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Price Stability under Inflation Targeting in Brazil: Empirical analysis of the monetary policy transmission mechanism based on a VAR model, 2000-2008

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Abstract

With a view to offering a body of empirical evidence to assess the costs and benefits of Brazilian stabilization policy, we undertake an econometric analysis of the monetary policy transmission mechanism in Brazil during the period from the adoption of the inflation targeting regime (onwards ITR) to the *subprime* crisis (2000-2008). The exchange rate was the main channel of monetary policy transmission during that time frame. Furthermore, inflation sensitivity to the interest rate is low. Thus, a rise in the basic interest rate (Selic) generates relatively small benefits (a fall in inflation). However, an interest rate increase generates substantial costs: a slowdown in economic activity, the appreciation of the exchange rate, and an increase in public debt. Inflation's low sensitivity to interest rates is seen as a result of problems in the transmission mechanism: a broken transmission mechanism reduces the efficiency of monetary policy. Price stability under ITR thus requires an excessively rigid monetary policy. The final outcome is, on the one hand, that inflation hardly gives in. On the other hand, the costs of high interest rates escalate. We conclude that the balance of costs and benefits of price stability under ITR is unfavorable.

Key words: inflation, monetary policy transmission mechanism, Selic rate.
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Introduction

In an inflation targeting regime (onwards ITR), the basic interest rate is the main instrument for controlling inflation. In fact, ever since ITR was adopted in mid-1999, the basic interest rate (Selic)[1] has been the sole instrument used to ensure price stability in Brazil. It worth mentioning that this is not a critique of the theoretical foundations and operational procedures of that monetary regime, although much could be said about those issues (see Modenesi, 2005; Vernengo, 2008; Haight, 2007, and Epstein and Yeldan, 2009; among many others). The purpose of this article is to offer a body of empirical evidence supporting the assessment of the main costs and benefits arising from Brazil's current stabilization policy. This will be done through an empirical analysis of how variations in Selic affect or are transmitted to the main macroeconomic variables, namely: inflation, the exchange rate, and economic activity.

On the one hand, an increase in the basic interest rate reduces inflation; as stressed by ITR advocates, price stability promotes efficiency, from which the whole functioning of the economic system will benefit and thus contribute to boost economic growth. On the other hand, an increase in interest rates contributes to slow down the economy, to appreciate the domestic currency, and to increase public debt. Hence, a rise in interest rates jeopardizes economic performance.

With the purpose of identifying and assessing the costs and benefits of the monetary policy practiced in Brazil for nearly a decade, we shall undertake an empirical analysis of the transmission mechanism, defined as the process through which variations in the basic interest rate affect the general price level. The *sacrifices* imposed by stabilization policy, conceived as the social and economic costs resulting from an increase in interest rates, will be evidenced by using a vector autoregression (VAR) model.

Traditionally, this kind of exercise is done by estimating the so called "sacrifice ratio", or the ratio of the output loss –the deviation of real Gross Domestic Product (GDP) from its potential– to the associated changes in inflation (see Okun, 1978; Gordon and King, 1982).[2] The present study addresses this issue in

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[1] In Brazil, the basic interest rate goes by the acronym Selic (Sistema Especial de Liquidação e de Custódia), the settlement system for most of the Brazilian central government's domestic securities.

[2] Blinder (1987) applies this concept to the deflation operated by Paul Volcker in the period between 1980 and 1984. Ball (1993) studies 65 episodes of deflation in Organisation for Economic Co-operation

a broader sense than usual, as it focuses on the concurrence of three detrimental effects of an increase in the basic interest rate: the slowdown in economic activity, the appreciation of the domestic currency, and the expansion of public debt. Econometric analysis will allow us to systematize and quantify the main negative outcomes of an increase in Selic, as well as its impact on inflation. Thus, we will be able to compare the effect of variations in Selic on prices in face of its detrimental effects on exchange rate, economic activity, and public debt.

This article is divided into three sections, in addition this introduction and a conclusion. Next section states that in an ITR the monetary authority sustain an institutional commitment to make price stability the main long-run goal of monetary policy. The third section presents the VAR model. Section four analyzes the monetary policy transmission mechanism, stressing the interactions among the basic interest rate (Selic), inflation (as measured by the consumer price index, IPCA), the exchange rate, the level of economic activity (using industrial output as a proxy), and public debt (measured by the debt/GDP ratio). The empirical evidence corroborates the already widespread hypothesis that Brazil's monetary policy has been very costly to the country's economy. In short, we will provide a body of significant empirical evidence showing that Brazil's monetary policy under ITR, besides having little effect in inflation control, has imposed a high level of sacrifice.

Inflation targeting: the emphasis on price stability

From an operational standpoint, ITR is a monetary regime marked by the monetary authority's institutional commitment to adopt price stability as the main long-run goal of monetary policy, to which all remaining objectives are subordinated (see Bernanke and Mishkin, 1997; Mishkin and Posen, 1997; Bernanke *et al.* 1999, and Mishkin, 1999; 2000). ITR is characterized by: 1) setting a medium-run inflation target; 2) reduced importance of intermediate targets, such as, for instance, monetary aggregates; 3) greater transparency in conducting monetary policy, substantiated in the efforts to improve communication between the Central Bank and economic agents, allowing for a greater accountability of Central Bank; 4) independence of Central Bank instruments (Fischer, 1995)

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and Development (OECD) member countries, between 1960 and 1990. See also Tödter and Zeibarth (1997) and Buiter and Grafe (2001).

or greater ability to achieve its targets; that is, requires that the Central Bank be free to determine monetary policy instruments.[3]

The ITR had a sort of *golden age* from when it was first adopted by New Zealand in 1990 to the 2008 subprime crisis. According to the so-called *new consensus macroeconomics*, ITR is *the correct* way of monetary policy-making, in a way that this regime has been adopted globally. However, as one of the aftermaths of the 2008 subprime crisis, central banks' blind faith in ITR has been substantially reduced. At the same time, we have witnessed a shy move by orthodox theory toward the recognition that monetary policy should target other variables than inflation. For instance, Blanchard, Dell'Ariccia and Mauro (2010) and Eichengreen *et al.* (2011) consider that monetary policy should also target asset prices –in order to prevent financial crisis.

This late orthodox criticism reinforces a general criticism shared by many heterodox economists. From a theoretical standpoint, most ITR critics rightfully emphasize that the adoption of ITR implies the acceptance of long-run money neutrality resulting from the assumption of the natural rate of unemployment hypothesis (Friedman, 1968). From a more operational perspective, there is plenty of criticism on: 1) the use of a *single* instrument (the interest rate) to curb inflationary pressures,[4] and 2) the belief that any rise (fall) in inflation should always be followed by a rise (fall) in interest rates, regardless of the nature of the inflation (aligned with the Taylor rule).[5]

Those who advocate ITR generally justify the emphasis given to price stability on the grounds of an alleged *consensus* against the use of discretionary monetary

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[3] It is not this article's intention to present an exhaustive explanation of ITR. For more details see Modenesi (2005: Chapter 3), who discusses the advantages and disadvantages of ITR and its theoretical foundations. Also see Lima (2008).

