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Estimating the Credibility of Brazilian Monetary Policy using Forward Measures and a State-Space Model

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Non-technical Summary

The credibility of a central bank is crucial within an inflation-targeting regime. It is directly related to the central bank's ability to coordinate and properly anchor inflation expectations, but also reflects the past history of observed inflation *vis-à-vis* the respective inflation targets and tolerance intervals.

The objective of this study is to estimate the credibility of the monetary policy in Brazil from 2006 until mid-2017. To do so, we use a Kalman filter approach based on two distinct measures of inflation expectations: (i) breakeven inflation (from financial data); and (ii) the consensus inflation expectation from the Focus survey (with professional forecasters) conducted by the Central Bank of Brazil.

The results indicate that credibility based on breakeven inflation declined in mid-2008, during the U.S. subprime mortgage crisis, remained relatively stable from early 2009 to mid-2015, strong declined by the end of 2015 and recovered from mid-2016 until mid-2017 (end of the sample). The Focus survey credibility exhibited a more regular behavior, reflecting the degree of anchoring of the survey-based inflation expectations for the considered medium/long-term forecast horizon.

In addition, by associating the estimated credibility with financial and macroeconomic variables, we have also found that credibility is relatively persistent and seems not to be influenced by short-run movements of such variables.

Sumário Não Técnico

A credibilidade de um banco central é crucial num regime de metas de inflação e está diretamente associada à capacidade da autoridade monetária em coordenar e ancorar as expectativas de inflação, além de também refletir o histórico inflacionário *vis-à-vis* as respectivas metas de inflação e seus intervalos de tolerância.

O objetivo deste estudo é estimar a credibilidade da política monetária no Brasil no período de 2006 até 2017. Neste sentido, utilizamos um filtro de Kalman com base em duas medidas distintas de expectativas de inflação: (i) inflação implícita (expectativa de inflação extraída de dados financeiros); e (ii) expectativa de inflação da pesquisa Focus (com analistas profissionais) conduzida pelo Banco Central do Brasil.

Os resultados indicam que a credibilidade baseada na inflação implícita diminuiu em meados de 2008, durante a crise hipotecária nos EUA, manteve-se relativamente estável desde o início de 2009 até meados de 2015, caiu fortemente ao final de 2015 e recuperou-se desde meados de 2016 até meados de 2017 (final da amostra). A credibilidade baseada na pesquisa Focus apresentou um comportamento mais regular, refletindo o grau de ancoragem das expectativas de inflação da pesquisa Focus no horizonte de projeção considerado.

Adicionalmente, ao associar a credibilidade estimada com variáveis macroeconômicas e financeiras, os resultados indicam que a credibilidade é relativamente persistente e aparentemente não é influenciada por movimentos de curto-prazo das referidas variáveis.

Estimating the Credibility of Brazilian Monetary Policy using Forward Measures and a State-Space Model [*]

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Abstract

The objective of this study is to estimate the credibility of the monetary policy followed by the Central Bank of Brazil (BCB) during the period from January 2006 to July 2017. To estimate this credibility, we use the Kalman filter in two measures of inflation expectations (breakeven inflation and Focus survey) with a medium/long-term forecast horizon. The results indicate four shifts in the perceived credibility based on breakeven inflation: (i) decline in mid-2008, during the U.S. subprime mortgage crisis; (ii) relative stability from early 2009 to mid-2015; (iii) strong decline by the end of 2015; and (iv) recovery from mid-2016 until mid-2017 (end of the sample). The credibility measure based on the Focus survey showed a more regular behavior, reflecting the degree of anchoring of the survey-based inflation expectations for the considered horizon. By associating the estimated credibility with financial and macroeconomic variables, we have also found that credibility is relatively persistent and seems not to be influenced by short-run movements of such variables.

Keywords: Credibility, Kalman filter, monetary policy.

JEL Classification: E4, E5.

