The Transmission Mechanisms of Monetary Policy in Brazil

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Abstract

We develop and estimate a semi-structural economic model to decompose the monetary policy transmission mechanisms in Brazil for the inflation targeting period. We decompose the channels into the exchange rate channel, consumption channel, and investment channel. The three channels play a relatively important in explaining the inflation dynamics when the economy is hit by a monetary policy shock. The exchange rate channel explains more than 30% of the reduction in inflation. The investment channel, in turn, is responsible for the largest part in the inflation reduction, accounting for more than 40% of the fall. This result disputes the common view that the investment channel in Brazil is limited.

Keywords: Monetary Policy Transmission Channels, Decomposition, Structural Model

JEL classification: E17, E52, C51

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1. Introduction

The effects of monetary policy shocks on real short-run dynamics is one of the most well documented facts in the macroeconomic literature\(^1\). However, the precise channels through which monetary policy innovations affect the real economy are much less documented and still subject to controversy. One reason for such discrepancy may be the lack, at least until recently, of a coherent methodology for identifying the various monetary policy channels\(^2\). However, Altissimo, Locarno and Siviero (2002), henceforth ALS, helped to fill in this gap. ALS build on the work of Mauskopf and Siviero (1994) and propose a fairly general approach to decompose the overall response of an economic model to a shock into the contributions associated with its distinct channels.

ALS’ methodology is very general in several dimensions. First, it can be applied to both calibrated and estimated models. Second, it allows to decompose not only monetary policy shocks, but also other types of shocks. Third, it can be successfully applied to both backward-looking and forward-looking models. Last but not least, it can handle monetary models with both exogenous and endogenous interest rate rules. The only technical condition ALS’ approach requires is a linear model. The authors show that in the case of linear models, the channel decomposition is exact, that is, the sum of the individual effects that transit through each individual channel exactly equals the overall effect\(^3\). Since mid-1990s many researchers and central banks have used ALS’ approach—or of its predecessors Mauskopf and Siviero—to quantify the various channels of the monetary policy transmission mechanism, including BIS (1995), van Els et al. (2001), McAdam and Morgan (2001) and others.

In this paper we use ALS’ methodology to decompose the monetary policy transmission

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\(^1\)See, for instance, a comprehensive survey by Walsh (2003), and a thorough analysis of the U.S. case by Christiano et al. (1998).

\(^2\)As will become clear later, we refer to economic rather than statistical identification.

\(^3\)ALS’ approach also works for non-linear models as long as the residuals due to the inexact decomposition do not affect the relative contribution of the individual channels.
channels in Brazil. In order to achieve this goal we proceed in three steps as follows. First, we
develop a medium-size, semi-structural economic model for the Brazilian economy during the
inflation targeting regime. This model can be thought as a reduced-form version of a more
primitive, micro-founded newkeynesian model. We believe our model is a fair representation
of the basic structure of the Brazilian economy, as well as the modus operandi of the Brazilian
monetary authority in recent years. Therefore, it allows us to analyze the monetary policy
channel decomposition in a meaningful way. Second, we estimate the parameters of the
model using data for the inflation targeting period. In this first pass, we estimate the model
equation-by-equation, though we plan to estimate it using system methods in order to assess
the loss of efficiency due to single-equation estimation. Third, and most importantly, we use
ALS’ methodology to decompose the monetary policy channels implied by our model.

The estimated model allows us to identify three main operating channels. The first
channel operates through the exchange rate. This channel captures the effects, via the UIP
condition, of interest rate movements on the real exchange rate and thus on the real marginal
cost of firms and on exports and imports. We call this the “exchange rate channel”. The
second channel captures the effects of the policy rate on the household lending rate, which
has a direct effect on household consumption decisions. We call this the “consumption
channel”. The third channel captures the effects of the policy rate on our proxy for the user
cost of capital, namely, the real interest rate that is relevant for investment decisions. We
label this the “investment channel”. These three channels capture the effects of monetary
policy shocks on aggregate demand via its main components, net exports, consumption and
investment, respectively, and directly on firms’s costs.

According to the estimated model and the above decomposition, we have the following
results concerning the decomposition of inflation behavior following a positive shock to mon-
etary policy. The three channels play a relatively important role in explaining the inflation
dynamics when the economy is hit by a monetary policy shock. The exchange rate channel
is responsible for 31.2% of the total reduction in inflation over a period of two years (and 39.5% considering three years). The consumption channel, in turn, responds for 24.7% in inflation fall (19.7% in three years), and the investment channel is responsible for the higher share: 44.1% (40.8% in three years).

These results are coherent with the strong evidence of the important role played by the exchange rate in the inflation dynamics in Brazil. However, it records a higher than expected effect through the investment channel. In Brazil, long-term credit is supplied mainly by the National Bank of Economic and Social Development (BNDES) at rates lower than the base interest rate. These results shows that, in spite of the reduction in the strength of the transmission mechanism brought by this system, increases in the base interest rate affect significantly the gross formation of fixed capital. This probably occurs because of the effects on other lending rates more sensible to the policy rate and of the expected effects on consumption, leading to current reductions in investment.