[4] For instance, we may say that for most post-Keynesians, using the interest rate to fight inflation is deemed problematic. For example, fighting cost-push inflation by managing aggregate demand is inadequate, since it affects only the symptoms, instead of the causes of that kind of inflation (Davidson, 1978; 2003). See also Vernengo (2007; 2008) and the book edited by Epstein and Yeldan (2009), according to whom, "Modern central banking ought to have more policy space in balancing out various objectives and instruments. In particular, employment creation, poverty reduction, and more rapid economic growth should join inflation stabilization and stabilization more generally as key goals of central bank policy" (Epstein and Yeldan, 2009: 7).

[5] Arestis and Chortareas (2006; 2007) and Mihailov (2006) present a critical appraisal of the Taylor rule. Haight (2008) presents a post-Keynesian critique of the so-called *Taylor principle*, the proposition that interest rates should always be raised (reduced) proportionally more than a given rise (fall) in the inflation rate.

policies, with the purpose of reducing unemployment, as proposed by Keynesian macroeconomic tradition, according to which money is not neutral in the long run. There are three paradigmatic moments in the challenge to monetary policy discretion: 1) evidence of lags in monetary policy transmission, reported by Friedman (1948); 2) denial of the existence of a long-run trade-off between inflation and unemployment, originally proposed by Friedman (1956; 1968) and Phelps (1967; 1968) and furthered by Lucas (1972; 1973), Sargent (1981), and Sargent and Wallace (1981a; 1981b); and 3) development of the time-inconsistency problem and the resulting *inflation bias*, by Kydland and Prescott (1977), Calvo (1978), and Barro and Gordon (1983a; 1983b).[6]

Historically, the costs of inflation –as well as the channels through which inflation reduces the level of utility of economic agents and, thus, of social welfare– has been a recurrent theme in orthodox monetary theory. This literature, which we do not intend to review here, is extremely vast, since its origins date back to the mercantile period. Contemporarily, one could highlight Bailey's contribution (1956) in defining the loss of social welfare to inflation as the cosumer surplus that would be generated were the nominal interest rate brought down to zero. Inspired by Bailey (1956), Lucas (2000) argued, regarding the US economy, that "the gain from reducing the annual inflation rate from 10 percent to zero is equivalent to an increase in real income of slightly less than one percent".[7]

In accordance with that literature, the following inflation-related issues are worth mentioning: 1) the super-sizing of the financial system; 2) the economy's vulnerability to financial crises due to the greater fragility of its financial system (compared to economies with stable prices); 3) the deterioration of the tax system, since taxes are usually not indexed, bringing on several negative consequences such as the Tanzi effect;[8] 4) distributive effects, since indexation mechanisms do not fully protect the income of the different economic groups; 5) menu costs

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[6] See also Mishkin and Posen (1997) and Modenesi (2005: Chapters 2 and 3).

[7] The vast literature available on the theme also includes: Feldstein (1979; 1980; 1997), Cooley and Hansen (1989), Imrohoroglu and Prescott (1991), Gomme (1993), Gilman (1993; 1995), Haslag (1994), Jones and Manueli (1995), Dotsey and Ireland (1996), Lacker and Schreft (1996), Akerlof, Dickens, and Perry (1996), Shiller (1996), Abel (1997), Bakhshi, Haldane and Hatch (1998), Sinn (1999), Cysne (2003), Rossi (2003), Bullard and Russel (2004). On the Brazilian case, see Pastore (1997), Fava and Rocha (2003), and Rossi (2008), among others.

[8] It is worth noting that, according to Bacha (1994; 1995), this was not a problem in pre-real Brazil. On the contrary, whereas tax revenue was indexed, expenses were not, generating a *reverse Tanzi* effect.

from changing prices; and 6) market failures and ineffective resource allocation –due to imperfect signaling of the price system–, which in turn decreases the productivity of production factors and, thus, jeopardizes economic growth.

Among those issues, the latter is particularly relevant, given that it supports the idea that price stability is a necessary condition for economic growth: "As a great deal of prior theory predicts, the results presented here [for the US economy] imply that inflation reduces growth by reducing investment, and by reducing the rate of productivity growth" (Fischer, 1993: 22).

Bernanke *et al.* (1999) also stress that inflation decreases economic efficiency, jeopardizing economic growth. According to them, price stability is thus a necessary condition for achieving other macroeconomic goals, such as high GDP growth and low unemployment. That is one of the main reasons for adopting ITR, which, the authors state, could also be justified on the grounds that: 1) the inflation target works as a nominal anchor; and 2) money is neutral in the long run. In their words: "[…] there is by now something of a consensus that even moderate rates of inflation are harmful to economic efficiency and growth, and that the maintenance of a low and stable inflation rate is important, perhaps necessary, for achieving other macroeconomic goals" (Bernanke *et al.*, 1999: 10).

The belief that reduced levels of inflation are a fundamental precondition for sustained economic growth is widespread. According to that belief –which we do not intend to question here–, price stability is an absolute priority.[9] The fact that Brazil has experienced a long period of chronic high inflation contributes to the almost unconditional acceptance of that belief by great part of academia and opinion-makers. Thus, little attention has been given to the costs arising from fighting inflation (Epstein, 2003).[10] And that is precisely one of the contributions of this article: to draw attention to the main costs of the current price stabilization policy.

It is not our intention here to address, from a theoretical standpoint, the process through which a rise in the basic interest rate generates social and economic

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[9] As expressed in the 1995 US *Economic Growth and Price Stability Act*, "Because price stability leads to the lowest possible interest rates and is a key condition to maintaining the highest possible levels of productivity, real incomes, living standards, employment, and global competitiveness, price stability should be the primary long term goal" (US Congress, 1995).

[10] See Epstein and Schor (1990) and Epstein (2000) for a political-economy perspective on monetary policy-making.

costs, and thus reduces welfare. This mechanism –which finds ample support in economic theory– will be summarized in simple terms as follows. A rise in interest rates: 1) discourages private investment, reducing aggregate demand and thus reducing the GDP growth rate; 2) by making financial assets denominated in domestic currency more attractive, it impacts positively on the capital account, causing the domestic currency to appreciate, therefore reducing the competitiveness of domestic output –which, in turn, deteriorates the balance of payments–, and 3) increases debt-servicing expenditure, raising public debt.[11]

For the three reasons mentioned above, we argue that a rise in the basic interest rate imposes a cost on society. It is worth taking into consideration that this article in no way intends to explore all the potential negative impacts of a rise in the basic interest rate. For instance, monetary policy may produce perverse distributive effects (Areosa and Areosa, 2006).[12] Nevertheless, for the purpose of this article, the three previously mentioned effects are sufficient.

In short, the adoption of ITR is, to a great extent, grounded on the belief that inflation is highly detrimental to economic growth and thus price stability becomes the main objective of monetary policy.[13] However, little importance is given to the costs of achieving and/or maintaining price stability. Orthodox theory tends to amplify the relevance of inflation costs. However, even if one takes for granted that inflation is detrimental, the net impact on social welfare of a rise in interest rates remains, in principle, undefined.

The balance of costs and benefits related to inflation control depends on the actual manner through which the effects of interest rate movements are transmitted to the remaining macroeconomic variables. A broken transmission mechanism may produce an unfavorable balance of costs and benefits in monetary policy. In other words, the more sensitive inflation is to interest rates, the less rigid will monetary policy need to be in order to ensure the achievement of a given inflation target. Alternatively, transmission flaws may reduce

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[11] Raising Selic increases the debt stock in two manners: 1) directly, considering that a significant portion of the debt is composed of floating Treasury bonds (Letras Financeiras do Tesouro, LFT), indexed to Selic, and 2) indirectly, given that, upon a rise in Selic, bond demanders tend to require higher returns in order to buy pre-fixed bonds.

