

Evidences of Incomplete Interest Rate Pass-Through, Directed Credit and Cost Channel of Monetary Policy in Brazil

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Abstract

The aim of this study is to analyze the operationality of the monetary policy cost channel in Brazil, highlighting the role played by the banks. For that, We present a New-Keynesian DSGE model in which the costs of the firms are directly influenced by the level of the banks loan rate. The model also tried to incorporates the possibility of a limited interest rate pass-through and the directed credit. I estimate the model by adopting a minimum distance approach (Matching). The results indicate that: the cost channel plays a decisive role in the monetary policy transmission, explaining the Price-Puzzle; there is no evidence of incomplete interest rate pass-through; and, the directed credit reduces the monetary policy capacity to modify the credit conditions.

Keywords: Monetary Policy, Interest Rate Pass-Through, Cost Channel, Directed Credit.

Resumo

O objetivo deste artigo é analisar a operacionalidade do canal de custo da política monetária no Brasil, destacando o papel desempenhado pelos bancos. Para tanto, desenvolve-se um modelo DSGE Novo-Keynesiano, no qual o custo das firmas é diretamente influenciado pelo nível da taxa de juros cobrada pelos bancos. O modelo também incorpora a possibilidade de *pass-through* incompleto da taxa de juros e o crédito direcionado. O modelo foi estimado por meio do método da distância mínima (*Matching*). Os resultados indicam que: o canal de custo desempenha papel relevante na transmissão da política monetária (explicando o *Price-Puzzle*); não há evidência de *pass-through* incompleto; e, o crédito direcionado reduz a capacidade da política monetária modificar as condições de crédito.

Palavras-Chave: Política Monetária, *Pass-Through* da Taxa de Juros, Canal de Custo, Crédito Direcionado.

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1 Introduction

A growing literature has addressed the possibility that monetary policy action do not only affect aggregate demand, but also exert an influence on economic variables through the supply side (Gaiotti and Secchi, 2006). Accordingly to the the cost channel mechanism of monetary policy, some production costs increase with the interest rate, hence a monetary contraction can promote an increase in prices instead of a decrease (Rabanal and Rubio-Ramírez, 2007).

There is, at least, two kinds of evidence that point to the short run effects in the supply side. The first evidence is the price-puzzle of the monetary policy observed in several studies that applied the VAR methodology. These studies find, as a result, that the prices level increase after an increase in the interest rate. The second evidence is the degree of amplification. This evidence suggests that monetary policy shocks that induce to relatively small and transitory movements in open-market interest rates have large and persistent effects on output (Barth and Ramey, 2002).

The cost channel is incorporated in recent theoretical models. Christiano et al. (2005) present a New-Keynesian DSGE model that incorporates the hypothesis of the credit for working capital. The firms need to pay for the production factors before receiving revenue from sales. As a result, the marginal costs of the firms depend positively on the interest rate. Besides, a monetary contraction induce an upward pressure on prices. Ravenna and Walsh (2006) introduce other economic shocks (productivity, preferences and government spendings) in the model and they find important implications in terms of the conduction of the monetary policy: the shocks imply in the trade-off between stabilization of the product and inflation; and, under optimal monetary policy, product and inflation return gradually to their steady state value. Rabanal (2007), in turn, innovates by considering that only a fraction of firms depends of the credit for working capital. Hülsewig et al. (2009) insert banks that extend loans to firms in an environment of monopolistic competition by setting their loan rates in a staggered way (only a fraction of the banks is able to adjust the loans interest rate in each period), which means that the adjustment of the aggregate loan rate to a monetary policy shock is sticky¹. De Fiori and Tristani (2013) present a model that consider assymmetric information (under costly state verification set-up *a la* Townsend) and default risk, and, because of this, the bank lending rate incorporate a spread over the deposit rate. Accordingly to the model, the inflation rate increases with the spread and the deposit rate.

According to Hülsewig et al. (2009), a number of studies have shown that the cost channel is empirically relevant in developed economies, e.g. Barth and Ramey (2002), Dedola and Lippi (2005), Fabiani et al. (2006), Christiano et al. (2005), Ravenna and Walsh (2006), Chowdhury et al. (2006) and Tillmann (2008). Hülsewig et al. (2009) also find evidence that this transmission channel is important to explain the inflation inertia which emerges after a monetary policy shock in the Euro area, but its effect is mitigated because of a disproportionate adjustment of loan rates to changing money market rates.

Few studies, on other hand, analyze the cost channel of monetary policy for developing economies. Agénor and Montiel (2008) argue that the cost channel may be relevant in these countries because the bank debt is a significant source of financing operations for firms, including the acquisition of fixed capital assets, and the stock and corporate bond markets are weak. However, Glen and Singh (2004) observe a significant cross-country variation and a declining trend of leverage ratio. According to Malikane (2012), it suggests that the cost

¹Hülsewig et al. (2009) give a crucial role to the loan market structure. The cost channel operationality depends on the banks' capacity reacting to monetary policy shocks. If the proportion of banks that are able to adjust their rates is reduced, then the effect of the monetary policy over the aggregate loan rate is also reduced, and the cost channel is not relevant.

channel may be as important in emerging markets as it is in developed economies and it may be declining in importance².

The study of the relevance of the cost channel seems to be crucial to improve the understanding of the monetary policy effects in the Brazilian economy due to a number of reasons. First, the Brazilian firms resort to credit for working capital in a significant amount. According the Brazilian Central Bank, the relative importance of this kind of credit indeed increased among the firms from approximately 20% in 2007 to 30% in 2013.

Another motivation to analyze the cost channel is because the Brazilian firms have significant financial expenses. According to the Annual Survey of Industry (The Brazilian Institute of Geography and Statistics – IBGE), the financial expenses represented around 11% of the total costs of the Brazilian industrial firms between 2009 and 2012. Just for comparison, the labor expenses represented 14% of the total costs in the same period. Hence, it is very likely that changes in the total amount of financial expenses influence the price and production decisions.

There is, also, monetary policy price-puzzle evidences in VAR model estimations for the Brazilian economy, e.g. [Rabanal and Schwartz \(2001\)](#), [Arquete and Jayme-Jr. \(2003\)](#), [Sales and Tannuri-Pianto \(2005\)](#) and [da Silva Guimarães and Monteiro \(2014\)](#). It is worth to point that, even for other studies in which the price-puzzle is not observed, the monetary policy effect in inflation is reduced, lagged and temporary, e.g. [Fernandes and Toro \(2005\)](#) and [Céspedes et al. \(2008\)](#).

Some changes in the Brazilian economy also motivate the cost channel analysis. The monetary policy implementation was altered recently³, so there is no plenty understanding about the policy transmission mechanisms in Brazil. Besides, [Minella and Souza-Sobrinho \(2009\)](#) argue that the relative importance of the monetary policy transmission channels may have been altered recently because of the, among other reasons, credit market expansion and financial markets development.

As observed for the other emerging economies, few studies analyze the cost channel in Brazilian economy including [Martins \(2011\)](#), [Malikane \(2012\)](#), [Kawamoto and Oreiro \(2011\)](#) and [Santos \(2011\)](#). There are significant differences among these studies in terms of the theoretical model, empirical strategy and results – only [Martins \(2011\)](#) and [Kawamoto and Oreiro \(2011\)](#) find evidences for the cost channel. Despite the differences, all of these studies neglected the banks behaviour, as well the capacity of the interest rate, instrument of the monetary policy, modify the credit conditions faced by the firms.

