliminate the commentaries about the CBB's reaction function, the estimated coefficient $\rho_R = 0{,}8704$ indicates high persistence of nominal interest rates and therefore a relatively smooth interest rate path.

The other estimated parameters also yielded values that are coherent with the economic theory and with the Brazilian reality. An exception is the high value estimated for α, showing that Brazil has a considerable level of trade liberalization, a result that is not confirmed by studies on this topic. Nonetheless, the interpretation of α in this type of model loses some of its value, as argued by Lubik and Schorfheide (2005) and Justiniano and Preston (2005). This occurs since this parameter should have an acceptable value in the strict restrictions imposed by the relationships between equations, not reliably showing the level of trade liberalization and thus justifying $\alpha = 0{,}4265$.

Even though the estimated results seem to indicate that the CBB considers exchange rate movements in the conduct of the monetary policy, it is interesting to use statistical tests to validate this conclusion. The natural choice in Bayesian econometrics is to use Bayes factor, which is intuitive and is equivalent to the likelihood ratio test in classic econometrics.

To do that, in addition to the estimated model, without additional restrictions on the parameters, known as M_1, it is necessary to estimate another model, M_2, by imposing only restriction $\psi_3 = 0$. Then, through the ratio of the marginal likelihood functions of each model, one can conclude whether M_1 or M_2 reflects the data more reliably and, consequently, the dynamics of the Brazilian economy as well. After the estimation of M_2, we obtain the value of 302.41 for the marginal likelihood function, whereas the value obtained for M_1 is 303.77. Formally, to assess whether the data favor M_1 more strongly than M_2:

$$\xi = \frac{303,77}{302,41} = 1,0045 \quad (3.22)$$

Where ξ is the Bayes factor, which should be compared with the values predefined to conclude in favor of one of the models. These values are shown in Table 3.3:

Table 3.3 – Harold Jeffreys

ξ	dB	bits	Strength of Evidence
<1:1	<0	-	Negative
1:1 to 3:1	0 to 5	0 to 1.6	Barely Worth Mentioning
3:1 to 10:1	5 to 10	1.6 to 3.3	Substantial
10:1 to 30:1	10 to 15	3.3 to 5.0	Strong
30:1 to 100:1	15 to 20	5.0 to 6.6	Very strong
>100:1	>20	>6.6	Decisive

Source: Jeffreys (1961).

Table 3.3 provides the intervals for the Bayes factor in the first column and the intensity of the evidence in columns 2 and 3, given by the logarithms of ξ in different bases, corresponding to decibans and bits, respectively. One easily notes that the Bayes factor has an interpretation scale, instead of a condition, as in the hypothesis tests of traditional econometrics.

According to Jeffreys's (1961) table, it is possible to conclude that the evidence in favor of M_1, when compared to M_2, given by $\xi = 1,0045$, is too weak. Therefore, it is not possible to state that $\psi_3 \neq 0$. So, the central bank of Brazil does not change its conduct of the monetary policy due to exchange rate movements. This does not mean that the CBB does not follow exchange rate movements, but rather that it does not react systematically by changing interest rates based on these movements.[7]

This conclusion is consistent with the assumption that the CBB controls only the indirect impacts of exchange rate on inflation through the exchange rate impact on inflation expectations and its consequent effect on current inflation. This way, a very strong exchange rate devaluation, for instance, would deteriorate inflation expectations which, in

[7] There is qualitative evidence that the CBB seeks to reduce the exchange rate volatility, but that does not mean that the interest rate path is systematically changed due to such actions.

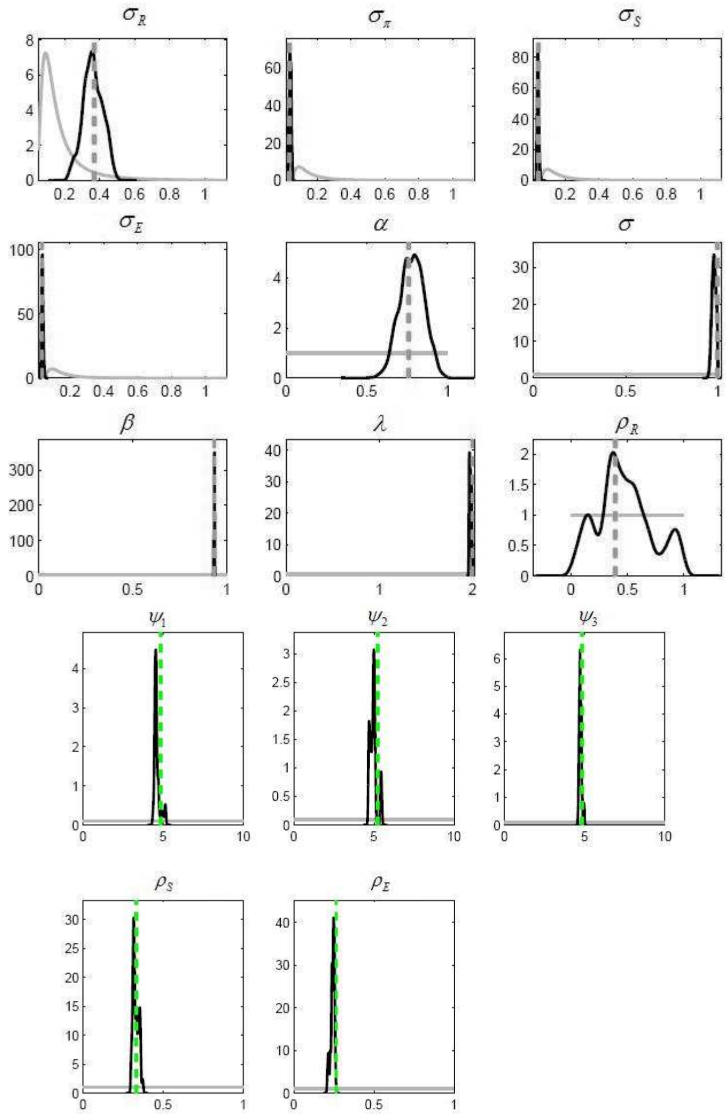
turn, would increase the pressure on current inflation and could lead the CBB to raise interest rates.