[12] Indeed, there are many others problems with ITR. For instance, Braunstein and Heintz (2009) investigate "gender-specific impacts of policy responses during inflation reduction episodes" (p. 110).

[13] Bernanke (2007) postulates that "price stability […] is a good thing in itself" and "[i]n the long term, low inflation promotes growth, efficiency, and stability –which, all else being equal, support maximum sustainable employment […]" (p. 1).

inflation's sensitivity to interest rates and, consequently, will jeopardize the efficiency of monetary policy in controlling inflation. As a result, and aligned to the ITR framework, it becomes *necessary* to apply relatively higher doses of interest rates to ensure stability. In that case, the costs arising from the policy tend to escalate. Thus, an evaluation of the current stabilization policy must be based on an empirical analysis of the transmission mechanism of monetary policy. We shall do that in next section.

Empirical evidence

Database and unit root tests

The implementation of ITR in Brazil, on June 21, 1999, represented a significant shift in the monetary regime, as well as a deep change in the conduct of monetary policy, which until then had been based on an exchange rate targeting regime (Modenesi, 2005: Chapters V and VI). As a result, to enhance robustness, we excluded the first six months of ITR from our sample, which therefore covers the period from January 2000 to August 2008. The subprime crises after the collapse of Lehman Brothers (September 2008) represents a major structural break. After that, the conduct of monetary policy has changed deeply worldwide –for instance, with the adoption of the so-called quantitative easing program by the Federal Reserve (Fed)–, and we have seen an *abnormal* decline of the main central banks' rates (the Fed, Bank of England, European Central Bank, Bank of Japan). So, we have decided to limit our sample to the pre-subprime crisis period, which includes 104 monthly observations and thus grants robustness to our results.

The list of variables to be applied is as follows: *Selic* is the basic interest rate (per year); *IPCA* is the consumer price index; *Ind* is the index of physical industrial output (quantum; seasonal adjustments apply); *Exchange* is the nominal exchange rate (real/$US, monthly average), and *Div* is the public debt as a proportion of GDP. Banco Central do Brasil (BCB) provides the Selic rate and the exchange rate, whereas the Instituto Brasileiro de Geografia e Estatística (IBGE) provides the index of industrial output and also the IPCA. The public debt stock is provided by the Secretaria do Tesouro Nacional. As for the debt/GDP ratio, this is the authors' calculation. To all variables the logarithmic scale applies; for instance, the term *Selic* always refers to the *Selic* Neperian logarithm (*logSelic*).

In order to determine whether the variables follow a stationary process, the augmented Dickey-Fuller test (ADF) and the Phillips-Perron (PP) test were carried out in the series at the level and its first difference (see tables 1 and 2; see Hamilton (1994: Chapter XVII). The null hypothesis of a unit root (non-stationary) is not rejected for all variables at the 1% level.

Table **1**
Augmented Dickey-Fuller test: Level and first difference

Variable	Lags	*t*-statistics	Critic value		
			1%	*5%*	*10%*
Selic	1	–3.0560	–4.0505	–3.4544	–3.1529
IPCA	0	–1.1834	–4.0505	–3.4544	–3.1529
Exchange	1	–1.6303	–4.0505	–3.4544	–3.1529
Ind	0	–2.4792	–4.0505	–3.4544	–3.1529
Debt	0	–2.1539	–4.0505	–3.4544	–3.1529
DSelic	0	–3.2368	–4.0505	–3.4544	–3.1529
DIPCA	0	–4.7657	–4.0505	–3.4544	–3.1529
DExchange	0	–7.4262	–4.0505	–3.4544	–3.1529
DInd	0	–11.406	–4.0505	–3.4544	–3.1529
DDebt	0	–11.035	–4.0505	–3.4544	–3.1529

Note: ADF with trend and intercept.

However, the null hypothesis is rejected for all variables at first difference (at the usual levels of significance). Thus, we may conclude that the series are integrated of order 1, I(1).

Table **2**
Phillip-Perron test: Level and first difference

Variable	Lags	*t*-statistic	Critic value		
			1%	*5%*	*10%*
Selic	1	–1.9729	–4.0495	–3.4540	–3.1526
IPCA	0	–0.8097	–4.0495	–3.4540	–3.1526
Exchange	5	–1.3849	–4.0505	–3.4544	–3.1529
Ind	4	–2.3582	–4.0505	–3.4544	–3.1529
Debt	5	–2.8094	–4.0505	–3.4544	–3.1529
DSelic	0	–3.2368	–4.0505	–3.4544	–3.1529
DIPCA	0	–4.7419	–4.0505	–3.4544	–3.1529
DExchange	4	–7.4553	–4.0505	–3.4544	–3.1529
DInd	12	–12.110	–4.0505	–3.4544	–3.1529
DDebt	4	–10.996	–4.0505	–3.4544	–3.1529

Note: PP with trend and intercept.

Cointegration

Having determined that the series are non-stationary and I(1), two cointegration tests shall be performed. The null hypothesis (no cointegration relationship) is not rejected at the 5% significance level, either for trace statistics or for maximum eigenvalue statistics (see table 3).

Table **3**
Cointegration tests

	Trace statistics			**Maximun-Eigen statistics**		
	Eigen value	*Critical value*	*Probability 5%*	*Eigen value*	*Critical value*	*Probability 5%*
None	60.01641	60.06141	0.0504	24.36238	30.43961	0.2363
At most 1	35.65403	40.17493	0.1326	17.85088	24.15921	0.2830
At most 2	17.80315	24.27596	0.2626	10.34641	17.79730	0.4494

Given the strong evidence indicating the non-existence of a cointegrating vector and that the series are I(1), we will estimate a VAR model for the series at first difference. Figure 1 shows the variables at first difference and allows the series behavior to be visualized.