To our knowledge, we are the first to document the relative contribution of individual channels of the monetary policy transmission mechanism in Brazil during the inflation targeting regime. Our contribution to the monetary policy literature in Brazil is relevant in several aspects. First, by quantifying the relative importance of the individual channels, we offer novel insights on the works of monetary policy in Brazil. Such insights are not possible to obtain from standard VARs exercises, usually restricted to measure only the overall effects of monetary policy shocks. Second, our model can be helpful in the development of truly micro-founded models for the Brazilian economy. Third, our model can be used as a complementary tool in monetary policy decision-making.

Besides the works cited above, our paper relates to the broad literature on monetary policy transmission mechanism. This has been a fertile field of research in the last two decades and has gained prime time recently, in the wake of the U.S. crisis in the subprime mortgage market and the global surge of inflation. In part motivated by the economic
developments in the early 1990s in the U.S. economy, Mishkin (1995) stresses that policy makers should have a good understanding of the various monetary policy channels in order to implement successful policies. These channels include not only the traditional interest rate channel, highlighted by Taylor (1995), but also the credit channel (Bernanke and Gertler (1995)), the exchange rate channel in the case of open economies (Obstfeld and Rogoff (1995)) and even asset price channels in the case of financially developed economies (Meltzer (1995)). Macroeconomic stability and the availability of better data also turned possible to conduct thorough studies of monetary transmission channels in developing countries (see, for instance, BIS (1998) and BIS (2008)). However, most of such studies try to quantify the aggregate effects on monetary policy via statistical methods instead of decomposing the monetary channels via structural models, as we do in this paper.

This paper has four remaining sections. Section 2 briefly describes important facts about monetary policy in Brazil since the adoption of the inflation targeting regime in 1999. Section 3 develops and estimates the model used in the channel decomposition. Section 4 presents the channel decomposition and other important quantitative results. Section 5 concludes.

2. Key Stylized Facts

In this section we present key facts about monetary policy in Brazil for the period covering the inflation targeting regime. Unless noted otherwise, the data used here and in the next sections are in log and filtered by Hodrick-Prescott (HP) filter, at quarterly frequency. Panel A of Figure 1 depicts the correlation structure of the policy interest rate (Selic) and key macroeconomic variables, namely, real GDP, CPI inflation and the real exchange rate. As expected for an emerging economy, there is a negative comovement between interest rate and GDP at relevant lags and leads over the business cycle. Moreover, the interest rate appears to lead the cycle by a quarter. On the other hand, the cross-correlations between
interest rate and the other two variables are either positive or zero at the relevant lags and leads. Both inflation and real exchange rate appear to anticipate changes in the interest rate by 1-2 quarters over the cycle. This last correlation structure actually reflects the reaction of monetary policy to supply shocks that hit the economy during the inflation targeting period, particularly in 2001-2003. These episodes were characterized by large exchange rate depreciations that fueled inflation, which prompted the Central Bank of Brazil (CBB) to hike interest rates.

Panel B of Figure 1 depicts the duration, magnitude and shape of a typical interest rate cycle for the inflation targeting period. The figure reveals three important features about the behavior of policy rate. First, the typical cycle lasts two years on average, that is, the interest rate takes about 8 quarters to return to its value at the beginning of the cycle. Second, the interest rate reaches its peak roughly a year after the initial hike. At its peak over the cycle, the interest rate is about 30 percent higher than its initial value. Finally, the cycle is approximately symmetric, that is, the rate hiking phase is roughly equal to the rate cutting phase.

Figure 2 reveals that except for the turbulent years of 2001-2003—characterized as a stress test for the inflation targeting regime—inflation has been fairly under control and close to the targets pursued by the monetary authority.

Figure 3 depicts a strong correlation between the country risk premium and the real exchange rate. Positive innovations to the risk premium, due to either internal factors (e.g., political uncertainty, supply shocks) or external factors (e.g., shifts in foreign investors’ risk aversion, contagion) translates into exchange rate devaluations, which pass-through inflation.

Last but not least, Figure 4 presents the impulse responses to a 30 basis points increase in the policy rate. The responses are generated by a parsimonious one-lag VAR, which includes only the following four variables (in this order): GDP, inflation, real exchange rate
and interest rate. This ordering is identical to the one proposed by Christiano et al. (1998)\(^4\). As we can see, output reacts relatively quick to a monetary policy shock. The largest output drop is significant and occurs two quarters after the initial interest rate hike. The largest effect on inflation takes a little longer (around a year), but is not as significant as the reaction of output. Notice that the real exchange rate barely moves with the monetary contraction. Finally, the economy completely adjusts to the shock within two years or so.

Statistical methods like VARs have two important limitations in quantifying the monetary transmission channels. First, they only describe the aggregate effects of monetary policy innovations. In general, these methods cannot uncover the various channels through which monetary policy affects the decisions of economy agents. Second, they fail to provide a coherent economic story for the magnitude, shape and timing of the impulse response functions. Structural economic models are natural candidates for filling in these gaps. Besides being powerful tools of story telling, structural models, if designed in a meaningful way, allow us to identify the monetary policy channels that are active in a given economy. In the next section we propose a semi-structural model for the Brazilian economy. We then use this model to uncover the channels of the monetary policy transmission mechanisms during the inflation targeting regime.

3. Model

Ideally, we should study transmission mechanisms using an economic model with solid theoretical foundations, such as the new generation of dynamic stochastic general equilibrium (DSGE) already in use by many central banks\(^5\). One limitation of such models, however, is the strong set of restrictions they impose on the data. More specifically, we can view

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\(^4\)Alternative ordering had little effect on the impulse responses. However, different lag structure did change the responses of inflation.

