# **Regime-dependent “price puzzle” in the Brazilian economy: evidence from VAR and FAVAR Approaches**

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## **Abstract**

## The paper examines the effectiveness of the monetary policy instrument in the Brazilian economy. More precisely, we estimate the Central Bank reaction function using the standard VAR and FAVAR models to investigate the presence of the “price puzzle”, considering the period from July 2003 to December 2016. The hypothesis to be tested is whether the “price puzzle”, found in previous empirical studies, consists of a model misspecification or a characteristic of the Brazilian economy. The results suggest that the puzzling response of prices to a monetary policy tightening is persistent, standing out as a characteristic of the economy only in periods of economic slowdown. We find evidence that the “price puzzle” anomaly is regime dependent, the price index responds differently to a monetary policy contraction in periods of economic slowdown when compared to expansions. Hence, we argue that the use of the short-term interest rate, as inflation rate control instrument, presents inconsistent results. The Central Bank should consider the use of the interest rate to control inflation only in moments of economic “booms”, when we do not observe the perverse response of prices. Additionally, the monetary authority should incorporate such regime dependent response of prices into its conduct and, when appropriate, select alternative monetary policy instruments to target the inflation rate.

**Key words**: Monetary policy transmission mechanism; price puzzle; VAR; FAVAR.

**Resumo**

O artigo examina a efetividade do instrumento de política monetária na economia brasileira. Mais precisamente, nós estimamos a função de reação do Banco Central utilizando os modelos VAR e FAVAR padrões para investigar a presença do “price puzzle”, considerando o período de julho de 2003 a dezembro de 2016. A hipótese a ser testada é se o “price puzzle”, encontrado nos estudos empíricos anteriores, consiste de uma má especificação do modelo ou de uma característica da economia brasileira. Os resultados sugerem que a resposta inesperada dos preços a um aperto na política monetária é persistente, destacando-se como uma característica da economia nos períodos de desaceleração econômica. Nós encontramos evidência de que o “price puzzle” é dependente do regime, o índice de preços responde de forma diferente a uma contração da política monetária em períodos de desaceleração econômica quando comparado aos momentos de expansão. Portanto, nós argumentamos que o uso da taxa de juros de curto prazo, como um instrumento de controle da inflação, apresenta resultados inconsistentes. O Banco Central deveria considerar o uso da taxa de juros no controle inflacionário apenas nos momentos de “booms” econômicos, quando nós não observamos a resposta perversa dos preços. Adicionalmente, a autoridade monetária deveria incorporar a dependência da resposta dos preços ao regime econômico na sua conduta, e quando apropriado, selecionar instrumentos de política monetária alternativos para atingir a inflação.

**Palavras Chave: Mecanismo de transmissão da política monetária; price puzzle; VAR; FAVAR**

**Jel Classification:** E52, E58, E59

**Area 4 – Macroeconomia, Economia Monetária e Finanças**

# **Introduction**

During the 1990s and 2000s, a growing number of countries implemented formal inflation rate targets, usually associated with the adoption of floating exchange rate regimes (Baxa et al., 2014). Since 1999 the Brazilian Central Bank has implemented two major changes in the monetary policy: the exchange rate has become floating[[3]](#footnote-3) and the basic interest rate, the SELIC[[4]](#footnote-4), has gained its position as the main monetary instrument used in the “inflation targeting regime”. A question that still ranks among the most controversial in the Brazilian economy is the way monetary policy affects the price level.

The purpose of this article is to examine the effectiveness of the monetary policy instrument used in the Brazilian economy. We investigate the presence of the “price puzzle”, during the period from July 2003 to December 2016. The “price puzzle” occurs when a contractionary monetary policy shock generated in a VAR model is followed by an increase in the price level, rather than a decrease, which contradicts the conventional economic theory (Bernanke et al., 2005; and Sims, 1992). This anomaly can possibly be explained by the analysis of the determinants of inflation. In particular, a rise in the short-term interest rate can affect the price level through various channels: 1) the reduction of inflation expectations; 2) the decline of demand inflation (contraction of investment and consumption); 3) the exchange rate pass-through (ERPT) to the general price level; and 4) the increase of production costs due to the rising cost of capital. Depending on which of these effects are dominant, the final impact on the overall price level may be negative or positive (Juselius, 2001).

The positive correlation between interest rate and inflation has been examined in the literature mainly by models embedding the “cost channel”. Cash-constrained firms must borrow money from financial intermediaries to perform its activities. Since, the interest paid to lenders becomes a component of its marginal cost, a contractionary monetary policy increases the marginal cost of production, affecting the prices of goods and services. This generates a positive correlation between interest rate and aggregate inflation (Ravenna and Walsh, 2006; Henzel, 2009; Tillmann, 2008; and Surico, 2008).[[5]](#footnote-5) Additionally, Ali and Anwar (2016, 2017) argue that a contractionary monetary shock that leads to exchange rate appreciation could put a negative pressure on domestic inflation (ERPT). The “price puzzle” could be reduced or even solved, depending on the degree of the ERPT prevailing in the economy. However, the authors emphasize that in the context of developing economies, the cost channel can be prevalent given the presence of less developed stock markets that forces firms to finance their production via bank loans. Another strand of existing literature suggests that the “prize puzzle” arises due to the omission of relevant variables in the VAR model (Castelnuovo, 2009; Castelnuovo and Surico, 2010; Sims et al., 1992; Christiano et al., 1996, 1999; and Bernanke et al., 2005). Castelnuovo (2009) argues that inflation expectations are strongly influenced by the monetary policy firmness. Therefore, the cost of financing would have a smaller effect on inflation under a firm monetary policy, given its persistence. Likewise, Kapinos (2011) estimates a new-Keynesian DSGE model and concludes that the cost channel can generate the “price puzzle” only in misspecified models, where the anticipated shocks and forward looking monetary policy are not allowed.

According to Sims et al. (1992), Christiano et al. (1999) and Mishkin et al. (2010), the “price puzzle” could possibly be solved by the inclusion of variables that contain information about future inflation, such as commodity prices and inflation expectations. Several authors have estimated the three variable standard VAR model of monetary policy (which consists of aggregate measures of inflation and output, besides a short-term interest rate), with different additional variables, sample periods and identification assumptions (Christiano et al., 1996, 1999; Leeper and Roush, 2003; Hanson, 2004; Brissimis and Magginas, 2006; and Castelnuovo and Surico, 2010). Other researchers argue that the responses of a policy shock are similar whether a Divisia (for example, M4) or the short-term interest rate is used as the policy instrument (Keating et al., 2013; 2014). Giordani (2004) suggests that the output gap should replace the output level to solve the puzzle in the VAR models. Finally, Uhlig (2006) introduces a new strategy to ensure that the VAR model presents only standard economic predictions to shocks, therefore solving the “price puzzle”, the imposition of sign restrictions.

To preserve the degree of freedom the standard VAR model is constrained to employ a small number of variables that is unlikely to span the information set used by Central Banks. Therefore, the implementation of a contractionary monetary policy in anticipation of an expected surge in inflation would be incorrectly understood by researchers, who would interpret the rise in the price level as a consequence of the increase in interest rates. The result would be an incorrect estimation of economic variables responses to monetary innovations (Bernanke et al., 2005; and Sims, 1992).

Bernanke et al. (2005) argue that the FAVAR approach could potentially solve the problem, since the latent factors extracted from a large set of economic indicators would represent more accurately the Central Bank decision-making environment. This strategy would also be more efficient than the *ad hoc* inclusion of variables to solve the puzzle. The authors estimate the Central Bank reaction function for the US economy, for the period from 1959:M01 to 2001:M08. Initially, the “price puzzle” is found in the standard VAR model results. However, the estimation based on the FAVAR brings a significant reduction in the “price puzzle”. The authors conclude that working with the standard VAR leads to biased estimates. Mishkin et al. (2010), Stock and Watson (2005), and Boivin and Giannoni (2008) follow a similar approach to investigate the US economy and Blaes (2009) applies the FAVAR to analyze the Eurozone.

The papers that focus on the Brazilian economy do not directly analyze the Monetary Policy Transmission Mechanism (MPTM) and the “price puzzle” through the FAVAR model. Accordingly, Carneiro and Wu (2004) apply the Ordinary Least Squares (OLS) to estimate the Central Bank reaction function and reveal the presence of the “price puzzle” for the period from 1994 to 2000. Araujo et al. (2015) also find the anomaly for the intervals from 1996 to 2001 and from 2000 to 2013, based on the Markov Switching VAR model. By contrast, Fernandes and Toro (2005), Modenesi (2008), Catao and Pagan (2010), Bezerra et al. (2014), Tomazzia and Meurer (2009) and Cespedes et al. (2008) identify a negative effect of the interest rate on inflation, based on the standard VAR/VEC model and the OLS.

