ISSN 1518-3548

BANCO CENTRAL DO BRASIL

Working Paper Series 181

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April, 2009

ISSN 1518-3548
CGC 00.038.166/0001-05

Working Paper Series	Brasília	n. 181	Apr.	2009	p. 1-57

Working Paper Series

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Monetary Channels in Brazil through the Lens of a Semi-Structural Model*

André Minella**
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Abstract

We develop and estimate a medium-size, semi-structural model for Brazil's economy during the inflation targeting period. The model captures key features of the economy, and allows us to investigate the transmission mechanisms of monetary policy. We decompose the monetary channels into *household interest rate*, *firm interest rate*, and *exchange rate channels*. We find that the household interest rate channel plays the most important role in explaining output dynamics after a monetary policy shock. In the case of inflation, however, both the household interest rate and the exchange rate channels are the main transmission mechanisms. Furthermore, using a proxy for an *expectation channel*, we also find that this channel is key in the transmission of monetary policy to inflation.

Keywords: Monetary Policy Transmission Mechanisms, Semi-Structural Model, Brazil.
JEL Classification: E17, E52, C51.

*We are grateful to Adriana S. Sales for her participation in early stages of the project. We also thank Carlos Hamilton Araújo, Mário Mesquita, and the participants of 2008 Cemla meetings in Lima and Mexico City for their comments and suggestions.
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1 Introduction

This paper investigates the monetary policy channels in Brazil using a semi-structural model for the inflation targeting period. Inflation targeting was implemented in 1999, right after the adoption of a floating exchange rate system. These policy changes implied a major shift in the monetary transmission mechanisms in Brazil[1]. Until recently, however, any attempt to better identify these channels was challenged by the small sample size associated with the regime in place.

Nevertheless, some initial efforts to identify the transmission mechanisms in Brazil are now possible to be undertaken. The sample size is larger, and new developments in the literature have made available better tools for the task. Altissimo, Locarno and Siviero (2002), henceforth ALS, based on the work of Mauskopf and Siviero (1994), proposed a fairly general approach to decompose the overall response of an economic model to a shock into the contributions associated with its distinct channels. In the case of linear models, the channel decomposition is exact, that is, the sum of the individual effects that transit through each channel exactly equals the overall effect. Since mid-1990s many researchers and central banks—including BIS (1995), Els et al. (2001), and McAdam and Morgan (2001)—have used this approach to quantify the various channels of the monetary policy transmission mechanisms.

We proceed in two steps to decompose the monetary channels. First, we develop and estimate a medium-size, semi-structural economic model for the Brazilian economy during the inflation targeting regime. We borrow many insights from semi-structural models developed by Alves and Muinhos (2003), Bank of England (2000), and Garcia et al. (2003). Our model can be thought as a reduced-form version of a micro-founded new Keynesian model. We believe it fairly represents key features of the Brazilian economy, allowing us to analyze the monetary policy channels in a meaningful way. Second, we apply ALS' methodology to

[1] The end of high inflation in 1994 represented another major change in the monetary channels, besides rendering monetary policy more effective (see Lopes (1997)).

decompose the channels implied by the model.

The estimated model allows us to identify three main operating channels. The first is the *household interest rate channel*, which captures the effect of the policy rate on the household lending rate, and its impact on household consumption decisions. The second is the *firm interest rate channel*, which describes the policy rate effect on our proxy for firms' external financing costs, and its consequence for investment. These two channels comprise the traditional *interest rate channel*. The third transmission mechanism operates through the exchange rate. It captures the effects, via the uncovered interest parity (UIP) condition, of policy interest rate movements on the real exchange rate and thus on the real marginal cost of firms and aggregate demand components. We name it *exchange rate channel*. Since expectations play an important role in the model, we conduct a further exercise and measure the transmission mechanisms operating through expectations, calling it *expectation channel*. It captures the effects of monetary policy shocks through changes in inflation expectations.

When we do not identify the expectation channel, the main results of the decomposition are as follows. The household interest rate channel plays the most important role in explaining output dynamics after a monetary policy shock. It accounts for 62% of the output fall in an one-year horizon. The firm interest rate channel, in turn, plays a less significant role (24% of the output fall), in part reflecting the lower share of investment in the GDP. This finding is also consistent with the fact that significant part of private investment in Brazil is financed through state-owned development banks, which tends to impair the transmission mechanisms.

Regarding inflation, both the household interest rate and the exchange rate channels are the main transmission mechanisms, each accounting for around 40% of the inflation reduction at all considered horizons (up to three years). This result is in line with the relevance of the exchange rate for the inflation dynamics in Brazil.

In the exercise considering the expectation channel, the household interest rate channel is still the most important transmission mechanism for output. However, we found that the expectation channel may account for the largest part in the transmission of monetary policy to inflation. This finding is consistent with the importance attributed to inflation expectations in the conduct of monetary policy in Brazil (see Bevilaqua et al. (2008)).

To our knowledge, we are the first to estimate a medium-size, semi-structural model for Brazil using only the inflation targeting period[2]. We also believe the paper is the first to document the relative contribution of the individual transmission channels of monetary policy in Brazil during the inflation targeting regime. Such insights are not possible to obtain from standard VARs exercises, usually restricted to measure only the overall effects of monetary policy shocks.

Actually, we believe the model can be used not only for the channel decomposition, but also for policy analysis and other simulations. The estimated model is able to generate impulse responses of relevant macroeconomic aggregates to different shocks—not only monetary ones—with shape and timing consistent with those found in standard VAR models. The model can also be helpful in the development of micro-founded models for the Brazilian economy since it provides relevant information about its dynamics.

Using a more traditional econometric approach, we also show that market interest rates in Brazil are quite sensitive to changes in the policy rate. This additional evidence is consistent with the importance of the interest rate channel in the model decomposition.

This paper relates to the broad literature on monetary policy transmission mechanisms. This topic has been a fertile field of research in the last two decades and has gained prime time recently, in the wake of the global financial crisis triggered by problems in the U.S. subprime mortgage market. In part motivated by the economic developments of 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

[2] The important work by Alves and Muinhos (2003) used a sample period usually starting in mid-nineties. Although we lose information from previous periods, the structural breaks in 1994 and 1999 are large enough to justify a smaller sample. Furthermore, we are concerned about the transmission mechanisms during the inflation targeting period.

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 have also turned possible to conduct thorough studies of monetary transmission channels in developing countries (see, for instance, BIS (1998) and BIS (2008)).

This paper is organized as follows. Section 2 deals with the pass-through of the policy interest rate to banking rates, and Section 3 describes the estimated model. Section 4 presents the model results and the channel decomposition, and Section 5 concludes the paper.

2 Interest Rate Pass-Through

Studying interest rates movements and their relationship with the policy rate is a key step for understanding the monetary transmission channels. Hence, before we present our model and the decomposition exercises, we assess the sensitivity of representative interest rates to changes in the policy rate. In particular, we measure the pass-through of the policy rate to deposit and lending rates faced by corporations and households. We use monthly data covering the inflation targeting period, from July 1999 to August 2008, to investigate the pass-through for eight representative deposit and lending interest rates, shown in Figure 1. The figure reveals that, although market interest rates are more volatile than the policy rate, they seem to track the policy rate very closely over time. The figure also reveals the well documented fact that average levels of lending rates in Brazil are very high, even for Latin American standards[3].

For each interest rate r_i, we estimate the following pass-through regression, which is a

[3] Afanasieff et al. (2002) investigate the determinants of high bank interest spreads in Brazil, and Souza-Sobrinho (2008) analyzes the welfare implications of such high spreads.

linear error correction model relating the ith interest rate to the policy rate r:

$$\Delta r_{it} = \alpha_0 ECT_t + \beta_0 \Delta r_t + \sum_{j=1}^{J} \beta_j \Delta r_{t-j} + \sum_{k=1}^{K} \gamma_k \Delta r_{it-k} + \varepsilon_{it}, \tag{1}$$

where the error correction term ECT is given by

$$ECT_t = \alpha_0 \left(r_{it-1} - \alpha_1 - \alpha_2 r_{t-1} - \alpha_3 t \right).$$

We follow Espinosa-Vega and Rebucci (2003) and add a constant and a time trend to the error correction term. The time trend captures other determinants of bank interest spread not modelled explicitly here. The coefficients of interest are α_0, which measures the speed of adjustment to the long run (it is expected to be negative and smaller than one in absolute value); β_0, which measures the short-run (within a month) pass-through; α_1, which measures the long-run spread between interest rate i and the policy rate; and α_2, which measures the long-run (steady state) pass-through. We restrict the maximum lag length J and K to six. The regressions also include time dummies to control for outliers.

Table 1 shows the regression results for time deposit and lending rates in eight different categories, shown in Figure 1—overall averages, household and firms averages, and two more disaggregated lending rates (personal credit and working capital). Personal credit accounts for almost half of all bank loans at market interest rates to households, whereas working capital responds for forty percent of all market loans received by corporations. Overall, the diagnostic tests suggest that the regression residuals are well behaved, with no sign of autocorrelation. Almost all coefficients of interest have the expected sign and are statistically significant. Moreover, the last two rows of the table show that we cannot reject the null hypothesis of complete pass-through for both deposit and lending rates in the short run (except for the firm average lending rate). However, deposit rates seem to be stickier (smaller α_2) than lending rates in the long run. Alencar (2003) also found a similar result, though with a shorter sample period and estimating regressions in levels instead of using an error correction model. Notice also that the point estimate (absolute value) of α_0 is larger for corporate rates than for household rates, hence the former tend to adjust faster than the latter. Furthermore, since the point estimate of β_0 is larger for average lending rates than for deposit rates, bank interest spreads tend to increase after a positive monetary policy shock. Lastly, the high levels of the lending rates translate into equally large long-run spreads (α_1).

Overall, the results show that banking interest rates are responsive to the policy rate in Brazil. In fact, the behavior of Brazilian banking rates is not atypical, and is comparable to that of Germany (Weth (2002)), Euro Area (Bondt (2002), Bondt et al. (2005)) or Chile (Berstein and Fuentes (2003), Espinosa-Vega and Rebucci (2003)). Considering such results, in the economic model we present in Section 3 we use the average lending rate charged to households as the representative lending rate for consumption decisions. However, given the absence of a well developed long-term credit market in Brazil, we do not use the average lending rate charged to firms as the representative lending rate for investment decisions. We use the 360-day swap pre-DI rate instead.

3 Model

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 economic agents' decisions. Second, they fail to provide a coherent economic story for the magnitude, shape and timing of the impulse response functions. Models with an economic structure are natural candidates for filling in these gaps. If designed in a meaningful way, they allow us to identify the monetary policy channels that are active in a given economy[4].