Estimation: lag order selection and granger causality

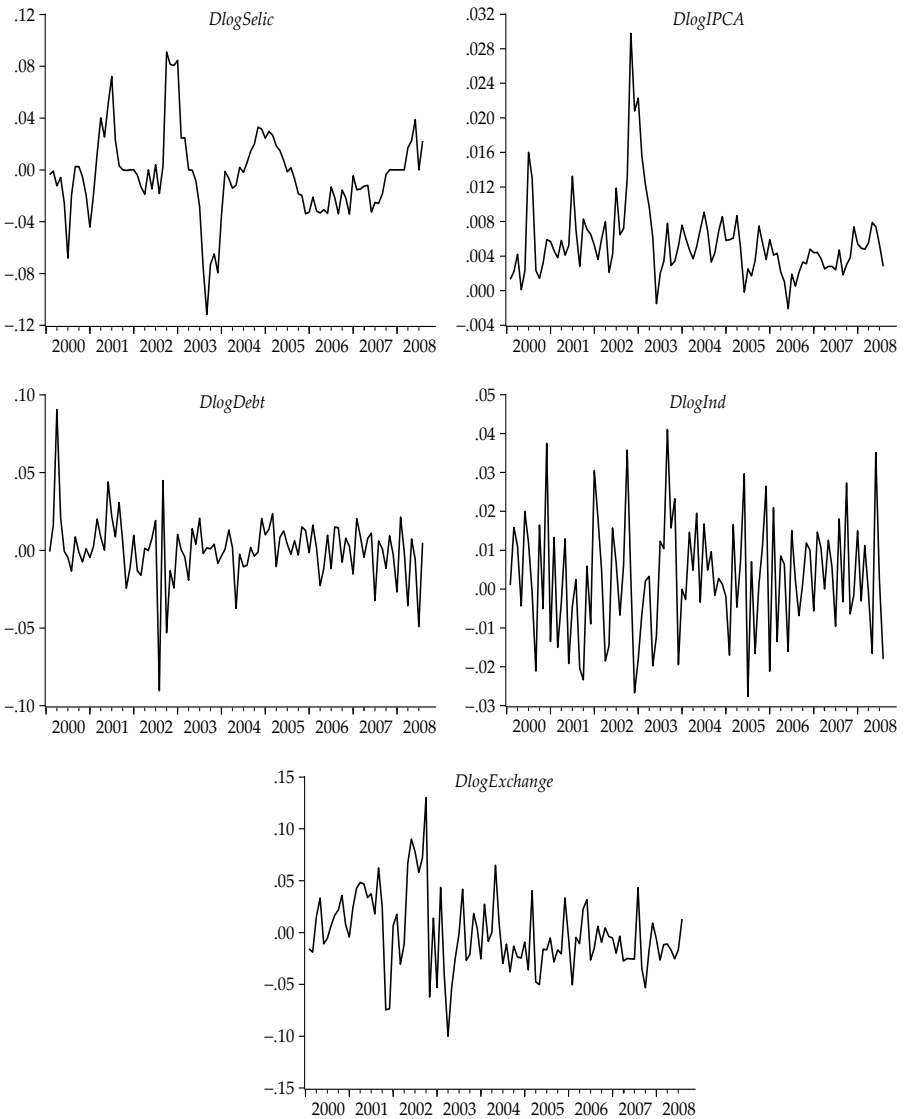
To determine the number of lags to be included in the model, the usual tests apply. The SC and HQ information criteria suggest only one lag, as shown in table 4. The LR, FPE and AIC criteria suggest the inclusion of three lags.

Table **4**
VAR Lag order selection criteria

Lags	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	1 274.098	NA	1.71e-18	–26.71785	–26.58343	–26.66353
1	1 385.360	208.4707	2.79e-19	–28.53390	–27.72741*	–28.20802*
2	1 410.061	43.68213	2.82e-19	–28.52761	–27.04905	–27.93016
3	1 436.245	43.54774*	2.78e-19*	–28.55253*	–26.40190	–27.68351
4	1 458.594	34.81755	3.00e-19	–28.49672	–25.67402	–27.35614
5	1 483.176	35.70770	3.14e-19	–28.48791	–24.99313	–27.07576
6	1 506.104	30.89307	3.45e-19	–28.44430	–24.27745	–26.76058

Note: LR = likelihood ratio criterion; FPE = final prediction error; AIC = Akaike information criterion; SC = Schwarz, and HQ = Hannan-Quinn.

Figure 1
DSelic, DIPCA, DInd, DDebt and DExchange
2000/January-2008/August



The VAR models with one or three lags show residuals that are strongly autocorrelated, heteroscedastic, and non-Gaussian. To avoid that problem, a successively larger number of lags was introduced, until a model with *well-behaved* residuals

could be obtained. Finally, we decided to estimate the model with six lags, therefore satisfying the basic conditions of robustness (see next item), according to equations [1]-[5]:[14]

$$DlogSelic_t = \alpha_{10} + \alpha_{11}DlogIPCA_{t-1} + \alpha_{12}DlogInd_{t-1} + \alpha_{13}DlogDebt_{t-1} + \alpha_{14}DlogExchange_{t-1} + \varepsilon_{t-1} \quad [1]$$

$$DlogIPCA_t = \alpha_{20} + \alpha_{21}DlogSelic_{t-1} + \alpha_{22}DlogInd_{t-1} + \alpha_{23}DlogDebt_{t-1} + \alpha_{24}DlogExchange_{t-1} + \varepsilon_{t-1} \quad [2]$$

$$DlogInd_t = \alpha_{30} + \alpha_{31}DlogSelic_{t-1} + \alpha_{32}DlogIPCA_{t-1} + \alpha_{33}DlogDebt_{t-1} + \alpha_{34}DlogExchange_{t-1} + \varepsilon_{t-1} \quad [3]$$

$$DlogDebt_t = \alpha_{40} + \alpha_{41}DlogSelic_{t-1} + \alpha_{42}DlogIPCA_{t-1} + \alpha_{43}DlogInd_{t-1} + \alpha_{44}DlogExchange_{t-1} + \varepsilon_{t-1} \quad [4]$$

$$DlogExchange_t = \alpha_{50} + \alpha_{51}DlogSelic_{t-1} + \alpha_{52}DlogIPCA_{t-1} + \alpha_{53}DlogInd_{t-1} + \alpha_{54}DlogDebt_{t-1} + \varepsilon_{t-1} \quad [5]$$

where $i = 1, 2, 3, 4, 5, 6$; D indicates the first difference; and $\varepsilon \sim (0,\sigma^2)$.[15]

Table 5 shows the results from the Granger causality test performed to check if a given variable temporally precedes –or causes, in the Granger sense– another.

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[14] This is the normal procedure, commonly found in literature; for example, Luporini (2007) uses eight lags.

[15] The order chosen for the VAR model is *Selic, IPCA, Ind, Div* and *Exchange*. *Selic* was chosen as the most exogenous variable, since it is the instrument of monetary policy and, as a rule, is adjusted only eight times per year at Comité de Política Monetaria (COPOM) meetings. The exchange rate was chosen as the most endogenous variable, given that through the expectations channel, it can be affected contemporaneously by all other variables. Inflation contemporaneously affects *Debt* because a portion of debt stock is indexed to IPCA. It is more difficult to justify the effect of inflation on GDP; however, table 5 shows that *IPCA* precedes *Ind*. Identifying the ordering of variables by means of Granger causality test might not be appropriate in principle. Cholesky ordering indicates a contemporary causality between the variables, whereas Granger indicates a temporal precedence. However, Granger can be used as a method to sort the variables within Cholesky ordering, considering that there is a positive correlation between Granger causality probability and contemporary causality. *Debt* is affected contemporaneously by *Selic* and *IPCA* because debt stock is in part indexed to IPCA (NTN-B) and in part to Selic (LFT). The contemporary effect of *Ind* on *Debt* can be explained by *Debt* being the debt/GDP ratio.