\(^5\)For instance, the DSGE models of Sweden (RAMSES), Canada (ToTEM), Norway (NEMO), England (BEQM), Euro Area (NAWM), Chile (MAS), Peru (MEGA-D), and Colombia (PATACON).
DSGE models as VARs with strong set of restrictions on the lag structure and on the variance-covariance matrix of the shocks. Instead of having a truly structural (hence, highly restricted) model, we decided to develop a semi-structural model that combines economic theory as well as specific features of the Brazilian data. Before we present the model, it is important to make some important remarks about it. First, even though the model is not derived from first principles, it can be interpreted as a unrestricted version of a more primitive (unrestricted) log-linearized DSGE model. Second, the model fairly describes the structure of the Brazilian economy and the behavior of monetary policy in Brazil, thus it can be meaningfully used to identify the relevant monetary policy channels. The model has six blocks of equations: aggregate demand, aggregate supply, external sector, financial sector, government sector and rest of the world. Third, the model is linear in the variables because we want to have an exact channel decomposition. Fourth, to keep the model simple we consider a one-good economy, thus abstracting from changes in domestic relative prices. See Appendix A for details about the derivations. In developing the model, we borrow many insights from Bank of England (2000), Alves and Muinhos (2003) and Garcia et al. (2003).

3.1. Estimation procedures

We estimate the model equation by equation with two-stage least squares (2SLS) or ordinary least squares (OLS) methods. We use quarterly data, and the sample period goes from 1999Q3 through 2008Q1, including thus only the inflation targeting period. Because of the availability of data, mainly inflation expectations collected from a survey conducted by the CBB, the sample period may start a little later. Lagged values were also restricted to start in 1999Q1, excluding therefore the period of the managed exchange rate regime.

All series are HP filtered, using the 1996Q1-2008Q1 period. The variables (and the corresponding source) used in the estimation were the following. Output, private consumption, investment, exports and imports are chain-weighted seasonally adjusted series from the Na-
tional Accounts, calculated by the IBGE. This institution is also responsible for the data on labor market (wage, employment, unemployment rate) and for the inflation measure, given by the IPCA (Broad Consumer Price Index). Real effective exchange rate, Selic interest rate, household lending interest rate, swap pre-DI rate, net external debt, and net exports series come from the CBB. Rate of capacity utilization is supplied by Getulio Vargas Foundation. Country-risk premium is measured by the Embi, calculated by JP Morgan. and foreign investors’ risk aversion is measured by the Ravi, calculated by Merrill Lynch. World inflation is proxied by CPI inflation in the US and the world interest rate, by the Fed funds rate. World imports is a weighted average (by trade volumes) of the real imports of Brazil’s top fifteen trade partners (from IFS statistics).

3.2. Aggregate Demand

The National Accounts’ main identity is the starting point of our model. The log-linear version of aggregate expenditure is approximately described by:

\[ y_t = s_c c_t + s_i i_t + s_g g_t + s_x x_t - s_m m_t \]  

(1)

where \( y_t \) is real GDP, \( c_t \) is private consumption, \( i_t \) is investment, \( g_t \) is government expenditure, \( x_t \) is exports and \( m_t \) is imports. We calibrate the corresponding shares to the following values: \( s_c = 0.62, s_i = 0.16, s_g = 0.20, s_x = 0.14, s_m = 0.12 \), which correspond to the average values during the sample period. The next identity is the domestic absorption equation, given by:

\[ a_t = \left( \frac{s_c}{s_a} \right) c_t + \left( \frac{s_i}{s_a} \right) i_t + \left( \frac{s_g}{s_a} \right) g_t, \]  

(2)

where \( s_a \) is the ratio of nominal domestic absorption to nominal GDP, calibrated to 0.98.

We estimate behavioral functions for each component of aggregate demand. Private consumption depends on past consumption, expected real interest rate, current income (real
payroll), and the real effective exchange rate, reflecting a mixture of the permanent income hypothesis and rule-of-thumb behavior:

\[
    c_t = 0.39c_{t-1} - 0.62\left(r_{ht} - \pi_{t,t+4}^e\right) + 0.15(w_t + n_t) - 0.03 q_t
\]

(3)

2SLS, Instrumented var.: \(r_{ht} - \pi_{t,t+4}^e, (w_t + n_t), q_t, \) SP: 2000Q3-2008Q1, \(R_A^2 = 0.92,\)

\(LM_1 = 0.18[0.67], LM_4 = 4.08 [0.40], \) White = 12.08 [0.74], \(JB = 0.47 [0.79],\)

where the numbers in parenthesis are Newey-West corrected standard errors, \(r_{ht}\) is the average nominal lending rate charged by banks on household loans, \(\pi_{t,t+4}^e\) is time \(t\) one-year-ahead expected inflation, \(w_t\) is the real wage rate, \(n_t\) is employment level, and \(q_t\) is the real effective exchange rate. We do not use one-quarter-ahead inflation expectation because the average maturity of household loans is slightly over a year. SP stands for sample period. In the line corresponding to the estimation diagnosis, \(R_A^2\) is the adjusted \(R^2,\) \(LM_1\) and \(LM_4\) is the Breusch-Godfrey Lagrangian multiplier test (number of observations times \(R^2\) for serial correlation in the residuals up to order one and four (null hypothesis is absence of autocorrelation), White is the White heteroskedasticity test for the residuals (null hypothesis is absence of heteroskedasticity) and \(JB\) is the Jarque-Bera \(\chi^2\) test for normality in the residuals (null hypothesis is of normality). For each test, the number outside square brackets is the value of the test statistics, whereas the number inside square brackets is the corresponding \(p\)-value. In principle, in the estimations, we try to use the period 1999Q3-2008Q1. However, because of the availability of some series used as instruments, the sample used may be shorter.