Ideally, we should study transmission mechanisms using an economic model with solid theoretical foundations, such as the new generation of dynamic stochastic general equilib-

[4]For the effects of monetary policy shocks in Brazil using a VAR approach, see Céspedes et al. (2008), Minella (2003), and Sales and Tannuri-Pianto (2007).

rium (DSGE) models, in development or already in use by several central banks[5]. The microfoundations of DSGE models impose a clear set of restrictions on the data. More specifically, linear versions of DSGE models resemble VARs with strong restrictions on the coefficients and on the variance-covariance matrix of shocks. Therefore, the use of such models for decomposing the monetary policy channels requires the researcher to take a stand on what is the underlying structure of the economy. We have decided to develop a semi-structural model because it imposes less restrictions on the data, allows more flexibility in the modeling process, and still brings some discipline from the economic theory. Furthermore, the estimated model provides some insights that can be useful in the development of micro-founded models for the Brazilian economy.

When compared to small-size models, medium-size ones offer a much richer structure. Small-size models are more parsimonious and are widely used for projections and basic policy analysis (see Berg et al. (2006)). However, they have hard time capturing or identifying the different transmission mechanisms in the economy, and do not provide answers to questions concerning the behavior of important macroeconomic variables.

Our model has five blocks: aggregate demand, aggregate supply, financial sector, monetary policy, and rest of the world. Aggregate demand comprises household consumption, investment, government consumption, exports, and imports. The aggregate supply side, in turn, involves the modeling of the unemployment rate, the rate of capacity utilization, real wage, and inflation. Financial variables are the household lending rate, swap rate, the real exchange rate, the country-risk premium, and net-foreign assets (NFA). Monetary policy is modeled as a Taylor-type rule, and the rest-of-the-world variables—world imports, interest rate, inflation and foreign investors' risk aversion—as ARMA processes. The model is linear in the variables because we want to have an exact channel decomposition.

[5]For instance, the DSGE models of Brazil (SAMBA), Sweden (RAMSES), Canada (ToTEM), Norway (NEMO), England (BEQM), Euro Area (NAWM), Chile (MAS), Peru (MEGA-D), Colombia (PATACON), and Portugal (PESSOA). We could not compare our results with those of SAMBA because the latter is still an ongoing research.

3.1 Estimation

We estimate the model equation by equation with two-stage least squares (2SLS) or ordinary least squares (OLS), using quarterly data since the implementation of the inflation targeting regime (1999Q3 to 2008Q2). Because data on inflation expectations are available from 2000 onwards, the sample period is shorter for some equations. Most lagged values were also restricted to start in 1999Q1, therefore excluding the period of the managed exchange rate regime.

All series are filtered with the Hodrick-Prescott (HP) filter, using the 1996Q1-2008Q2 period to reduce the beginning-of-the-sample problem associated with this filter. The variables and the corresponding sources used in the estimation are the following. Output, private consumption, government consumption, investment, exports and imports are chain-weighted seasonally adjusted series from the National Accounts, calculated by the Brazilian Institute of Geography and Statistics (IBGE). This institution is also responsible for the data on labor market (wage, employment, unemployment rate, and working-age population) and for the CPI-based inflation, given by the Broad National Consumer Price Index (IPCA). Data on real effective exchange rate, Selic interest rate, household lending rate, and net external debt (our proxy for NFA) come from the Central Bank of Brazil (CBB). Data on inflation expectations is also taken from the CBB, through a survey conducted among professional forecasters. The 360-day swap pre-DI rate is provided by the Brazilian Mercantile & Futures Exchange (BM&F), and the rate of capacity utilization 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 the US CPI inflation, and the world interest rate by the Fed funds rate. World imports are a weighted average of the total import volumes of European Union, United States, China, Argentina and Japan—Brazil's top-five trade partners—and are obtained from the IFS and national statistics institutes. We take the natural log of all series, except for net exports, Ravi and net external debt. In the case of inflation and interest rates, we use log of the gross rates, and express them as percentage per quarter in the estimations.

3.2 Aggregate Demand

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

$$y_t \simeq s_c c_t + s_i i_t + s_g g_t + s_x x_t - s_m m_t, \tag{2}$$

where y_t is real GDP, c_t is private consumption, i_t is investment, g_t is government consumption, x_t is exports, m_t is imports, and s_j are the corresponding shares. We calibrate these shares to the following values: $s_c = 0.622$, $s_i = 0.166$, $s_g = 0.198$, $s_x = 0.137$, $s_m = 0.123$, which correspond to the average values during the sample period. The next identity is the domestic absorption equation, given by:

$$a_t \simeq \left(\frac{s_c}{s_a}\right) c_t + \left(\frac{s_i}{s_a}\right) i_t + \left(\frac{s_g}{s_a}\right) g_t, \tag{3}$$

where s_a is the ratio of nominal domestic absorption to nominal GDP, calibrated to 0.986.

We estimate behavioral functions for each component of aggregate demand. Private consumption depends on past consumption, expected real interest rate, current income (measured by real payroll), and the real effective exchange rate:

$$c_t = \underset{(0.12)}{0.33} c_{t-1} - \underset{(0.09)}{0.54} \left(r_t^h - \pi_{t,t+4}^e\right) + \underset{(0.04)}{0.19} (w_t + n_t) - \underset{(0.01)}{0.02} q_t - \underset{(0.21)}{2.15} d_{01Q3} + \underset{(0.12)}{1.44} d_{07Q4} + \varepsilon_t^c, \tag{4}$$

$R_A^2 = 0.93$; $LM_1 = 0.17[0.68]$; $LM_4 = 6.41[0.17]$; $HET = 11.96[0.75]$; $JB = 0.57[0.75]$
Method: 2SLS; Sample: 2000Q3-2008Q2
Instrumented variables: $\left(r_t^h - \pi_{t,t+4}^e\right); (w_t + n_t); (q_t)$
Instruments: $\left(r_{t-1}^h, r_{t-2}^h, \pi_{t-1,t+3}^e, \pi_{t-2,t+2}^e\right); (w_{t-1} + n_{t-1}, w_{t-2} + n_{t-2}); (q_{t-1}, q_{t-2})$

where the numbers in parenthesis are Newey-West corrected standard errors, r_t^h is the average nominal lending rate charged by banks on household loans, $\pi_{t,t+4}^e$ is one-year-ahead expected inflation at time t (taken from the CBB's survey), w_t is the real wage rate, n_t is employment,

q_t is the real effective exchange rate, d_{01Q3} and d_{07Q4} are time dummies for 2001Q3 and 2007Q4, respectively, and ε_t^c is the regression residual. The term $w_t + n_t$ (real payroll) is our proxy for current aggregate income earned by households. We use four-quarter-ahead inflation expectation instead of one-quarter-ahead inflation expectation because the average maturity of household loans is slightly over a year. We present the following diagnostic tests: R_A^2 - adjusted R^2; LM_1 and LM_4 - Breusch-Godfrey Lagrangian multiplier test statistics for serial correlation in the residuals up to orders one and four, respectively; HET - White heteroskedasticity test for the residuals (including cross terms whenever possible); and JB - Jarque-Bera χ^2 test for normality in the residuals. 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. Actual sample periods may be shorter than 1999Q3-2008Q2 due to the availability of instruments. For the sake of space, throughout the paper, we omit from the list of instruments the regressors that are not instrumented, such as lagged consumption in the previous equation. All regressions include a constant term, which is usually not statistically significant and thus is not reported.

Aggregate investment, measured by gross formation of fixed capital (GFFC)[6], is a function of past investment, real swap interest rate (our proxy for firms' external financing costs), output (traditional accelerator effect), the relative price of investment goods, and a measure of changes in macroeconomic uncertainty, proxied by the country-risk premium. For the interest rate, we use the 360-day swap pre-DI interest rate. Given the thin market for long-term lending in Brazil, swap pre-DI is a reasonable proxy for the term structure of interest rate. It is also highly correlated with banking lending rates (see Figure 1) and captures well the stance of monetary policy. Lastly, the relative price of investment goods is the ratio of the GFFC deflator to the GDP deflator. The resulting investment equation is given by:

$$i_t = \underset{(0.18)}{0.56} i_{t-1} - \underset{(0.66)}{1.37} \left(r_{t-1}^s - \pi_{t-1,t+3}^e \right) + \underset{(0.59)}{1.10} y_{t-1} - \underset{(0.12)}{0.36} \left(\frac{q_{t-1}^i + q_{t-2}^i}{2} \right) - \underset{(1.04)}{2.15} \Delta\phi_{t-3} + \varepsilon_t^i, \quad (5)$$

[6] We do not model inventory changes.

$R_A^2 = 0.77$; $LM_1 = 0.02[0.88]$; $LM_4 = 6.40[0.17]$; $HET = 19.11[0.51]$; $JB = 0.48[0.79]$
Method: OLS; Sample: 2000Q2-2008Q2

where r_t^s is the 360-day swap pre-DI rate, $\Delta\phi_t = \phi_t - \phi_{t-1}$ is the country-risk premium change, and q_t^i is the relative price of investment. The main determinant of the relative price of investment is the real exchange rate:

$$q_t^i = \underset{(0.17)}{0.38} q_{t-1}^i + \underset{(0.03)}{0.07} q_t + \varepsilon_t^{q^i}, \tag{6}$$

$R_A^2 = 0.39$; $LM_1 = 0.30[0.59]$; $LM_4 = 3.79[0.43]$; $HET = 17.96[0.00]$; $JB = 8.21$ $[0.02]$
Method: 2SLS; Sample: 2000Q3-2008Q2
Instrumented variables: (q_t)
Instruments: $\left(q_{t-1}, q_{t-2}, r_{t-1} r_{t-2}, \pi_{t-1,t+1}^e, \pi_{t-2,t+1}^e, \pi_{t-1,t+1}^{e*}, \pi_{t-2,t+1}^{e*}\right)$

where r_t is the Brazilian nominal policy interest rate (Selic), and $\pi_{t,t+1}^{e*}$ is one-quarter ahead inflation expectation in the rest of the world. This formulation for the relative price of investment is consistent with the evidence that real exchange rate appreciations boost imports of machinery and equipment and hence investment in Brazil (see, for instance, Silva Filho (2007)). However, instead of inserting the exchange rate directly into the investment equation, we found more intuitive to model its effects through the relative price of investment goods.