Another relevant aspect of monetary policy refers to the changes brought by the major economic events. Economic history suggests that the instruments and monetary policy channels undergo substantial changes after the occurrence of extreme events, such as financial crises, depressions and wars (Cukierman, 2013). Precisely, the performance of a set of economic variables, such as price indexes and exchange rates could be regime-dependent. The key point is that in one regime the disturbances to the economy are different of what they are in another regime. The disturbances affect economic variables, therefore the behavior of variables such as inflation, interest rates and exchange rates could be different in the different regimes (Engel and Hamilton, 1990; Evans and Lewis, 1995).

Between 2003 and 2016 the Brazilian economy was marked by two remarkably different periods: from July 2003 to December 2009 and from January 2010 to December 2016. Figures 1.1 to 1.6 of Appendix A confirm the two different economic regimes experienced by the economy. Specifically, Figure 1.1 displays that the first term was marked by a positive activity trend. The monthly GDP growth, and its 12 and 24-month moving average reinforce the growth path of the economy during this interval. A “boom” in the stock market (Ibovespa index), exchange rate appreciation, and a reduction of the SELIC also characterized this period. The Hodrick-Prescott Filter, shown in Figure 1.2, confirms the change in the GDP trend from January 2010 onwards. In this period, the Brazilian economy experienced the consequences of the Global Financial crisis propagation. The domestic economic slowdown was accompanied by exchange rate depreciation, a decline in the stock market and an increase in both the inflation and interest rates. Therefore, the subset of data used to characterize the economy under two different regimes is well defined on the basis of the output growth behavior.

In the paper we investigate the so-called“price puzzle” in the Brazilian economy over the period from July 2003 to December 2016. The econometric strategy is based on the partition of the period under analysis in two different economic regimes: the first one, from July 2003 to December 2009 (the economic “boom”) and the second one, from January 2010 to December 2016 (the economic slowdown). More precisely, we estimate the Central Bank reaction function through the standard VAR and FAVAR models, considering the whole period (the baseline model) and each sub-interval (the economic “boom” and slowdown regimes). The main advantage of this framework is that it allows the researcher to identify a possible regime dependent behavior of the economy. The hypothesis to be tested is whether the “price puzzle”,found in previous studies, consists of an omission of relevant variables in the model or a feature of the Brazilian economy. A large body of empirical and theoretical literature has examined the underlying relationship between monetary policy and inflation. However, the regime dependence of the “price puzzle” has received little attention from researchers. Therefore, the motivation behind this work lies in the relevance of controlling inflation for long-term economic growth and on the importance of further investigating the puzzling responses of prices to monetary policy in different economic regimes.

The contribution of this paper is directly connected to the differences it presents when compared to the empirical literature that addresses the issue for the Brazilian economy. Moreover, this study has clear policy implications in terms of how the short-term interest rate should be considered in formulating monetary policy. The paper departs from the existing literature in three distinctive aspects: I) the use of the FAVAR approach that allows to mimic the Brazilian Central Bank decision-making environment, by considering a comprehensive set of economic indicators; II) the generation of impulse response functions following a monetary policy innovation for a broad set of economic indicators; and III) the adoption of an estimation strategy dividing the estimation period in two different intervals, aiming at investigating both the presence of the “price puzzle” and the possible regime-dependent behavior of the relation between interest rate and the price level.

The results of the paper suggest that the presence of the “price puzzle” stands out as a characteristic of the Brazilian economy only in periods of economic slowdown. We find evidence that the “price puzzle” anomaly is regime dependent. The price index responds differently to a monetary policy tightening in periods of economic slowdown when compared to expansions. Hence, we argue that the use of the *SELIC* interest rate, as inflation rate control instrument, presents inconsistent results. The rest of the paper is organized in the following manner. Section 2 discusses the theoretical and empirical methodological strategy. Section 3 reports the results of the dynamics of the economy in response to a monetary policy innovation. Finally, Section 4 draws some conclusions and final remarks.

1. **Methodological Strategy**
   1. **The Theoretical Model**

The theoretical specification of this paper follows Bernanke et al. (2005). The authors use a simplified version of the model developed by Rudebusch and Svensson (1999) whose aim is to evaluate the performance of monetary policy rules in inflation rate targeting economies. Rudebusch and Svensson (1999) model an inflation targeting policy regime loss function over policy goals, where inflation targeting always involves an attempt to minimize deviations of inflation from the explicit target. Additionally, the inflation targeting loss function also incorporates the variability of output gap.

In examining the policy rules that are consistent with inflation targeting two classes of models are considered: instrument rules and targeting rules. In the first, monetary policy would be an explicit function of economic information available to agents. In the second, the Central Bank would act to reduce deviations from a predetermined target. Monetary authority would use all the information available, instead of restricting its view to economic indicators that translate the goal to be reached. Based on this model, Bernanke et al. (2005) describe the dynamics of the economy as being led by a set of macroeconomic forces in the following manner:

*πt = δπt-1 + κ(yt-1 – ynt-1) + st (1)*

*yt = Φyt-1 – φ(Rt-1 - πt-1) + dt (2)*

*ynt = ρynt-1 + ηt (3)*

*st = ψst-1 + vt (4)*

Where, *πt* denotes the inflation rate, *yt* is the current output, *ynt*  seeks to measure the potential output, *Rt*  is the nominal interest rate, *st*  is the cost push shock, *dt*  captures the demand shock. Finally, *ηt* and *vt* are the residuals mutually uncorrelated. Equation (1) represents an aggregate supply Phillips curve, and the aggregate demand or IS curve is identified by equation (2). Equations (3) and (4) specify that the potential output and the cost-push shock are both AR(1) processes. The Central Bank function completes the model:

*Rt = βπt + γ(yt – ynt) + ϵt (5)*

Where, *ϵt* represents the residual with normal distribution, zero mean and unit variance. Equation (5) implies that the Central Bank responds to inflation and the output gap. The model defines the dynamic of the economy business cycle where a set of N observable economic indicators (*Xt*) is assumed to be related in the following manner:

*Xt = Ʌ(ynt st πt yt Rt)’ + et (6)*

Bernanke et al. (2005) point out that the model comprising equations (1) to (6) can be written in the form of a vector *(F’t Y’t )’ = (ynt st πt yt Rt)’*. Where the choice of the estimation methodology (VAR or FAVAR), depends ultimately on the information structure being assumed available for agents.

As will be discussed in the next section, the distribution of variables between *Ft* and *Yt* depends on the assumption about the variables that are directly observed by the Central Bank and the researchers who evaluate the model. If all the variables exactly match the empirical measures that are observed, *Y’t = (ynt st πt yt Rt)’, Ft* equates to an empty set, and the model is estimated using a standard VAR. As emphasized by Bernanke et al. (2005), Central Banks literally follow a broader set of variables. The concept of real interest to the monetary authority, such as the level of real activity and inflation, cannot be measured perfectly by individual economic indicators. Moreover, as argued by Boivin and Giannoni (2006), the representation of the dynamics of some key macroeconomic variables (for example, inflation rate) by only one indicator (for example, a price index) would be incomplete, due to the existence of measurement errors and other statistical problems.

Therefore, Bernanke et al. (2005) suggest that a more realistic assumption on the information structure being assumed would consider that part of the information would not be observable. This would imply a biased estimation of the standard VAR model. Consequently, the FAVAR methodology would be more appropriate, where *Y’t* would represent the vector of observable variables and *F’t*  the set of latent factors. The authors argue that the most appropriate assumption about the data set structure of the model would be that both, the Central Bank and the researchers, only observe the monetary policy instrument (the nominal interest rate) and a large set of economic indicators with imperfections. First, due to the revision procedure by which macroeconomic data is subject. Second, because the theoretical concept of the variables does not match precisely with the data series of indicators available. Thus, equation (6) would be represented by *Yt = Rt* and *F’t = (ynt-1 st πt yt )*'. Based on this structure, the monetary authority would focus on the information covered in *Xt*, when conducting the monetary policy formulation. In addition, researchers would be able to describe the Central Bank behavior through the FAVAR approach.

**2.2 Econometric and Empirical Models**

## **2.2.1 The Analytical VAR Model Framework**

The vector autoregressive (VAR) is a multiequacional model that is composed by an equation for each variable, where each equation is a function of that variable lagged value ​​and the lagged values of the ​​other system variables. The standard VAR model representation is defined in the following manner:

Where, the ~ iid N (0, Ω), *Wt* is the vector of endogenous variables of the system and represents a coefficient matrix Lutkepohl, 2005).