Considering the previous discussion, the aim of this paper is to analyze the channel cost of monetary policy, highlighting the role played by the banks, by employing a DSGE New-Keynesian model. In the model, the aggregate level of the loan rate directly influences the costs of the firms. Besides, the model features financial market rigidity, only a fraction of the banks is able to adjust the loan rate each period. As a consequence, the reaction of the aggregate loan rate to a monetary policy shock may be sticky (limited pass-through).

The novelty of the model presented in this paper is the incorporation of the directed credit. The share of directed credit is significant in Brazil. According to the Brazilian Central Bank, the directed credit represented 43% of total of the credit operations in 2013. Besides, the Brazilian directed credit presents peculiar features which influence the monetary capacity in modifying the economy's credit conditions. We can highlight three of these characteristics: the directed credit loan rates are lower and more stable than the other credit

²[Malikane \(2012\)](#), by using robust estimation of the Phillips curve, does not find evidence of the cost channel in a group of emerging economies (Brazil included), the only exception is Mexico.

³The money targeting regime was replaced by the inflation target regime only in 1999. Since then, the Selic rate (the banks' overnight rate) is the most important instrument of monetary policy implementation ([Sales and Tannuri-Pianto, 2007](#)).

modalities; the directed credit has public and private funds; and, the directed credit operations have been made mostly by large state owned banks. Hence, in the model, we assume that a constant and exogenously determined fraction of the loans is made through directed credit operations and the directed credit loan rate is also constant over time and exogenously determined.

It's worth to mention that, except by [Santin \(2013\)](#) and [Sato \(2013\)](#), no effort has been made to shed some light about the relation among monetary policy and directed credit, in spite of the media discussion. In this sense, we present a contribution to the policymakers, once we develop and estimate a model for Brazil that features the proportion of the directed credit as a determinant of the monetary policy capacity in modifying the economy's credit condition.

We estimate the DSGE for the Brazilian economy by using the Minimum Distance approach, which consists in two steps. First, we estimate a VAR model to generate empirical impulse responses to a monetary policy shock. Second, we estimate the model parameters by matching the theoretical impulse responses as closely as possible to the empirical impulse responses. Considering the estimated model, we analyze the relevance of the channel cost. Besides, we look for evidences of limited interest rate pass-through and the directed credit influence over the monetary policy effect.

The remainder of this paper is organized as follows. In section 2, we display our economic model. In section 3, we discuss our econometric methodology. In section 4, we present and discuss the empirical analysis results. In section 5, we summarize the main findings.

2 The Model

[Hülsewig et al. \(2009\)](#) build a New Keynesian DSGE model on the framework of [Christiano et al. \(2005\)](#) and [Smets and Wouters \(2003\)](#)⁴ in order to study the relevance of the cost channel. The model consists of firms, households and banks.

The firms are partitioned into final and intermediate good producers. The firms that produce the final good operate under perfect competition, and they use only the intermediate goods as inputs. The intermediate good producers, in turn, operate under monopolistic competition, it means that each firm have some monopoly power over prices that are set in a staggered way as in [Calvo \(1983\)](#). The inputs of the intermediate goods are capital and labor services. We account for a cost channel by assuming that a fraction of firms require loans from banks as they are obliged to pay their wage bill in advance of selling their product.

Households obtain utility from consumption and leisure, they supply a differentiated type of labor, own the capital stock and make investment decisions. They decide on their wages, which are also set in a staggered way.

Finally, banks extent loans to firms in an environment of monopolistic competition. They face frictions when changing their loan rates, which implies that the aggregate loan rate reacts stickily to a monetary policy shock.

The equilibrium in the final goods market is characterized by the equality of production and demand by households for consumption and investment adjusted for the resource costs attached to variable capital utilization. The market clearing conditions in the capital rental market, the loan market and the labor market require that supply equals demand at the prevailing market prices.

⁴According to [Vereda and Cavalcanti \(2010\)](#), these models have been the inspiration of the medium scale DSGE models of several central banks.

The solution of the model was derived by taking a log-linear approximation around the non-stochastic steady state of the economy with zero inflation. The model is closed by specifying the reaction function of the central bank, which is described by a log-linearized interest rate rule.

We modify the model employed by [Hülsewig et al. \(2009\)](#) in order to incorporate the directed credit which is an important feature of Brazilian economy. Specifically, we divided the financial intermediaries into the banks that operate directed credit and the ones that operate free credit. Similar to the model of [Hülsewig et al. \(2009\)](#), we assume that the free credit banks extend loans to firms in an environment of monopolistic competition, and they face frictions when changing their loan rates, which implies that the aggregate loan rate reacts stickily to a monetary policy shock.

Next, we present the bank sector of our model. Firms and households are not discussed in detail because we use the same formulation of [Hülsewig et al. \(2009\)](#). Then, we summarize the relevant log-linearized relationships.

2.1 Banks

Banks indexed by $k \in [0, 1]$ extend loans to firms in an environment of monopolistic competition. Profits by bank k are given by:

$$\Pi_t^{bank}(k) = R_t^l(k)L_t(k) - R_t^d D_t(k) - R_t^M B_t(k), \quad (1)$$

where $L_t(k)$ is the loan volume, $R_t^l(k)$ is the gross loan rate, $D_t(k)$ is the level of deposits, $R_t^d(k)$ is the gross deposit rate, $B_t(k)$ is the net position on the money market and $R_t^M(k)$ is the gross money market rate, which is controlled by the central bank. Profits are distributed to households at the end of each period.

For each bank the balance sheet constraint is:

$$L_t(k) = D_t(k) + B_t(k), \quad (2)$$

which relates the loan volume to the level of deposits and the net position on the money market. Deposit and money market credits are assumed to be perfect substitutes for refinancing, which implies that $R_t^d = R_t^M$.

Bank k maximizes profits subject to the balance sheet constraint and the downward sloped loan demand. In a flexible loan market, each bank would set its loan rate as a *mark-up* over nominal marginal costs. Since banks are exposed to identical marginal costs it holds that the loan rate would be the same for each one of them.

However, banks face frictions when setting their loan rates. First, a fraction τ_2 of the banks extend directed credit (DC) which loan rate is determined exogenously. The remaining $1 - \tau_2$ of the banks extend free credit (FC) and can choose their loan rates. Considering this, the aggregate loan rate is given by:

$$R_t^L = (R_t^{FC})^{1-\tau_2} (R_t^{DC})^{\tau_2}. \quad (3)$$

Profit maximization by the free credit banks that are allowed to set their loan rates optimally leads to the following first-order condition:

$$E_t \sum_{l=0}^{\infty} \tau^l \Lambda_{t,t+l} L_{t+l}(k) \left[R_t^{L*}(k) - \frac{\zeta}{\zeta - 1} R_{t+l}^M \right] = 0, \quad (4)$$

where $R_t^{L*}(k)$ is the optimal loan rate and $\Lambda_{t,t+l}$ is the stochastic discount factor. Using the loan demand and solving the equation (4) for the optimal loan rate gives:

$$R_t^{L*}(k) = \frac{\zeta}{\zeta - 1} \frac{E_t \left[\sum_{l=0}^{\infty} \tau^l \Delta_{t,t} (R_{t+l}^L)^{\zeta} L_{t+l} R_{t+l}^M \right]}{E_t \left[\sum_{l=0}^{\infty} \tau^l \Delta_{t,t} (R_{t+l}^L)^{\zeta} L_{t+l} \right]}, \quad (5)$$

which is identical for all banks, $R_t^{L*}(k) = R_t^{L*}$. Banks are assumed, in contrast to firms and households, to re-optimize their loan rates in each period after the realization of any disturbances.