[*] An earlier version of this paper circulated as *"Estimating the credibility of Brazilian monetary policy using a Kalman filter approach"*, based on a shorter forecast horizon and using a sample from January 2006 to December 2015.

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1. Introduction

During the past two decades, a number of countries have adopted inflation-targeting monetary policies. Currently, 28 countries use such a regime; half of these are emerging or low-income countries.[5] Brazil adopted such a regime in 1999, and other pioneering countries include New Zealand (1990), Canada (1991), the United Kingdom (1992), and Sweden (1993). In general, the results achieved by these countries have been very positive.

Inflation targeting is a monetary policy regime that encompasses five elements: (i) the public announcement of numeric, medium-term inflation targets; (ii) institutional commitment to price stability as the prime objective; (iii) an information strategy in which a number of variables (both monetary and nonmonetary) are used in making decisions; (iv) improved transparency, via communication with the public and the market concerning the monetary authority's plans, objectives, and decisions; and (v) increased central bank responsibility for achieving inflation targets (Mishkin, 2000).

Thus, in an inflation-targeting regime, the transparency of the monetary authority's actions, communication with the public and the market, and anchoring of inflation expectations are essential for the central bank to be able to use its instruments at the lowest possible cost for society and the greatest possible efficiency.

Furthermore, in an inflation-targeting regime, the anchoring of inflation expectations is directly and intrinsically tied to the monetary policy's perceived credibility. Bernanke's (2010) statement summarizes the importance of credibility: *"When the central bank is not credible, the public will expect high inflation and, accordingly, demand more rapid increases in nominal wages and in prices."*

In this framework, in which a central bank follows an inflation-targeting monetary policy regime, the central bank's credibility may be defined by whether the private sector's inflation expectations coincide with the inflation target. Because inflation expectations can be estimated by, for example, professional forecasts' surveys or a comparison of nominal yield curves and real yield curves, the central bank's credibility also can be measured explicitly.

[5] Jahan (2012).

Thus, one of the many benefits associated with the announcement of inflation targets is the ease with which their credibility can be measured. Another benefit is that credibility introduces considerable mean reversion of inflation to its target, which reduces the need for monetary policy to affect real economic activity (e.g., production and employment) to achieve the target inflation.[6] As pointed out by Svensson (2000), *"credibility improves the tradeoff between inflation variability, output-gap variability, and instrument variability, and makes it easier for the central bank to meet its inflation target."*

The objective of this study is to estimate the credibility of the monetary policy followed by the Central Bank of Brazil (BCB) during the past twelve years (2006–2017). It contributes to the existing literature by employing Svensson's (1993) credibility test and extending it within an econometric framework of state-space, allowing for the probabilistic estimation of the credibility of the monetary policy implemented by the BCB. We use the Kalman filter approach to estimate the subjective confidence of market agents in the inflation targets set by the National Monetary Council (CMN).

The results of this study suggests the existence of four shifts in inflation credibility based on breakeven inflation along 2006-2017. In turn, the inflation credibility based on the Focus survey showed a more regular pattern, reflecting the degree of anchoring of the survey-based inflation expectations in the medium/long run.

By associating the estimated credibility with financial and macroeconomic variables, including economic cycles, we have found that credibility is relatively persistent and seems not to be influenced by short-run movements of such variables.

In addition, we have found that the credibility based on breakeven inflation helps predicting some macroeconomic/financial variables. On the other hand, there is no Granger causality comprising the Focus survey credibility and the macroeconomic/financial variables. Also, there is no Granger-causality between the two credibility measures.

The remainder of this article is organized as follows: Section 2 presents a summary of the relevant literature. Section 3 describes the methodology used to estimate the credibility of the BCB's monetary policy. Section 4 describes and analyzes the data used in the study. Section 5 presents the empirical results. Finally, section 6 summarizes the conclusions of the study.

[6] For additional details, see Svensson (2000).