The Central Bank reaction function represented by equation (5) was estimated through a standard VAR model. We also extended the basic model with the inclusion of the spot exchange rate to adjust for the case of open economies (Taylor, 2001). Additionally, the standard VAR model was estimated with the incorporation of the commodity prices and inflation expectation, following the methodological strategy adopted by Mishkin et al. (2010) and Sims (1992). The VAR model selection and estimation procedure includes the choice of the set of endogenous variables of the system and the process of identification of contemporary relations. The identification of the system was based on the ordering of the variables assigned for the estimation of the impulse response functions (IRFs). The vectors of endogenous variables and the ordering for the orthogonalised IRFs’ were defined in the following manner[[6]](#footnote-6):

1. First relation: *Wt = ((yt – ynt), ipcat , SELICt,)*
2. Second relation: *Wt = (pcomt, (yt – ynt), ipcat, SELICt,)*
3. Third relation: *Wt = ((yt – ynt), ipcat, EIPCAt+12, SELICt)*
4. Fourth relation: *Wt = (pcomt, (yt – ynt), ipcat,, EIPCAt+12, SELICt)*
5. Fifth relation: *Wt = ((yt – ynt), ipcat,, SELICt, spott)*
6. Sixth relation: *Wt = ((yt – ynt), ipcat, EIPCAt+12, SELICt, spott)*
7. Seventh relation: *Wt = (pcomt , (yt – ynt), ipcat,, SELICt, spott)*

Where, *yt* denotes the annual real GDP in local currency (January 2000 = 100), *ipcat* is the IPCA price index*[[7]](#footnote-7)*, *SELICt*  is the annual SELIC rate, *pcomt* denotes the international commodity price index, *EIPCAt+12* measures the expectation of the annual consumer price inflation rate (twelve months ahead) and *spott*  is the average price of the buying and selling US Dollar spot exchange rate at the end of period (R$/US$). The current real output discounted by a linear trend (*yt* – *ynt*) seeks to measure the output gap[[8]](#footnote-8).

The ordering of the variables in the *Wt* vectors followed the exogeneity criteria: the most contemporaneously exogenous variables represent the goods market, monetary policy instruments form the intermediate set, and the most endogenous variables belong to the financial market, suffering the impacts of the first two sets of variables, despite not affecting them contemporaneously. Therefore, output does not respond contemporaneously to other variables since, production decisions and their effect on the final output occur with a lag, which is higher than the monthly order adopted in this study. Inflation, inflation expectation is affected contemporaneously only by the output level, considering the speed of price adjustment to changes in aggregate supply and demand. The SELIC responds contemporaneously to GDP, the price of commodities, inflation and inflation expectation. It is plausible to assume that Central Banks hold information on the four variables and incorporate it into their decisions. Finally, spot exchange rate responds to all other variables contemporaneously, due to its dynamic property and commodity prices do not suffer the effect of any domestic variable. The chain of economic relations that justifies the order of the variables is similar to Minella (2003) and Christiano et al. (1999). The VAR model selection consisted of the following stages:

1. First, the number of lags used in the estimations was selected by resorting to the information criteria (Akaike (AIC), Schwarz Bayesian Criterion (SBIC) and Hanna Quinn (HQIC)) and the Likelihood Ratio statistic (LR), limited to a maximum of eight lags, since it contains a sufficiently rich structure of information;
2. The VAR model was estimated and tested for the presence of autocorrelation and normality in the residuals (both at 5% significance level), besides the stability condition (absence of eigenvalues ​​greater than unity). Those with autocorrelation or stability problems were discarded and replaced by others with the number of lags selected by the information criteria. In the event of conflicting results between the LR statistics and the information criteria applied when selecting the number of lags, the residual normality test and the lowest number of lags (criterion of parsimony) were employed to support the choice.

**2.2.2 The Analytical FAVAR Model Framework**

The FAVAR model, that is an extension of the standard VAR, is employed to estimate equation (5). The basic idea of the FAVAR is to merge a large amount of macroeconomic data into a sufficiently small number of factors to be used in the standard VAR. The model can be represented as follows:

*(8)*

Where, *Yt* is a vector M x 1 of observable variables, *Ft* is a vector K x 1 of unobservable factors that summarize information not captured by *Yt*.*θ(L)* denotes a polynomial with finite lags and *vt*  is an error term with mean zero and covariance matrix Q. In equation (8), the vector *Yt* contains only the SELIC interest rate, similar to the baseline model employed by Bernanke et al. (2005).

Equation (8) is a VAR in (*F’t, Y’t*) and cannot be directly estimated because of the presence of the unobservable factors, *Ft*. The model estimation is performed by using the technique of the principal components (Stock and Watson, 1998). The factors are interpreted as latent variables representing a distinguished feature of the data. Therefore, considering a vector of variables *Xt* of dimension N x 1[[9]](#footnote-9), where N >> K + M, related to both *Yt* and *Ft*, it follows that:

*Xt = ᴧfFt + ᴧyYt + et (9)*

Where, ***ᴧf*** is a K x N matrix of factor loads, ***ᴧy*** is an N x M matrix, and *et* is an N x 1 vector containing the error terms with zero mean, being allowed the existence of a small degree of cross-correlation to be extinguished with increasing N (Stock and Watson, 2002).

The estimation procedure of the Central Bank reaction function equation consists of the use of the two stage methodology proposed by Bernanke et al. (2005). This approach is based on a non-parametric method of obtaining the area spanned by the common components, *Ct = (F’t, Y’t)*. The Central Bank reaction function is estimated considering a large data set of macroeconomic indicators and the SELIC as the only perfectly observable variable. The selection of the FAVAR model begins by extracting the common factors employing the method of principal components, considering the set of 69 macroeconomic variables presented in Tables 1A, 1B, 1C and 1D of Appendix B. The identification strategy used to generate the Impulse Response Functions follows Bernanke et al. (2005). In particular, we divide the set of indicators in two groups: 1) “Slow-moving” variables, which do not respond contemporaneously to unanticipated changes in monetary policy (such as industrial production, capacity utilization rate, etc.); and 2) “Fast-moving” variables, which respond contemporaneously to monetary policy shocks (such as asset prices, exchange rate, etc.).

Subsequently, the number of eight common factors was selected based on their explanatory power (the proportion of the data set total variance captured) and the suitability of the constructs. Lastly, we employed the AIC, SBIC and HQIC to choose the number of six lags for the estimation of the baseline model, given that it contains a sufficiently rich structure of information, (Bernanke et al. (2005) select between seven and thirteen lags, Shibamoto (2007) estimates the FAVAR model with ten lags for Japan, and Blaes (2009) uses two lags to analyze the Eurozone). The model estimations for the economic “boom” and slowdown periods were performed with six common factors and four lags.

## **Data set and Estimation Period**

The choice of the series followed Bernanke et al. (2005), adjusting for the availability of the data for Brazil. The data set consists of 70 monthly macroeconomic time series, covering the period from 2003:M07 to 2016:M12[[10]](#footnote-10). The series can be classified within four categories: 1) Real Output, Employment and Income; 2) Interest Rates, Foreign Exchange Rates and Money Aggregates; 3) Price Indexes, and 4) International Indicators. The inclusion of international macroeconomic time series aimed to capture the importance of foreign economic fluctuations for the Central Bank decision process. Appendix B (Tables 1A, 1B, 1C and 1D) displays the data series provided by the following institutions: the Brazilian Steel Institute (IBS), the State System of Data Analysis, Research and Unemployment Foundation (SEADE Foundation), the Center Foundation for Foreign Trade Studies (FUNCEX), the Brazilian Association of Financial and Capital Market Institutions (ANBIMA), the Institute of Applied Economic Research (IPEA), the National Confederation of Industry (CNI), the Federal Reserve Bank (FED), the Investing company (US-based financial investment company), the US Bureau of Labor Statistics (BLS) and the International Monetary Fund (IMF).

1. **Empirical Results and Discussion**

## **3.1 Stationarity, Autocorrelation, Normality and Stability Testing**

We examined the stationary property of the series using the commonly unit root tests: the Augmented Dickey and Fuller (Dickey and Fuller, 1979), the Dickey and Fuller modified by the method of generalized least squares (DF-GLS), the Phillips and Perron (1988), the KPSS (Kwiatkowski et al.,1992) and the Perron (1997)[[11]](#footnote-11). As shown in Tables 1A, 1B, 1C and 1D of Appendix B, the non-stationary variables were differenced to induce stationarity. Tables 2A, 2B, and 2C of Appendix C report the results of the residual autocorrelation (Lagrange Multiplier) and normality tests (Jarque and Bera, 1980). The probability values of the Lagrange Multiplier test confirm the absence of residual autocorrelation in every VAR model estimation of the Relations 1 to 7, defined in section 2.2. The excess kurtosis was the main reason behind the presence of non-normality in the residuals of some estimated models [[12]](#footnote-12). All the estimated VAR models passed in the test of stability (absence of eigenvalues ​​greater than unity).