Free credit banks face frictions when setting their loan rates. Following [Calvo \(1983\)](#), we assume that only a fraction $1 - \tau_1$ of free credit banks re-optimize their loan rates in each period, while the remaining fraction τ_1 keeps their loan rates unchanged:

$$R_t^{FC} = \left[(1 - \tau_1)(R_t^{L*})^{1-\zeta} + \tau_2(R_{t-1}^{FC})^{1-\zeta} \right]^{\frac{1}{1-\zeta}}. \quad (6)$$

2.2 Interest Rate Pass-Through

We linearize the (3), (5) and (6) by a first-order Taylor-series expansion, which gives:

$$R_t^L = \frac{(1 - \tau_2)\beta\tau_1}{1 + \beta\tau_1^2} E_t(R_{t+1}^{FC}) + \frac{(1 - \tau_2)\tau_1}{1 + \beta\tau_1^2} R_{t-1}^{FC} + \frac{(1 - \tau_2)(1 - \beta\tau_1)(1 - \tau_1)}{1 + \beta\tau_1^2} R_t^M + \tau_2 R_t^{CD}. \quad (7)$$

The equation (7) show that the evolution of the aggregate loan rate depends on the relevance of the parameters τ_1 and τ_2 . If τ_1 and τ_2 go to zero, the aggregate loan rate tends to equal the money rate and the pass-through becomes complete.

2.3 Additional Considerations on Loan Rates

We assume additionally that the loan rate of the directed credit (R_t^{DC}) is constant over time:

$$R_t^{DC} = \bar{R}^{DC}. \quad (8)$$

Besides, considering that there is not enough information about the aggregate loan rate for the Brazilian economy, we replace R_t^L in equation (7), in order to determine the equation of the dynamics of the free credit loan rate:

$$R_t^{FC} = \frac{\beta\tau_1}{1 + \beta\tau_1^2} E_t(R_{t+1}^{FC}) + \frac{\tau_1}{1 + \beta\tau_1^2} R_{t-1}^{FC} + \frac{(1 - \beta\tau_1)(1 - \tau_1)}{1 + \beta\tau_1^2} R_t^M. \quad (9)$$

2.4 The Linearized Model

The following equations consist the log-linear approximation of the relevant model equations around the symmetric equilibrium steady state with zero inflation. The representation \hat{X}_t denotes the log-linear deviation from the steady-state value of the variable X , $\hat{X}_t = \ln(X_t) - \ln(\bar{X}_t)$, where \bar{X}_t is the steady-state value.

The dynamics of real product (\hat{Y}_t) is described by the equilibrium of the goods market:

$$\hat{Y}_t = \gamma_c \hat{C}_t + (1 - \gamma_c) \hat{I}_t + \alpha \left(1 - \frac{1}{\epsilon} \right) \hat{u}_t, \quad (10)$$

where \hat{C}_t is the consumption, \hat{I}_t is the investment and

$$\gamma_c = 1 - \left[\alpha \delta \left(1 - \frac{1}{\epsilon} \right) / \left(\frac{1}{\beta} - 1 + \delta \right) \right].$$

The consumption and investment equations are given by:

$$\hat{C}_t = \frac{1}{1+h} E_{t-1} \hat{C}_{t+1} + \frac{h}{1+h} \hat{C}_{t-1} - \frac{1-h}{(1+h)\sigma} E_{t-1} (\hat{R}_t^M - \pi_{t+1}), \quad (11)$$

$$\hat{I}_t = \frac{\beta}{1+\beta} E_{t-1} \hat{I}_{t+1} + \frac{1}{1+\beta} \hat{I}_{t-1} + \frac{1}{\bar{S}''(1+\beta)} E_{t-1} \hat{Q}_t, \quad (12)$$

h is the external habit formation, the inflation rate π_t is defined as $\pi_t = \hat{P}_t - \hat{P}_{t-1}$, \hat{Q}_t is the real shadow price of installed capital (Tobin's Q) and \bar{S}'' are investment adjustment costs.

The equations of real shadow value of capital, capital accumulation, real rental rate of capital and capital utilization are respectively:

$$\hat{Q}_t = \beta(1-\delta) E_{t-1} \hat{Q}_{t+1} + [1-\beta(1-\delta)] E_{t-1} \hat{r}_{t+1}^k - E_{t-1} (\hat{R}_t^M - \pi_{t+1}). \quad (13)$$

$$\hat{K}_t = (1-\delta) \hat{K}_{t-1} + \delta \hat{I}_t, \quad (14)$$

$$\hat{r}_t^K = \hat{Y}_t - \hat{u}_t - \hat{K}_{t-1} + \hat{\varphi}_t. \quad (15)$$

$$\hat{u}_t = \psi \hat{r}_t^K, \quad (16)$$

where $\psi = \Psi'(1)/\Psi''(1)$, assuming that the utilization rate equals one in steady state.

The evolution of inflation is described by the following New Keynesian Phillips curve:

$$\pi_t = \gamma_f E_{t-1} \pi_{t+1} + \gamma_b \pi_{t-1} + \kappa_p E_{t-1} \hat{\varphi}_t, \quad (17)$$

where:

$$\begin{aligned} \gamma_f &= \frac{\beta \theta_p}{\theta_p + \omega_p [1 - \theta(1 - \beta)]}, \\ \gamma_b &= \frac{\omega_p}{\theta_p + \omega_p [1 - \theta(1 - \beta)]}, \\ \kappa_p &= \frac{(1 - \theta_p)(1 - \beta \theta_p)(1 - \omega_p)}{\theta_p + \omega_p [1 - \theta(1 - \beta)]}. \end{aligned}$$

The parameter κ_p measures the sensitivity of inflation with respect to real marginal costs ($\hat{\varphi}_t$) which are given by:

$$\hat{\varphi}_t = \alpha \hat{r}_t^k + (1 - \alpha)(\hat{W}_t - \hat{P}_t + \nu \hat{R}_t^L). \quad (18)$$

The real marginal costs, and consequently the inflation, depend on the gross loan rate as emphasized by the cost channel of monetary policy.