2. Literature Review

Since the seminal article by Kydland and Prescott (1977), in which the authors showed that a discretionary central bank could generate an inflationary bias, the intertemporal consistency of monetary policy has been the subject of empirical investigation. In this regard, the credibility of monetary policy has become an interesting subject of study for various market agents.

Tronzano (2005) identified empirical literature that sought to evaluate the credibility of monetary policy within a framework characterized by inflation targets. He emphasized that the literature about the credibility of inflation-targeting regimes can be divided into two lines of research.

The first line of research explores the existence of significant macroeconomic effects induced by changes in monetary policy rules. One clear characteristic of this line of research is the indirect evaluation of the credibility of monetary policy, because there is no theoretical framework to constitute a basis for empirical analysis. Tronzano (2005) pointed to the studies by Fischer and Orr (1994), Almeida and Goodhart (1998), Groeneveld et al. (1998), Minella et al. (2003), and Matousek and Taci (2003) as articles in this line. With regard to the Brazilian market, it is also worth mentioning Moreira (2015).

The second line of research focuses on direct evaluation of the credibility of the inflation target. In contrast to the first line, this line generally relies on a relevant theoretical relationship, such as the Fisher equation, the term structure of interest rates, or the concept of marginal credibility. Tronzano (2005) highlighted studies by Svensson (1993), Ruge-Murcia (2000), and Maliszewski (2002) in this line.

In this article, we seek to contribute to the second line of research by directly evaluating the credibility of the BCB's monetary policy during a period in which an inflation-targeting regime already had been implemented. Therefore, we build on some of the main articles in this line of research, as is described below.

Svensson (1993) developed what he called the *"simplest test of inflation-target credibility"*, which assesses when an inflation target is credible based on whether market agents believe that in the future inflation will be within a specified range of the target. He distinguished two concepts of inflation-target credibility. The first, a concept of strong credibility that he named absolute credibility, occurs when agents believe, with 100% probability, that future inflation will be within the specified range of the target. The

second concept, weaker credibility or credibility in expectation, occurs when agents expect that future inflation will be within the specified range of the target. In other words, the agents believe that there is a nonzero probability that the inflation target will not be achieved.

Svensson's credibility test consists of estimating, for a specified future time horizon, the minimum and maximum inflation rates consistent with the target inflation range. These minimum and maximum inflation rates then are subtracted from the nominal yields of government bonds of similar maturity to calculate corresponding real interest rates. If the real interest rates are outside the interest-rate range consistent with the target inflation range, both absolute credibility and credibility in expectation are rejected.[7]

In Svensson's study, the results of the credibility test are inconclusive for Canada and tends to reject credibility during the first years of inflation-targeting regime in New Zealand and Sweden. His results indicate that, to achieve the desired credibility, some time may be required following the announcement of an inflation target.

Ruge-Murcia (2000) proposed an econometric model, based on data from December 1992 through August 1999, for estimating Canada's inflation rate in an inflation-targeting regime. Using the Fisher equation and a term structure of interest rates, which he estimated based on Canadian government bonds, Ruge-Murcia implemented economic restrictions in the joint process that determines inflation rates and long-term interest rates, assuming that the central bank follows an explicit inflation-targeting policy. He analytically derived and empirically tested two versions of the model. The first version assumed that the announced inflation target is credible, such that all deviations outside the target range are transitory and are generated by random shocks. In the second version, monetary policy is assumed to be inconsistent with the announced inflation target but compatible with an implicit range that differs from the publicly announced range. He applied both versions of the model to the Canadian market, and the results included the following: The first version was rejected in favor of the second version, and compared to the publicly announced target range, the implicit range has the same size but is asymmetrically distributed around its mean. These results demonstrate the persistent

[7] Svensson's (1993) credibility test relies on the assumptions that arbitrage is possible in the markets for fixed-income bonds and that the inflation risk premium is relatively low.