However, as mentioned above, ρ_R can impose strong restrictions on (3.3), producing specification errors and therefore invalidating the conclusions obtained from the previous estimation. The alternative is to estimate another reaction function for the CBB, described by equation (3.4), which does not impose such restrictions, shown in subsection 3.2.

3.2. Unrestricted Reaction Function

The estimation results for the model with the alternative (unrestricted) reaction function are shown in Figure 3.2, together with the *a priori* and *a posteriori* distributions, and in Table 3.4:

Figure 3.2 – A Priori and a Posteriori Distributions



Source: Elaborated by the Authors.

Table 3.4 – Parameter Estimation

	A Priori Distribution	A Posteriori Distribution	
Parameter	**Mean**	**Mean**	**Confidence interval (95%)**
α	0.5000	0.7487	$[0,6434;0,8926]$
σ	0.5000	0.9755	$[0,9650;0,9989]$
β	0.5000	0.9337	$[0,9309;0,9365]$
λ	1.0000	1.9758	$[1,9614;1,9916]$
ρ_R	0.5000	0.5150	$[0,1033;0,9272]$
ψ_1	5.0000	4.6812	$[4,3706;4,9238]$
ψ_2	5.0000	5.0990	$[4,6678;5,4163]$

ψ_3	5.0000	4.7498	$[4,6132;4,8582]$
ρ_S	0.5000	0.3384	$[0,3064;0,3611]$
ρ_E	0.5000	0.2358	$[0,2160;0,2581]$
σ_R	0.2000	0.4042	$[0,2745;0,4580]$
σ_π	0.2000	0.0427	$[0,0325;0,0505]$
σ_S	0.2000	0.0416	$[0,0306;0,0468]$
σ_E	0.2000	0.0397	$[0,0297;0,0446]$

Source: Elaborated by the Authors.

Table 3.4 shows the means of *a priori* and *a posteriori* distributions in addition to the 95%CI for the estimated coefficients, using the reaction function for the CBB given by equation (3.4). The estimated coefficients yielded similar results to those obtained with the previous estimation, except for the values of α and ρ_R, which do not change the conclusions drawn from the estimation of the model.

Again, the estimated value of $\psi_3 = 4,7498$ seems to indicate that the CBB reacts to exchange rate movements in order to define the interest rate path. To guarantee the validity of this conclusion, in addition to the estimated model, without additional restrictions on the parameters, known as M_3, another model, M_4, is estimated by imposing restriction $\psi_3 = 0$ and, finally, the Bayes factor is computed. With a value of 248.49 for the marginal likelihood function value of M_4, vis-à-vis the value of 266.55 obtained for M_3, we have:

$$\xi = \frac{266,55}{248,49} = 1,0727 \qquad (3.23)$$

By comparing the Bayes factor value with the values predefined in Jeffreys's (1961) table it is possible to conclude that the evidence in favor of M_3, comparatively to M_4, given by $\xi = 1,0061$, is weak, i.e., one cannot assert that $\psi_3 \neq 0$. This result is consistent with the one obtained by the estimation of the model with the original (restricted) reaction function, supporting the hypothesis that the CBB does not systematically change its conduct of the monetary policy due to exchange rate movements.

Thus, the conclusion is that the CBB only reacts to current inflation and output movements in order to determine the interest rate path, which should be interpreted with caution, as this result only holds under the hypotheses of the model and only for the analyzed period, from the first quarter of 2000 to the third quarter of 2007.

4. Simulation Evidence

Section 4 meets the second goal of this paper by investigating the accommodation of induced shocks on the economy. To do that, evidence regarding the simulation of the simplified model, including two versions, is provided: using the central bank's restricted reaction function and the unrestricted one. It is common knowledge that in any simulation exercise it is necessary to first calibrate the parameters of the model. Since the purpose of this section is to assess the time necessary for the accommodation of induced shocks by the economy, we use the coefficients estimated in subsections 3.1 and 3.2.