**3.2 Principal Component Analysis of the Central Bank Data Set**

There are two most widely used methods to estimate a factor model. The first method is the Principal Component analysis, which does not require the normality assumption of the data and the prior specification of the number of common factors. The Maximum Likelihood method, the second form, on the other hand is based on the normal density function and requires pre-specification of the number of factors. The first step in the factor analysis method is to test whether the set of variables has a normal distribution. Both the Henze and Zirkler (1990) and Doornik and Hansen (2008) multivariate normality tests were employed and rejected the hypothesis of the joint normal distribution, assuming a 10% significance level. Hence, we applied the method of Principal Component to the set of variables presented in Tables 1A, 1B, 1C and 1D of Appendix B, except for the SELIC, as it is the monetary policy instrument.

Regarding the criteria for choosing the number of factors, Stock and Watson (2002) point out this determination should be based on the quality of the model fit. Bai and Ng (2002) develop a methodology to determine the optimal number of factors, considering that N and T → ∞, which would not be appropriate, given the set of data used in this study. Additionally, Bernanke et al. (2005) emphasize that the criteria suggested by Bai and Ng (2002) does not necessarily address the choice of the number of factors to be included in the VAR model. In this context, it is rather common to use an *ad hoc* strategy: Bernanke et al. (2005) uses one, three and five factors, Lagana and Mountford (2005) consider both five and seven factors, Blaes (2009) chooses eight, Favero et al. (2005) allows for up to twelve and Shibamoto (2007) determines the estimation of the model with six common factors.

Therefore, eight latent factors were retained, which together accounts for approximately 64% of the data set total variance[[13]](#footnote-13). All the eigenvalues of the factors extracted are greater than one and their spree-plot representation (not reported but available from the authors upon request) reveals that the slope of the curve levels off after the eighth element. Hence, a model with eight factors appears to adequately capture the main patterns of the correlation in the data. The factor loads, commonality and the percentage of explained variance of the data set for each factor were attained after the application of the Varimax orthogonal rotation method (Kayser, 1958)[[14]](#footnote-14). Table 3 below reports the latent dimensions retrieved from the factors structure of the data. We identified the dimensions based on the analysis of the relationship found between the factor loads and the set of economic indicators. The eight factors turn out to have an intuitive interpretation summarizing the information used by the Central Bank in monetary decisions

**Table 3 -** Latent Dimensions of the Central Bank Data Set

|  |  |
| --- | --- |
| Dimension | Description of Indicators |
| Factor 1 - Interest Rates | CDI Over[[15]](#footnote-15), The Term Structure of Interest Rates of 1, 3, 6 and 12 months, Swap DI X Fixed Interest Rate of 30, 60, 90, 120, 180 and 360 days[[16]](#footnote-16), INCC, Embi + and GDP Gap. |
| Factor 2 - International Stock Market | Ibovespa Index, Shanghai Composite, Nikkei 225, CAC 40, FTSE 500, DAX, Standard and Poor's 500 and Dow Jones 30. |
| Factor 3 - International Prices | US PPI, US CPI, Eurozone PPI, Eurozone CPI, Export Prices, Import Prices and Commodity Price Index. |
| Factor 4 - Current and Future Domestic Producer Prices | IGPDI, IPADI and IPCA Inflation Expectations, IGPDI, IGPOG, IPAEP, US Dollar Real Exchange Rate, Expectation of Future US Spot Exchange Rate, Foreign Portfolio Investment and US Dollar Future Exchange Rate. |
| Factor 5 - Industrial Production | Capital Goods Production, Consumer Goods Production, Durable Consumer Goods Production, Intermediate Goods Production, People Hiring, Brazilian Central Bank Economic Activity Index, Retail Sales, Retail Expanded Sales, Hours Worked in Industry and Real Monetary Aggregate M3. |
| Factor 6 - Domestic Consumer Prices | IPCA, IPC, INPC, IPCA Free Prices, IPCA Free Tradable Prices and Core IPCA[[17]](#footnote-17), Unemployment Rate and Purchasing Power Parity. |
| Factor 7 - Money Demand | Real Monetary Aggregates M0, M1 and M4, US Dollar Spot Exchange Rate, Euro Spot Exchange Rate, General Industrial Production and Industry Payroll. |
| Factor 8 - Economic Activity | Capacity Utilization, Total Imports, Total Exports, Real Monetary Aggregate M2 and Industry Revenue. |

This table reports the latent dimensions retrieved from the factors structure of the series presented in Tables 1A, 1B, 1C and 1D of Appendix B, after the application of the Varimax rotation method.

To evaluate the goodness-of-fit of the model we estimated the anti-image correlation matrix that confirmed the sampling adequacy of the individual variables included in the factor analysis (not reported but available from the authors upon request). The Bartlett test of sphericity rejected the null hypothesis that the correlation matrix was an identity matrix, considering a 1% significance level. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy reached 0.74. It is important to mention that the individual KMO index for the following variables achieved a level lower than 0.60: INCC (0.44), Total Exports (0.59), Foreign Portfolio Investment (0.53), Monetary Aggregate M2 (0.42), Capital Goods Production (0.57), Unemployment Rate (0.48), Retail Expanded Sales (0.55) and Eurozone CPI (0.47). However, these series were also maintained to estimate the factors, due to their importance for the Central Bank decision-making. Moreover, the Cronbach´s Alpha index confirmed the high scale reliability and the internal consistency of the data set structure. The index measure of each individual group of variables (dimensions) confirmed the internal consistency of the constructs formed.[[18]](#footnote-18)

**3.3 Results of the Monetary Policy Transmission Mechanism – VAR Approach**

We investigate the “price puzzle” through the analysis of a set of Impulse Response Functions (IRF), considering a temporary positive exogenous shock of one standard deviation in the SELIC interest rate. The orthogonalized IRF (solid line) within a two standard deviation confidence interval (dashed line) displays the outcome of the shock. The identification of the monetary policy is carried out via Cholesky decomposition. Appendix D displays the responses of the variables for the VAR estimations, following a positive one-off impulse in the SELIC, considering the sample period from 2003:M07 to 2016:M12. We also show the effects of a monetary policy tightening over the IPCA index for the two different economic regimes: the “boom” (from 2003:M07 to 2009:M12) and the slowdown (from 2010:M01 to 2016:M12).

Regarding the IPCA, the impulse in the SELIC results in an increase of the price level that peaks around the eighth month, assumes a downward trend, and eventually returns to its starting level, where the effect ceases. The impact on the IPCA inflation expectation is qualitatively similar to the inflation index. It is important to note that in all estimations we confirmed the presence of the “price puzzle”in the Brazilian economy. The IRF analysis of the response of the IPCA to a monetary contractionary shock for the two different regimes reinforced the puzzling behavior of the price level. In addition, the relations (2), (4) and (7) were estimated following the specification of Peersman and Smets (2003) and Blaes (2009), with the inclusion of the international commodity price index as an exogenous variable. The results were similar to the benchmark model. Both Minella (2003) and Araújo et al. (2015) also identify the “price puzzle” in the Brazilian economy, unlike the outcomes of Tomazzia and Meurer (2009) and Fernandes and Toro (2005). Cespedes et al. (2008) reach multiple results depending on the model specification.

The findings of this paper are also consistent with Bjorland et al. (2010). The authors use a standard VAR to examine the MPTM in Norway, Sweden and the UK, between 1983 and 2006. Bjorland et al. (2010) find the “price puzzle” in Norway and the United Kingdom. Eventually, the monetary shock ceases its impact on prices in the UK and reduces inflation marginally in Sweden in the long run. Castelnuovo and Surico (2010) examine the relationship between interest rates and inflation in the USA between 1966 and 1979, and 1979 and 2006, employing a structural VAR. The authors observe the “price puzzle”only in the first term, where monetary policy was characterized as passive[[19]](#footnote-19), being in line with the results found by Boivin and Giannoni (2006) considering a similar period for the US economy.

Chowdhury et al. (2006) investigate the influence of the cost channel on the MPTM in the G7’s countries from 1980 to 1997. The authors find evidence of the presence of the “price puzzle”,and the pass-through of increases in the firms’ cost of capital to the prices of goods. Chowdhury et al. (2006) reinforce that the cost channel is more pronounced in the UK and in the USA than in the continental European countries and Japan, due to differences in the financial market structures. Finally, Mishkin et al. (2010) initially estimate the Taylor (1995)’s equation using the standard VAR and FAVAR models, and subsequently by a DSGE. The authors investigate the US economy from 1962:Q1 to 1973:Q3 and from 1984:Q1 to 2008:Q4. The authors identify the presence of the “price puzzle” even with the inclusion of the commodity price index. Nonetheless, incorporating inflation expectation solves the problem and leads the authors to the conclusion that this anomaly is related to the omission of relevant variables in the model.