process of undershooting the inflation target, perhaps due to the monetary authority's asymmetric inflation preference.[8]

Although Svensson (1993) and Ruge-Murcia (2000) estimated credibility by using the concept of arbitrage, through the Fisher equation and relationships among macroeconomic variables, respectively, Maliszewiski (2008) used the concept of marginal credibility, defined by Cukierman and Meltzer (1986). Marginal credibility is the monetary authority's ability to influence market expectations by making announcements regarding monetary policy. Maliszewiski (2008) adopted an econometric approach that employs three sources of information: the inflation target announced by the central bank (target model), the expected inflation estimated via Bayesian vector autoregression (BVAR model), and the expected inflation from surveys. The main assumption of his study is that expected inflation from surveys is derived from aggregate predictive densities of the target model and the BVAR model. Because each agent's prediction is assumed to be a weighted average of the predictions of the target model and the BVAR model, the weight associated with the target model's prediction is an estimate of marginal credibility. Maliszewiski's (2008) empirical investigation of the Polish experience confirmed strong credibility effects: The predictive densities of the alternative models showed, after the introduction of a new inflation target, increased concentration of survey-based expectations around the announced target. Additional empirical estimates of the weight associated with the target model (Tronzano et al., 2000) corroborated this finding. Generally speaking, this indicator of marginal credibility appears to increase during the analyzed period, particularly after the formal introduction of the inflation-targeting regime in Poland, which took place in 1999. According to Maliszewiski (2008), the dynamics appear to depend on institutional reforms, past deviations of inflation from established targets, and the predictive ability of the time-series models.

Demir and Yigit (2008) used inflation expectations from market surveys in the United Kingdom and New Zealand. By estimating a state-space model, they sought to construct a time-varying measure of credibility and show that the accuracy and frequency of announced changes in inflation targets positively affect the confidence of market agents in the central bank's announced targets.

[8] Ruge-Murcia (2000) showed that systematic undershooting of the inflation target may occur in a framework in which the central bank weights positive deviations more heavily than negative deviations.

Amisano and Tronzano (2010) extended Svensson's (1993) credibility test by inserting it within a Bayesian econometric framework. Their article contributed to the literature regarding monetary-policy credibility by developing time-varying estimates of the credibility of the European Central Bank's (ECB's) and providing a quantitative evaluation of the consistency of monetary policy over the long term in an inflation-targeting regime. The results showed that the ECB was successful in its objective of building and maintaining high credibility during the first years of the Eurosystem (composed of the European Central Bank and the national central banks of the member states whose currency is the euro).

Driven by concern that the 2008 economic crisis might have undermined the Bank of England's credibility, Biefang-Frisancho et al. (2011) used Kalman filtering and Bayesian estimation in constructing four measures of inflation expectations to estimate the Bank of England's credibility in the years after the adoption of an inflation-targeting regime in 1992. The results showed that these credibility measures were stable until the start of the economic crisis in 2007 but deteriorated thereafter.

Of the studies of the Brazilian market, we highlight that of Guillén and Garcia (2014), who developed an index of the BCB's credibility during the period between mid-2002 and 2007. They used Markov chains and base their study on the hypothesis that the heterogeneity of long-term expectations arises from distinct beliefs in relation to the BCB's aversion to inflation.

3. Methodology

3.1 Credibility Indicators Previously Suggested in the Literature

In order to estimate the credibility of the monetary policy and compare the results to those of Svensson's test, four additional widely used methodologies, proposed by Cecchetti and Krause (2002), Sicsú (2002), Mendonça (2004), and Mendonça and Souza (2009), were used.