It should be highlighted that the values of the coefficients considered for the different reaction functions are those in which the CBB does not take exchange rate movements into account to define the interest rate path. This decision is based on the values obtained for the Bayes factors of the models, which indicate that such behavior is adopted by the CBB. Therefore, the model used for the simulation, based on the coefficients estimated with the restricted reaction function, is given by the set of equations (4.1)-(4.7):

$$y_t = E_t\{y_{t+1}\} - 1{,}0067(r_t - E_t\{\pi_{t+1}\}) + 0{,}0644 - 0{,}2579E_t\{\Delta s_{t+1}\} - 0{,}0054E_t\{\Delta y^*_{t+1}\} \quad (4.1)$$

$$\pi_t = 0{,}9399E_t\{\pi_{t+1}\} + 0{,}2408E_t\{\Delta s_{t+1}\} - 0{,}2562\Delta s_t + 1{,}9600(y_t - \bar{y}_t) \quad (4.2)$$

$$r_t = 0{,}6729r_{t-1} + 0{,}3271[5{,}6059\pi_t + 5{,}0154y_t] + \varepsilon_t^R \quad (4.3)$$

$$\pi_t = \Delta e_t + 0{,}7438\Delta s_t + \pi_t^* \quad (4.4)$$

$$\Delta e_t = 0{,}6331\Delta e_{t-1} + \varepsilon_t^E \quad (4.5)$$

$$\Delta s_t = 0{,}6071\Delta s_{t-1} + \varepsilon_t^S \quad (4.6)$$

$$1{,}0067\Delta s_t = \Delta y_t^* - \Delta y_t \quad (4.7)$$

The simulated model that uses the coefficients estimated with the unrestricted reaction function is represented by the following equations:

$$y_t = E_t\{y_{t+1}\} - 1{,}0425(r_t - E_t\{\pi_{t+1}\}) + 0{,}0696 - 04804E_t\{\Delta s_{t+1}\} - 0{,}0904E_t\{\Delta y^*_{t+1}\} \quad (4.8)$$

$$\pi_t = 0{,}9374E_t\{\pi_{t+1}\} + 0{,}4288E_t\{\Delta s_{t+1}\} - 0{,}4608\Delta s_t + 1{,}8666(y_t - \bar{y}_t) \quad (4.9)$$

$$r_t = 0{,}2229r_{t-1} + 5{,}4971\pi_t + 4{,}2216y_t + \varepsilon_t^R \quad (4.10)$$

$$\pi_t = \Delta e_t + 0{,}5392\Delta s_t + \pi_t^* \quad (4.11)$$

$$\Delta e_t = 0{,}4994\Delta e_{t-1} + \varepsilon_t^E \quad (4.12)$$

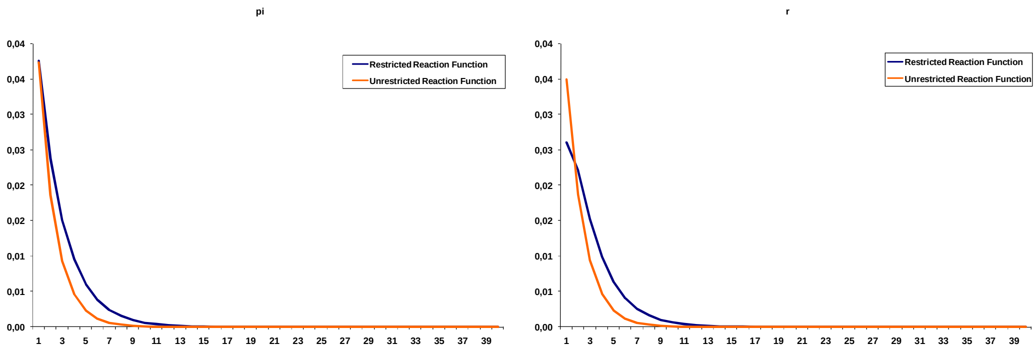
$$\Delta s_t = 0{,}3345\Delta s_{t-1} + \varepsilon_t^S \quad (4.13)$$

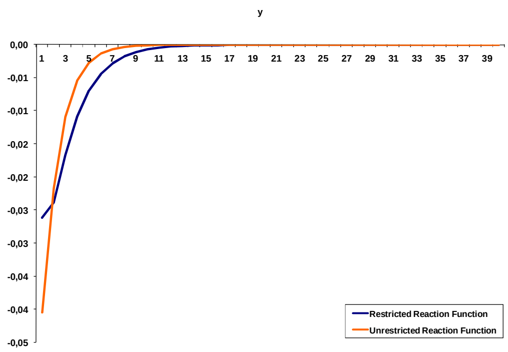
$$1{,}0425\Delta s_t = \Delta y_t^* - \Delta y_t \quad (4.14)$$

The Dynare package for Matlab, including 10,000 periods, was used for the simulation exercise. This program induces temporary shocks on the system, and through impulse response functions and illustrative tables, the dispersion of these shocks is analyzed, that is, one analyzes the time necessary for variables to return to their respective steady states.

Four different types of shocks, which affect the economy separately, are considered: shocks on the exchange rate, on the terms of trade, on the interest rate, and on global inflation. The first shock is on the exchange rate, where ε_t^E is presented in the following impulse response functions:

Figure 4.1 – Impulse Response Functions of a Shock on ε_t^E





Source: Elaborated by the Authors.