Table **5**
Granger causality test

Null hypothesis:	*Observations*	*F-statistic*	*Probability*
DIPCA does not Granger-cause *DSelic*	100	1.37575	0.25508
DSelic does not Granger-cause *DIPCA*		2.58356	0.05797
DInd does not Granger-cause *DSelic*	100	3.01592	0.03386
DSelic does not Granger-cause *DInd*		4.18677	0.00794
DDebt does not Granger-cause *DSelic*	100	5.35645	0.00190
DSelic does not Granger-cause *DDebt*		0.32906	0.80434
DExchange does not Granger-cause *DSelic*	100	3.69121	0.01464
DSelic does not Granger-cause *DExchange*		0.72581	0.53911
DInd does not Granger-cause *DIPCA*	100	0.29639	0.82792
DIPCA does not Granger-cause *DInd*		2.63378	0.05446
DDebt does not Granger-cause *DIPCA*	100	1.91775	0.13209
DIPCA does not Granger-cause *DDebt*		4.90880	0.00328
DExchange does not Granger-cause *DIPCA*	100	9.20958	2.1E-05
DIPCA does not Granger-cause *DExchange*		0.81421	0.48919
DDebt does not Granger-cause *DInd*	100	0.13587	0.93840
DInd does not Granger-cause *DDebt*		1.32037	0.27249
DExchange does not Granger-cause *DInd*	100	0.66098	0.57811
DInd does not Granger-cause *DExchange*		0.40047	0.75298
DExchange does not Granger-cause *DDebt*	100	1.76989	0.15832
DDebt does not Granger-cause *DExchange*		6.45619	0.00051

One should note that there is strong evidence that *DExchange* causes, in the Granger sense, *DIPCA* (at the 1% significance level). Also, there is evidence that *DExchange* causes, in the Granger sense, *DSelic* (at the 1% level). It should also be stressed that *DSelic* causes, in the Granger sense, *DInd* (1%). Finally, one should mention that the evidence also shows that *DSelic* causes, in the Granger sense, *DIPCA* at the 10% significance level. Next section explores these findings.

Robustness tests

The usual robustness tests were applied. Initially, we checked for autocorrelation in the model's residuals. There is no evidence to reject the null hypothesis (non-existence of serial autocorrelation) after the inclusion of the third lag in the model (see table 6).

Table 6
VAR residual serial correlation LM

Lags	*LM-statistic*	*Probability*
1	47.54057	0.0042
2	56.27419	0.0003
3	31.96744	0.1590
4	24.29755	0.5022
5	31.89766	0.1610
6	23.44589	0.5515

Note: LM = *Lagrange multiplier*.

Table 7 highlights the evidence against the rejection of the null hypothesis that residuals are homoscedastic, indicating heteroscedasticity to be non-existent.

Table 7
VAR residual heteroskedasticity tests (joint test)

Chi-square	*Degree of freedom*	*Probability*
901.1952	900	0.4825

The Jarque-Bera normality test suggests the rejection of the hypothesis that errors follow a normal distribution (see table 8). However, that problem can be minimized on the grounds of the central limit theorem.[16]

Table 8
VAR residual normality tests (Jarque-Bera)

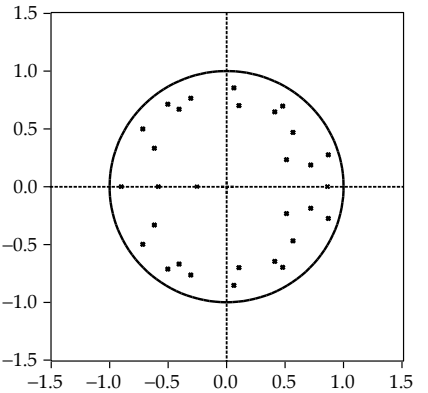
Component	*Jarque-Bera*	*Probability*
1	10.79051	0.0045
2	8.316471	0.0156
3	11.50875	0.0032
4	10.27291	0.0059
5	9.521215	0.0086
Joint	50.40986	0.0000

Note: six lags; 97 observations.

Finally, we checked for the model's stability. According to figure 2, all inverse roots of the autoregressive characteristic polynomial lie inside the unit circle, meaning that the VAR system is stable.

[16] Accordingly, as the size of the sample of any given variable increases, the sample distribution average will tend to normal.

Figure 2
Inverse roots of autoregressive characteristic polynomial



In short, robustness tests indicate that in the estimated model (with six lags), residuals are non-correlated and homoscedastic, despite not being normal.

The relationship among interest rate, exchange rate, inflation, output, and public debt in Brazil: An empirical analysis of the monetary policy transmission mechanism

The estimated model allows us to analyze the interaction among five vitally important macroeconomic variables. By establishing bilateral relations between all variables, the VAR model is proven suitable to our goals. The intuition behind variable selection is simple.

On the one hand, economic theory shows that the series used here are related; in some cases the relationship is mutual, in others bilateral, and so on. For instance, a rise in interest rates prompts: 1) a decrease in inflation; 2) a slowdown in economic activity; 3) an appreciation of domestic currency, and 4) a rise in public debt. Accordingly, it is reasonable to consider that an exchange rate devaluation: 1) is transferred into domestic prices; 2) impacts on public debt, due to the existence of exchange rate indexed bonds; etcetera.[17] As a conclusion, according to economic theory, the variables in the model are bound to be widely interrelated.

[17] According to the 2002 and 2009 BCB reports, the percentage of exchange-rate-indexed public bonds added up to 28.6% in 2001; 22.4% in 2002; and 0.7% in 2009.

On the other hand, in accordance with the Taylor rule, BCB reacts to inflation and output levels by setting the basic interest rate.[18] Apart from that, it is reasonable to consider that the BCB's reaction function can be widened by including the exchange rate and the debt/GDP ratio. Many authors have included the exchange rate in their Taylor rule estimates. Additionally, the importance given to the exchange rate by the BCB's Comité de Política Monetaria (COPOM) justifies the inclusion of this variable. According to COPOM meeting proceedings, Selic is fixed taking a given exchange rate level as a parameter. In other words, the BCB reacts to the exchange rate when setting the basic interest rate: depreciation is expected to make the BCB raise the basic interest rate with the purpose of inhibiting an exchange rate pass-through.

The relationship between monetary and fiscal policies has increasingly been studied, both in national and international literature. The volume edited by Chrystal (1998) is a good reference, as it compiles articles presented at the Bank of England's seminar on the theme. Dornbusch (1998) is among the pioneers who stated that public debt management may jeopardize the efficiency of monetary policy. He proposes that debt stock and, notably, debt structure may turn consumption into a positive function of the basic interest rate. In case public debt holders retain a substantial portion of the short-term debt, a rise in interest rates generates an increase in income, which, in turn, can be translated into increased aggregate demand. In that case, the efficiency of monetary policy is affected. Bell-Keaton and Ballinger (2005) present a post-Keynesian perspective on the theme. They also provide evidence that, in highly indebted countries, interest rates and the GDP are positively correlated.

The great participation of floating treasury bonds indexed to Selic (known as Letras Financeiras do Tesouro, LFT) in the total debt stock[19] may create a detrimental transmission channel in monetary policy, or a *financial wealth effect in reverse*, as proposed by Dornbusch (1998). In that case, a rise in the basic interest rate would increase aggregate demand, bumping prices. Based on that premise, Parreiras (2007) includes the relationship between federal domestic debt and the GDP in his estimate of the BCB's reaction function.[20] Pires (2008)

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[18] For a review of the Taylor rule, see Modenesi, Martins and Modenesi (2013).

[19] During the period, LFT accounts for from more than one-third to nearly a half of the total debt stock.

[20] It is worth noting that the author does not prove the existence of such a mechanism in the Brazilian economy.

also addresses the interaction between monetary and fiscal policies in Brazil and provides evidence that "the wealth effect might explain part of the inefficiency of Brazil's monetary policy" (Pires, 2008: 25).