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

$$x_t = \underset{(0.23)}{1.02} \left(\frac{m_t^* + m_{t-1}^*}{2} \right) - \underset{(0.34)}{0.63} \left(\frac{a_{t-1} + a_{t-2}}{2} \right) + \underset{(0.05)}{0.12} q_{t-1} + \underset{(1.82)}{12.89} \left(d_{02Q3} + d_{02Q4} \right) + \varepsilon_t^x, \tag{7}$$

$R_A^2 = 0.48$; $LM_1 = 0.43[0.51]$; $LM_4 = 3.98[0.40]$; $HET = 8.90[0.63]$; $JB = 2.74[0.25]$
Method: OLS; Sample: 1999Q3-2008Q2

where m_t^* is our proxy for world imports. Imports also depend on the real exchange rate and on economic activity:

$$m_t = \underset{(0.13)}{0.55} m_{t-1} + \underset{(0.90)}{1.98} y_t - \underset{(0.05)}{0.17} q_{t-1} + \varepsilon_t^m. \tag{8}$$

$R_A^2 = 0.77$; $LM_1 = 0.11[0.74]$; $LM_4 = 3.19[0.53]$; $HET = 16.41[0.06]$; $JB = 0.64$ [0.73]
Method: 2SLS; Sample: 1999Q3-2008Q2
Instrumented variables: (y_t)
Instruments: $\left(y_{t-1}, y_{t-2}, r_{t-1}^s, r_{t-2}^s\right)$

Notice that all terms in equations (7) and (8) have the expected sign. The point estimate of the income elasticity of imports is higher than one, a robust result for Brazil. The point estimates also indicate that imports react more to exchange rate movements than exports do. Net exports-to-GDP ratio is given by:

$$nx_t^y \simeq s_x x_t - s_m m_t + (s_x - s_m)(q_t - y_t), \tag{9}$$

where the last term is an "accounting component", which we ignore in the simulations. Since we are concerned about the transmission mechanisms of monetary policy, we model government spending as an ARMA(2,1) process. This setup implies that fiscal policy does not react to monetary policy shocks, and therefore does not affect the monetary channels.

3.3 Aggregate Supply

On the supply side, we model the following variables: employment level, real unit labor cost, unemployment rate, rate of capacity utilization, real wage, and inflation. First, we calibrate the following relationships:

$$n_t \simeq wap_t - \frac{\overline{U}}{1-\overline{U}} u_t, \tag{10}$$

$$ulc_t = w_t - (y_t - n_t), \tag{11}$$

where employment level (n_t) depends on the working-age population (wap_t) and on the unemployment rate (u_t), and real unit labor cost (ulc_t) depends on real wage and labor productivity $(y_t - n_t)$. $\overline{U}$ is the long-run unemployment rate, calibrated according to the sample average (0.105). Working-age population is modeled as an ARMA(2,1) process, whereas the estimated equation for the unemployment rate captures the negative relationship with output and the rate of capacity utilization:

$$u_t = \underset{(0.04)}{0.66} u_{t-1} - \underset{(0.06)}{0.15} y_t - \underset{(0.03)}{0.12} y_{t-1} - \underset{(0.04)}{0.13} \left(\frac{1}{4} \sum_{j=1}^{4} u^k_{t-j} \right) + \varepsilon^u_t. \tag{12}$$

$R^2_A = 0.90$; $LM_1 = 1.72[0.19]$; $LM_4 = 6.12[0.19]$; $HET = 23.17[0.06]$; $JB = 1.37[0.50]$
Method: 2SLS; Sample: 1999Q3-2008Q2
Instrumented variables: (y_t)
Instruments: $\left(y_{t-1}, y_{t-2}, r^s_{t-1}, r^s_{t-2}\right)$

The rate of capacity utilization (u^k_t), in turn, depends positively on output and negatively on past investment, which captures the positive effect of investment on the capital stock:

$$u^k_t = \underset{(0.12)}{0.44} u^k_{t-1} + \underset{(0.16)}{0.50} y_t - \underset{(0.03)}{0.13} \left(\frac{1}{4} \sum_{j=1}^{4} i_{t-j} \right) + \varepsilon^{u^k}_t. \tag{13}$$

$R^2_A = 0.61$; $LM_1 = 0.52[0.47]$; $LM_4 = 1.93[0.75]$; $HET = 6.95[0.64]$; $JB = 0.40[0.82]$
Method: 2SLS; Sample: 1999Q3-2008Q2
Instrumented variables: (y_t)
Instruments: $\left(y_{t-1}, y_{t-2}, r^s_{t-1}, r^s_{t-2}\right)$

The real wage depends positively on output and negatively on the unemployment rate. In other words, real wage is pro-cyclical, capturing the effects of higher or lower tightness of the labor market over the cycle. Since nominal wages are usually adjusted once a year, average real wage also depends negatively on inflation:

$$w_t = \underset{(0.09)}{0.65} w_{t-1} + \underset{(0.21)}{1.04} y_t \underset{(0.41)}{-1.27} \left(\frac{1}{3} \sum_{j=2}^{4} u_{t-j} \right) - \underset{(0.14)}{0.49} \pi_{t-1} + \varepsilon^w_t. \tag{14}$$

$R_A^2 = 0.84$; $LM_1 = 0.00[0.96]$; $LM_4 = 0.29[0.99]$; $HET = 8.19[0.88]$; $JB = 2.15[0.34]$
Method: 2SLS; Sample: 1999Q3-2008Q2
Instrumented variables: (y_t)
Instruments: $\left(y_{t-1}, y_{t-2}, r^s_{t-1}, r^s_{t-2}\right)$

Lastly, 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, Galí and Gertler (1999)). We proxy the real marginal cost by real unit labor cost and real exchange rate. Our specification also includes an output term, which is statistically significant even in the presence of both variables measuring real marginal cost:

$$\begin{aligned} \pi_t &= \underset{(0.13)}{0.45}\left(\frac{1}{4}\sum_{j=1}^{4}\pi_{t-j}\right) + \underset{(0.13)}{(1-0.45)}\left(\frac{1}{4}\sum_{j=1}^{4}\pi_{t+j}\right) + \underset{(0.08)}{0.20}\Delta ulc_{t-1} \\ &\quad + \underset{(0.02)}{0.04}\Delta q_{t-1} + \underset{(0.09)}{0.20}\left(\frac{y_{t-1}+y_{t-2}}{2}\right) + \underset{(0.33)}{3.15}\left(d_{02Q4}+d_{03Q1}\right) + \varepsilon^\pi_t. \end{aligned} \tag{15}$$

$R_A^2 = 0.78$; $LM_1 = 0.20[0.65]$; $LM_4 = 4.93[0.29]$; $HET = 10.17[0.86]$; $JB = 3.42[0.18]$
Method: 2SLS; Sample: 1999Q3-2007Q2
Instrumented variables: $\left(\frac{1}{4}\sum_{j=1}^{4}\pi_{t+j}\right)$
Instruments: $\left(\frac{1}{4}\sum_{j=1}^{4}\pi_{t-j}, r^s_{t-1}, r^s_{t-2}\right)$

The presence of the output term can be interpreted as a measure of output gap estimated using the HP filter, and 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 lagged inflation, instead of last quarter inflation, improves significantly the fit of the regression. Additionally, this procedure helps to smooth out the high volatility of inflation at quarterly frequency. Similarly, we use the four-quarter moving average of future inflation instead of inflation expectations because it generates a better fit and a less volatile inflation profile. The estimated short-run exchange rate pass-through, in equation (15), is roughly in line with other estimates in the literature, including those of Belaisch (2003), and Correa and Minella (2006).

According to our aggregate supply setup, positive demand pressures tend to increase output and hence reduce the unemployment rate (equation 12). These two effects tend to increase the wage rate (equation 14), thus raising real labor unit costs (equation 11)[7]. The rise in real labor unit costs, together with higher output, raises inflation (equation 15). These relationships are further explored in the simulation exercises of section 4.

3.4 Financial Variables

In this section we model market interest rates, real exchange rate, country-risk premium, as well as the accumulation of net foreign assets. The two key market interest rates in the model—the household lending and the swap rates—depend on their own lagged values, the policy rate and the country-risk premium. Adding other fundamentals, such as inflation and output, did not improve the regressions. The rate on household lending is given by:

$$r^h_t = \underset{(0.12)}{0.89} r^h_{t-1} - \underset{(0.08)}{0.26} r^h_{t-2} + \underset{(0.11)}{0.34} r_t + \underset{(0.09)}{0.50} \phi_t + \varepsilon^{r^h}_t. \tag{16}$$

$R^2_A = 0.92$; $LM_1 = 0.89[0.35]$; $LM_4 = 1.25[0.87]$; $HET = 22.92[0.06]$; $JB = 1.16[0.56]$
Method: 2SLS; Sample: 1999Q3-2008Q2
Instrumented variables: $(r_t)\,;(\phi_t)$
Instruments: $\left(r_{t-1}, r_{t-2}, \pi_{t-1}, \pi_{t-2}, r^s_{t-1}, r^s_{t-2}\right);\left(\phi_{t-1}, \phi_{t-2}\right)$

As mentioned before, we use the 360-day swap pre-DI rate as a proxy for the long-term rate relevant for investment decisions. Market lending rates are highly correlated with the swap rate (see Figure 1). Additionally, since the swap rate reflects the expectations over the future path of the policy rate, it also captures the expected stance of monetary policy. Therefore, the swap rate is modeled as depending on future Selic rate and the current

[7] The net effect on real unit labor cost also depends on the behavior of labor productivity.

country-risk premium:

$$r_t^s = \underset{(0.11)}{0.39} r_{t-1}^s + \underset{(0.22)}{0.56} \left(\frac{1}{4} \sum_{j=0}^{3} r_{t+j} \right) + \underset{(0.10)}{0.38} \phi_t + \underset{(0.04)}{0.63} d_{01Q3} + \varepsilon_t^{r^s}. \tag{17}$$

$R_A^2 = 0.92$; $LM_1 = 0.03[0.87]$; $LM_4 = 4.44[0.35]$; $HET = 14.54[0.15]$; $JB = 0.84[0.66]$
Method: 2SLS; Sample: 1999Q3-2007Q3
Instrumented variables: $\left(\frac{1}{4} \sum_{j=0}^{3} r_{t+j} \right); (\phi_t)$
Instruments: $(r_{t-1}, r_{t-2}, r_{t-3}, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}); (\phi_{t-1}, \phi_{t-2}, \phi_{t-3})$

The real exchange rate is determined by a hybrid UIP condition, in real terms:

$$\begin{aligned} q_t &= \underset{(0.04)}{0.64} q_{t-1} + (1 - \underset{(0.04)}{0.64}) q_{t+1} - \left[\left(r_t - \pi_{t,t+1}^e \right) - \left(r_t^* + \phi_t - \pi_{t,t+1}^{e*} \right) \right] - \underset{(0.05)}{0.27} \Delta b_t^{y*} \\ &\quad - \underset{(0.53)}{7.83} \left(d_{02Q1} + d_{02Q2} \right) + \varepsilon_t^q, \end{aligned} \tag{18}$$

$R_A^2 = 0.96$; $LM_1 = 0.25[0.62]$; $LM_4 = 3.28[0.51]$; $HET = 8.30[0.31]$; $JB = 1.47[0.48]$
Method: 2SLS; Sample: 2000Q3-2008Q1
Instrumented variables: $(q_{t+1}); (r_t); (\pi_{t,t+1}^e); (\phi_t); (\Delta b_t^{y*})$
Instruments: $(q_{t-1}, q_{t-2}); (r_{t-1}, r_{t-2}); (\pi_{t-1,t}^e, \pi_{t-2,t-1}^e, \pi_{t-1}, \pi_{t-2}); (\phi_{t-1}, \phi_{t-2});$
$(\Delta b_{t-1}^{y*}, \Delta b_{t-2}^{y*}, CA_{t-1}^y, CA_{t-2}^y)$

where r_t^* is world nominal interest rate, ϕ_t is the country-risk premium, π_t^* is world inflation, b_t^{y*} is the NFA-to-GDP ratio, and CA_t^y is the current account-to-GDP ratio. We impose the restriction that the reaction of the real exchange rate to the interest rate differential is equal to one. We add the NFA change as an additional fundamental to the UIP equation. Notice that increases in the NFA-to-GDP ratio tend to appreciate the real exchange rate[8].