A positive shock on the exchange rate produces an increase in the terms of trade and its effect on inflation expectations also makes the current inflation edge up. Therefore, the central bank reacts by increasing interest rates, and this contractionary policy winds up reducing output in the short run. The effects of this shock take 24 periods or 6 years to disperse fully in the case of restricted reaction function, and 16 periods or 4 years in the case of unrestricted reaction function.

Note that some of this timeframe refers to the lagged effects of monetary policy on the economy, which may have a delay of 6 to 9 months until they are totally absorbed, thus justifying the paths outlined in Figure 4.1. Nevertheless, most of the shock absorption occurs between the first and second years, as shown in Table 4.1:

Table 4.1 – Percentage of Shock on ε_t^E Absorbed in Each Period

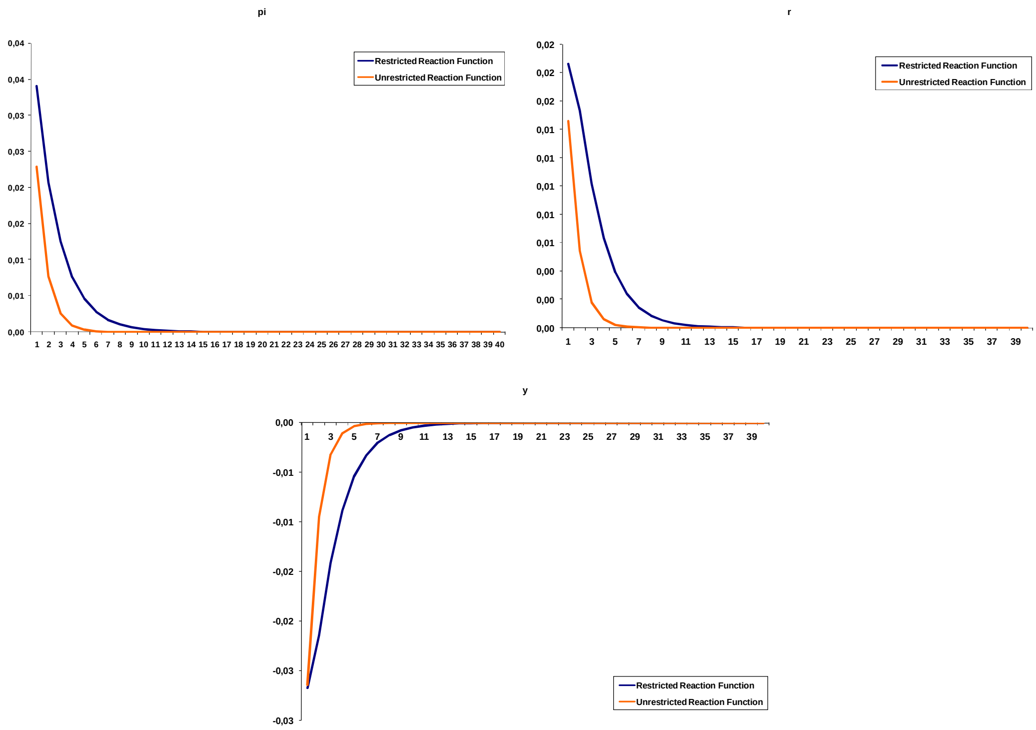
	Restricted Reaction Function			Unrestricted Reaction Function		
Period	**y**	**r**	**pi**	**y**	**r**	**pi**
1	0.00	0.00	0.00	0.00	0.00	0.00
2	8.86	15.10	36.69	46.25	46.36	50.06
3	36.30	41.60	59.92	73.02	73.08	75.06
4	58.37	62.02	74.62	86.52	86.55	87.54
5	73.36	75.74	83.93	93.27	93.28	93.78
6	83.08	84.59	89.83	96.64	96.65	96.89
7	89.27	90.23	93.56	98.32	98.32	98.45

8	93.21	93.82	95.92	99.16	99.16	99.23
9	95.70	96.08	97.42	99.58	99.58	99.61
10	97.28	97.52	98.37	99.79	99.79	99.81
11	98.28	98.43	98.97	99.90	99.90	99.90
12	98.91	99.01	99.35	99.95	99.95	99.95
13	99.31	99.37	99.59	99.97	99.97	99.98
14	99.56	99.60	99.74	99.99	99.99	99.99
15	99.72	99.75	99.83	99.99	99.99	99.99
16	99.82	99.84	99.89	100.00	100.00	100.00
17	99.89	99.90	99.93	100.00	100.00	100.00
18	99.93	99.94	99.96	100.00	100.00	100.00
19	99.96	99.96	99.97	100.00	100.00	100.00
20	99.97	99.97	99.98	100.00	100.00	100.00
21	99.98	99.98	99.99	100.00	100.00	100.00
22	99.99	99.99	99.99	100.00	100.00	100.00
23	99.99	99.99	100.00	100.00	100.00	100.00
24	100.00	100.00	100.00	100.00	100.00	100.00

Source: Elaborated by the Authors.

Figure 4.2 shows the impulse response functions of a shock on the terms of trade, ε_t^S:

Figure 4.2 – Impulse Response Functions of a Shock on ε_t^S



Source: Elaborated by the Authors.