The nominal wage inflation ($\Delta \hat{W}_t$) is given by:

$$\begin{aligned} \Delta \hat{W}_t &= \beta \rho_1 E_{t-1} \Delta \hat{W}_{t+1} + \omega_w \rho_1 \Delta \hat{W}_{t-1} - \beta \theta_w \rho_2 E_{t-1} \pi_t \\ &\quad + \rho_2 \pi_{t-1} + \kappa_w E_{t-1} [\hat{M} \hat{R} S_t - \hat{W}_t + \hat{P}_t], \end{aligned} \quad (19)$$

where:

$$\rho_1 = \frac{\theta_w}{\omega_w + \theta_w [1 - \omega_w (1 - \beta \theta_w)]},$$

$$\rho_2 = \frac{\omega_w(1 - \theta_w)}{\omega_w + \theta_w[1 - \omega_w(1 - \beta\theta_w)]},$$

$$\kappa_w = \frac{(1 - \theta_w)(1 - \beta\theta_w)(1 - \omega_w)}{\omega_w + \theta_w[1 - \omega_w(1 - \beta\theta_w)](1 + \eta\phi)}.$$

Nominal wage inflation is determined by future expected and past nominal wage inflation, by the current and past inflation rate and by the gap between the marginal rate of substitution ($\hat{M}\hat{R}S_t$) and the real wage ($\hat{W}_t - \hat{P}_t$). The expression for $\hat{M}\hat{R}S_t$ are:

$$\hat{M}\hat{R}S_t = \frac{\eta}{1 - \alpha}\hat{Y}_t - \frac{\alpha\eta}{1 - \alpha}(\hat{u}_t + \hat{K}_{t-1}) + \frac{\sigma}{1 - h}(\hat{C}_t - h\hat{C}_{t-1}). \quad (20)$$

The dynamic of the gross loan rate is given by:

$$\hat{R}_t^L = \beta v_1 E_t(\hat{R}_{t+1}^{FC}) + v_1(1 - \tau_2)\hat{R}_{t-1}^{FC} + v_2\hat{R}_t^M, \quad (21)$$

where:

$$v_1 = \frac{\tau_1(1 - \tau_2)}{1 + \beta\tau_1^2},$$

$$v_2 = \frac{(1 - \beta\tau_1)(1 - \tau_1)(1 - \tau_2)}{1 + \beta\tau^2}.$$

The loan rate is determined by the expected future loan rate, the past loan rate and the money market rate. The immediate pass-through from changes in the money market rate to changes in the loan rate becomes complete, if τ_1 and τ_2 goes to zero, which implies that $\hat{R}_t^L = \hat{R}_t^M$.

Equations (8) and (9) imply that the dynamic of aggregate free credit loan rate is given by:

$$\hat{R}_t^{FC} = \beta \iota_1 E_t(\hat{R}_{t+1}^{FC}) + \iota_1\hat{R}_{t-1}^{FC} + \iota_2\hat{R}_t^M, \quad (22)$$

where:

$$\iota_1 = \frac{\tau_1}{1 + \beta\tau_1^2},$$

$$\iota_2 = \frac{(1 - \beta\tau_1)(1 - \tau_1)}{1 + \beta\tau_1^2}.$$

From equations (21) and (22), it follows that:

$$\hat{R}_t^L = (1 - \tau_2)\hat{R}_t^{FC}. \quad (23)$$

Finally, we close the model by specifying the reaction function of the central bank which is described by the following log-linearized interest rate rule:

$$\hat{R}_t^M = \mu_1\hat{R}_{t-1}^M - \mu_2\hat{R}_{t-2}^M + (1 - \mu_1 - \mu_2) \left[\frac{\mu_\pi}{4} \sum_{s=0}^3 \pi_{t-s} + \frac{\mu_{\hat{Y}}}{2} E_t(\hat{Y}_{t+1} + \hat{Y}_{t+2}) \right] + \mu_{\Delta\hat{Y}}\Delta\hat{Y}_t + z_t^M. \quad (24)$$

The parameters μ_1 and μ_2 capture the degree of interest rate smoothing, μ_π is the reaction coefficient with respect to the present and past inflation rate, $\mu_{\hat{Y}}$ is the reaction coefficient with respect to the expected future output gap, $\mu_{\Delta\hat{Y}}$ is the coefficient of the change of the output gap and z_t^M is the monetary policy shock.

3 Empirical Methodology

We estimate the log-linear version of the DSGE model described in the previous section for the Brazilian economy in order to analyze the relevance of the cost channel of monetary policy, the interest rate pass-through and the directed credit. We apply the minimum distance approach as in [Christiano et al. \(2005\)](#), [Carrillo et al. \(2007\)](#), [Henzel et al. \(2009\)](#) e [Hülsewig et al. \(2009\)](#). This estimation method consists in two steps. First, a VAR model is specified to generate the empirical impulse-response functions, in our case, to a monetary policy shock. Second, the model parameters are estimated in order to approximate, as close as possible, the theoretical and empirical impulse-response functions.

3.1 Monetary Policy Shock and VAR Model

As [Christiano et al. \(2005\)](#), we define the monetary policy by the following equation:

$$R_t = f(\Phi_t) + \epsilon_t, \quad (25)$$

where R_t is the short-term interest rate (monetary instrument), f is a linear function, Φ_t is a set of information and ϵ_t is the monetary policy shock. We assume that the central bank allows money growth to guarantee that equation (25) holds in any circumstances and ϵ_t is orthogonal to the elements in Φ_t .

Considering the characterization of the monetary policy, the VAR model estimated for the Brazilian economy has the following specification:

$$\mathbf{Z}_t = A(L)\mathbf{Z}_{t-l} + \varepsilon_t, \quad (26)$$

where \mathbf{Z}_t is the endogenous variables vector, $A(L)$ is the parameters matrix and ε_t is the errors vector that we assume to be white noise. The vector \mathbf{Z}_t is composed by:

$$\mathbf{Z}_t = (GDP_t, INF_t, WINF_t, CPI_t, RM_t, RL_t), \quad (27)$$

where GDP_t is the real product, INF_t is the inflation rate, $WINF_t$ is the nominal wage inflation rate, CPI_t is the commodities price inflation rate, RM_t is the monetary policy rate and RL_t is the loan rate.

The responses of the variables in \mathbf{Z}_t to a monetary policy shock are estimated by the VAR model. The identification of the shock is made by applying the Choleski (recursive) decomposition. The variables ordering implies that the real product, inflation rate, nominal wage inflation rate and the commodities price inflation rate are affected by a monetary policy shock with a lag, while the monetary policy interest rate and the loan rate are contemporaneously affected. This identification scheme is debatable but the analysis is internally consistent in the sense that we make the same assumptions in the theoretical model.

3.2 Minimum Distance Approach

We estimate part of model parameters by minimizing the distance between the empirical and theoretical impulse response functions. The set of estimated parameters (ϱ) are:

$$\varrho = (h, \theta_p, \omega_p, \theta_w, \omega_w, \mu_1, \mu_{\hat{Y}}, \mu_\pi, \tau, \bar{S}''', \mu_2, \mu_{\Delta\hat{Y}}, \nu).$$

The estimator minimize the following distance function ([Christiano et al., 2005](#)):

$$J = (\hat{\Gamma} - \Gamma(\varrho))' \mathbf{V}^{-1} (\hat{\Gamma} - \Gamma(\varrho)), \quad (28)$$

where $\hat{\Gamma}$ is the empirical impulse-response function, $\Gamma(\varrho)$ is the theoretical function and V is the weighting matrix, with the sample variances of $\hat{\Gamma}$ on the diagonal. The weighting matrix assures that those point estimates with a smaller standard deviation are given a higher priority⁵ (Hülsewig et al., 2009).