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\(6\) This and some other regressions in this paper include time dummies to control for outliers. Additionally, all regressions include a constant term. For convenience, we omit them when presenting the equations.
Aggregate investment (gross formation of fixed capital) is a function of past investment and the interest rate (proxy for the user cost of capital), as in standard investment equations. For the interest rate, we use the 360-day swap pre-DI interest rate. In the absence of a developed market for long-term lending in Brazil, we decide to use a variable highly correlated with banking lending rates and that captures significantly the stance of monetary policy. The resulting investment equations is given by:

$$i_t = 0.84i_{t-1} - 3.05 (r_{st} - \pi_{t,t+4}^e),$$

(4)

2SLS Instrumented var.: \(r_{st} - \pi_{t,t+4}^e\), SP: 2000Q2-2008Q1, \(R_A^2 = 0.65,\)

\(LM_1 = 0.18 \,[0.67],\; LM_4 = 5.41 \,[0.25],\; White = 3.16 \,[0.67],\; JB = 19.8 \,[0.00].\)

Exports depend positively on world demand, and on the real exchange rate, as in standard export equations, and negatively on domestic absorption:

$$x_t = 1.15m^*_t - 0.53a_{t-1} + 0.09q_{t-1}$$

(5)

2SLS. Instrumented var.: \(m_t^*,\) SP: 1999Q3-2008Q1, \(R_A^2 = 0.69\)

\(LM_1 = 0.01 \,[0.92],\; LM_4 = 7.43 \,[0.11],\; White = 6.30 \,[0.51],\; JB = 0.60 \,[0.74]\)

where \(m_t^*\) is a weighted average (by trade volumes) of the real imports of Brazil’s top fifteen trade partners.

Imports, in turn, also depend on the real exchange rate and on the economic activity level:

$$m_t = 0.59m_{t-1} + 1.71y_t - 0.19q_{t-1}$$

(6)

\(^7\)We do not model inventory changes.
2SLS, Instrumented var.: $y_t$, SP: 2000Q2-2008Q1, $R^2_A = 0.80$,

$LM_1 = 0.70 \ [0.40]$, $LM_4 = 1.84 \ [0.77]$, $White = 12.14 \ [0.21]$, $JB = 0.55 \ [0.76]$

We model government spending as an ARMA(2,1) process. In this formulation, the transmission mechanism of monetary policy is not affected by possible reaction from the fiscal side:

$$g_t = 0.97 g_{t-1} - 0.51 g_{t-2} - 0.48 ma(1)$$  \hspace{1cm} (7)

$$R^2_A = 0.52, \ OLS, \ Sample \ period: \ 1999Q4-2007Q4$$

$LM_1 = 0.32 \ [0.57]$, $LM_4 = 5.84 \ [0.21]$, $White = 4.24 \ [0.51]$, $JB = 0.56 \ [0.75]$

3.3. Aggregate Supply

In the supply side, we model the following variables: inflation, real wages, unemployment rate, rate of capacity utilization, employment level, real unit labor cost, and real payroll.

We calibrate the following relationships:

$$wn_t = w_t + n_t,$$  \hspace{1cm} (8)

$$n_t \simeq wap_t - \frac{\bar{U}}{1 - \bar{U}} u_t,$$  \hspace{1cm} (9)

$$ulc_t = w_t - (y_t - n_t).$$  \hspace{1cm} (10)

Real payroll ($wn_t$) depends on the real wage ($w_t$) and on the employment level ($n_t$). The latter depends on the working-age population ($wap_t$) and on the unemployment rate ($ut$). $\bar{U}$ is the long-run unemployment rate, calibrated according to the average in the sample period (10.7%). The working-age population is modeled as an AR(2) process. The real unit labor cost depends on the real wage and on labor productivity.
According to the estimated equation, the rate of capital utilization \( \left( u^k_t \right) \) depends positively on the output level (production function) and negatively on past investment (effect of investment on the capital stock level):

\[
u^k_t = 0.56 \cdot u^k_{t-1} + 0.63 \cdot y_t - 0.08 \cdot i_{t-1},
\]

(11)

2SLS, Instrumented var.: \( y_t \), SP: 1999Q4-2008Q1, \( R_A^2 = 0.61 \),

\( LM_1 = 1.15 \ [0.28], \ LM_4 = 6.79 \ [0.15], \ White = 3.75 \ [0.93], \ JB = 0.41 \ [0.82]. \)

The estimated equation for the unemployment rate basically captures the negative relationship with output level:

\[
u_t = 0.79 \cdot u_{t-1} - 0.21 \cdot y_t - 0.12 \cdot y_{t-1},
\]

(12)