A shock on the terms of trade has a similar effect of a shock on the exchange rate, driving inflation up, and the central bank to increase interest rates and consequently to reduce output in the short run. Twenty-two periods or five and a half years later, the shock was totally absorbed in case of the restricted reaction function. The shock is completely absorbed by the model with unrestricted reaction function 11 periods or 2 years and 3 quarters later.

Table 4.2 shows that, just as in the case of the exchange rate, a bit longer than 1 year later, over 90% of the shock had already been absorbed:

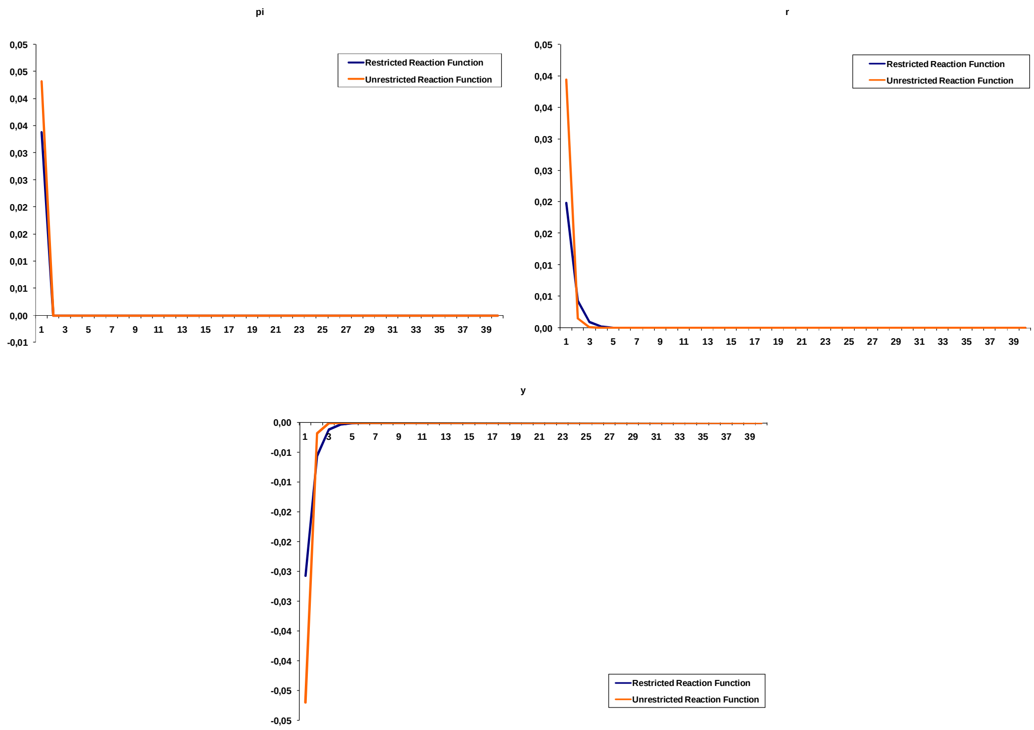
Table 4.2 – Percentage of Shock on ε_t^S Absorbed in Each Period

	Restricted Reaction Function			Unrestricted Reaction Function		
Period	**y**	**r**	**pi**	**y**	**r**	**pi**
1	0.00	0.00	0.00	0.00	0.00	0.00
2	19.84	17.70	39.29	64.11	62.85	66.55
3	47.14	45.38	63.14	87.91	87.44	88.81
4	67.00	65.83	77.62	95.95	95.79	96.26
5	79.77	79.04	86.42	98.65	98.59	98.75
6	87.68	87.23	91.75	99.55	99.53	99.58
7	92.51	92.24	94.99	99.85	99.84	99.86
8	95.45	95.28	96.96	99.95	99.95	99.95
9	97.24	97.14	98.15	99.98	99.98	99.98
10	98.32	98.26	98.88	99.99	99.99	99.99
11	98.98	98.94	99.32	100.00	100.00	100.00
12	99.38	99.36	99.59	100.00	100.00	100.00
13	99.62	99.61	99.75	100.00	100.00	100.00
14	99.77	99.76	99.85	100.00	100.00	100.00
15	99.86	99.86	99.91	100.00	100.00	100.00
16	99.92	99.91	99.94	100.00	100.00	100.00
17	99.95	99.95	99.97	100.00	100.00	100.00
18	99.97	99.97	99.98	100.00	100.00	100.00
19	99.98	99.98	99.99	100.00	100.00	100.00
20	99.99	99.99	99.99	100.00	100.00	100.00
21	99.99	99.99	100.00	100.00	100.00	100.00
22	100.00	100.00	100.00	100.00	100.00	100.00

Source: Elaborated by the Authors.

An analogous behavior is observed in the shock on global inflation, with transmission to the domestic economy through the terms of trade, with an impact on domestic inflation, domestic interest rates, and domestic output. In this case, the total absorption of the shock takes 2 years with the restricted reaction function and only 1 year and 1 quarter when the unrestricted reaction function is used.

Figure 4.3 – Impulse Response Functions of a Shock on π_t^*



Source: Elaborated by the Authors.