The other parameters are calibrated based on empirical evidence obtained from real economy data and, in some cases, observed on previous studies. The calibration of a subset of parameters is an usual practice in the case of the estimation of DSGE models because some parameters cannot be identified by applying an unrestricted estimation strategy. The decision of which parameters will be estimated is, on the other hand, rarely discussed and vary among the studies. Our choose of calibrated parameters follows Hülsewig et al. (2009).

According to Smets and Wouters (2003), the estimation of DSGE models by using a method that aims to aproximate as close as possible the theoretical and the data moments, as the minimum distance approach, has two advantages: these methods allows highlighting the features of the data for which the model is more relevant; and, the moments estimators frequently are more robusts than the maximum likelihood methods.

Still, it is important to point out that the maximum likelihood methods can incur in the problem of the stochastic singularity. More specifically, the DSGE models solutions determine identities that involve the variables, and, if these identities is not satisfied by the data, any attempt to adjust the model by using maximum likelihood methods won't be successful (Tovar, 2009). The stochastic singularity tend to occur when the number of theoretical shocks is lower than the number of the observable endogenous variables (Boivin and Gianoni, 2006). Our model considers only one economic shock, therefore the minimum distance approach is more properly to estimate the parameters.

3.3 Data

We use quartely data (2000:3 - 2013:4)⁶ of the log of the GDP chain index (IBGE), the inflation measured by the annualized quarterly change of GDP deflator (IBGE), the nominal wage inflation measured by annualized quarterly change of the usual nominal average income of the main job index (IBGE), annualized quarterly change of the commodities price index (FMI), short-term nominal interbank interest rate, Over-Selic (Central Bank of Brazil), and the average bank lending rate for free credit (Central Bank of Brazil).

4 Results

4.1 Theoretical Model Estimation

Figure 1 shows the graphics of the impulse-response functions of each VAR model variable to a monetary policy shock which is given by an increase of about 1.0 p.p. in the Selic interest rate⁷. The length of the responses is equal to 20 periods for all graphics. Real GDP decreases

⁵As Hülsewig et al. (2009), we use the MATLAB routine *fmincon* to solve this minimization problem, which attempts to find a constrained minimum of a scalar function of several variables starting at a initial estimate. The vector of initial conditions is $\varrho_0 = (0,5 \ 0,5 \ 0,5 \ 0,5 \ 0,5 \ 1,5 \ 1,5 \ 1,1 \ 0,5 \ 2,5 \ 0,5 \ 1,5 \ 0,5)$, which is the mean of the lower $\varrho_- = (0,0 \ 0,0 \ 0,0 \ 0,0 \ 0,0 \ 1,0 \ 0,0 \ 1,0 \ 0,0 \ 0,0 \ 0,0 \ 0,0 \ 0,0)$ and upper bounds $\varrho_+ = (1,0 \ 1,0 \ 1,0 \ 1,0 \ 1,0 \ 2,0 \ 3,0 \ 2,0 \ 1,0 \ 5,0 \ 1,0 \ 3,0 \ 1,0)$ of the constrained optimization.

⁶We choose the data period based on Vasconcelos and Divino (2012). These authors argue that, starting after the adoption of the inflation target regime by the Brazilian government in 1999, we avoid the inflationary instability period.

⁷The VAR model was estimated with two lags and three dummy variables. The first dummy is 1 in 2003:1 and 2003:2 that is the transition period between the governments of the presidents Fernando Henrique Cardoso

gradually until the second period after the shock when reaches a negative variation equal to 0.4%, then the shock tends to slowly dissipate. Inflation rate increases in the first period after the shock, then gradually decreases until the seventh period, after this it tends to back to the baseline. The first movement of inflation reflects the price-puzzle despite of the explicit introduction of the inflation of the commodities price. Nominal wage inflation also presents an positive variation in the first period after the shock but the confidence interval includes negative values. Finally, loan rate behaves very similar to Selic⁸.

It is worth to stress that the variable dynamics is similar to that one reported by [Hülsewig et al. \(2009\)](#) in a study for euro area in the case of real GDP, inflation and interest rates. There is a difference in the behaviour of the nominal wage inflation that, in the referred study, do not increase in the first period after the shock.

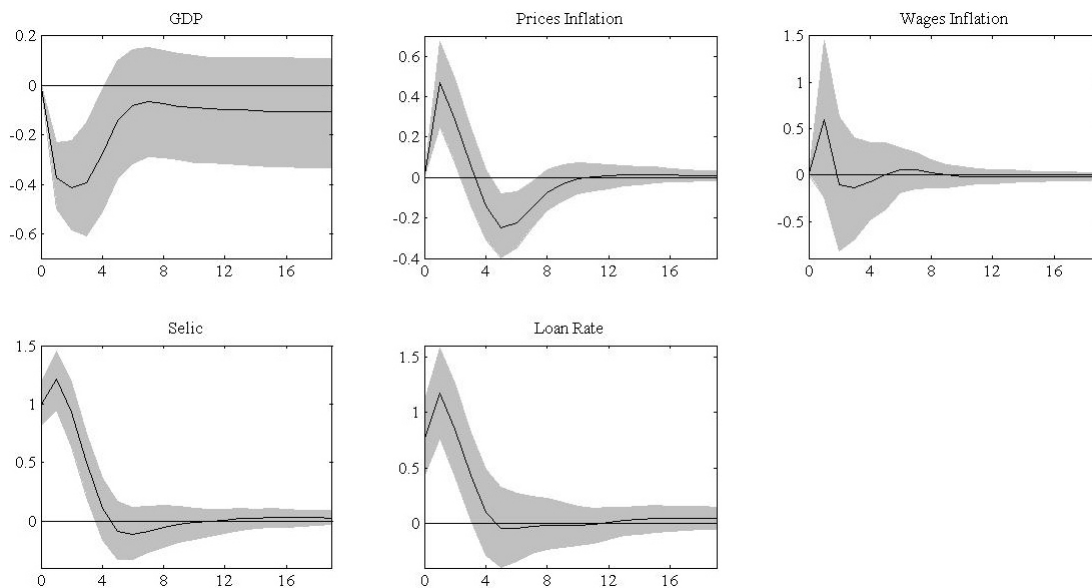


Figure 1: Monetary Policy shock

Note: The horizontal axis is in quarters. The solid lines denote the impulse-responses which are calculated as the mean derived from a bootstrap procedure with 2000 replications. The shaded areas are 95% confidence intervals of the bootstrapped impulse-responses

A subset of the model parameters was calibrated based on empirical evidences obtained from Brazilian economy informations. The calibrated values are also in line with the values used by other studies e.g. [Christiano et al. \(2005\)](#), [Smets and Wouters \(2003\)](#), [Smets and Wouters \(2007\)](#), [Rabanal and Rubio-Ramírez \(2007\)](#), [Hülsewig et al. \(2009\)](#), [Vereda and Cavalcanti \(2010\)](#), [Cavalcanti and Vereda \(2011\)](#), [Carvalho and Valli \(2011\)](#) and [Vasconcelos and Divino \(2012\)](#), the last four are specific to Brazil. Tabel 1 show the used values. Discount factor β is equal to 0.99 which implies that the steady-state real interest rate is equal to 4% in a quartely model. The utility function elasticities σ and η are equal to 2. The share of capital in the output (α) is fixed to 0.3. Depreciation rate (δ) is equal to 0.025 which implies an annual depreciation of capital equal to 10%. The parameters ϕ and ϵ are equal to 11, implying steady-state mark-ups of prices and wages equal to 10% in the steady-state. Capital

and Luís Inácio Lula da Silva and 0 otherwise. The second dummy is equal to 1 in 2002:2 and 0 otherwise to deal with an outlier in nominal wage inflation data that is a result of a methodology change of the research. Finally, the third dummy is 1 in 2008:4 and 2009:1 that is the peak of the effects of the last financial crisis in Brazil and 0 otherwise. We perform VAR model specification tests, the results of these tests are in the appendix.