2SLS, Instrumented var.: \( y_t \), SP: 1999Q4-2008Q1, \( R_A^2 = 0.88 \),

\( LM_1 = 0.74 \ [0.39], \ LM_4 = 3.38 \ [0.50], \ White = 12.74 \ [0.17], \ JB = 0.63 \ [0.73]. \)

Real wage, in turn, depends positively on output level and negatively on the unemployment rate. In other words, real wage is pro-cyclical, capturing the effects of the higher or lower tightness of the labor market over the cycle. Real wage also depends negatively on past inflation, capturing the fact that nominal wages are usually adjusted once a year. In other words, because of nominal wage rigidity, real wage is affected not only by current inflation, but also by past inflation:

\[
w_t = 0.77 \cdot w_{t-1} + 0.96 \cdot y_t - 0.90 \left( u_{t-2} + u_{t-3} \right) / 2 - 0.71 \cdot \pi_{t-1},
\]

(13)
We model inflation in a new Keynesian Phillips curve fashion, in which current inflation depends on expected inflation, past inflation and measures of real marginal cost (see, for instance, ?). We proxy the real marginal cost by the real unit labor cost and the real exchange rate. Our specification also includes an output term, which is statistically significant even in the presence of both variables capturing real marginal::

$$
\pi_t = \frac{0.47 (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4})}{4} + (1 - 0.47) \pi^{e}_{t,t+4} + 0.18 (ulc_{t-1} - ulc_{t-2}) + 0.04 (q_{t-1} - q_{t-2}) + 0.24 (y_{t-1} + y_{t-2})/2,
$$

(15)

The presence of the output term (which can be interpreted as a measure of output gap estimated using an HP filter) indicates that over the cycle there are other factors that affect prices, besides the two proxies for the real marginal cost, such as movements in the price of raw materials. The use of the four-quarter moving average of inflation as a lagged term, instead of the last quarter inflation, improves significantly the fit of the regression. We can also justify claiming that the quarter inflation measure is too noisy, and the moving average would capture more "fundamental" movements. Similarly, for expected inflation we are using the quarterly average of four-quarter ahead cumulative inflation (that is the reason why the sample period ends in 2007Q1). It also generates a better fit and is a less noisy measure of inflation. The estimated short-run exchange rate pass-through is roughly in line with other
estimates, such as those of Belaisch (2003) and Correa and Minella (2006)\textsuperscript{8}.

According to our aggregate supply setup, demand pressures tend to increase the real labor unit costs via rises in the real wage (increase in output and reduction in the unemployment rate), although they are mitigated by possible increases in labor productivity. The rise in the real labor unit cost and the higher output gap raises inflation. As a residual, the model also generates the path for the rate of capacity utilization and the employment level.

3.4. Financial variables

The real exchange rate is determined by a hybrid uncovered interest parity (UIP) condition, in real terms:

\[
q_t = 0.70 q_{t-1} + (1 - 0.70) q^e_{t,t+4} - \left[ (r_t - \pi^e_{t,t+4}) - (r^*_t + \phi_t - \pi^*_e_{t,t+4}) \right], \tag{16}
\]

2SLS, Instrumented var.: $q^e_{t,t+4}, \pi^e_{t,t+4}, \pi^*_e_{t,t+4}$, SP: 2002Q1-2008Q1, $R^2_A = 0.80,$

$LM_1 = 1.46 \ [0.23], \ LM_4 = 6.31 \ [0.18], \ White = 3.73 \ [0.44], \ JB = 3.90 \ [0.14],$

where $r_t$ is the Brazilian nominal policy interest rate (Selic), $r^*_t$ is world nominal interest rate, $\phi_t$ is the country-risk premium, $\pi^*_t$ is world inflation rate. We use the Embi Brazil for measuring the country risk, the federal funds rate for the world interest rate, and the US CPI inflation for the world inflation. We impose the restriction that the reaction of the real exchange rate to the interest rate differential is equal to one. Adding alternative fundamentals to the UIP equation, such as net foreign assets and net exports, does not increase the fit of the regression. Similarly to the Phillips curve, we use expectational variables referring to $t+4$ because they are less noisy measures. In the simulation, however,

\textsuperscript{8}These authors, however, estimate the pass-through using the nominal exchange rate.
we employ the expectational variables as referring to \( t + 1 \) in the UIP equation because we are using short-term interest rates.

In the financial sector, we model two interest rates, besides the policy rate: the household lending rate and the 360-day swap pre-DI rate. The rate on household lending depends on the policy rate, and on the country-risk premium:

\[
r_{ht} = 1.01 r_{ht-1}^{(0.11)} - 0.33 r_{ht-2}^{(0.07)} + 0.25 r_t^{(0.10)} + 0.51 \phi_t^{(0.13)}
\]  

(17)

2SLS, Instrumented var.: \( r_t, \phi_t \)  
SP: 1999Q3-2008Q1,  
\( R^2_A = 0.92 \),  
\( LM_1 = 0.87 [0.35], \ LM_4 = 2.21 [0.70], \ White = 23.03 [0.06], \ JB = 1.28 [0.53] \)