Only two periods after the shock, its effects on the economy are negligible, and in some cases, they are absorbed immediately after the shock, such as in domestic inflation. Table 4.3 shows this dynamics:

Table 4.3 – Percentage of Shock on π_t^* Absorbed in Each Period

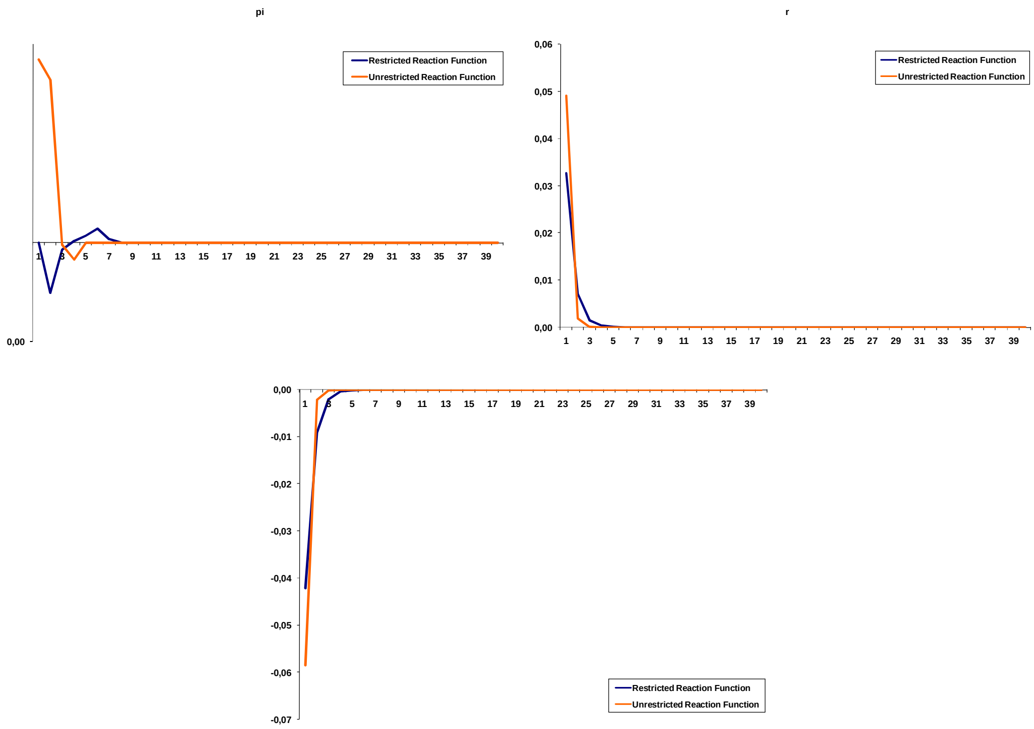
	Restricted Reaction Function			Unrestricted Reaction Function		
Period	**y**	**r**	**pi**	**y**	**r**	**pi**
1	0.00	0.00	0.00	0.00	0.00	0.00
2	78.42	78.42	100.00	96.30	96.30	100.00
3	95.34	95.34	100.00	99.86	99.86	100.00
4	98.99	98.99	100.00	99.99	99.99	100.00
5	99.78	99.78	100.00	100.00	100.00	100.00
6	99.95	99.95	100.00	100.00	100.00	100.00
7	99.99	99.99	100.00	100.00	100.00	100.00
8	100.00	100.00	100.00	100.00	100.00	100.00

Source: Elaborated by the Authors.

Finally, the effects of an induced shock on the interest rate are considered. This shock, in turn, causes a reduction in output, in addition to small noises on the rate of inflation. For the model with the restricted reaction function, the shock is totally absorbed after eight periods or two years, whereas the unrestricted reaction function shows convergence of its variables to their respective steady states at a quicker pace: five periods or one year and one quarter.

The impulse response functions for this type of shock are shown in Figure 4.4:

Figure 4.4 – Impulse Response Functions of a Shock on ε_t^R



Source: Elaborated by the Author.

Table 4.4 summarizes the percentage of shock absorption in each period, making it clear that in less than one year a significant amount of the shock will have already been accommodated by the economy.

Table 4.4 – Percentage of Shock on ε_t^R Absorbed in Each Period

	Restricted Reaction Function	Unrestricted Reaction Function

Period	y	r	pi	y	r	pi
1	0.00	0.00	0.00	0.00	0.00	0.00
2	78.42	78.42	0.00	96.30	96.30	11.27
3	95.34	95.34	86.21	99.86	99.86	100.94
4	98.99	98.99	103.02	99.99	99.99	109.39
5	99.78	99.78	113.79	100.00	100.00	100.00
6	99.95	99.95	127.59	100.00	100.00	100.00
7	99.99	99.99	106.90	100.00	100.00	100.00
8	100.00	100.00	100.00	100.00	100.00	100.00

Source: Elaborated by the Author.

Regardless of the type of induced shock, it is possible to conclude that the proposed model can swiftly accommodate them, mainly when the unrestricted reaction function is used. It should be also underscored that this result is corroborated by similar works, for instance by Minella (2001). The author uses vector autoregressive (VAR) models to analyze, among other things, the shock absorption by the economy by way of impulse response functions.