As Appendix D reveals, the SELIC response reaches a maximum positive transitory effect and converges back towards the baseline (the zero line) or remains marginally different from zero, after around the fiftieth month in all model specifications. It is also observed a positive reaction of the GDP gap following a tightening monetary policy innovation. This effect remains for approximately ten months, which contradicts the standard economic theory prediction. The GDP gap response does not support the results normally found in the empirical studies for the Brazilian economy. Fernandes and Toro (2005) investigate the period from 1994 to 2001 and find a negative effect that ceases after eight quarters. Bezerra et al. (2014), Tomazzia and Meurer (2009) and Araújo et al. (2015) also identify a declining reaction of economic activity level following a monetary policy tightening shock. Bezerra et al. (2014) and Tomazzia and Meurer (2009) evaluate the Brazilian economy throughout the period from 1995 to 2010 and 1999 to 2008, respectively. Araujo et al. (2015) assess the MPTM covering the interval from 2000 to 2013.

Smets et al. (2001) investigate the MPTM in the Eurozone and in the USA through a standard VAR model, applying various identification schemes and considering the period from 1980 to 1988. In general, the authors identify a temporary decrease of output as a consequence of a positive shock in the short-term interest rate. However, in some specifications, Smets et al. (2001) detect an initial upward move in output, which eventually assumes a downward direction. Mishkin et al. (2010) confirm the negative response of GDP to a positive shock in the short-term interest rate in the US Economy.

The US Dollar spot exchange rate reacts to a tightening monetary shock by initially depreciating, and then converging back towards the zero line after about five months. This response is not consistent with the conventional economic theory, which asserts the occurrence of an appreciation following an interest rate increase. The result found in this paper confirms the presence of the “exchange rate puzzle”[[20]](#footnote-20) and corroborates the outcome found by Cespedes et al. (2008) for the Brazilian economy. Bloor and Matheson (2010) explore the dynamics of the MPTM in New Zealand between 2000:Q1 and 2007:Q4. The authors find that after an initial appreciation, the exchange rate declines, ceasing its effect after three years.

**3.4 Results of the Monetary Policy Transmission Mechanism – FAVAR Approach**

Appendix E displays the responses of a set of variables to a positive one-off standard deviation impulse in the SELIC interest rate, as a result of the FAVAR estimation for the sample period from 2003:M07 to 2016:M12. The response of the IPCA index highlights the fact that the “price puzzle” is solved through the application of the FAVAR approach. A rise in the short-term interest rate is followed by an immediate decrease in the price index. It is important to reinforce that the other price indexes (the IGP-DI and the IPA-EP) exhibit a similar pattern. The inflation concerning the three price indexes, initially assumes a declining trend, followed by a short rise and a subsequently decrease, returning to the zero line.

This outcome is in line with Mishkin et al. (2010) and Bernanke et al. (2005). Both authors identify a strong reduction in the “price puzzle”*,* when the FAVAR model is applied in the US economy. Similarly, Shibamoto (2007) investigate the behavior of price indexes in Japan between 1988:M11 and 2001:M02. The author identifies a significant reduction in the “price puzzle” when the estimation is performed by the FAVAR compared to the VAR. In the case of the FAVAR, the “price puzzle” appears only marginally different of zero. Favero et al. (2005) estimate the FAVAR for the USA, Germany, France, Italy and Spain, considering the interval from 1959 to 1998 (USA) and from 1982 to 1997 (for the others). In the USA, the “price puzzle” found in the estimation of the VAR disappears completely by the use of the FAVAR model. The European countries results were also similar to the USA. Finally, Blaes (2009) investigates the MPTM in the Eurozone from 1986 to 2006. The author find the “price puzzle” even when the commodity price index is included in the model. However, the estimation through the FAVAR solves the puzzle.

The SELIC initially reflects its own positive shock, reaches a peak and assumes a downward path, ceasing the effect in the long term. The GDP gap firstly responds positively to the monetary policy contraction, however, after around eight months it assumes a declining path and returns to the baseline line after thirty months. This finding reinforces the understanding that the use of the short-term interest rate as the monetary policy instrument is effective in controlling output level in the medium and long terms. The reaction of the Industrial Production, Capacity Utilization, Retail Expanded Sales, Industry Revenue and Unemployment Rate provides further evidence of the negative effect of a monetary tightening shock on the level of economic activity. Therefore, it is possible to infer the long-run efficiency of the use of the SELIC interest rate, as a monetary policy tool, in controlling the aggregate demand. This outcome corroborates the empirical evidence for the Brazilian economy (Fernandes and Toro, 2005 and Bezerra et al., 2014).

Lagana and Mountford (2005) estimate the FAVAR model for the UK considering the period from 1992:M10 to 2003:M01. The authors use multiple specification schemes and find similar results for the variables related to economic activity level, (industrial production, capacity utilization, etc.) when the model is estimated considering specifications analogous to this paper. Bernanke et al. (2005) also arrive at a similar outcome concerning the variables related to economic activity level, when the FAVAR is estimated with three and five factors, except for the capacity utilization, which presents an initial positive response. However, this movement reverses after the third month, towards the starting level.

The behavior of the Term Structure resembles the dynamics followed by the SELIC rate. This finding illustrates the importance of the term structure of interest rates, which indicates that the longer-term rates reflects an average of expected future shorter-term rates, enabling a direct impact on investment and consumption. Regarding the monetary aggregates, a negative reaction is observed in all of them, confirming the absence of the “liquidity puzzle”[[21]](#footnote-21) in the Brazilian economy. Blaes (2009) finds a negative reaction of M1 and a positive one for M2 and M3 in its FAVAR model following a restrictive monetary innovation. However, M2 and M3 assume a downward trend after the seventh month onwards, and eventually turn out to be negative in the long run. The author associates this behavior to portfolio reallocations due to the change in interest rates.

The Ibovespa stock index first declines following the monetary tightening, and presents a marginal rise after the fifteenth month. The impact on exports and imports are analogous, the interest rate shock decreases the level of both. Blames (2009) finds a similar pattern for the level of exports in the Eurozone. On the other hand, the spot exchange rate depreciates marginally, uncovering the presence of the “exchange rate puzzle” in the Brazilian economy. Based on the FAVAR model, Shibamoto (2007) also finds that a rise in interest rate is followed by currency depreciation in Japan. On the other hand, Lagana and Mountford (2005) and Blaes (2009) detect an appreciation of the Pound Sterling in the UK and the Euro in the Eurozone. Both authors argue that an increase in the short-term interest rate triggers capital inflows, as a consequence of more attractive investment, causing currency appreciation.

Appendices F and G reveal the distinctive behavior of the IPCA index in the two different economic regimes. Appendix F shows that during the “boom” period, from 2003:M07 to 2009:M12, an unexpected tightening in monetary policy results in a decrease in the IPCA. However, Appendix G displays a positive response of the IPCA to an increase in the SELIC, confirming the presence of the “price puzzle” during the economic slowdown period. The same pattern occurs to the IGP-DI and IPA-EP price indexes, strengthening the evidence in favor of the puzzling responses of prices to monetary policy shocks. This outcome suggests that despite the effectiveness achieved by using the SELIC to drive the activity level, it cannot be inferred the same with respect to inflation control. The persistent “price puzzle” is an evidence of the prevalence of the cost channel over the aggregate demand in periods of economic downturn. An additional finding revealed by this paper refers to the operation of the expectations channel on the MPTM. In particular, the Central Bank acts aiming to influence agents' expectations on the level of future output and inflation. Inflation expectations (the IPCA, the IGP-DI and the IPA-DI forecasts) exhibit a declining response following an increase in the SELIC in both periods. Thus, the Brazilian Central Bank is efficient in directing the inflation expectations.

A comparison of the impact of a contractionary monetary policy over unemployment between the two periods reveals that the adjustment of the work force is more intense when the economy is slowing down. The rise in the unemployment rate is higher in the second period, following a rise in the short-term interest rate. During the “boom” period, the stock prices drop in reaction to an unexpected monetary tightening, but converge toward the zero line in the medium term. The opposite occurs during the downturn period, where the Ibovespa index reacts with a rise and return to the baseline line after ten months. The exchange rate behavior is similar in both periods, when an appreciation follows the increase in the SELIC rate. Hence, the “exchange rate puzzle”, found in the VAR estimation, is solved by the information set spanned in the FAVAR approach. In summary, the results of the FAVAR model are mostly in line with the prevalent expectations regarding the qualitative effects of monetary policy. However, the results suggest that the price indexes behave according to the economic regime. Precisely, in economic “booms” a rise in the short-term interest rate causes a reduction in the price, while in periods of activity slowdown the result is the “price puzzle”.

**3.5 Robustness Analysis**

In order to figure out whether the main findings hinge on a particular aspect of the model specification and estimation strategy we accomplished the following robustness exercises:[[22]](#footnote-22)

We included the future interest rates (the 1, 3 and 6 month Term Structure of Interest Rates and the 1, 3 and 6 month Swap DI X Fixed Interest Rate) in place of the commodity prices and inflation expectation to control for the monetary policy expectations, as suggested by Brissimis and Magginas (2006). However, similar results were derived from the estimation of the VAR model. We also estimated the VAR model with the IPCA inflation rate in exchange for the IPCA price index. Overall, the IRF provided similar responses to the baseline model for all variables, considering the relations (1) to (7) defined previously. The “price puzzle” was found to be persistent in all estimations.