In the absence of a developed long-term bond market, we model the 360-day swap rate. Lending rates are highly correlated with the swap rate. Besides, since the swap rate reflects the expectations of the future path for the policy rate, it captures somehow future movements in the policy rate, reflecting in some way the stance of monetary policy. The swap rate is modeled as depending on future Selic rate and on the current country-risk premium:

\[
r_{wt} = 0.22 r_{wt-1}^{(0.09)} + 0.45 r_{t,t+1}^{(0.12)} + 0.45 \phi_t^{(0.06)}
\]  

(18)

2SLS, Instrumented var.: \( r_{t,t+1}, \phi_t \)  
SP: 2000Q1-2007Q4,  
\( R^2_A = 0.93 \),  
\( LM_1 = 0.98 [0.32], \ LM_4 = 6.76 [0.15], \ White = 18.65 [0.04], \ JB = 3.06 [0.22] \)

The vast literature on emerging market bond spreads suggests that the country-risk premium should depend upon idiosyncratic factors (e.g., debt level, credit ratings, inflation, fiscal stance, economic growth) as well as common factors (e.g., contagion effects, world interest rate, investor’s willingness towards risk). In the specific case of Brazil, we found
that the most important factors are the net financial foreign assets position and foreign investors’ willingness to take risk:

\[
\phi_t = 0.19 \psi_t^* - 0.07 b_t^y + 0.04 b_{t-1}^y
\]

(19)

2SLS, Instrumented var.: \(\psi_t^*, nfa_t\) SP: 1999Q3-2008Q1, \(R^2_A = 0.58\), \(LM_1 = 0.09 [0.77]\), \(LM_4 = 1.01 [0.91]\), \(White = 21.0 [0.01]\), \(JB = 0.23 [0.89]\),

where \(\psi_t^*\) is the Merrill Lynch’s risk aversion index, and \(b_t^y\) is the net financial foreign asset position, measured by the negative of the net external debt as a proportion of GDP.

We derive the following law of motion for net foreign assets as a ratio of GDP:

\[
b_t^y \simeq \Phi_R^* (b_{t-1}^y + nx_t^y) + \Phi_R^* B^g^* (\phi_t + r_t^*) + \Phi_R^* B^g^* (\Delta q_t - \Delta y_t - \pi_t^*)
\]

(20)

where upper bars denote long-run averages, and \(nx_t^y\) is net export-to-GDP ratio (in foreign currency). The calibrated long-run values of gross country-risk premium, gross nominal world interest rate and the ratio of net foreign assets to (quarterly) GDP are the following: \(\Phi = 1.02\), \(R^g = 1.01\), \(B^g^* = -0.841\). Since the debt duration is larger than one quarter, changes in the external rate affect only partially the income balance in the Balance of Payments. In order to capture this feature, we apply a factor 0.039 to \(B^g^*\), calculated using the average external debt duration. The last term is an "accounting term", because it reflects the effect of the real exchange rate on the GDP measured at foreign currency and the effect of changes in the GDP on the ratio. For simulation purposes, we do not include this accounting term because we are interested in the effects of net exports on the net foreign asset position, abstracting from accounting effects.

Net exports-to-GDP ratio is foreign currency is given by:

\[
nx_t^y \simeq s_x x_t - s_m m_t + (s_x - s_m) (q_t - y_t),
\]

(21)
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where the last term, similarly to the previous equation, is an "accounting term". We also disregard this term when conducting the simulations.

3.5. Monetary policy

The goal of the monetary authority is to stabilize inflation around its target using a Taylor-type interest rate rule with a smoothing component:

\[
\hat{r}_t = 1.11 \hat{r}_{t-1} - 0.40 \hat{r}_{t-2} + (1 - 0.71)(2.30) \left( \pi_{t,t+4}^e - \tilde{\pi}_{t+4} \right),
\]  

(22)

2SLS, Instrumented var.: \( \pi_{t,t+4}^e \)  
SP: 2000Q3-2008Q1, \( R^2_\lambda = 0.91 \),  
\( LM_1 = 1.58 [0.21], \)  
\( LM_4 = 2.31 [0.68], \)  
\( White = 11.52 [0.24], \)  
\( JB = 4.12[0.13]. \)

This estimated Taylor rule suggests that the Central Bank of Brazil (CBB) reacts to deviations of expected inflation from the inflation target and is also concerned about interest rate smoothing. In this estimation, for the inflation expectations term (\( \pi_{t,t+4}^e \)), which refers to the quarterly average of the four-quarter ahead cumulative inflation, we use market inflation expectations collected from a survey conducted by the CBB. We use two lagged terms for the interest rate because the fit is better and the residuals are better behaved. The estimated coefficients are similar to those found in 1 for a shorter sample period.

3.6. Rest of the World

Rest-of-the-world variables are modeled as exogenous AR(1) processes. Therefore, they do not affect the impulse responses to a policy interest rate shock. For completeness, we show briefly the estimated processes. World imports: \( m_t^* = 0.81 m_{t-1}^* \), world interest rate: \( \hat{r}_t = 0.93 r_{t-1}^* \), world inflation: \( \pi_t^* = -0.36 \pi_{t-1}^* \), foreign investor’s risk aversion \( \psi_t^* = 0.79 \psi_{t-1}^*. \)
4. Channel Decomposition

4.1. Methodology

We now explain ALS’ methodology for decomposing the monetary policy transmission channels into their individual contributions. The most important result of this approach is that the decomposition is exact, that is, it leaves no unexplained residuals: the sum of the individual contributions is equal to the overall effects. The only relevant requirement for this result is that the model must be linear. We now describe all the steps proposed by the authors in order to identify and quantify the transmission channels.