⁸Once we consider the commodities price only as a control variable, its response was not reported in the figure 1. As robustness analysis, the VAR model was estimated considering the commodities price as an exogenous variable. The results were basically the same.

utilization elasticity ψ is set to 100. Finally, τ_2 is equal to 0.4, implying that the proportion of the banks that operate directed credit is 40% which is roughly the average proportion of the volume of this modality of credit in Brazil during 2013.

Table 1: Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.99
σ	Degree of risk aversion	2.00
η	Labor supply elasticity	2.00
ϕ	Households monopoly power	11.00
δ	Depreciation rate	0.025
α	Output share of capital	0.30
ϵ	Firms monopoly power	11.00
ψ	Capital utilization elasticity	100.00
τ_2	Proportion of the banks that operate directed credit	0.40

The remaining parameter of the model is estimated by the minimization of the distance between the empirical and theoretical impulse-response functions. Figure 2 show the result of this approximation procedure. The estimated model seems to be able to replicate the data once the theoretical impulse-response functions lie inside the empirical confidence interval.

Table 2 shows the estimates obtained to the parameters in vector ϱ and their respective standard deviation values. The degree of habit formation in consumption (h) is equal to 0.99, implying that the consumption response to a monetary policy is strongly driven by the habits and the policy has a tiny direct effect. This value is greater than the values reported in other studies for Brazilian economy e.g. [Carvalho and Valli \(2011\)](#) and [Vasconcelos and Divino \(2012\)](#) that estimated something around 0.6, however it is more close to the 0.825 used by [Vereda and Cavalcanti \(2010\)](#).

The estimate of the adjustment cost of investment (\bar{S}'') is 2.44. This value is close to the 2.35 estimated by [Carvalho and Valli \(2011\)](#) for Brazilian economy.

The results also indicate a low degree of price rigidity. Parameter θ_p is equal to 0.18. On the other hand, the share of the firms that adopt the indexation rule (ω_p) is significant being equal to 0.35.

Wage rigidity is high. The estimate of θ_w and ω_w are equal to 0.98 and 0.80 respectively. These results are in line with [Vereda and Cavalcanti \(2010\)](#), [Cavalcanti and Vereda \(2011\)](#), [Carvalho and Valli \(2011\)](#) e [Vasconcelos and Divino \(2012\)](#).

There is no strong evidence of incomplete interest rate pass-through once the parameter τ_1 is equal to 0.36 i.e. 36% of the free credit banks cannot re-adjust their loan rates. Therefore, the financial market shows a low degree of rigidity in Brazil.

The result for parameter ν is an evidence for the relevance of the channel cost of monetary policy. This parameter is equal to 1.00 i.e. 100% of the firms depend on bank lending to finance the production and, consequently, an increase of the interest rate promotes in an increase of the production costs.

Finally, the estimates for the Taylor rule parameter are the following: inflation coefficient (μ_π) is equal to 1.05, output *gap* coefficient ($\mu_{\hat{Y}}$) is 0.02, growth rate of the output gap coefficient ($\mu_{\Delta\hat{Y}}$) is 0.68 and the degree of interest rate smoothing that is given by the difference between the autorregressive coefficients (μ_1 and μ_2) is equal to 0.74⁹.

⁹The smoothing degree value is similar to the ones estimated by [Vereda and Cavalcanti \(2010\)](#), [Cavalcanti and Vereda \(2011\)](#), [Carvalho and Valli \(2011\)](#) e [Vasconcelos and Divino \(2012\)](#).

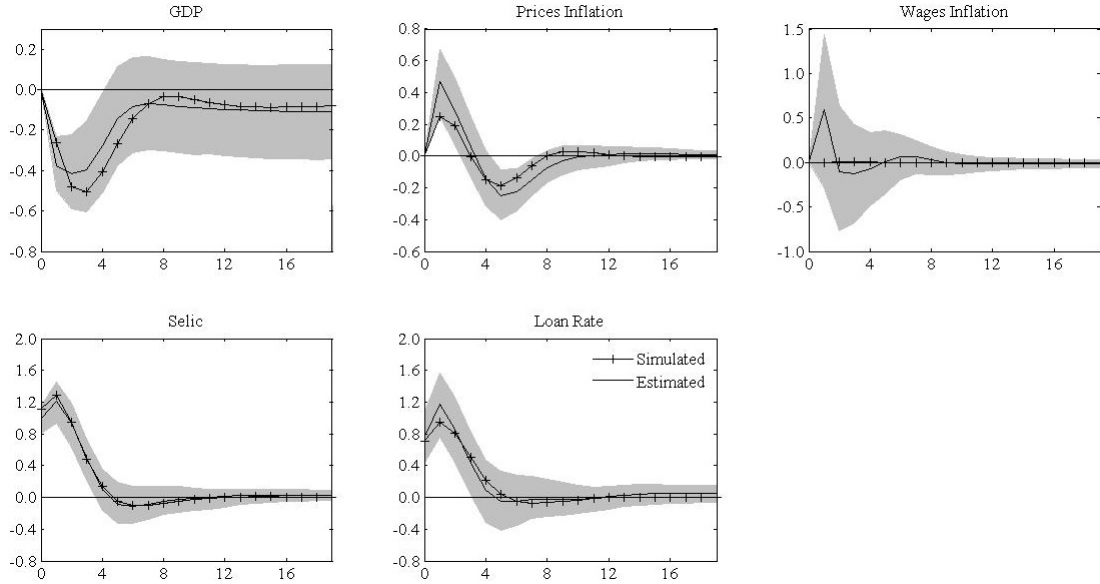


Figure 2: IRFs Matching

Note: The horizontal axis is in quarters. The solid lines denote the impulse-responses which are calculated as the mean derived from a bootstrap procedure with 2000 replications. The shaded areas are 95% confidence intervals of the bootstrapped impulse-responses. The marked lines are the theoretical impulse-response functions.