Cecchetti and Krause (2002) proposed a normalized credibility index, between zero and one, that measures deviations in inflation expectations ($E(\pi_t)$) from the inflation target (π_t):

$$CI_{Ceccheti\ and\ Krause} = \begin{Bmatrix} 1 & ; & if\ E(\pi) \leq \pi_t \\ 1 - \frac{E(\pi) - \pi_t}{0.2 - \pi_t}; & & if\ \pi_t < E(\pi) < 20\% \\ 0 & ; & if\ E(\pi) \geq 20\% \end{Bmatrix} \quad (1)$$

For the Brazilian market, Sicsú (2002) proposed an indicator of inflation expectations ($E(\pi)$) similar to that proposed by Cecchetti and Krause (2002), based on the inflation target (π_t) and its upper limit (π_t^{max}):

$$CI_{Sicsú} = 100 - \left(100 * \frac{|E(\pi) - \pi_t|}{\pi_t^{max} - \pi_t}\right) \quad (2)$$

Mendonça (2004) proposed a normalization of Sicsú's index, which can have negative values, so that it lies in the [0,1] range; in this normalization, $\pi_t^* = \{\pi_t^{min}; \pi_t^{max}\}$ are the lower and upper limits of the inflation target:

$$CI_{Mendonça} = \begin{Bmatrix} 1 & ; & if\ E(\pi_t) = \pi_t \\ 1 - \frac{E(\pi_t) - \pi_t}{\pi_t^* - \pi_t} & ; & if\ \pi_t^{min} < E(\pi_t) < \pi_t^{max} \\ 0 & ; & if\ E(\pi_t) \geq \pi_t^{max}\ or\ E(\pi_t) \leq \pi_t^{min} \end{Bmatrix} \quad (3)$$

Mendonça and Souza (2009) proposed credibility indicators based on the assumption that credibility can be measured by medium- to long-term reputation over time. Like reputation, these measures of credibility consider observed inflation and therefore have backward-looking characteristics.

$$R = \begin{Bmatrix} 1 & if\ \pi_t^{min} \leq \pi_t^{obs} \leq \pi_t^{max} \\ 1 - \frac{\pi_t^{obs} - \pi_t^{max}}{0.2 - \pi_t^{max}}; & if\ \pi_t^{max} < \pi_t^{obs} < 20\% \\ 1 - \frac{\pi_t^{obs} - \pi_t^{min}}{-\pi_t^{min}}; & if\ 0\% < \pi_t^{obs} < \pi_t^{min} \\ 0 & if\ \pi_t^{obs} \geq 20\%\ or\ \pi_t^{obs} \leq 0\% \end{Bmatrix} \quad (4)$$

$$CI_{Mean} = \frac{\sum_{i=1}^{n} R_i}{n} \quad (5)$$

in which R is the monetary authority's reputation, π_t^{obs} is the inflation observed during the preceding twelve months, π_t^{min} and π_t^{max} are, respectively, the lower and upper limits of the inflation target. In that study, Mendonça and Souza estimated two credibility indices: CI_{Mean}, defined in equation (5), is the central bank's mean reputation over time and $CI_{Weighted}$, defined in equation (6) is the central bank's weighted-average reputation over time.

$$CI_{Weighted} = \frac{\sum_{i=1}^{n}(R_i * p_i)}{\sum_{i=1}^{n}(p_i)} \quad (6)$$

The weight ($p_i = k_i/n$) decreases as a function of time t, that is, because the weight p_i is the ratio of k_i, which decreases as a function of time t, and n, it is limited to the interval [0,1].

3.2 Svensson's Credibility Test

The methodology implemented in this subsection, and in the following one, is based on the methodologies proposed by Svensson (1993), Amisano and Tronzano (2010), and Biefang-Frisancho et al. (2011).