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,

[8]We use the (instrumented) actual exchange rate for the expected values because of data availability. We constructed a series of expected real exchange rate, using data on expected nominal exchange rate and on expected inflation differential. However, this procedure implies a significant loss of observations because data on expected nominal exchange rate are available only from 2001Q4 onwards.

fiscal stance, economic growth) as well as common factors (e.g., contagion effects, world interest rate, investor's willingness towards risk). In the case of Brazil, we found that the most important factors are NFA and foreign investors' willingness to take risk:

$$\phi_t = \underset{(0.07)}{0.16}\psi_t^* - \underset{(0.01)}{0.06}b_t^{y*} + \underset{(0.01)}{0.03}b_{t-1}^{y*} + \varepsilon_t^{\phi}, \tag{19}$$

$R_A^2 = 0.68$; $LM_1 = 0.33[0.56]$; $LM_4 = 2.63[0.62]$; $HET = 16.44[0.06]$; $JB = 0.16[0.93]$
Method: 2SLS; Sample: 1999Q3-2008Q2
Instrumented variables: $(b_t^{y*})\,;(\phi_t)$
Instruments: $\left(b_{t-1}^{y*}, b_{t-2}^{y*}, CA_{t-1}^{y}, CA_{t-2}^{y}\right);\left(\phi_{t-1}, \phi_{t-2}\right)$

where ψ_t^* is the Merrill Lynch's risk aversion index. Notice that the country-risk premium falls when NFA improves (the sum of the coefficients on the NFA terms is negative). Lastly, we derive the following law of motion for the NFA-to-GDP ratio:

$$b_t^{y*} \simeq \overline{\Phi R}^* \left(b_{t-1}^{y*} + nx_t^y\right) + \overline{B}^{y*}\left(\phi_t + r_t^*\right) + \overline{\Phi R}^* \overline{B}^{y*}\left(\Delta q_t - \Delta y_t - \pi_t^*\right), \tag{20}$$

where $\overline{\Phi}, \overline{R}^*, \overline{B}^{y*}$ denote long-run averages of country-risk premium (in gross terms), world nominal interest rate (in gross terms), and NFA-to-GDP ratio, respectively. The calibrated parameter values are $\overline{\Phi} = 1.02$, $\overline{R}^* = 1.01$, $\overline{B}^{y*} = -0.841$. Since the external debt duration is larger than one quarter, changes in the world interest rate affect only partially the income balance in the Balance of Payments. We then apply a factor 0.421 to $\overline{B}^{y*}$ on the second term of (20), based on the average maturity of external debt and the share of fixed interest rate debt. Finally, as in the net export equation, the last part of (20) is an "accounting term", which we ignore in the simulation exercises.

3.5 Monetary policy

The Brazilian monetary authority aims at stabilizing inflation around its target using a Taylor-type interest rate rule with a smoothing component:

$$r_t = \underset{(0.13)}{1.13}r_{t-1} - \underset{(0.12)}{0.51}r_{t-2} + (1 - \underset{(0.13)}{1.13} + \underset{(0.12)}{0.51})\left(\underset{(0.45)}{1.57}\left(\pi_{t,t+4}^e - \bar{\pi}_{t+4}\right) + \bar{\pi}_{t+4}\right) + \varepsilon_t^r, \tag{21}$$

$R_A^2 = 0.91$; $LM_1 = 0.64[0.42]$; $LM_4 = 1.92[0.75]$; $HET = 9.93[0.36]$; $JB = 4.58[0.10]$
Method: 2SLS; Sample: 2000Q3-2007Q2
Instrumented variables: $\left(\pi^e_{t,t+4}\right)$
Instruments: $\left(\pi^e_{t-1,t+3}, \pi^e_{t-2,t+2}, \sum_{j=1}^{4} \pi_{t-j}, \sum_{j=2}^{5} \pi_{t-j}, q_{t-1}, q_{t-2}, ulc_{t-1}, ulc_{t-2}, y_{t-1}, y_{t-2}\right)$

where ε_t^r is the discretionary component of the policy rule. This estimated Taylor rule suggests that the CBB reacts to deviations of expected inflation from the inflation target and also smooths interest rate movements[9]. We use two lagged terms for the interest rate, instead of only one, to eliminate serial correlation in the residuals. Finally, we model inflation target as an AR(2) process.

3.6 Rest of the World

We model the rest-of-the world variables as exogenous processes. We approximate world imports by an ARMA(2,1), world inflation by an AR(1), world interest rate by an AR(2), and world risk aversion by an AR(1). We do not present those equations here because they do not affect the channel decomposition.

4 Results

4.1 Business Cycle Properties

This subsection checks whether the model is capable of replicating key cyclical properties of the Brazilian economy during the inflation targeting period. In particular, we compare the moment conditions generated by the model with those in the data.

First, we conduct a stochastic simulation. We turn on all shocks in the model and run 100,000 simulations, each having the same number of periods in the data sample (36

[9] Minella et al. (2003) find similar estimated coefficients for the Taylor rule, though using a shorter sample period.

quarters)[10]. For each simulation and variable, we compute the average of the following second moments: standard deviation, autocorrelation, and contemporaneous cross-correlations with output.

Table 2 compares the simulation results for key selected variables with those in the data. Overall, the model replicates fairly well most empirical moments. In general, the volatility of the variables in the model is very close to that in the data. For example, the simulated standard deviations of output and inflation are 1.00 and 0.94 percentage point, whereas the empirical ones are 1.04 and 1.07. Consistent with the data, consumption in the model is more volatile than output, and investment is over three times more volatile than output[11]. Given its rich lag structure, the model is also able to replicate well the observed persistence, as measured by the first-order autocorrelations. Lastly, the model also generates cross-correlations with output that are roughly consistent with their empirical counterparts. However, the model is at odds with the data in some dimensions. For instance, it overestimates the cross-correlations between inflation and output, and misses the correct sign of the cross-correlations between net exports and output.

We also compare the actual cross-correlation structure with the simulated one. Figure 2 shows the cross-correlations of output (at different lags and leads) with aggregate demand components and with three supply side variables (capacity utilization rate, unemployment rate, and inflation rate). The model cross-correlations closely track the empirical ones, except in the case of net exports and, to a lesser degree, in the case of inflation.

4.2 Impulse Responses

In this subsection, we assess the overall impulse responses to a demand (consumption) shock and to a monetary policy shock. The behavior of the aggregate demand has been an im-

[10] In the simulations, we use the estimated variances of the residuals in each behavioral equation as proxies for the variances of shocks. In each simulation, we discard the first 100 observations in order to reduce the influence of the initial conditions.

[11] Neumeyer and Perri (2005) document these and other stylized facts for several emerging market economies.

portant driver of Brazilian output and inflation in recent years; in turn, monetary policy innovations are at the center of the channel decomposition we perform in the next section.

Figure 3 shows the responses of the main macroeconomic variables to an one percentage point shock to aggregate consumption. The sudden increase in consumption boosts aggregate demand and output. In order to meet the higher demand, employment increases (i.e., the unemployment rate goes down) and so do wages and real unit labor cost. Part of the larger-than-expected demand is met by an increase in imports, which contributes to the trade balance deterioration and real exchange rate depreciation. Together, the rise in labor cost, the exchange rate depreciation and the increase in the output gap put pressure on inflation (measured in the figure as the four-quarter inflation). The monetary authority then raises the policy rate in order to curb the inflationary pressures. The policy action is successful although it takes a while to bring inflation close to its target.

Figure 4 shows the responses to a positive shock of 100 basis points (or 0.25 percentage point per quarter) to the policy interest rate. In this simulation, once the economy is hit by the shock, the policy interest rate is allowed to change according to the estimated Taylor rule, as in the previous experiment[12]. The responses have the expected sign and the hump shape. Both the household and the swap interest rates (not shown) rise after the shock, reducing consumption and investment, and thus GDP. The output contraction reduces investment even further via the accelerator effect. It also decreases consumption through a fall in real payroll and a rise in the unemployment rate. Notice that the fall in investment is around two times larger than that in consumption. Lower output and higher unemployment depress real wages and thus real unit labor cost. In turn, lower labor costs, together with the negative output gap, help to bring inflation down. As expected, the rise in the domestic interest rate appreciates the real exchange rate (via UIP), further reducing inflation.

The exchange rate appreciation also harms exports, whereas the fall in domestic absorption raises them. Since the price effect dominates, the net result is an export reduction. By

[12] For the first quarter, however, the shock is chosen in such way that the policy interest rate is 100 basis points.

the same token, the appreciation benefits imports, and the fall in output reduces them. In this case, however, the income effect prevails, that is, imports fall in the first year since, as mentioned before, the income elasticity of imports is substantially high. Given that the decrease in imports overpasses that in exports, the outcome is a trade surplus in the first year. After that, as output returns to its steady-state value more quickly than the exchange rate, the traditional price effect prevails and net exports turn negative.

Since the shock is deflationary, the reaction of the monetary authority (to its own shock) is to reduce the interest rate. Initially, the interest-rate smoothing component of the Taylor-type rule prevails, but in the fourth quarter the policy rate becomes negative. As a result, consumption and investment move upwards, pushing output towards its steady-state level. Since the real interest rate becomes negative as the central bank is trying to push the inflation rate back to its steady-state level, consumption and investment overtake their long-run levels but eventually also converge to their steady states. In a nutshell, the monetary policy shock leads to a reduction in inflation and output, an increase in unemployment, and an exchange rate appreciation. Net exports are initially positive, but become negative in the second year. Overall, the impulse responses are qualitatively similar to those generated by traditional VAR models.

In terms of magnitude, the trough of output is 0.2 percent and of the four-quarter inflation is 0.6 percentage point. The maximum reduction in output takes place in the third quarter, while the trough of the four-quarter inflation occurs in the fifth quarter (third and fourth quarters for the quarterly inflation—not shown)[13]. As in Figure 3, most variables display hump-shaped responses.