Table 2: Estimated Parameters

Parameter	Description	Coefficient	Std. Dev.
h	Habit formation	0.99	0.21
θ_p	Price stickiness	0.18	0.60
ω_p	Degree of price indexation	0.35	0.32
θ_w	wage stickiness	0.98	0.04
ω_w	Degree of wage indexation	0.80	0.58
\bar{S}''	Investment adjustment costs	2.44	1.86
μ_1	Taylor rule: smoothing	1.41	0.39
μ_2	Taylor rule: smoothing	0.67	0.37
$\mu_{\hat{Y}}$	Taylor rule: output	0.02	0.48
μ_{π}	Taylor rule: inflation	1.05	0.39
$\mu_{\Delta \hat{Y}}$	Taylor rule: growth	0.68	0.13
τ_1	Loan rate stickiness	0.36	0.43
ν	Share of cost channel firms	1.00	0.61

Note: the value of distance function is 46.28 with a probability of 0.99. The probability is calculated by employing a χ^2 distribution with 84 degrees of freedom. The number of degrees of freedom is calculated as the difference between the number of estimated observations on the impulse-response functions (97) and the number of estimated parameters (13). As the value of the distance function is below the 1% critical value, the imposed overidentifying restrictions cannot be rejected.

4.2 Scenarios Analysis

We equal the proportion of firms that depends on credit to finance the production to zero ($\nu = 0$) in order to analyze the relevance of the cost channel. The other parameters of the model still with the values previously estimated. Figure 3 shows the effects of this modification in terms of the responses of the variables to a monetary policy shock. Marginal costs

and inflation do not increase after a monetary policy shock immediately after the shock when $\nu = 0$. It is not possible to notice by figure 3 that inflation in fact decreases a little since the first period after the shock. The behaviour of the inflation is better depicted by figure 4. This is an evidence that the cost channel plays a relevant role in the transmission of the monetary policy in Brazil, helping to explain the price-puzzle observed in the VAR model estimation. This result corroborates with [Martins \(2011\)](#), for Brazilian economy, and the empirical evidence of other studies e.g. [Barth and Ramey \(2002\)](#), [Gaiotti and Secchi \(2006\)](#), [Christiano et al. \(2005\)](#), [Ravenna and Walsh \(2006\)](#), [Chowdhury et al. \(2006\)](#), [Tillmann \(2008\)](#), [Hülsewig et al. \(2009\)](#). On the other hand, the response of the GDP does not present a significant change, implying, in this case, that the monetary policy works by the demand side.

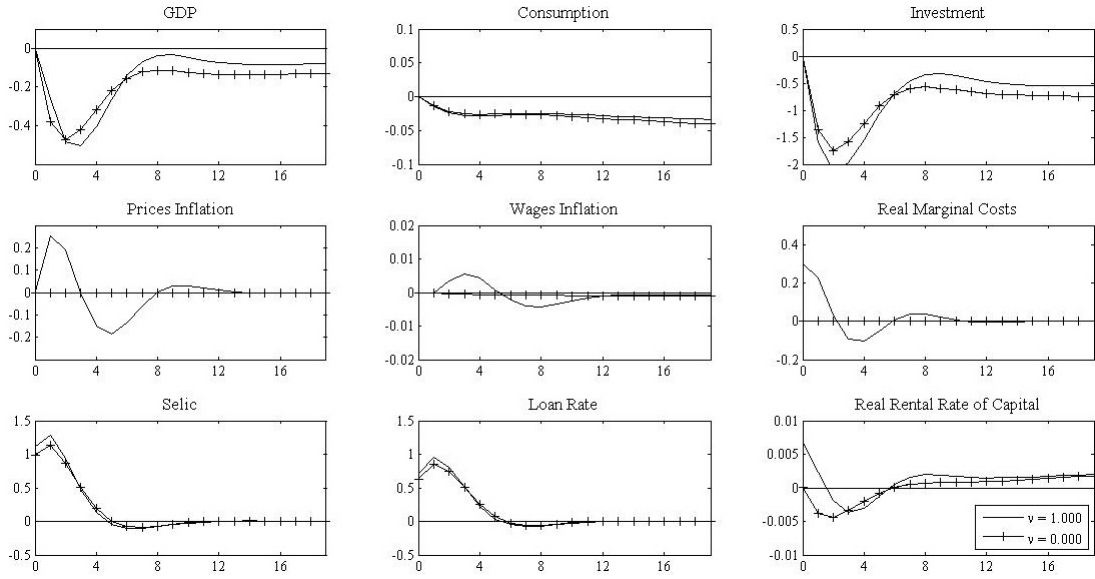


Figure 3: Monetary policy shock without Cost Channel

Note: Solid lines denote the responses of the model considering $\nu = 1.00$ and the marked lines denote the responses of the model considering $\nu = 0$.

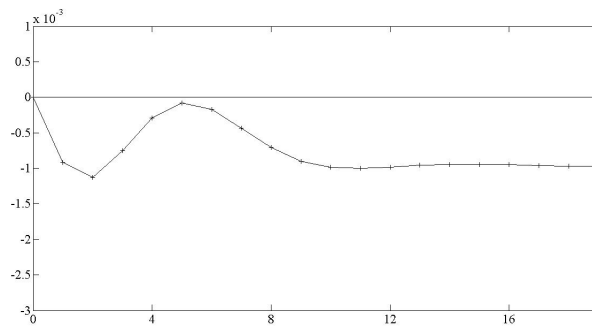


Figure 4: Inflation Response to a Monetary Policy Shock without Cost Channel

Figure 5 presents the model variable responses to a monetary policy shock in a scenario of complete interest rate pass-through ($\tau_1 = 0$). The modification in the value of τ_1 doesn't change the response of any variable significantly, except the loan rate that in this scenario respond the shock in the same intensity of the Selic. Therefore, it seems that there is no rigidity in the financial market in Brazil, at least in terms of free credit.

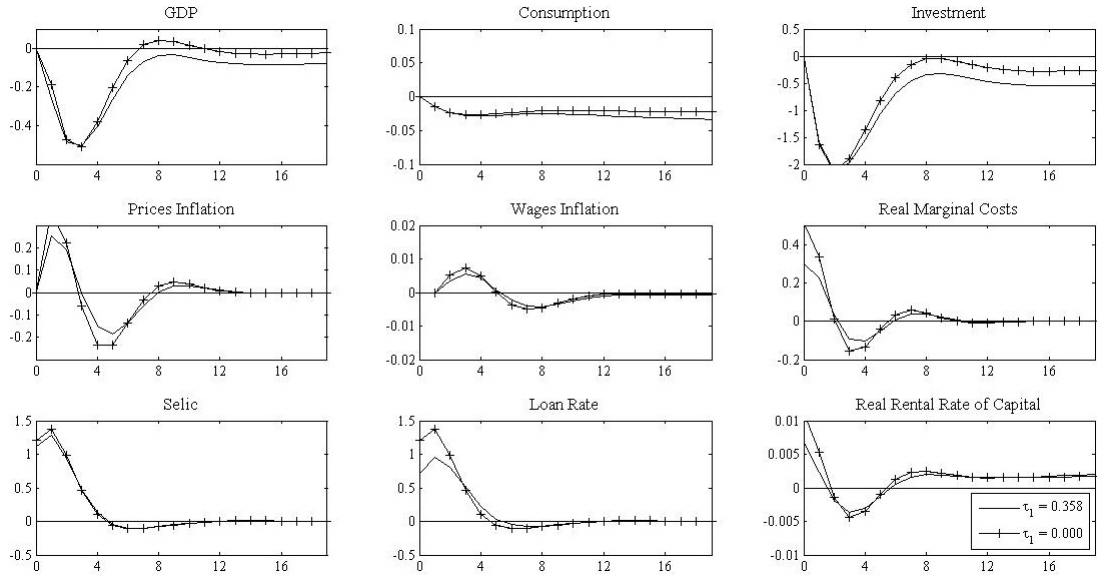


Figure 5: Monetary Policy Shock with Complete Interest Rate Pass-Through

Note: Solid lines denote the responses of the model considering $\tau_1 = 0.36$ and the marked lines denote the responses of the model considering $\tau_1 = 0$.