The FAVAR model was estimated allowing for up to nine common factors and lags. Different feasible combinations between the number of factors and lags were used in the estimations. The outcomes were qualitatively similar to those achieved by the benchmark model of eight factors and six lags, and six factors and four lags, for the whole sample and the sub samples, respectively. The “price puzzle” persisted during the economic slowdown period. We also estimated the FAVAR model by replacing the IPCA, IGP-DI, IGP-OG, INCC, INPC, IPC and IPA-EP price indexes for their respective inflation measures and keeping the same number of lags and factors used in the baseline models. The results for the economic “boom” and slowdown periods were both not sensitive to this change, and the “price puzzle” appeared with greater intensity in the second interval. However, the puzzling responses of prices to monetary policy shocks were also observed when the whole sample was used (from 2003:M07 to 2016:M12). The responses of the other variables were qualitatively similar to the baseline model.

We also examined whether the results of the VAR and FAVAR models were robust to alternative sample periods. We used the Rolling Window methodology with a forty eight month window size and a twelve month increment between successive rolling windows. For the first period the sample intervals were: from 2003:M07 to 2007:M06, from 2004:M07 to 2008:M06 and from 2005:M07 to 2009:M06. For the second period the sample intervals were: from 2010:M01 to 2013:M12, from 2011:M01 to 2014:M12, from 2012:M01 to 2015:M12 and from 2013:M01 to 2016:M12. The subsample FAVAR models were estimated with feasible combinations between up to four lags and five common factors. The lag length of the subsample VAR models were chosen based on the AIC, SBIC and HQIC, limited to a maximum of four lags. Both the VAR and FAVAR results were robust to the change in the sample periods. The IRF displayed the same pattern generated by the benchmark model in both the economic “boom” and slowdown period. The only important difference lies in the response of exchange rate and the degree of the “price puzzle” for the period from 2013:M01 to 2016:M12. The IRF revealed the occurrence of the “exchange rate puzzle” and a sizable increase in the “price puzzle”. A possible explanation for this result could be related with the high degree of the ERPT to the general price level observed in the Brazilian economy, especially during the exchange rate depreciations (Couto and Fraga, 2014; Pimentel et al., 2016). Precisely, a rise in domestic interest rate would not only raise the cost of capital, but also trigger local currency depreciation (“exchange rate puzzle”). The result would be a surge in domestic price level reinforced by the high degree of the ERPT.

The above adjustments did not change the qualitative nature of the results, providing further evidence of the “price puzzle” persistency only in periods of economic downturn. We argue that the “price puzzle” anomaly can be characterized as regime dependent in the Brazilian economy, which went through two distinct economic regimes. The first term marked by lower inflation, falling interest rates, currency appreciation and economic expansion experienced the absence of the “price puzzle”. The second interval identified by higher inflation, increasing interest rates, currency depreciation and economic slowdown witnessed the presence of a puzzling response of prices to monetary policy tightening. The economy performed differently in expansions and contractions, in a switching regime behavior. Likewise, the escalation of uncertainty about domestic monetary policy can lead external suppliers to determine their export prices in foreign currency, what, in turn strengthens the ERPT to the overall price level (Devereux and Yetman, 2010; Devereux et al., 2004). Hence, the presence of the “exchange rate puzzle” and a possible higher degree of the ERPT due to the increased level of uncertainty, can be combined to partially explain the higher level of “price puzzle” found between 2013:M01 and 2016:M12.

1. **Conclusions**

In the paper we estimated the Central Bank reaction function for the Brazilian economy, covering the period from July 2003 to December 2016, through the VAR and FAVAR approaches. The sample period was divided in two intervals, from 2003:M07 to 2009:M12 and from 2010:M01 to 2016:M12. With this strategy, we aimed to investigate whether the “price puzzle” found in previous empirical studies, consisted of a model misspecification or a characteristic of the Brazilian economy.

Our findings suggest that the “price puzzle” phenomenon is regime dependent, the price index responds differently to a monetary policy tightening in periods of economic slowdown when compared to expansions. We found that the “price puzzle” is persistent in period of economic slowdown. Hence, we argue that the use of the SELIC, as inflation rate control instrument, presents inconsistent results.

However, based on the relationship found between the SELIC and the set of economic activity indicators (industrial production, unemployment, etc.) and inflation rate expectations, an additional insight can be raised. According to our estimates, a contractionary monetary policy leads to a reduction in economic activity level in the medium and long terms, regardless of the economic regime. Thus, the Central Bank should consider the use of the SELIC to control inflation only in moments of economic “booms”, when we do not observe the perverse response of prices. Particularly, in moments of economic slowdown followed by increases in inflation (driven, for example, by supply shocks), the rise in short-term interest rates would result in an upward pressure over inflation. The monetary authority should incorporate such regime dependent response of prices into its conduct and, when appropriate, select alternative monetary policy instruments to target the inflation rate.

The research problem addressed by this paper was limited to the use of macroeconomic indicators in the assessment of the “price puzzle” anomaly and the MPTM of the Brazilian economy. For future work, we suggest the use of disaggregated economic data from various sectors of the economy to better understand the monetary transmission mechanism through which the cost of capital channel operates.

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**Appendix A. Economic Regimes**

  

Fig. 1.1. Monthly GDP Growth (%). Fig. 1.2. Hodrick-Prescott Filter. Fig. 1.2. SELIC (% p.a).

  

Fig.1.3. Spot E. Rate (R$/US$). Fig. 1.5. Ibovespa Index (points). Fig. 1.6. IPCA Inflation (% p.a).

**Appendix B. Data Description**

The data set consists of 71 time series covering the period from 2003:M07 to 2016:M12. The transformation codes are: 1 - No change; 2 – First difference; 3 - Logarithm; and 4 - First difference of logarithm. The "S / F" shows whether the variable is assumed to be slow-moving (Slow - S), or fast-moving (Fast - F).

**Table 1A -** Real Output, Employment and Income

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Code | S / F | Transf | Description | Source |
| 1 | PIBR | S | 1 | Annual Real GDP Gap (January 2000 = 100) in (R$) | Brazilian Central Bank |
| 2 | CAPIN | S | 4 | Industrial Capacity Utilization SA (%) | CNI |
| 3 | PIND | S | 4 | Industrial Production Total Index SA (average 2012 = 100) | IBGE |
| 4 | PINBI | S | 4 | Industrial Production Intermediate Goods Index SA (average 2012 = 100) | IBGE |
| 5 | PINBC | S | 4 | Industrial Production Consumer Goods Index SA (average 2012 = 100) | IBGE |
| 6 | PINBK | S | 4 | Industrial Production Capital Goods Index SA (average 2012 = 100) | IBGE |
| 7 | PINCD | S | 4 | Industrial Production Durable Consumer Goods Index SA (average 2012 = 100) | IBGE |
| 8 | FATIN | S | 4 | Real Industry Revenue Index SA (average 2006=100) | CNI |
| 9 | VRVJO | S | 4 | Real Retail Sales Index SA (average 2014 = 100) | IBGE |
| 10 | VENR | S | 4 | Real Expanded Retail Sales Index SA (average 2014 = 100) | IBGE |
| 11 | HTIND | S | 4 | Hours Worked Industry SA (average 2006 = 100) | CNI |
| 12 | CONRH | S | 3 | Net Hiring Employees (monthly balance) \* | Ministry of Labor |
| 13 | TDESP | S | 4 | Unemployment Rate (%) \* | SEADE / PED Foundation |
| 14 | FPGSP | S | 4 | Monthly Payroll Industry Average Index (average 2006 = 100) | FIESP |
| 15 | IATEC | S | 4 | Brazilian Central Bank Economic Activity Index SA (2002 = 100) | Brazilian Central Bank |
| 16 | EXP | S | 4 | FOB Exports (US$) \* | Foreign Trade Secretary |
| 17 | IMP | S | 4 | FOB Imports (US$) \* | Foreign Trade Secretary |