He concludes that shock absorption occurs quickly and that a remarkable amount of these shocks is often absorbed within a bit longer than one year. His work can be regarded as a robustness check of the simulation proposed in the present paper. This is so because the period analyzed in Minella (2001)[8] spans from 1994 to 2000 and, in spite of that, the results are similar, confirming the assumption of higher predictability of the Brazilian economy after the implementation of the Real Plan.

5. Conclusion

The paper is a simplified version of the model proposed by Gali and Monacelli (2005), with the main goal of assessing whether the central bank of Brazil (CBB) changes its conduct of the monetary policy due to exchange rate movements. Obviously, the changes proposed in the original model do not change the basic principles of the model, but they made it suitable for representing the reality of the Brazilian economy. These changes can be summarized in the imposition of intertemporal elasticity of substitution on unit, besides rendering labor supply perfectly elastic.

[8] Actually, Minella (2001) splits the analyses into three periods: 1975-1985, 1895-1994 and 1994-2000. However, due to structural breaks, it is interesting to compare the analysis of the present paper only with that one carried out for the Real Plan period, which have virtually the same structures.

Thereafter, the model was estimated using the Bayesian method, by means of two different reaction functions. The results were consistent with those reported in the literature. Our conclusion is that the central bank of Brazil follows an anti-inflationary policy, which is an expected result for a central bank that conducts monetary policy through an inflation targeting regime. We can also state that the CBB reacts strongly to output, as shown by the value estimated for ψ_2.

The most important for the objective of this study were the values obtained for ψ_3, which seem to indicate a reaction by the CBB to exchange rate movements to define the interest rate path. However, it is interesting to use statistical tests to guarantee the legitimacy of results and thus validate this conclusion. The Bayes factor allows concluding that the central bank of Brazil does not change its conduct of the monetary policy due to exchange rate movements, but that it reacts systematically by increasing the interest rates.

In the fourth and last section, a simulation exercise assessed the absorption of induced shocks by the economy, meeting the second goal of the paper. Four types of temporary shocks were simulated, affecting the economy separately: shocks on the exchange rate, on the terms of trade, on the interest rates and on global inflation. The conclusion is that the economy represented by the proposed model quickly accommodates the shocks, since they are often totally absorbed within four quarters or one year.

Finally, it is important to interpret the results obtained in the present paper in a judicious manner. First, these conclusions are valid only for the analyzed period, extending from the first quarter of 2000 to the third quarter of 2007. Besides, it should be recalled that there are assumptions in the model of Gali and Monacelli (2005) which might not be valid for modeling the economy of certain countries.

One of these assumptions is the modeling of the world economy based on several open economies represented by the interval $[0,1]$, which means that each economy is extremely small and that their domestic policy decisions have no impact on other world economies. However, the economy of some developed countries, such as the United States, has an impact on the world economy, see the real estate crisis and its developments that broke out in August 2007 in the USA.

Another possible criticism to the model concerns the use of continuous time. Even though the model has desirable characteristics, some authors, after properly considering the dynamics of small economies, suggest the use of discrete time. Therefore, one could introduce heterogeneity among countries, which is left as a suggestion for further studies on this topic.

References

ADES, A.; BUSCAGLIA, M.; MASIH, R. Inflation targeting in emerging market countries: too much exchange rate intervention? A test. Working Paper, n. 1658, **Asociación Argentina de Economía Política**, 2002.

AGHION, Philippe; HOWITT, Peter. A Model of Growth Through Creative Destruction. **Econometrica**, Vol. 60, p. 323-351, 1992.

BACCHETTA, P; VAN WINCOOP, E. Does Exchange Rate Stability Increase Trade and Welfare? **American Economic Review**, Vol. 90, p. 1093-1109, 2000.

BANCO CENTRAL DO BRASIL. Disponível em <http://www.bcb.gov.br>.

BAUMOL, W. The Transactions Demand for Cash. **Quarterly Journal of Economics**, Vol. 67, p. 545-556, 1952.

BETTS, C.; DEVEREUX, M.B. Exchange Rate Dynamics in a Model of Pricing-to-Market. **Journal of International Economics**, Vol. 50, p. 215-244, 2000.

BRISCHETTO, A.; VOSS, G. A structural vector autoregression model of monetary policy in Australia. Research Discussion Paper, n. 11, **Bank of Australia**, 1999.

CALVO, G. Staggered Prices in a Utility Maximizing Framework. **Journal of Monetary Economics**, Vol. 12, p. 383–398, 1983.

CANOVA, Fabio. **Methods of Applied Macroeconomic Research**. Princeton University Press, 2007. 492 p.

CLARIDA, R.H.; GERTLER, M. How the Bundesbank conducts monetary policy. In: ROMER, C.D.; ROMER, D. (Org.). **Reducing Inflation**: Motivation and Strategy. Chicago: The University of Chicago Press, 1997. p. 363-406.

CLARIDA, R.H.; GALI, J.; GERTLER, M. Monetary policy rules in practice: some international evidence. **European Economic Review**, Vol. 42, p. 1033-1067, 1998.

CLOWER, R.W. A Reconsideration of the Microfoundations of Monetary Theory. **Western Economic Journal**, Vol. 6, p. 1-9, 1967.