- **Step 1: Identify all the empirically relevant channels in the model.** In general, there can be as many channels as the number of equations in the model. However, the methodology also applies to cases in which there are fewer channels than the number of equations in the model.

- **Step 2: Flag the channels.** For each channel identified above, introduce a dummy variable which take values 0 or 1 ("flag variables"). The flag associated with channel $j$ takes value 1 if we want to identify channel $j$ in the simulations, and 0 otherwise.

- **Step 3: Flag the policy variable.** Replace the policy variable, wherever it appears in the model, with the sum of the following two components: (i) the shocked policy variable, multiplied by the corresponding flag and (ii) the baseline policy variable, multiplied by one minus the flag. For example, in equation $j$, replace the policy interest rate by $f_j r_t^S + (1 - f_j) r_t^B$, where $f_j$ is the flag (the dummy variable), $r_t^S$ is the value of the policy rate after the shock and $r_t^B$ is the baseline value (zero or another baseline value). This way, channel $j$ will be on if the flag is activated, otherwise it will be off. It turns out that this approach does not work quite well in the presence of policy reaction functions, a problem that has led the ALS to suggest the following alternative
approach, which we adopt in this paper: \textit{flag the discretionary component of the policy variable instead of the policy variable itself.}

- \textbf{Step 4: Simulate the model}. Run as many simulations as the number of channels (or flags). In each simulation only one flag is activated, whereas all others are set to zero. Therefore, each simulation will identify and quantify the effects of the channel associated with the activated flag.

4.2. \textit{Results}

The estimated model allows us to identify three main operating channels. The first channel operates through the exchange rate. This channel captures the effects, via the UIP condition, of interest rate movements on the real exchange rate and thus on the real marginal cost of firms and on exports and imports. We call this the “exchange rate channel”. The second channel captures the effects of the policy rate on the household lending rate, which has a direct effect on household consumption decisions. We call this the “consumption channel”. The third channel captures the effects of the policy rate on our proxy for the user cost of capital, namely, the real interest rate that is relevant for investment decisions. We label this the “investment channel”. These three channels capture the effects of monetary policy shocks on aggregate demand via its main components, net exports, consumption and investment, respectively, and directly on firms’s costs.

As we explained earlier, the channel decomposition experiment consists of shocking the model with a one-time monetary policy shock, which our estimation procedure has identified. Then, relying on the channel decomposition mentioned above, we measure the effects on the main components of aggregate demand, output, unemployment, unit labor cost, real exchange rate and inflation. In particular, we assume a quarterly 100 basis points unexpected increase in the policy rate and graph the impulse response functions of our variables of
interest, taking into account the effects coming from each individual channel.

Figure 5 displays in the bottom panels the overall response of different variables, and in the top panels the respective decomposition into the three channels. Since the model is linear, the sum of the individual effects exactly equals the overall effect. The overall response seems to be in line with the expected. The increase in the interest rate leads to a reduction in consumption and investment, leading to a fall in output. The reduction in output tends to decrease real wages and thus the real unit labor costs. The rise in the interest rate also appreciates the real exchange rate (via UIP). The reduction in real unit labor costs, in the real exchange rate and in output leads to a reduction in inflation. In spite of the exchange rate appreciation, exports rise because of the reduction in domestic absorption, and imports decrease because of the output reduction. Therefore, net exports increase after a monetary policy shock. Note that, since it is a one-time shock and the central bank reacts to the resulting negative inflation with a reduction in the interest rate, this variable is positive only for two quarters. As a result, inflation tends to return to its steady-state level.

According to the figures showing the channel decomposition, we can see that the three channels are relatively important. The exchange rate channel is responsible for 31.2% of the total reduction in inflation over a period of two years (and 39.5% considering three years). The consumption channel, in turn, responds for 24.7% in inflation (19.7% in three years), and the investment channel is responsible for the higher share: 44.1% (40.8% in three years). The latter two channels tend to move together, with a stronger effect coming from the investment channel.

These results are coherent with the strong evidence of the important role played by the exchange rate in the inflation dynamics in Brazil. However, it records a higher than expected effect through the investment channel. In Brazil, long-term credit is supplied mainly by the National Bank of Economic and Social Development (BNDES) at rates lower than the base interest rate. These results show that, in spite of the reduction in the strength
of the transmission mechanism brought by this system, increases in the base interest rate affect significantly the gross formation of fixed capital. This probably occurs because of the effects on other lending rates more sensible to the policy rate and of the expected effects on consumption, leading to a reduction in current investment.

5. Concluding remarks

To our knowledge, we are the first to document the relative contribution of individual channels of the monetary policy transmission mechanism in Brazil during the inflation targeting regime. We develop and estimate a semi-structural economic model to this end, and decompose the channels into the exchange rate channel, consumption channel, and investment channel. The three channels play a relatively important in explaining the inflation dynamics when the economy is hit by a monetary policy shock. The exchange rate channel explains more than 30% of the reduction in inflation. The investment channel, in turn, is responsible for the largest part in the inflation reduction, accounting for more than 40% of the fall. This result disputes the common view that the investment channel in Brazil is limited.