**Table 1B -** Interest Rates, Foreign Exchange Rates and Money Aggregates

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Code | S / F | Transf | Description | Source |
| 18 | SELIC | F | 2 | Annual SELIC Interest Rate (% p.a.) | Brazilian Central Bank |
| 19 | ETTJ1 | F | 2 | 1 Month Term Structure of Interest Rates - LTN (% p.a.) | ANBIMA |
| 20 | SWAP3 | F | 2 | 30 Day Swap DI X Fixed Interest Rate - End of Period (% p.a.) | Brazilian Central Bank |
| 21 | SWAP6 | F | 2 | 60 Day Swap DI X Fixed Interest Rate - End of Period (% p.a.) | Brazilian Central Bank |
| 22 | ETTJ3 | F | 2 | 3 Month Term Structure of Interest Rates - LTN (% p.a.) | ANBIMA |
| 23 | SWAP9 | F | 2 | 90 Day Swap DI X Fixed Interest Rate - End of Period (% p.a.) | Brazilian Central Bank |
| 24 | SWAP12 | F | 2 | 120 Day Swap DI X Fixed Interest Rate - End of Period (% p.a.) | Brazilian Central Bank |
| 25 | ETTJ6 | F | 2 | 6 Month Term Structure of Interest Rates - LTN (% p.a.) | ANBIMA |
| 26 | SWAP18 | F | 2 | 180 Day Swap DI X Fixed Interest Rate - End of Period (% p.a.) | Brazilian Central Bank |
| 27 | ETTJ12 | F | 2 | 12 Month Term Structure of Interest Rates - LTN (% p.a.) | ANBIMA |
| 28 | SWAP36 | F | 2 | 360 Day Swap DI X Fixed Interest Rate - End of Period (% p.a.) | Brazilian Central Bank |
| 29 | CDI | F | 2 | Annual CDI Interest Rate (% p.a.) | Brazilian Central Bank |
| 30 | IBOV | F | 4 | Real Ibovespa Stock Price Index: Composite (January 2000 = 100) | ANBIMA |
| 31 | M0 | F | 4 | Real Monetary Aggregate M0 (January 2000 = 100) - End of Period (R$) | Brazilian Central Bank |
| 32 | M1 | F | 4 | Real Monetary Aggregate M1(January 2000 = 100) - End of Period (R$) | Brazilian Central Bank |
| 33 | M2 | F | 4 | Real Monetary Aggregate M2 (January 2000 = 100) - End of Period (R$) | Brazilian Central Bank |
| 34 | M3 | F | 4 | Real Monetary Aggregate M3 (January 2000 = 100) - End of Period (R$) | Brazilian Central Bank |
| 35 | M4 | F | 4 | Real Monetary Aggregate M4 (January 2000 = 100) - End of the Period (R$) | Brazilian Central Bank |
| 36 | SPOT | F | 4 | Bid Quotation of Spot Exchange Rate R$/US$ - End of Period (R$) | Brazilian Central Bank |
| 37 | EURO | F | 4 | Bid Quotation of Spot Exchange Rate R$/Euro - End of Period (R$) | Brazilian Central Bank |
| 38 | CREAL | F | 4 | Real Exchange Rate R$/US$ - End of Period (R$) | IPEA |
| 39 | ICART | F | 4 | Monthly Net Foreign Portfolio Investment (US$) | Brazilian Central Bank |
| 40 | FUTURE | F | 4 | 1 Month US Dollar Future Exchange Rate R$/US$ | BMF Bovespa |
| 41 | EMBI | F | 4 | EMBI + Index - Country Risk | JP Morgan |
| 42 | ECAM | F | 4 | Expectation of Future US Spot Exchange Rate - End of Next Year: Bulletin Focus (R$/US$) | Brazilian Central Bank |
| 43 | PIMP | F | 4 | Import Price Index (average 2006 = 100) | FUNCEX |
| 44 | PEXP | F | 4 | Export Price Index (average 2006 = 100) | FUNCEX |

**Table 1C -** Price Indexes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Code | S / F | Transf | Description | Source |
| 45 | IPAEP | S | 1 | IPA-EP - Broad Producer Price Index | Getulio Vargas Foundation |
| 46 | IGPOG | S | 1 | IGP-OG - Hybrid Price Index | Getulio Vargas Foundation |
| 47 | IGPDI | S | 1 | IGP-DI - Hybrid Price Index | Getúlio Vargas Foundation |
| 48 | INCC | S | 2 | INCC – Construction Price Index | Getúlio Vargas Foundation |
| 49 | IPCA | S | 1 | IPCA – Broad Consumer Price Index (All Items) | IBGE |
| 50 | IPCAL | S | 2 | IPCA Free Prices – Narrow Consumer Price Index | IBGE |
| 51 | IPCALC | S | 2 | IPCA Free Prices Marketable Goods – Narrow Consumer Price Index | IBGE |
| 52 | IPCAN | S | 2 | Core IPCA – Consumer Price Index | IBGE |
| 53 | IPC | S | 1 | IPC – Consumer Price Index (All Items) | Getúlio Vargas Foundation |
| 54 | INPC | S | 2 | INPC Consumer Price Index (All Items) | IBGE |
| 55 | PPC | S | 4 | Purchasing Power Parity rate of Household Consumption | IPEA |
| 56 | EIPCA | S | 2 | IPCA Inflation Expectation for the next 12 months (% p.a.) | Brazilian Central Bank |
| 57 | EIGPDI | S | 2 | IGD-PI Inflation Expectation for the next 12 months (% p.a.) | Brazilian Central Bank |
| 58 | EIPADI | S | 2 | IPA-DI Inflation Expectation for the next 12 months (% p.a.) | Brazilian Central Bank |
| 59 | PCOM | S | 4 | International Commodity Price Index | IMF |

**Table 1D -** International Indicators

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Code | S / F | Transf | Description | Source |
| 60 | SHANGHAI | S | 4 | Shanghai Stock Price Index: Composite - Monthly Closing | Investing.com |
| 61 | CAC40 | S | 4 | CAC40 Stock Price Index - Monthly Closing | Investing.com |
| 62 | FTSE | S | 4 | FTSE 500 Stock Price Index - Monthly Closing | Investing.com |
| 63 | DAX | S | 4 | DAX Stock Price Index - Monthly Closing | Investing.com |
| 64 | SP500 | S | 4 | Standard and Poor's 500 Stock Price Index: Composite - Monthly Closing | Inveting.com |
| 65 | Dow30 | S | 4 | Dow Jones 30 Stock Price Index - Monthly Closing | Investing.com |
| 66 | NIKKEI | S | 4 | Nikkei 225 Stock Price Index - Monthly Closing | Investing.com |
| 67 | PPIUSA | S | 4 | Producer Price Index – USA | Federal Reserve Bank |
| 68 | CPIUSA | S | 4 | Consumer Price Index – USA | Federal Reserve Bank |
| 69 | PPIEURO | S | 4 | Producer Price Index – Eurozone | IMF |
| 70 | CPIEURO | S | 4 | Consumer Price Index – Eurozone | IMF |

SA - Seasonally adjusted by the source. \* Seasonally adjusted by the Census X-13 ARIMA methodology (US Census Bureau).

**Appendix C. Autocorrelation and Normality Tests - Probability Values[[23]](#footnote-23)**

**Table 2A -** Period of Estimation: from 2003:M07 to 2016:M12

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  | Autocorrelation Test (LM) | | | | | Normality Test (JB) | | Lags | | Relation | Order 1 Order 2 | | Order 3 | Order 4 | Order 5 | |  |  | | Relation 1 | 0.1099 0.1278 | 0.1366 | | 0.5369 | 0.9050 | | 0.1814 | 8 | | Relation 2 | 0.1056 0.2241 | 0.1013 | | 0.2679 | 0.6764 | | 0.0301 | 4 | | Relation 3 | 0.5380 0.0916 | 0.0764 | | 0.4135 | 0.4004 | | 0.1917 | 4 | | Relation 4 | 0.0747 0.5617 | 0.2623 | | 0.4042 | 0.3164 | | 0.0011 | 6 | | Relation 5 | 0.1380 0.0473 | 0.2119 | | 0.3876 | 0.6160 | | 0.0510 | 7 | | Relation 6 | 0.1171 0.4779 | 0.3008 | | 0.6918 | 0.6611 | | 0.0000 | 7 | | Relation 7 | 0.1323 0.1822 | 0.5338 | | 0.2255 | 0.7038 | | 0.0155 | 4 |   This table reports the probability values of the residual autocorrelation (LM) and the Jarque Bera Normality (JB) tests of the  VAR estimations. The sample is from 2003:M07 to 2009:M12. |

**Table 2B -** Period of Estimation: from 2003:M7 to 2009:M12

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Autocorrelation Test (LM) | | | | | Normality Test (JB) | | Lags |
| Relation | Order 1 Order 2 | | Order 3 | Order 4 | Order 5 | |  |  |
| Relation 1 | 0.3419 0.1392 | 0.6991 | | 0.5100 | 0.2657 | | 0.8420 | 6 |
| Relation 2 | 0.3412 0.4814 | 0.2509 | | 0.2230 | 0.2297 | | 0.9614 | 6 |
| Relation 3 | 0.0546 0.8657 | 0.2704 | | 0.5934 | 0.2586 | | 0.9650 | 3 |
| Relation 4 | 0.1637 0.7251 | 0.4174 | | 0.8789 | 0.2673 | | 0.7552 | 3 |
| Relation 5 | 0.3755 0.1582 | 0.9034 | | 0.6760 | 0.1904 | | 0.0495 | 6 |
| Relation 6 | 0.1398 0.0973 | 0.0753 | | 0.1005 | 0.8024 | | 0.9941 | 4 |
| Relation 7 | 0.7977 0.1315 | 0.7131 | | 0.4504 | 0.3988 | | 0.6173 | 5 |

This table reports the probability values of the residual autocorrelation (LM) and the Jarque Bera Normality (JB) tests of the

VAR estimations. The sample is from 2003:M07 to 2009:M12.