CORSETTI, G.; PESENTI, P. Welfare and Macroeconomic Interdependence. **Quarterly Journal of Economics**, Vol. 116, p. 421-446, 2001.

DUNGEY, M.; PAGAN, A. A structural VAR model of the Australian economy. **The Economic Record,** Vol. 76, p. 321-342, 2000.

DYNARE. Available at: <http://www.cepremap.cnrs.fr/dynare>.

FUNDAÇÃO CENTRO DE ESTUDOS DO COMÉRCIO EXTERIOR. Disponível em <http://www.funcex.com.br>.

FUNDO MONETÁRIO INTERNACIONAL. Disponível em <http://www.imf.org>.

GALI, Jordi; MONACELLI, Tommaso. Monetary policy and exchange rate volatility in a small open economy. **Review of Economic Studies**, Vol. 72, p. 707-734, 2005.

GERLACH, S.; SMETS, F. MCIs and monetary policy. **European Economic Review**, Vol. 44, p. 1677-1700, 2000.

GROSSMAN, G.; HELPMAN, E. **Innovation and Growth in the Global Economy**. Cambridge, Massachusetts: The MIT Press, 1991a.

GROSSMAN, G.; HELPMAN, E. Quality Ladders in the Theory of Growth. **Review of Economic Studies**, Vol. 58, p. 43-61, 1991b.

JEFFREYS, Harold. **The Theory of Probability**. Oxford, 1961. 432 p.

HÜFNER, Felix. **Foreign Exchange Intervention as a Monetary Policy Instrument**: Evidence for Inflation Targeting Countries. Physica-Verlag Heidelberg, 2006. 175 p.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Disponível em <http://www.ibge.gov.br>.

JUSTINIANO, A.; PRESTON, B. Can Structural Small Open Economy Models Account for the Influence of Foreign Disturbances? **Columbia University**, 2005.

KEYNES, John M. **A Tract on Monetary Reform**. London: Macmillan, 1923. 194 p.

KIYOTAKI, N.; WRIGHT, R. On Money as a Medium of Exchange. **Journal of Political Economy**, Vol. 97, p. 927-954, 1989.

LUBIK, Thomas A.; SCHORFHEIDE, Frank. A Bayesian Look at New Open Economy Macroeconomics. **NBER Macroeconomics Annual**, Vol.20, p. 313-366, 2005.

LUBIK, Thomas A.; SCHORFHEIDE, Frank. Do central banks respond to exchange rate movements? A structural investigation. **Journal of Monetary Economics**, 2007.

LUCAS, Robert E., Jr. Econometric Policy Evaluation: A Critique. **Carnegie-Rochester Conference Series on Public Policy**, Vol. 1, p. 19-46, 1976.

LUCAS, Robert E., Jr. On the Mechanics of Economic Development. **Journal of Monetary Economics**, Vol. 22, p. 3-42, 1988.

MINELLA, André. Monetary Policy and Inflation in Brazil (1975-2000): A VAR Estimation. Working Paper Series, n.33, **Banco Central do Brasil**, 2001.

OBSTFELD, M.; ROGOFF, K. Exchange Rate Dynamics Redux. **Journal of Political Economy**, Vol. 102, p. 624-660, 1995.

OBSTFELD, M.; ROGOFF, K. New Directions for Stochastic Open Economy Models. **Journal of International Economics**, Vol. 50, p. 117-153, 1999.

RAMSEY, F.P. A Mathematical Theory of Saving. **The Economic Journal**, Vol. 38, p. 543-559, 1928.

REBELO, Sergio. **Long-run Policy Analysis and Long-run Growth**. University of Rochester, manuscript, 1987.

ROMER, David. **Advanced Macroeconomics**. McGraw-Hill, 3rd Edition, 2005. 696 p.

ROMER, Paul M. Increasing Returns and Long-run Growth. **Journal of Political Economy**, Vol. 94, p. 1002-1037, 1986.

ROMER, Paul M. **Crazy Explanations for Productivity Slowdown**, NBER Macroeconomics Annual. Cambridge, Massachusetts: The MIT Press, 1987.

ROMER, Paul M. Endogenous Technological Change. **Journal of Political Economy**, Vol. 98, p. 71-103, 1990.

SAMUELSON, P.A. An Exact Consumption-Loan Model of Interest With or Without the Social Contrivance of Money. **Journal of Political Economy**, Vol. 66, p. 467-482, 1958.

SIDRAUSKI, M. Rational Choice and Patterns of Growth in a Monetary Economy. **American Economic Review**, Vol. 57, p. 534-544, 1967.

SOLOW, R. A Contribution to the Theory of Economic Growth. **Quarterly Journal of Economics**, Vol. 70, p. 65-94, 1956.

TOBIN, J. The Interest Elasticity of the Transactions Demand for Cash. **Review of Economic and Statistics**, Vol. 38, p. 241-247, 1956.

WALSH, Carl E. **Monetary Theory and Policy**. Cambridge, Massachusetts: The MIT Press, 2003. 633 p.

WOLLMERSHÄUSER, Timo. Should central banks react to exchange rate movements? An analysis of the robustness of simple policy rules under exchange rate uncertainty. **Journal of Macroeconomics**, Vol. 28, p. 493-509, 2006.