Figure 6 shows the responses of the variables to a monetary policy shock in a scenario in which there is no directed credit ($\tau_2 = 0$). The responses of real GDP, investment, inflation, nominal wage inflation, marginal costs and rental rate are intensified. This result indicates that the higher is the directed credit share, the lower is the influence of the monetary policy. Again, the consumption response don't change substantially, implying that its dynamics is mostly determined by habit formation.

Considering that there is no evidence of limited interest rate pass-through, at lower levels of directed credit share, the monetary policy potentializes its effect on the credit conditions because the free credit loan rate becomes more representative. More specifically, A contractionary monetary policy given by an increase in the interest rate promotes a more significant increase in the loan rate. Then, the effect of the monetary policy in the financial costs of the firms will also be intensified, increasing consequently the price-puzzle.

This result corroborates the findings of [Sato \(2013\)](#) and [Santin \(2013\)](#). According to [Sato \(2013\)](#), the monetary policy promotes significant change in the supply of credit in Brazil but the impact of the credit conditions on production is reduced. To [Santin \(2013\)](#), the force of the monetary policy decreases with the adoption of credit policies, specially, the inflation rigidity becomes higher.

5 Conclusions

We aimed to analyze the cost channel of monetary policy in Brazil, highlighting the role played by the banks. For that, we developed a DSGE New-Keynesian model in which: the aggregate loan rate directly influences the cost of the firms; the interest rate pass-through may be limited; and, part of the loans is made by directed credit.

We estimate the model for Brazilian economy by using the Minimum Distance approach. The results indicated that: there is a high level of price rigidity; there is no evidence of interest rate incomplete pass-through; the cost channel is relevant to explain the inflation dynamics (and the price-puzzle) after a monetary policy shock; and, the directed credit participation reduces the monetary policy capacity of modifying the credit conditions.

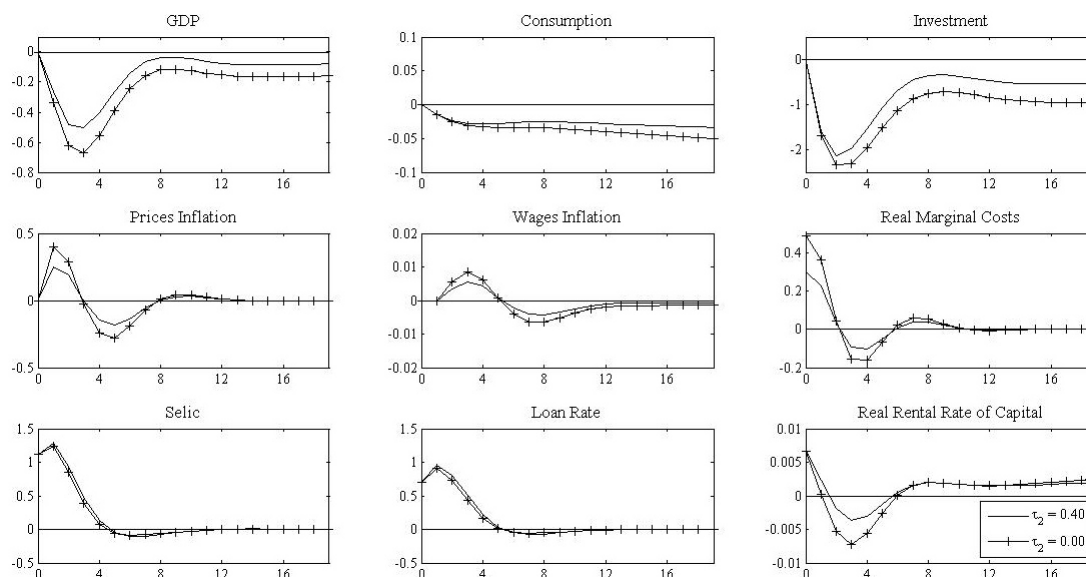


Figure 6: Monetary Policy Shock without Directed Credit

Note: Solid lines denote the responses of the model considering $\tau_2 = 0.40$ and the marked lines denote the responses of the model considering $\tau_2 = 0$.

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Appendix A. VAR Model Series and Specification Tests

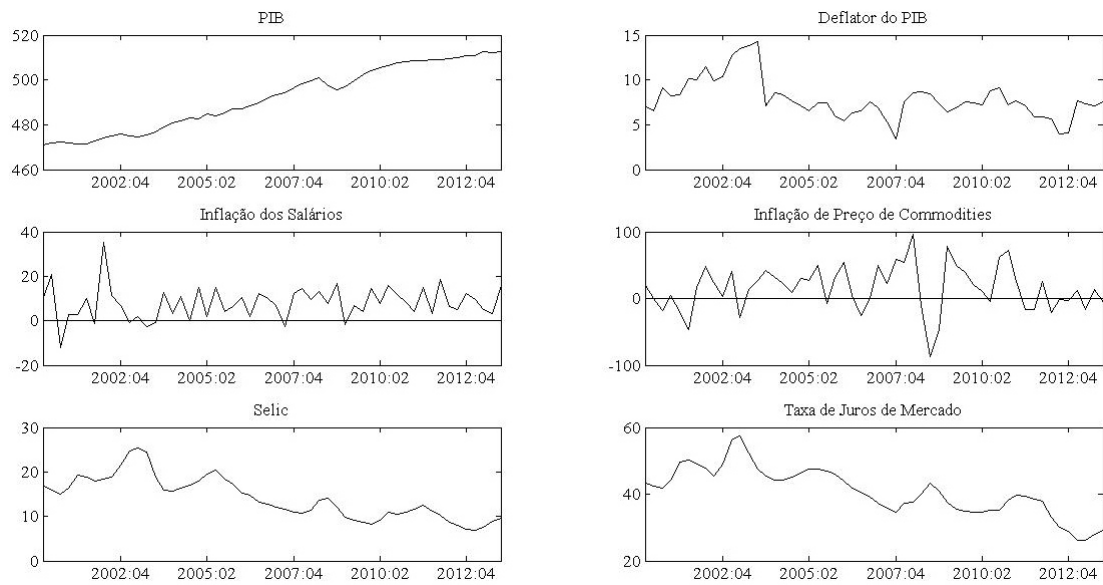


Figure 7: VAR Model Series

Table 3: VAR Model Specification Tests

Test		Distribution	Test Statistic	P-Value
Autocorrelation				
	LM[1]	$\chi^2_{(36)}$	33,87481	0,57005
	LM[4]	$\chi^2_{(144)}$	152,69269	0,29413
Normality				
	Doornik-Hansen	$\chi^2_{(12)}$	8,48423	0,74624