One limitation of this exercise is that the central bank reacts to its own shock as it follows a Taylor-type rule. We conduct an exercise where, as before, the interest rate increases by 100 basis points, but it is kept at this level for four quarters, following the Taylor-type rule afterwards. As we can see in Figure 5, the shapes of the responses are roughly equal to

[13] The timing of the responses is in line with that in Catão et al. (2008). The magnitude of the effect on the output gap and inflation, however, is slightly higher than in that paper.

those of the previous experiment. The difference lies in the magnitude of the responses and the duration of the process. Output reduction reaches 0.5 percent in the fifth quarter, and four-quarter inflation falls by 1.9 percentage points in the seventh quarter.

4.3 Channel Decomposition: 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. As mentioned in the introduction, the only relevant requirement for this result is that the model must be linear[14]. Their approach can be successfully applied to both backward- and forward-looking models. The steps proposed by the authors in order to identify and quantify the transmission channels are described below:

- Step 1: We identify all the empirically relevant channels in the model. The number of channels is equal to the number of equations that are *directly* affected by the policy rate, excluding the Taylor rule. Each of these equations is a "point of entry" for the monetary policy shock. In our model, they correspond to equations (16), (17), and (18).

- Step 2: We rename the policy rate that enters directly in these equations as r^j, where j corresponds to the identified channel. For instance, in the household interest rate equation, r_t is replaced by r_t^1, which is the point of entry of the household interest rate channel.

- Step 3: For each of these renamed variables, there is a corresponding central bank's reaction function, each with the same specification, as in equation (21). We then introduce a dummy variable in the shock term of each policy reaction function, which

[14] 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.

takes 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. In the previous example, we have the following policy reaction function $r_t^1 = \{endogenous\ terms\} + f^1 \varepsilon_t^r$.

- Step 4: We 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.

4.4 Channel Decomposition

As mentioned before, the policy rate enters the model through the equations of the household lending rate (16), swap rate (17), and the exchange rate (18), corresponding, respectively, to three channels in our model: *household interest rate*, *firm interest rate*, and *exchange rate* channels. The first channel captures the traditional intertemporal effects of monetary policy on consumption decisions; the second describes the effects through the firms' external financing costs; and the third captures the effects of interest rate movements on the real exchange rate and thus on the real marginal cost of firms and on aggregate demand components. In this subsection, we focus on the decomposition without identifying the expectation channel.

Figure 6 presents the impulse responses corresponding to each channel, following a positive 100 basis points shock to the policy rate (0.25 percent per quarter). In each panel, the black solid line represents the household interest rate channel, the blue dashed line describes the firm interest rate channel, and the red dotted-dashed line describes the exchange rate channel. The individual effects in each panel sum to the overall effects of the shock shown in Figure 4.

As expected, the three channels contribute to the output reduction, at least in the first five quarters. An increase in the policy rate immediately raises the household lending and swap rates (not shown) in both nominal and real terms, and reduces the real exchange rate.

The rise in the household lending rate directly reduces consumption, the increase in the swap rate lowers investment, and the exchange rate appreciation discourages net exports. Note, however, that the exchange rate channel stimulates consumption and investment. In terms of relative contribution, we can see that the household interest rate channel is the preponderant one.

Similarly, the three channels also contribute to the inflation fall. The two interest rate channels reduce inflation through their negative effects on output and real unit labor cost (two key terms in the Phillips curve). The exchange rate channel, in turn, affects inflation not only through output, but also directly through the exchange rate change term in the Phillips curve. Regarding relative contributions, the household interest rate and exchange rate channels are the most relevant ones.

The channel decomposition also allows to disentangle the opposing effects of the monetary policy shock on net exports, mentioned in subsection 4.2. The exchange rate channel discourages net exports since the real exchange rate appreciation depresses exports and boosts imports. On the other hand, the two interest rate channels tend to stimulate net exports as they reduce output and domestic absorption.

Table 3A presents the **cumulative** effects on output and inflation stemming from each individual channel, at four-, eight- and twelve-quarter horizons. The household interest rate channel is responsible for 62% of the output fall in the first year and about half in the first two years. The firm interest rate channel accounts for only 24% of the output drop in the first year, and the exchange rate, for 14%. The latter channel turns out to be more relevant at longer horizons, reflecting the fact that the exchange rate moves slowly to its long-run level in our model. In contrast, the interest rates move back quickly, actually becoming negative for some periods.

On the other hand, the household interest rate and the exchange rate channels are equally important for explaining the behavior of inflation, each accounting for around 40% at all horizons. The important role played by the exchange rate channel in the decomposition is consistent with the fact that exchange rate movements have been a key determinant of inflation dynamics in Brazil. Therefore, monetary policy has significantly strengthened when compared with the previous period of managed exchange rate. At that time, changes in the policy rate did not translate into exchange rate changes, implying that inflationary pressures warranted stronger central bank's reaction.

The firm interest rate channel plays a secondary role in the decomposition of both output and inflation, reflecting in part the smaller share of investment in the GDP. The result is also consistent with the fact that significant part of private investment in Brazil is financed through state-owned development banks, which tends to impair the transmission mechanisms. We conjecture that, if private institutions accounted for a larger share of investment funding, the interest-rate elasticity of investment would be higher and the firm interest rate channel would be stronger than what is suggested by our estimations.

4.5 The Role of Expectations

Both the literature and policy makers have emphasized the role played by expectations on macro dynamics. In particular, it is widespread the view that inflation expectations work as an important transmission mechanism of monetary policy. However, identifying and measuring a specific expectation channel is a difficult task because this channel is entangled with the other transmission channels. To better understand how the expectation channel is intertwined with the other channels, consider the case of the Phillips curve. Solving it forward, we find that agents' expectations of future inflation is translated into expectations of the driving forces of inflation (unit labor cost, real exchange rate, and output gap). The behavior of these driving forces at any moment in the future can be fully decomposed into the non-expectation channels, apparently leaving no role for a separate expectation channel.

In order to get a sense of this channel, we run the previous model (baseline model) assuming that private agents' inflation expectations do not respond to the monetary policy shock (exogenous-expectation model). In our setup, inflation expectation terms appear in equations (4), (5), (15) and (18). We then compare the response functions of the baseline model with those coming from the exogenous-expectation model. The difference between the two gives us a proxy for the expectation channel as it measures the contribution of inflation expectations to the behavior of the model variables. The decomposition of the exogenous-expectation model provides the contribution of the non-expectation channels.

Figure 7 compares the overall impulse responses under the baseline model with those under exogenous expectations. Even though all responses display similar pattern, they differ in terms of timing and magnitude. The output fall is smaller under exogenous expectations mainly because the real interest rate increases by less than in the baseline model. In the latter, expected inflation is negative after the shock, whereas it does not respond to the shock in the exogenous-expectation model. The reaction of inflation, in turn, is slower and weaker in the exogenous-expectation model because expectations regarding future inflation no longer moves current inflation.

Table 3B reveals that the expectation channel is relevant for output dynamics in the short run (up to a year), but weakens substantially as time goes by. Since the estimated equations display important lags, expectations tend to play a more important role in the short-run dynamics of output. Over time, however, the model internal dynamics is more relevant in the propagation of the initial monetary policy shock. Also notice that the household interest rate is robust to the explicit consideration of the expectation channel. It still remains as the most important channel for output (up to two years).

On the other hand, the expectation channel is the single most important channel for inflation. It accounts for about three quarters of the inflation fall in all horizons. We interpret this number as an upper bound measure of the true contribution of the expectation channel because actual inflation expectations probably move less than in models with consistent expectations. Even granting that our experiment overstates the expectation channel, the result is consistent with the theoretical view emphasizing the importance of expectations (see, for instance, Woodford (2003)). In the case of Brazil, Bevilaqua et al. (2008) and

Carvalho and Minella (2009) find that the inflation target works as an important anchor for inflation expectations. Our work further suggests that expectations are a key element in the transmission mechanism of monetary policy. In this sense, it is in line with the importance attributed to expectations in the implementation of monetary policy in Brazil (Bevilaqua et al. (2008)).

5 Concluding Remarks

To our knowledge, we are the first to document the channel decomposition of monetary policy in Brazil using an economic model and covering the inflation targeting regime. We develop, estimate and use the model to decompose the monetary policy effects into four important individual channels. We found that the household interest rate channel plays the most important role in explaining output dynamics. In the case of inflation, both the household interest rate and the exchange rate channels are the main transmission mechanisms. However, when we add a proxy for the expectation channel, this channel becomes key to understand the behavior of inflation. Using a more traditional econometric approach, we also showed that market interest rates in Brazil are quite sensitive to changes in the policy rate.

The estimated medium-size, semi-structural model represents an important effort to model Brazil's economy. It can be used to assess the effect of different shocks in the economy, not only monetary ones. In fact, the model can potentially be used for simulation and policy analysis, and, therefore, work as a complementary tool in monetary policy decision-making. However, our model describes only gaps (deviations from long-run trends) and thus has limitations in projection exercises and long-run analysis.

Looking into the future, we anticipate that other channels may play a relevant role as the Brazilian economy develops and financial and credit markets deepen. Among the potential competing channels, we highlight the so-called wealth and credit channels. The increase in the access to the stock market and the reduction in the share of interest-rate-linked public debt may contribute to the development of a wealth channel in Brazil. Also, the credit behavior—the credit-to-GDP ratio has doubled in the last few years—has recently become an important element in the country's business cycle. The assessment of the credit channel, however, involves the use of different tools and datasets[15]. Nevertheless, the ongoing worldwide financial crisis leaves no doubt about the importance of understanding better the credit channel and all related financial linkages.

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[15] So far, the empirical evidence about the credit channel in Brazil is not conclusive. The results seem to be sensitive to differences in methodology, datasets and sample periods. See, for instance, **?**, Souza-Sobrinho (2008), and Takeda et al. (2005).