The extensive literature addressing this issue indicates that the BCB may react to fiscal variables, thus justifying the inclusion of the debt/GDP ratio in the estimated model.[21] The intuition pointing to the existence of a positive relationship between the debt stock and Selic is simple. In face of a deterioration of the National Treasury's ability to make payments –caused by an increase in debt– agents tend to demand higher interest rates in order to continue absorbing the offer of government bonds.

Costs and benefits of monetary policy

Figure 3 shows the response of variables *DInd*, *DDebt*, *DIPCA*, *DExchange* to a shock (of a standard deviation and according to the Cholesky decomposition) in *DSelic*, and thus makes it possible to analyze the effect of a raise in the basic interest rate on the other variables included in the model.

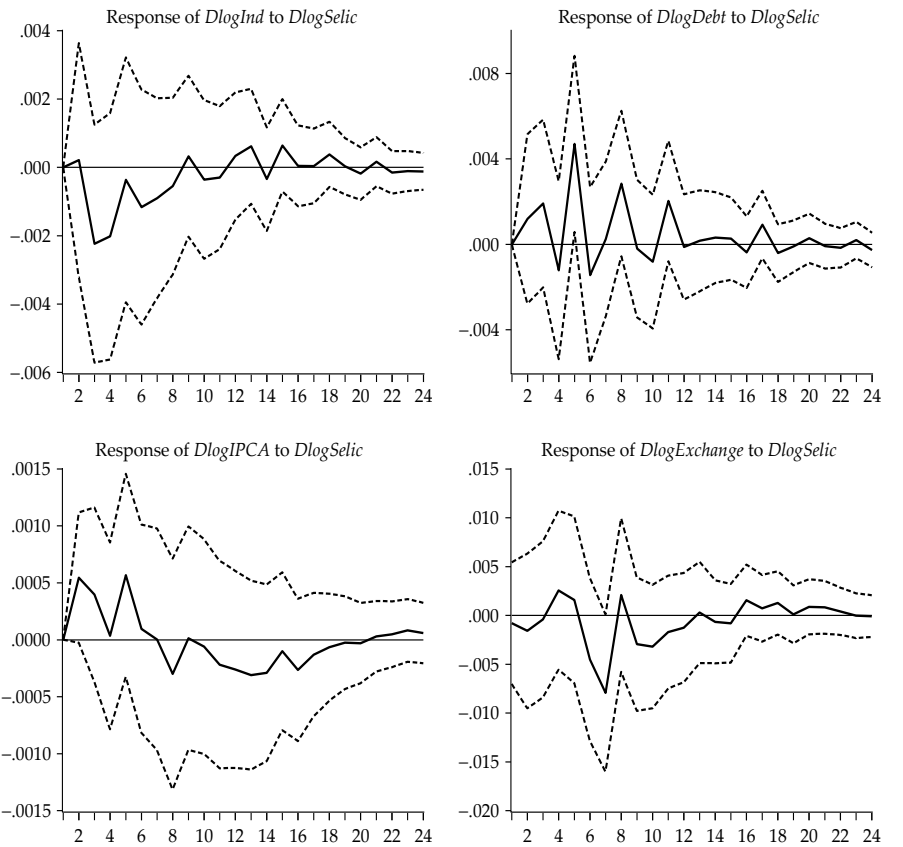
The *DIPCA*'s response to a shock in *DSelic* constitutes a typical *price-puzzle* situation (Walsh, 2003: Chapter I). Initially, inflation accelerates, peaking out in 2 and 5 months, respectively, and then declines, reaching a minimum in 12 to 14 months. After that, inflation accelerates again and, finally, the effect dissipates in about 18 months.

This behavior, though not backed by orthodox theory, has become a sort of rule in VAR models (Eichenbaum, 1992). These phenomena have also been verified in the Brazilian economy by Luporini (2007), for example. The most conventional explanation for this behavior is that it is due to a problem of misspecification: the variables included in the model do not cover the whole package of information at the BCB's disposal (Sims, 1992). Based on that premise, Christiano, Eichenbaum, and Evans (1996) and Sims and Zha (1998) eliminated the puzzle by introducing a commodity price index.

An alternative motivation, which has gained relevance lately, is that there is a *cost channel* in the transmission of monetary policy. In other words, a rise

[21] On this subject, see Garcia (2002), Bevilaqua and Garcia (2002), Blanchard (2004), Andrade and Moraes (2005), Barbosa (2005a; 2005b), Herrera (2005), Mattos (2005), Nakano (2005), and Neponucemo (2005).

Figure 3
Response of DIPCA, DInd, DExchange, and DDebt to DSelic
(Response to Cholesky one S.D. innovations ± 2 S.E.)



Note: S.E. = standard errors.

in interest rates increases production costs of firms which –depending on their market power and demand conditions– can be transferred into prices. This view is based on Kalecki's contribution (1978), who considers prices to be determined by a mark-up rule over production costs. A post-Keynesian approach to inflation costs is found in Palley (1996: Chapter XI) and Arestis (1992: Chapter VI), for example.[22] Podkaminer (1998) develops a theoretical

[22] For a historical perspective, see Humphrey (1986). Tooke (1983) and Laughlin (1909; 1911) are among the precursors of this conception.

model in which maintaining interest rates at a sufficiently high level is enough to generate inflationary pressures.

In accordance with this literature, a monetary contraction at first prompts an increase in costs that are quickly transmitted to prices. Later on, a rise in interest rates slows down economic activity and, finally, produces a negative impact on inflation. Therefore, the puzzle might result from a mismatch between the effects of monetary policy on production costs –which are more immediate– and its lagged impacts on aggregate demand and, finally, on prices.

Based on data provided by 2000 Italian companies, Gaiotti and Secchi (2006) found evidence in support of the existence of cost channels. Barth and Ramey (2000) arrived at the same conclusion regarding the US economy. One should also see Hannsgen (2006) on this matter. On the importance of such a channel in the Brazilian economy, see Marques and Fochezatto (2006).

More than the occurrence of a *price puzzle*, it is inflation's low sensitivity to interest rates that has drawn our attention. In that sense, the benefit –in terms of lowering inflation– of a rise in the basic interest rate proves to be quite small (and of little statistical significance).

The effect of raising the basic interest rate on industrial output (as a proxy of GDP) is negative, despite being of little statistical significance.[23] A shock in *DSelic* causes *DInd* to fall (though erratically), reaching a minimum within three months. From that point on, industrial output recovers; the effect of the shock wanes off after about 10 months and clears out completely in 20 months. Therefore, the final effect of a shock in interest rates on industrial output is negative.

The exchange rate increases in reaction to a shock in the basic interest rate. Initially, *DExchange* accelerates marginally. After the fourth period, it begins to decline, reaching a minimum in seven months. After that, *DExchange* slowly increases and the effect of the shock is completely dissipated after 21 months. The final result of a *DSelic* shock on *DExchange* is also negative; that is, the exchange rate appreciates in response to an increase in the basic interest rate.

Finally, debt increases in response to a rise in interest rates. The impact of a shock in *DSelic* peaks out in five months. From that point on, *DDebt* begins to decrease, though very erratically, and the effect wanes off in about 12 months.