**Table 2C -** Period of Estimation: from 2010:M01 to 2016:M12

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  | Autocorrelation Test (LM) | | | | | Normality Test (JB) | | Lags | | Relation | Order 1 Order 2 | | Order 3 | Order 4 | Order 5 | |  |  | | Relation 1 | 0.8348 0.6700 | 0.1091 | | 0.1948 | 0.3316 | | 0.0007 | 5 | | Relation 2 | 0.4090 0.5509 | 0.0866 | | 0.2640 | 0.7714 | | 0.0002 | 4 | | Relation 3 | 0.9535 0.7471 | 0.2967 | | 0.2674 | 0.7133 | | 0.0210 | 4 | | Relation 4 | 0.5145 0.5557 | 0.1023 | | 0.4988 | 0.3555 | | 0.0076 | 4 | | Relation 5 | 0.3610 0.9467 | 0.5639 | | 0.6315 | 0.4403 | | 0.0015 | 4 | | Relation 6 | 0.7428 0.9592 | 0.5876 | | 0.6917 | 0.5134 | | 0.1839 | 4 | | Relation 7 | 0.6900 0.5986 | 0.7506 | | 0.6581 | 0.7430 | | 0.0025 | 4 |   This table reports the probability values of the residual autocorrelation (LM) and the Jarque Bera Normality (JB) tests of the VAR estimations. The sample is from 2010:M01 to 2016:M12. |  |

**Appendix D. IRF: Impulse of one standard deviation in the SELIC interest rate.**

Period: from 2003:M07 to 2016:M12:

Relation 1

  

Relation 2

  

Relation 3

   

Relation 4

   

Relation 5

  

Relation 6

    

Relation 7

   

Period: from 2003:M07 to 2009:M12:

   

  

Period: from 2010:M01 to 2016:M12:

   

  

**Appendix E. IRF**: Impulse of one standard deviation in the SELIC, considering 8 common factors, 6 lags and 90%

confidence interval (standard bootstrap: 1000 replications). Period: from 2003:M07 to 2016:M12.



**Appendix F. IRF:** Impulse of one standard deviation in the SELIC, considering 6 common factors, 4 lags and 90% confidence interval (standard bootstrap: 1000 replications). Period: from 2003:M07 to 2009:M12.



**Appendix G. IRF:** Impulse of one standard deviation in the SELIC, considering 6 common factors, 4 lags and 90%

confidence interval (standard bootstrap: 1000 replications). Period: from 2010:M01 to 2016:M12.



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2. Professor Associado do Departamento de Economia Rural e do Programa de Pós-Graduação em Economia Aplicada da Universidade Federal de Viçosa (UFV). E-mail: lbmattos@ufv.br [↑](#footnote-ref-2)
3. Since the adoption of the floating exchange rate regime, the Brazilian Central Bank has intervened in the foreign exchange market several times to prevent excessive volatility of the Real (Carneiro and Wu, 2004). [↑](#footnote-ref-3)
4. It is the adjusted weighted average interest rate of financing in the interbank market, for one-day (or overnight) operations that have a bearing on federal government securities listed and traded on the Special System of Settlement and Custody (SELIC). It is the basic short-term interest rate used as the monetary policy instrument. [↑](#footnote-ref-4)
5. See Schabert et al. (2004) for a comprehensive discussion on the inclusion of the cost channel within Dynamic Stochastic General Equilibrium models (DSGE) to simulate the occurrence of the “price puzzle” in Italy and in the UK. [↑](#footnote-ref-5)
6. Lower case letters are used for variables in natural logarithm and upper case for variables in level. The Cholesky method was used in the decomposition of the matrix of variances and covariances of the model, ensuring the orthogonality of the errors. [↑](#footnote-ref-6)
7. Broad Consumer Price Index (all items) measured monthly by the Brazilian Institute of Geography and Statistics. The National Monetary Council (CMN) defines the annual inflation rate target based on the IPCA inflation. [↑](#footnote-ref-7)
8. It was employed the Hodrick-Prescott filter to generate the output gap with 129600 smoothing parameter, since the data series is in a monthly frequency (Ravn and Uhlig, 2002). Goodhart et al. (2005), Chadha et al. (2003), Favero et al. (2005) also use this filter to obtain the output gap in their research. [↑](#footnote-ref-8)
9. The data set consists of the indicators potentially used by the Brazilian Central Bank to adjust the SELIC interest rate and is formed by the 69 variables presented in Tables 1A, 1B, 1C and 1D of Appendix B. Boivin and Ng (2006) found that the extraction of common factors from a small set of variables (about 40 time series) showed good results, and marginally better when compared to a more extensive set (147 time series). The inclusion of series that add no information can reduce the explanatory power of the factors by adding noise to the estimation (“noisy series”). [↑](#footnote-ref-9)
10. No information was found on several variables used in this paper for years prior to July 2003 and, part of the series for the period after December 2016 is still under review. [↑](#footnote-ref-10)
11. The HQIC and SBIC were employed to determine the number of lags (limited to a maximum of six lags). The unit root tests were performed at a 10% significance level. The Perron (1997) test allows for the possibility of structural breaks in the time series. [↑](#footnote-ref-11)
12. According to Juselius (2006), the lack of residual normality does not seriously affect the results of the VAR model, especially when caused by excess kurtosis. [↑](#footnote-ref-12)
13. Hair et al. (2006) suggests that the process of the principal components extraction should continue until reaching at least a proportion of 60% of the total variance of the data set. [↑](#footnote-ref-13)
14. This method allows that the correlation coefficients between the variables and the factors (the factor loads) be set the closest to zero or one, in absolute value, to simplify and clarify the interpretation of the data structure (Osborne, 2005). [↑](#footnote-ref-14)
15. The CDI is the average interest rate, indicative against which a representative group of banks makes unsecured loans to each other in the Brazilian financial market. [↑](#footnote-ref-15)
16. The swap DI x Fixed Interest Rate is a floating for fixed swap contract. This is a contractual arrangement between two parties to swap interest cash flows floating and fixed rate loans, with those of floating rate loans held by another party. The principal of the underlying loans is not exchanged. The 360 day swap DI x Fixed Interest Rate provides the 360 day fixed interest rate. The DI is a floating interest rate retrieved from the CDI rate. [↑](#footnote-ref-16)
17. The IPCA, the IPC and the INPC are consumer price indexes with different construction methodologies. The IPA-EP is a broad producer price index. The INCC is a price index that measures the construction sector prices. The IGP-DI and the IGP-OG are both consumer and producer hybrid price indexes with different methodology approaches. The IGP-DI and the IGP-OG are built based on a weighted average of the IPA-DI, the IPC-DI and the INCC with weights of 60%, 30% and 10%, respectively [↑](#footnote-ref-17)
18. The Cronbach's Alpha is an index between 0 and 1 which attempts to measure the internal consistency of a set of variables (the closer to unity the higher the reliability of the construct). Hair et al. (2005) suggest a minimum value of 0.60 (exploratory research) and 0.70 (confirmatory research) to the index. The whole data set reached a value of 0.91, and the group of variables (dimensions 1 to 8) achieved the values: 0.95 0.93, 0.85, 0.85, 0.85, 0.82, 0.78 and 0.64, (standardized variables), respectively. [↑](#footnote-ref-18)
19. Monetary policy is set to be active (passive) when changes in nominal interest rates occur more (less) than proportionally in response to inflation movements. [↑](#footnote-ref-19)
20. The “exchange rate puzzle” occurs when there has been a change of behavior that cannot be explained by models of the exchange rate determination grounded in the theory of rational expectations (“the disconnect, the excess volatility and the non-normality puzzles”). In this paper, the “exchange rate puzzle” is associated with detecting domestic currency depreciation as a response to a rise in interest rates (see Grauwe et al., 2004). [↑](#footnote-ref-20)
21. The liquidity effect is originally set in a situation where does not occur a reduction in the interest rate after an increase in the money stock. In this paper, the concept of the “liquidity puzzle” is used more broadly, where the interest rate is the instrument of monetary policy and the money stock does not negatively respond to increases in interest rates. [↑](#footnote-ref-21)
22. The detailed results are not reported here, but are available from the authors upon request. [↑](#footnote-ref-22)
23. The null hypothesis is the presence of serial autocorrelation and non-normality. [↑](#footnote-ref-23)