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Table 1. Interest Rate Pass-Through Regressions

Coefficient of Interest	Time Deposit Rates: Households	Time Deposit Rates: Firms	Time Deposit Rates: Overall	Average Lending Rates: Households	Average Lending Rates: Firms	Average Lending Rates: Overall	Other Lending Rates: Personal Credit	Other Lending Rates: Working Capital
α_0	-0.11	-0.19**	-0.06	-0.12***	-0.18***	-0.16***	-0.08***	-0.16***
	(0.08)	(0.09)	(0.04)	(0.04)	(0.03)	(0.05)	(0.03)	(0.03)
α_1	8.65***	3.56***	3.10	40.86***	18.60***	31.18***	53.85***	15.40***
	(3.10)	(1.15)	(2.97)	(7.95)	(2.00)	(4.23)	(14.03)	(2.55)
α_2	0.46**	0.83***	0.73***	1.18***	1.04***	1.13***	1.24**	0.96***
	(0.21)	(0.05)	(0.20)	(0.33)	(0.12)	(0.16)	(0.56)	(0.16)
β_0	0.87***	0.97***	0.98***	1.26***	1.29***	1.06***	1.03***	0.86***
	(0.10)	(0.07)	(0.07)	(0.20)	(0.14)	(0.12)	(0.17)	(0.26)
Lag *j*	1, 3, 4, 6	1, 2, 5	1, 3, 6	2, 5, 6	5	5	5	1, 2, 5, 6
Lag *k*	1, 5	1, 5	1, 6	5	1, 6	6	none	1, 2
Adjusted R^2	0.75	0.83	0.83	0.52	0.58	0.43	0.52	0.54
LM_1	0.00 [0.94]	0.09 [0.76]	0.77 [0.38]	0.63 [0.43]	0.07 [0.79]	0.02 [0.88]	0.75 [0.39]	2.23 [0.14]
LM_3	5.02 [0.17]	0.83 [0.84]	1.06 [0.79]	5.27 [0.15]	0.33 [0.85]	0.35 [0.95]	1.23 [0.75]	4.78 [0.19]
LM_6	6.67 [0.35]	1.09 [0.98]	2.89 [0.82]	8.27 [0.22]	5.53 [0.48]	8.32 [0.22]	1.84 [0.93]	6.62 [0.36]
HET	67.0 [0.51]	62.9 [0.22]	30.5 [0.81]	76.0 [0.01]	42.3 [0.04]	59.8 [0.00]	33.0 [0.08]	61.9 [0.27]
JB	1.50 [0.47]	3.25 [0.20]	1.12 [0.57]	4.44 [0.11]	2.01 [0.37]	2.02 [0.36]	0.71 [0.70]	1.57 [0.46]
Wald: $\alpha_2 = 1$	6.47 [0.01]	11.1 [0.00]	1.78 [0.18]	0.30 [0.58]	0.13 [0.72]	0.69 [0.40]	0.18 [0.67]	0.06 [0.80]
Wald: $\beta_0 = 1$	1.57 [0.21]	0.21 [0.64]	0.08 [0.95]	1.75 [0.19]	4.44 [0.04]	0.25 [0.62]	0.03 [0.86]	0.29 [0.59]

*, **, *** Significant at 10%, 5%, and 1%, respectively. Newey-West standard errors in parenthesis. P-values in square brackets.

LM_1, LM_3, LM_6 are the Breusch-Godfrey Lagrangian multiplier test statistics for serial correlation in the residuals up to order one, three and six, respectively.

HET is the White heteroskedasticity test for the residuals. JB is the χ^2 Jarque-Bera test for normality of the residuals. Wald is the χ^2 Wald test for coefficient restrictions.

Table 2. Data and Simulated Moments

Variable	Standard Deviation		Relative Standard Deviation		Autocorrelation		Cross-Correlation with GDP	
	Data	Model	Data	Model	Data	Model	Data	Model
GDP	1.04	1.00	1.00	1.00	0.60	0.54	1.00	1.00
Consumption	1.44	1.15	1.38	1.14	0.77	0.71	0.61	0.60
Investment	4.20	3.57	4.02	3.55	0.77	0.66	0.78	0.52
Net Exports/GDP	1.07	0.87	1.02	0.87	0.79	0.55	-0.24	0.26
Inflation Rate	1.07	0.94	1.02	0.94	0.36	0.48	0.12	0.40
Unemployment Rate	0.68	0.72	0.65	0.72	0.84	0.85	-0.37	-0.47
Capacity Utilization Rate	1.21	1.19	1.16	1.18	0.69	0.57	0.58	0.58
Unit Labor Cost	2.95	2.61	2.82	2.60	0.84	0.76	0.26	0.21
Real Exchange Rate	8.94	10.05	8.56	10.00	0.70	0.88	-0.13	-0.04

Note: Data sample covers the period 1999Q3 to 2008Q2. All moments are generated by HP filtered data. Relative standard deviation is normalized to that of GDP.

Table 3. Relative Contribution of each Channel to GDP and Inflation (%)

A. Baseline Decomposition

Channel	4 Quarters	8 Quarters	12 Quarters
GDP			
1. Household Interest Rate	62.1	49.3	40.9
2. Firm Interest Rate	23.9	20.2	17.2
3. Exchange Rate	14.1	30.4	41.9
Total	100.0	100.0	100.0
1-Quarter Inflation			
1. Household Interest Rate	42.7	45.2	42.0
2. Firm Interest Rate	16.0	17.7	15.8
3. Exchange Rate	41.3	37.1	42.2
Total	100.0	100.0	100.0

B. Decomposition Identifying the Expectation Channel

Channel	4 Quarters	8 Quarters	12 Quarters
GDP			
1. Household Interest Rate	41.4	37.2	32.9
2. Firm Interest Rate	15.9	15.1	13.1
3. Exchange Rate	4.4	24.9	40.6
4. Expectation	38.4	22.7	13.5
Total	100.0	100.0	100.0
1-Quarter Inflation			
1. Household Interest Rate	6.4	10.4	9.3
2. Firm Interest Rate	1.7	4.0	3.5
3. Exchange Rate	12.5	8.8	10.0
4. Expectation	79.4	76.7	77.2
Total	100.0	100.0	100.0

Figure 1. Brazilian Interest Rates - Jul/1999 to Jun/2008

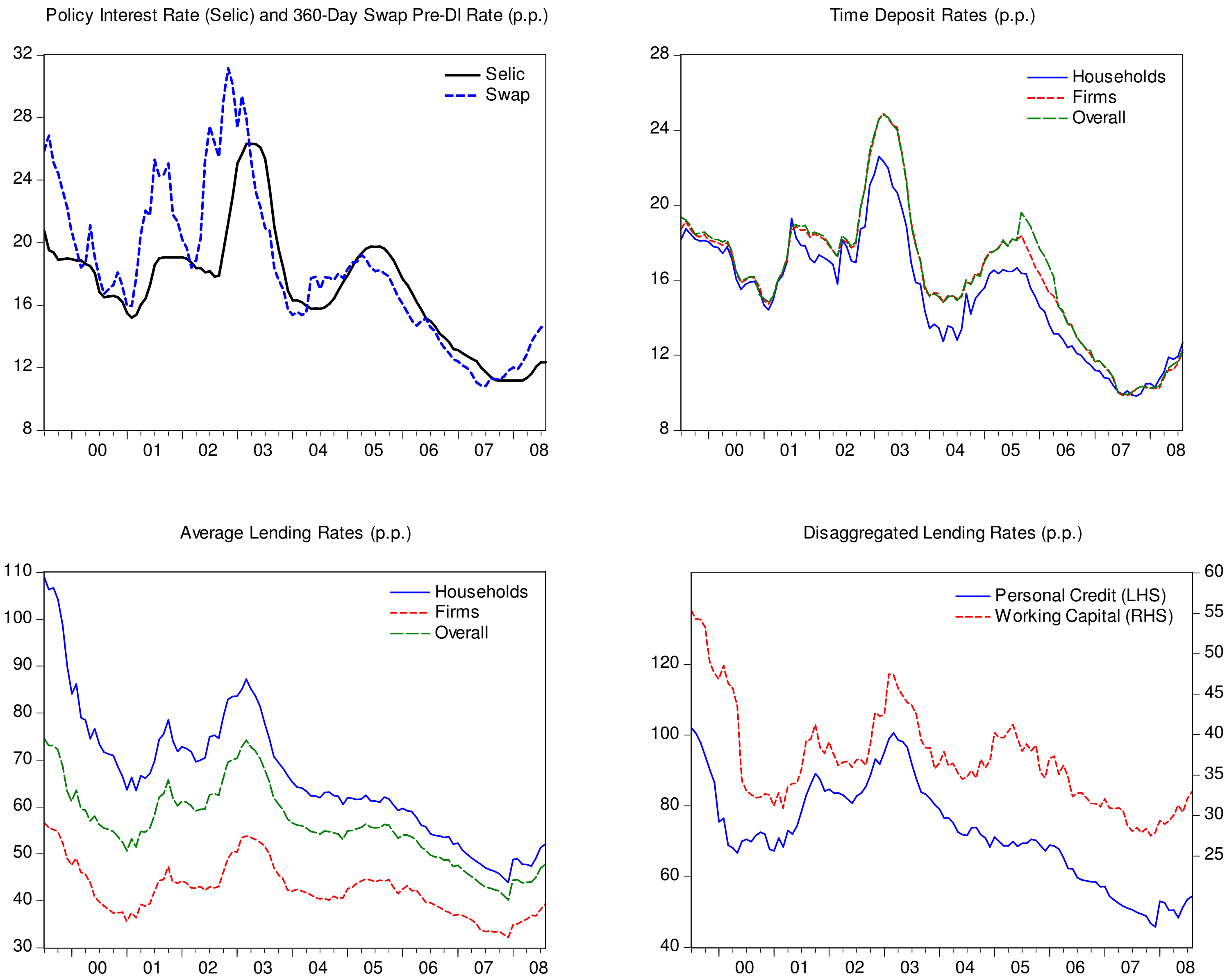


Figure 2. Cross-Correlations between GDP (at quarter *j*) and Variable (*i*)