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[23] Since a negative relationship between GDP and the interest rate is widely supported by the literature, this little significance might be in part a result of industrial production not being such a good proxy for GDP (more details on page 115-6).

The final effect of a shock in *DSelic* on *DDebt* is clearly positive, that is, the debt/GDP ratio increases.

Table 9 shows a measure of a monetary policy shock, based on a cumulative response of a Selic shock (at the end of *n* months) on industrial output, debt/GDP ratio, IPCA, and exchange rate.[24]

Table 9
Cumulative responses to Selic innovations
(percentages)

Months	*DInd*	*DDebt*	*DIPCA*	*DExchange*
6	–9.57	8.90	2.82	–5.36
9	–9.97	12.06	2.03	–17.76
12	–11.09	14.53	1.30	–28.56
18	–10.12	18.17	–0.61	–28.14
24	–10.14	16.91	–0.29	–22.86

At the end of 24 months, a 1% rise in Selic results in: 1) a 10.14% decrease in *DInd*; 2) a 16.91% increase in *DDebt*; 3) a 0.29% fall in *DIPCA*; and 4) a 22.86% rise in *DExchange*. Once again, our attention is drawn to inflation's low sensitivity to interest rates: the final effect of a monetary contraction on the IPCA is negative, though very limited in magnitude. Nevertheless, the cumulative impact of a raise in the Selic on the other variables is not negligible.

In sum, the empirical evidence shows us, on the one hand, that a given raise in Selic produces a relatively small benefit –measured by the consequent reduction of inflation–; and, on the other hand, shows that it generates costs that should not be underestimated, especially a slowdown in economic activity and an increase in the debt/GDP ratio. Besides that, a raise in interest rates causes domestic currency to appreciate in a way that jeopardizes domestic industry's competitiveness and, as a result, deteriorates external accounts and slows down economic activity even further (Bresser-Pereira, 2010a; 2010b). So, monetary policy has been imposing a heavy burden on Brazil's economy, as the cost of reducing inflation can be considered high.

Inflation's low sensitivity to interest rates can be interpreted, at least in part, as a result of a broken transmission mechanism: flaws in the transmission of

[24] Belaisch (2003) uses this methodology to estimate the impact of exchange-rate depreciation on inflation in Brazil.

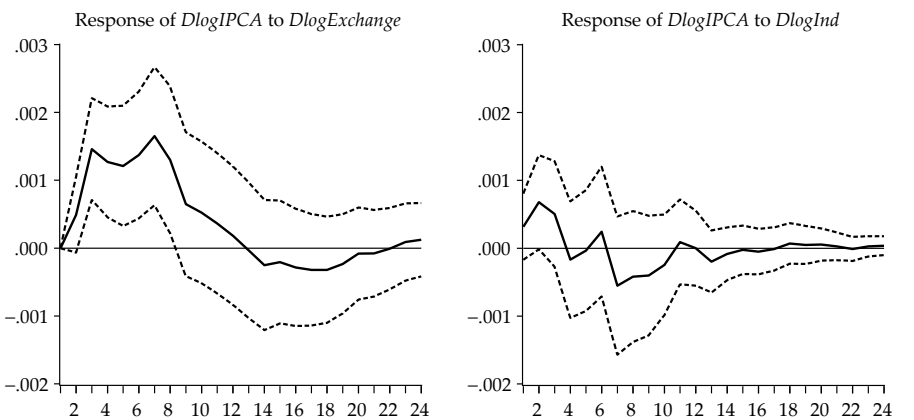
monetary policy are one of the factors that reduce its efficiency (Modenesi and Modenesi, 2012). Consequently, maintaining price stability under ITR *requires* setting the basic interest rate at relatively high levels. Thus, it is fair to argue that flaws in the transmission mechanism make for a less favorable balance of costs and benefits in monetary policy.

Transmission of monetary policy

Figure 4 presents the *DIPCA* response to a shock in *DExchange* and in *DInd* (by a standard deviation and according to the Cholesky decomposition). It shows how the effects of monetary policy are transmitted to inflation.

Inflation rates accelerate immediately after a shock in *DExchange*, peaking out after seven months. From that point on, inflation slows down gradually, with shock effects in *DExchange* dissipating only after more than 12 months. The impulse-response function only stabilizes after 22 to 24 months. It is worth mentioning that exchange rate depreciation is transferred into prices and its inflationary effect is considerably persistent: a year after the shock in *DExchange*, inflation is still above the initial level.

Figure 4
Response of DIPCA to DExchange and DInd
(Response to Cholesky one S.E. innovations ± 2 S.E.)



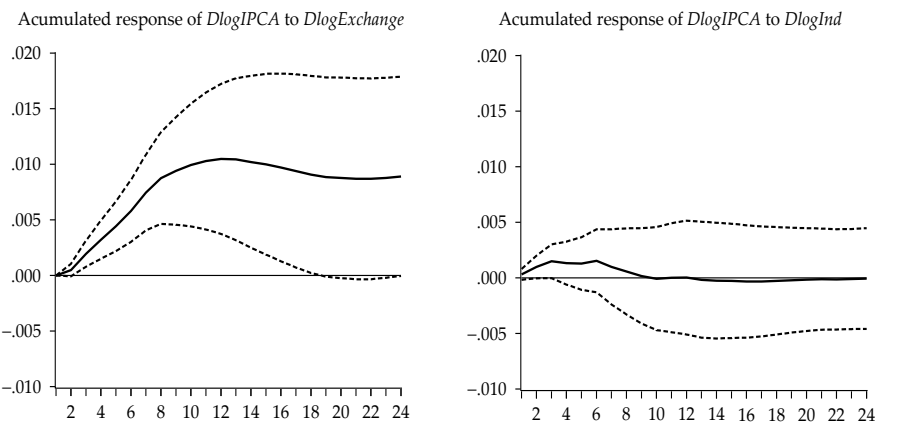
Conversely, inflation's response to an increase in the level of economic activity (measured by industrial output) is practically null. Inflation accelerates and peaks out in the second month after the shock in *DInd*. From the third month

onward, it slows down (erratically) and by the tenth month after the shock the effect ceases.

On the one hand, the fact that, in general, part of the increase in industrial output translates into an increase in business investment could explain that behavior. A greater amount of investment is reflected on the expansion of aggregate supply which, in turn, has a negative impact on the general price level. In sum, the inflationary effect of a higher level of economic activity (measured by industrial output) is almost negligible. That means that inflation does not follow the business cycle.

On the other hand, one might argue that such a result is a consequence, at least in part, of industrial activity not being a good proxy for GDP. Industrial output share in GDP is around 20%, so it might be an unreliable proxy for GDP. Nevertheless, it is reasonable to suppose that, on average, there is a positive correlation of the level of activity between the primary, secondary, and tertiary sectors. But at certain moments, they can also show diverging, sometimes even conflicting, behavior.[25] In face of that, a monthly indicator that gives a more accurate picture of GDP is needed. It is worth noting that, even so, industrial GDP is largely applied as a proxy for GDP in Brazilian literature, since those variables are highly correlated. Figure 5 shows the cumulative effects of a shock in *DExchange* and in *DInd* on *DIPCA*.

FIGURE **5**
Cumulative response of DIPCA to DExchange and DInd
(Accumulated response to Cholesky one S.D. innovations ± 2 S.E.)