A Appendix: Log-Linearization

This appendix presents the log-linear versions of all identities and definitions used in the model. We log-linearize the model around its steady state values. We take the averages over the period 1999:2-2008:1 as a rough proxy for the long-run values. We use upper-case letters do denote level variables, lower-case letter do denote log-deviations from the steady state and upper bars to denote long-run averages.
A1. Aggregate Expenditure

\[ P_Y t Y = P_{Ct} C_t + P_{It} I_t + P_{Gt} G_t + P_{Xt} X_t - P_{Mt} M_t \]

\[ y_t \approx sc_t + si_t + sg_t + sx_t - sm_t \]

where we disregard possible changes in relative prices, i.e., \( P_{Ct} \approx P_{It} \approx P_{Gt} \approx P_{Xt} \approx P_{Mt} \approx 1 \) and the share of each variable \( j \) is defined as:

\[ s_j \equiv \frac{P_{j} Y}{P_Y} \cdot \]

A2. Domestic Absorption

Nominal domestic absorption is defined as:

\[ P_t A_t = P_{Ct} C_t + P_{It} I_t + P_{Gt} G_t \]

The log-linear version of this, abstracting again from changes in relative prices, is:

\[ a_t \approx \left( \frac{P_{Ct} C_t}{P_A} \right) c_t + \left( \frac{P_{It} I_t}{P_A} \right) i_t + \left( \frac{P_{Gt} G_t}{P_A} \right) g_t \]

which can be simplified to:

\[ a_t \approx \left( \frac{sc}{sa} \right) c_t + \left( \frac{si}{sa} \right) i_t + \left( \frac{sg}{sa} \right) g_t \]

where \( sa \) is the ratio of nominal domestic absorption to nominal GDP.
A3. Employment

Use the definition of employment:

\[ N_t = (1 - U_t)WAP_t \]

and compute its log-linear version:

\[
\begin{align*}
\overline{N}n_t & \simeq -UWAP_t u_t + (1 - U)WAP_{wap} t \\
n_t & \simeq \frac{UWAP}{\overline{N}} u_t + \frac{(1 - U)WAP}{\overline{N}}_{wap} t
\end{align*}
\]

Using the fact that \( \overline{N} = (1 - U)WAP \) the above can be written as:

\[ n_t \simeq \frac{U}{1 - U} u_t \]

A4. Net Foreign Assets

The country balance of payments in local currency is:

\[ NX_t - \left( \frac{E_t B_t^*}{\Phi_t R_t^*} - E_t B_{t-1}^* \right) = 0 \]

Divide both sides by \( P_t Y_t \) and rearrange terms to get:

\[
\frac{B_t^{y*}}{\Phi_t R_t^*} = B_{t-1}^{y*} \frac{E_t P_t^*}{E_{t-1} P_{t-1}^*} \frac{P_{t-1} Y_{t-1}^*}{P_t Y_t} \frac{P_t^*}{P_t} + NX_t^y
\]

where the superscript \( y \) denotes the ratio of the corresponding variable to nominal GDP.

The above can be written as:

\[
\frac{B_t^{y*}}{\Phi_t R_t^*} = B_{t-1}^{y*} \frac{Q_t}{Q_{t-1}} \frac{Y_{t-1}}{\Pi_t Y_t} + NX_t^y
\]
where $\Pi_t^* $ is the world gross inflation rate. Linearizing the above yields:

$$\frac{b^\Pi_t}{\Phi_{R^*}} = \frac{B^{\Pi^*}_t}{\Phi_{R^*}} (\phi_t + r^*_t) = B^{\Pi^*}_t (q_t - q_{t-1} - \pi^*_t + y_{t-1} - y_t) + b^\Pi_{t-1} + nx^y_t$$

where we assume that $\Pi^* \simeq 1$. Simplifying and rearranging terms give:

$$b^\Pi_t \simeq \frac{\Phi_{R^*}}{\Phi_{R^*}} (b^\Pi_{t-1} + nx^y_t) + \frac{\Phi_{R^*}}{\Phi_{R^*}} B^{\Pi^*} (\Delta q_t - \Delta y_t - \pi^*_t)$$

A5. Net Exports

$$N X_t = P^X_t X_t - P^M_t M_t$$

Divide both sides by $P_t Y_t$ and linearize to get:

$$nx^y_t \simeq \left( \frac{P^X_t X_t}{P^Y_t} \right) (x_t - y_t + q_t) - \left( \frac{P^M_t M_t}{P^Y_t} \right) (m_t - y_t + q_t)$$

Rewrite this using the share notation defined above:

$$nx^y_t \simeq s_x x_t - s_m m_t + (s_x - s_m) (q_t - y_t)$$

References


Figure 1. Interest Rate Cross-Correlations and Cycle

A. Correlation of Interest Rate with Variable (quarter j)

B. Typical Interest Rate Cycle
Figure 2. Actual inflation and inflation targets in Brazil (1999-2007)

Figure 3. Country Risk Premium and Exchange Rate
Figure 4. Impulse Responses to a Monetary Policy Shock

A. GDP

B. Inflation

C. Real Exchange Rate

D. Interest Rate

Response to Cholesky One S.D. Innovations ± 2 S.E.
Figure 5.a. Decomposition of the transmission mechanisms of monetary policy in Brazil
Figure 5.b. Decomposition of the transmission mechanisms of monetary policy in Brazil