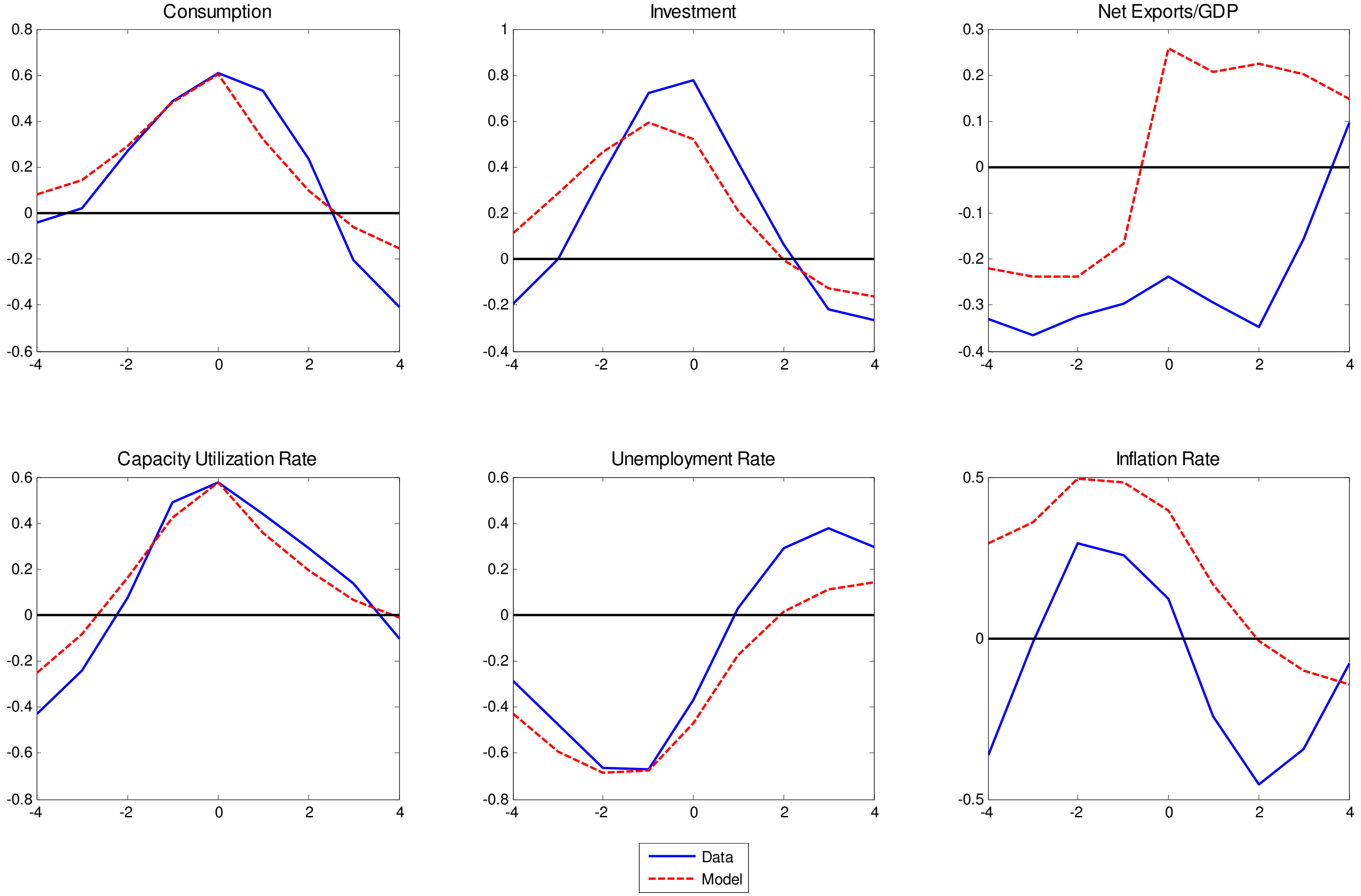


Figure 3. Impulse Responses to a Consumption Shock

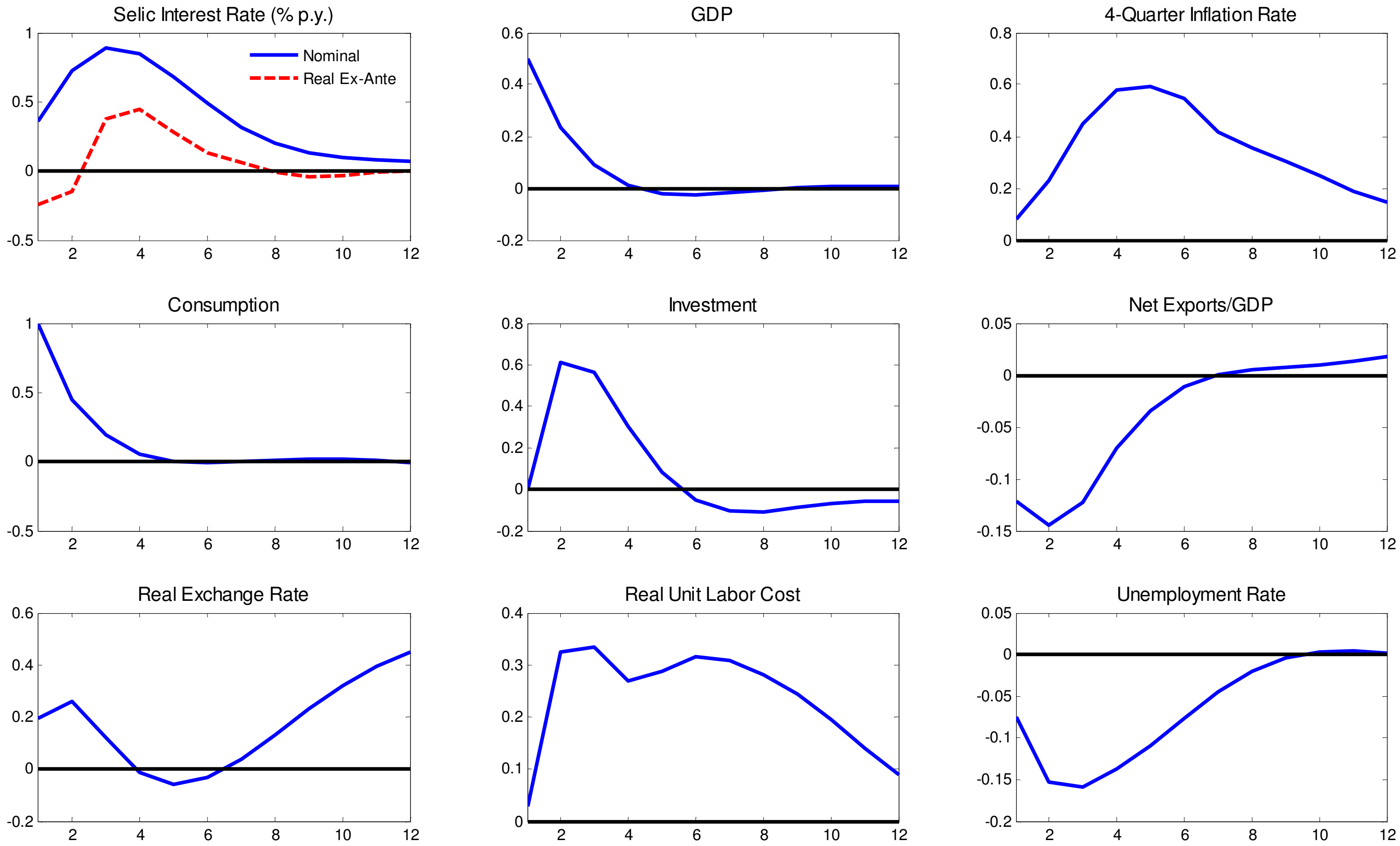


Figure 4. Impulse Responses to a Monetary Policy Shock

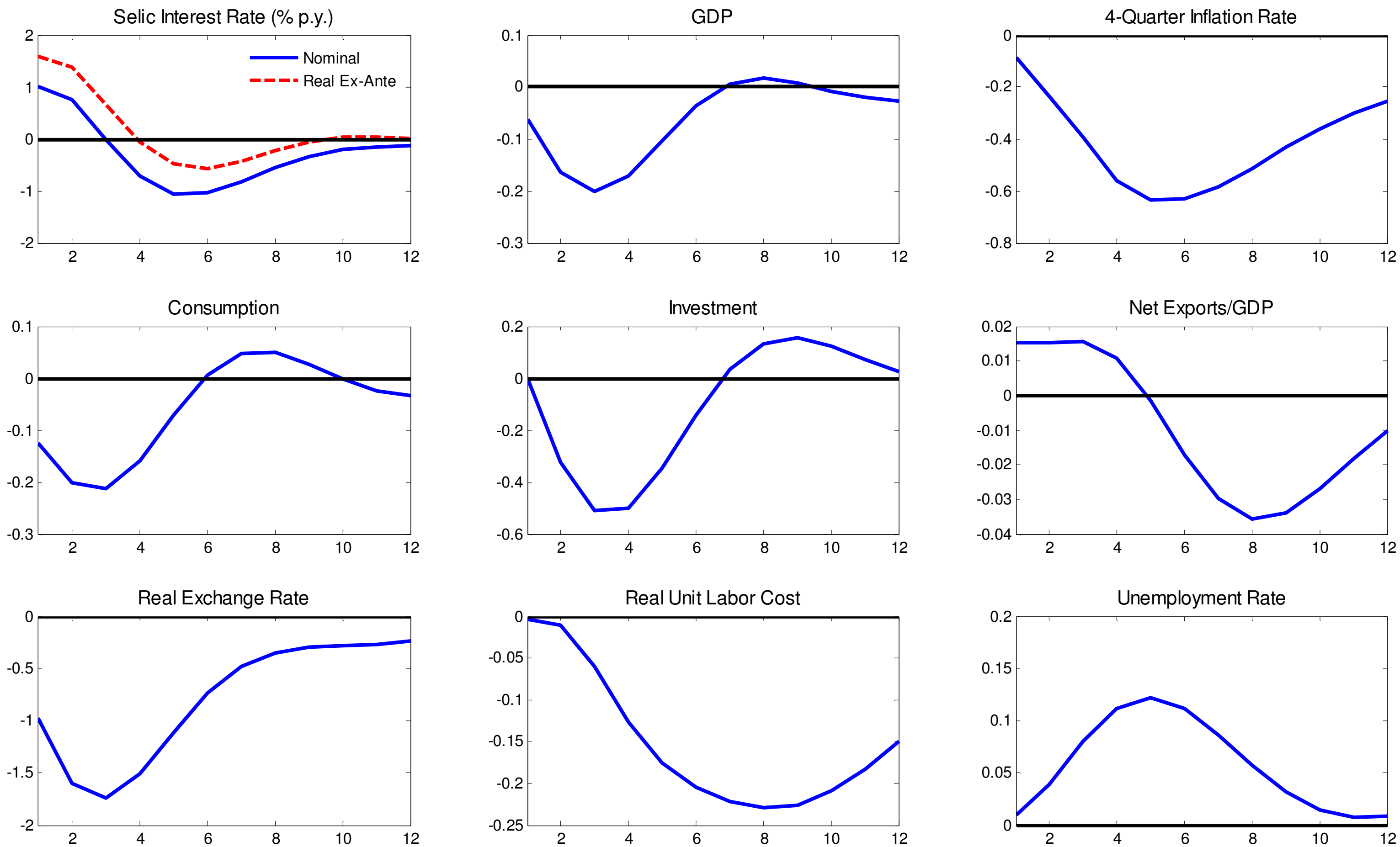


Figure 5. Impulse Responses to a Monetary Policy Shock with Fixed Policy