[25] For example, the inventory cycle makes the industrial sector's activity level more volatile than the service sector.

The relevance of the exchange rate channel

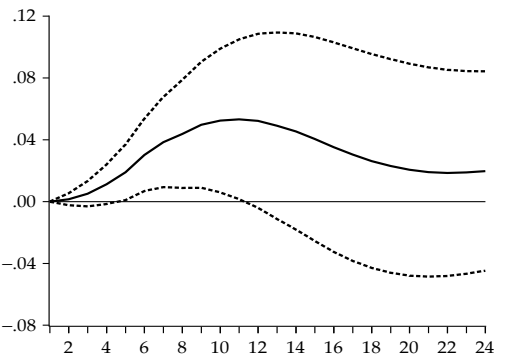
In previous sections we discussed that a rise (fall) in *DExchange* determines a rise (fall) in *DIPCA* and that a rise (fall) in *DSelic* prompts a rise (fall) in *DExchange*. Furthermore, *DExchange* causes *DIPCA* and also *DSelic*, in the Granger sense (see table 5). The combination of those empirical relationships makes for a passive monetary policy.

One can reasonably assume that the BCB is aware that variations in the exchange rate precede changes in inflation. Thus, in face of an exchange rate depreciation –with a view to holding down the consequent pass-through to prices– the monetary authority raises the basic interest rate. The following diagram illustrates the essence of the monetary policy operation in the time frame in question:

$$\uparrow Exchange_t \Rightarrow \begin{cases} \uparrow IPCA_{t+1} \\ \uparrow Selic_{t+1} \rightarrow \downarrow Exchange_{t+2} \rightarrow \downarrow IPCA_{t+3} \end{cases}$$

Figure 6 shows the cumulative response of *DSelic* to a shock in *DExchange* (by a standard deviation and according to the Cholesky decomposition). Right after the shock, *DSelic* is raised, and the accumulated effect peaks out by the tenth month after the shock. From then on, *DSelic* falls, with the shock effects clearing out after 20 months. This is, therefore, one more piece of evidence that, in the face of an exchangen rate depreciation, the BCB raises the basic interest rate.

Figure **6**
Cumulative response of DSelic to DExchange
(Accumulated response of *DlogSelic* to Cholesky one S.D. *DlogExchange* innovation)



As discussed before, monetary policy in Brazil is reasonably passive: the BCB has reduced autonomy to determine the basic interest rate, which responds to variations in the exchange rate, given the relevance of that channel in the monetary policy transmission mechanism. In fact, the importance of the exchange rate in the transmission mechanism has been noted in other works, such as Kregel (2004), Serrano (2006), Oreiro *et al.* (2008), and Serrano and Summa (2011).[26]

As a consequence, exchange rate appreciation cannot be considered an undesired by-product of setting the interest rate at a high level, as many point out. On the contrary, empirical evidence shows that this is the essence of the current stabilization policy: a rise in Selic appreciates the Brazilian real. Given the importance of the exchange rate in the evolution of IPCA, an appreciation of the real reduces inflation. This piece of evidence, together with the others already presented, reveals that the exchange rate is the main transmission mechanism of monetary policy.

Table 10 presents *DIPCA* variance decomposition, which reinforces the importance of the exchange rate in defining inflation behavior. *DIPCA* variance is to a great extent explained by the variance in *DExchange*: at the end of 12 months, the evolution of the exchange rate explains nearly half (45%) of inflation's behavior, which confirms its importance in the transmission mechanism of monetary policy. By contrast, economic activity explains only 6% of *DIPCA* variance. In other words, the analysis of variance decomposition reinforces the results obtained by the impulse-response functions (see figures 3, 4, 5) presented in previous sections.

Table **10**
Variance decomposition of DIPCA

Period	*Standard error*	*DInd*	*DDebt*	*DIPCA*	*DSelic*	*DExchange*
3	0.016666	6.657372	1.204679	69.07535	3.703791	19.35881
6	0.017662	4.422845	14.02493	41.86110	3.836597	35.85453
9	0.018199	5.668733	14.17741	32.17434	3.217717	44.76180
12	0.018381	5.760120	14.05483	31.48954	3.554980	45.14053

Cholesky ordering: *DSelic, DIPCA, DInd, DDebt, DExchange.*

[26] Goldfajn and Werlang (2000), Correa and Minela (2006), and Nogueira, Jr. (2007) estimate the exchange rate pass-through coefficient for the Brazilian economy.

Table 11 shows the variance decomposition of *DSelic*. It also corroborates the importance of exchange rate in determining the basic interest rate. *DSelic* variance is to a great extent explained by *DExchange* variance: at the end of 12 months about 30% of basic interest rate behavior is explained by the evolution of exchange rate.

Table **11**
Variance decomposition of DSelic

Period	*Standard error*	*DInd*	*DDebt*	*DIPCA*	*DSelic*	*DExchange*
3	0.016666	2.735550	13.27749	2.056785	79.66592	2.264252
6	0.017662	4.154006	17.10794	2.539432	56.19791	20.00071
9	0.018199	4.209698	17.01129	3.434756	49.25619	26.08807
12	0.018381	4.148671	16.79445	5.162524	48.03867	25.85569

Cholesky ordering: *DSelic, DIPCA, DInd, DDebt, DExchange*.

In sum, the evidence suggests that the exchange rate has been the main channel of monetary policy transmission: in face of an inflationary surge, the BCB raises the basic interest rate with a view to appreciating the currency (the real) and thus curbing prices. Therefore, exchange rate appreciation is not an undesirable result of monetary policy, but the essence of inflation control.

Conclusions

We have performed a sufficiently robust econometric analysis of the monetary policy transmission mechanism. The results of this analysis are a broad body of evidence that allows us to evaluate the main costs and benefits of the stabilization policy adopted in Brazil since 2000.

The exchange rate has proven to be the main channel of monetary policy transmission. Appreciation of the real cannot be considered an undesirable by-product of interest rate fixation at high levels. On the contrary, empirical evidence reveals the essence of Brazilian current stabilization policy: a high Selic rate appreciates the real. Given the importance of the exchange rate in the evolution of prices, exchange rate appreciation reduces inflation.

Empirical evidence also shows that inflation's sensitivity to interest rates is low. On the one hand, a rise in Selic rate generates a relatively small benefit, as measured by the consequent decrease in inflation. On the other hand, an interest rate rise produces considerable costs, notably when it causes economic activity to slow

down and the debt/GDP ratio to increase. Furthermore, a rise in Selic leads to an appreciation of the real, which, while undermining the competitiveness of domestic industries, tends to deteriorate external accounts and jeopardize economic activity. It should be noted that monetary policy imposes a great sacrifice on Brazilian economy: the cost of reducing inflation is considerably high.

Inflation's low sensitivity to interest rates can be interpreted as resulting, at least in part, from a broken transmission mechanism: flaws in the monetary policy transmission mechanism contribute to reducing its efficiency. Price stability under ITR thus *requires* an excessively rigid monetary policy. The final result is that inflation hardly gives in. We conclude that the balance of costs and benefits of price stability under ITR is unfavorable.

Finally, we must acknowledge that our results still need to be further. The body of evidence presented, though robust, needs to be improved. Therefore, a note of caution is warranted concerning the conclusions presented here: given the importance of the consequences involved, further studies are still called for.

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