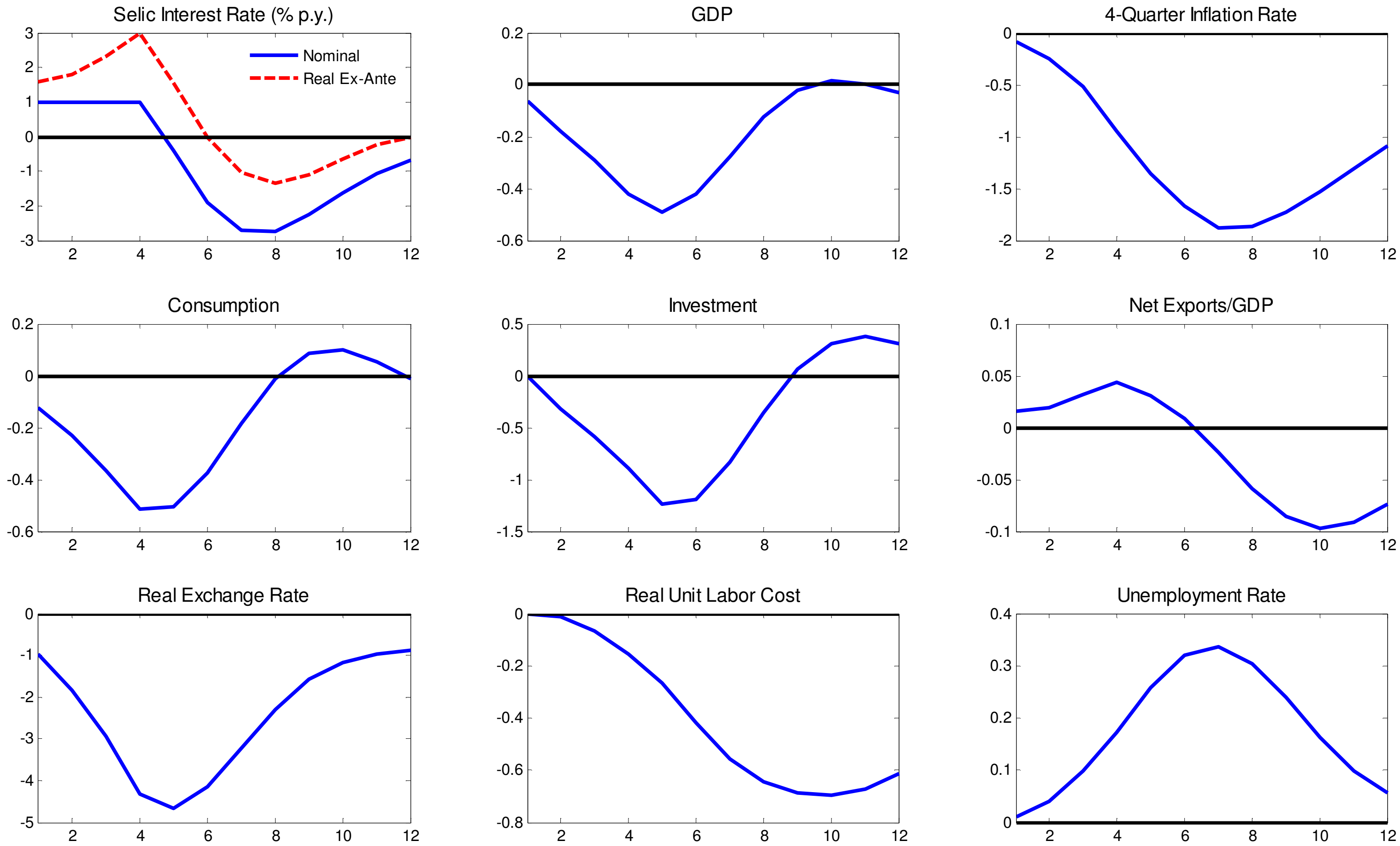


Figure 6. Baseline Channel Decomposition

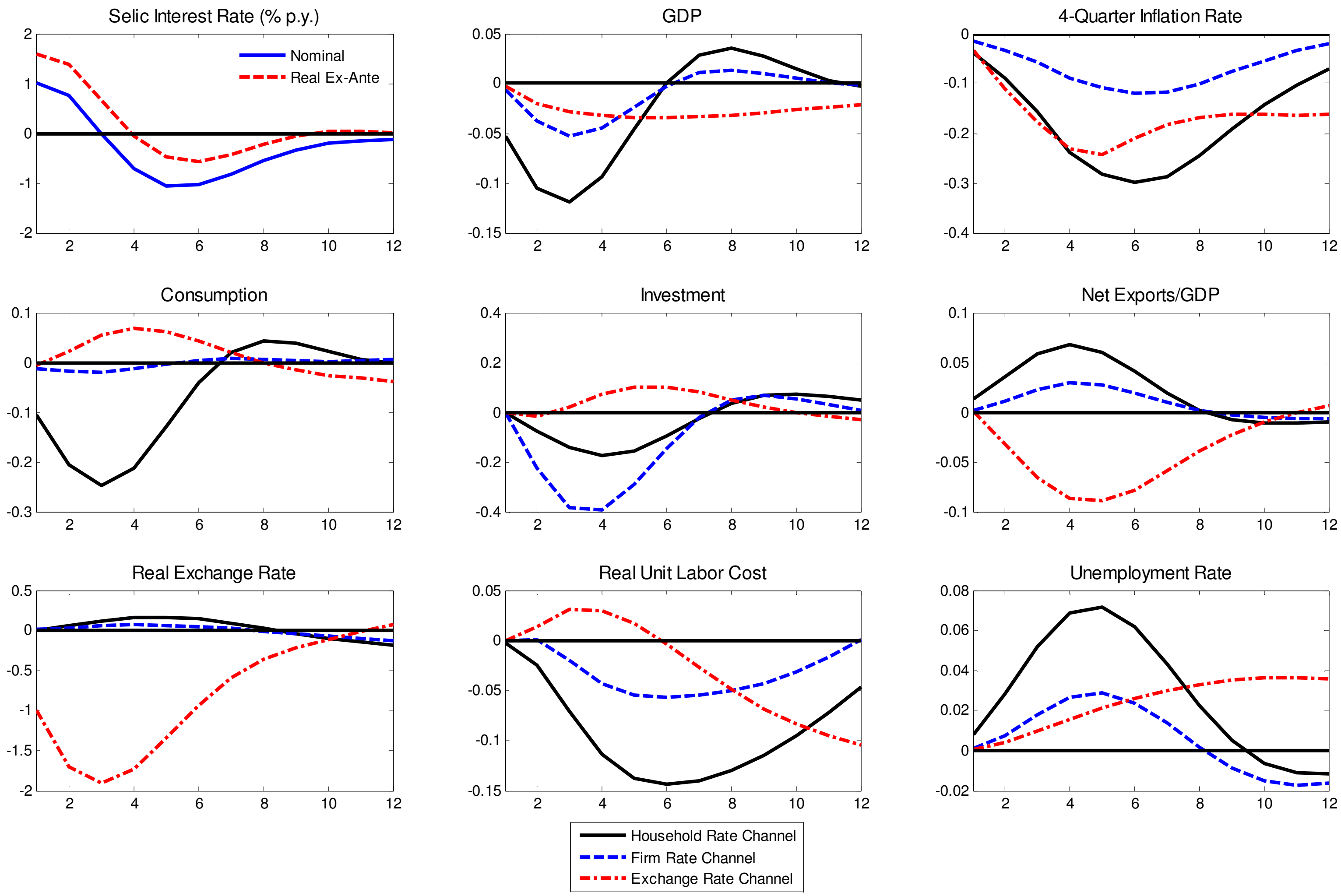
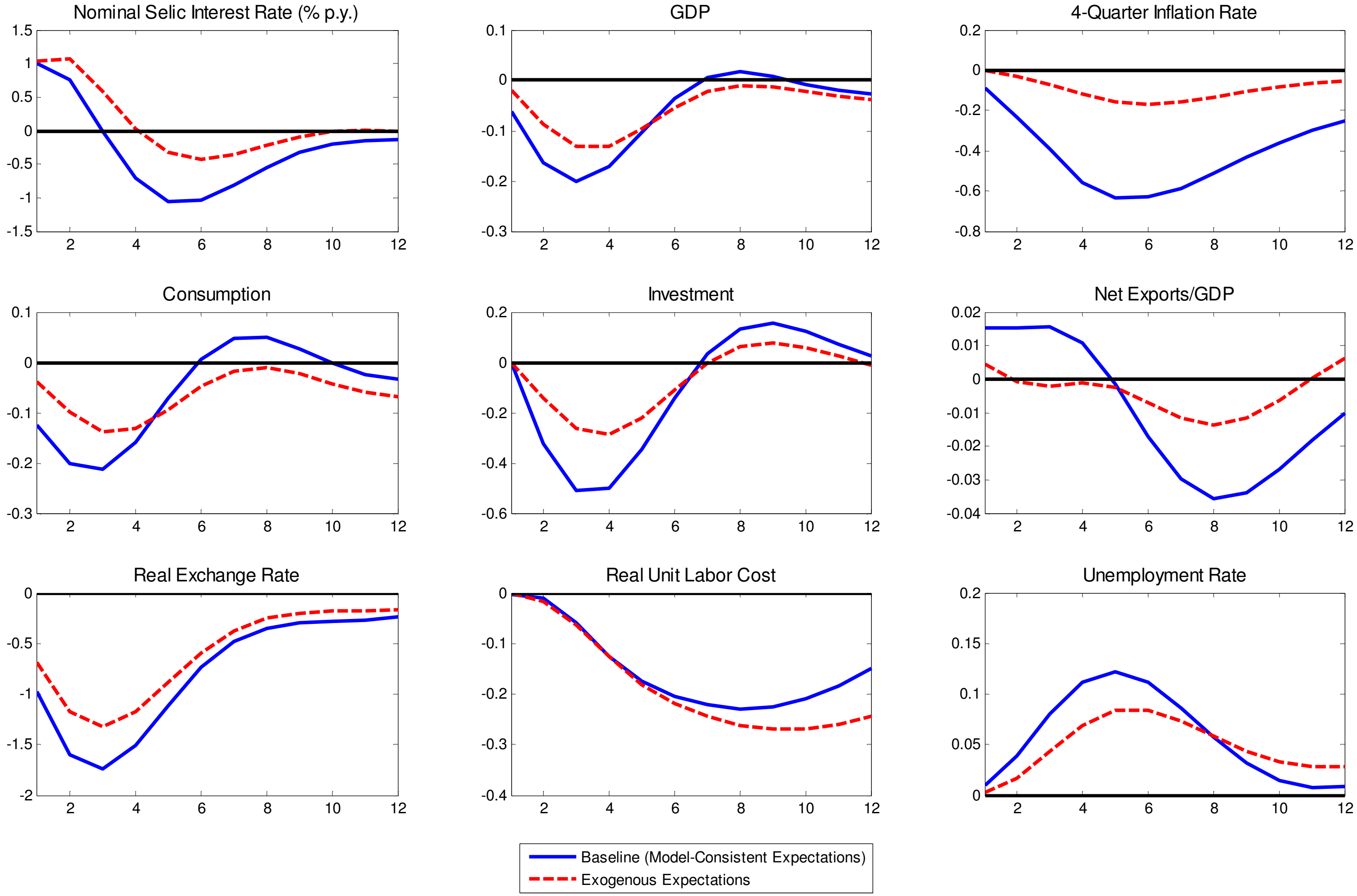


Figure 7. Channel Decomposition under Different Assumptions for Expectations



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