Svensson (1993) developed a test of the credibility of the monetary policy of an inflation-targeting regime in which the central bank sets and announces to the market a target, minimum (π_{min}), and maximum (π_{max}) for the inflation rate. In Svensson's test, the minimum and maximum real interest rates consistent with the inflation target tolerance intervals (CMmin and CMmax, respectively) are calculated by subtracting the target maximum inflation rate (π_{max}) and target minimum inflation rate (π_{min}) from the nominal yields of government bonds (i_t):

$$CM_{min} = i_t - \pi_{max} \quad (7)$$

$$CM_{max} = i_t - \pi_{min} \quad (8)$$

Actual real interest rates are then compared to this real-interest-rate target range to determine whether they lie within or outside the target range. If the actual real interest rate is outside the target range, the announced inflation targets (π_{min} and π_{max}) are not credible, because the agents may realize profits without risk, which is inconsistent with the equilibrium of an efficient capital market. Note, however, that as long as r_t, the real

interest rate, lies within the target range $(i_t - \pi_{max} \leq r_t \leq i_t - \pi_{min})$, the condition of arbitrage between real and nominal yields enables the estimation of the credibility of both inflationary and deflationary monetary policies.

Although easily implemented and interpreted, Svensson's (1993) test has deficiencies. First, it does not allow the extraction of information about the monetary policy's credibility level but rather allows only for determination of whether the target is successful. Second, it does not reveal how the central bank's reputation evolves over time, although it does reveal the success or failure of the monetary policy, which can be determined at each point in time. Therefore, Svensson's test prevents the estimation of the confidence of economic agents in the consistency of an inflation-targeting regime's monetary policy.

3.3 Extending Svensson's Test to a Probabilistic Framework

Amisano and Tronzano (2010) extended Svensson's (1993) analysis to a probabilistic model, which enables the monetary policy's credibility level. Given the restrictions previously defined, which correspond to the absence of an inflationary bias or a deflationary bias, respectively, in the monetary policy, inflation credibility exists if $r_t \geq i_t - \pi_{max}$ and deflationary credibility exists if $r_t \leq i_t - \pi_{min}$.

The auxiliary variables that represent these credibility restrictions are defined as follows:

$$z_u = r_t - (i_t - \pi_{max}) \tag{9}$$

$$z_l = r_t - (i_t - \pi_{min}) \tag{10}$$

In other words, inflation credibility exists if $z_u > 0$ and deflationary credibility exists if $z_l < 0$.

Inflation-target credibility can be estimated by analyzing the stochastic properties of the z_u and z_l series. A simple way of modeling these series is to assume that they can be characterized by a constant term plus a random disturbance:

$$z_u = \mu_u + \varepsilon_t \tag{11}$$

$$z_l = \mu_l + \varepsilon_t \tag{12}$$

in which ε_t is the independent error term, which is distributed as $N(\alpha, \sigma)$.

If equations (11) and (12) are estimated within a probabilistic framework, the means μ_u and μ_l can be treated as random variables about which the agents may form subjective opinions of probability. In this context, the restrictions imposed by Svensson's test (1993) correspond to the probability of μ_u being greater than zero and the probability of μ_l being less than zero. The main advantage of this approach is that the probabilities enable the estimation of the monetary policy's credibility level. In addition, because the probabilities can be updated recursively as new information becomes available, this approach enables the inference of how the credibility level changes over time.

More formally, focusing, for example, on the restrictions of inflation-target credibility, the monetary policy's credibility level at time t can be expressed as follows:

$$Pr\left(\mu_{u(t)} > 0 \middle| \mathrm{z_{u(t)}}, \mathrm{z_{u(t-1)}}, \ldots, \mathrm{z_{u(2)}}, \mathrm{z_{u(1)}}\right) \tag{13}$$

Amisano and Tronzano (2010) and Biefang-Frisancho et al. (2011) emphasized that this approach depends on the assumption that the time series $\mathrm{z_u}$ and $\mathrm{z_l}$ can be modeled as not serially correlated. However, that assumption is violated by the Brazilian and European data. Appendix A presents the correlograms of these series, which can be characterized as first-order autoregressive processes, AR(1), which exhibit a high level of persistence.

This empirical framework can be adapted to a situation in which serial correlation exists if equations (11) and (12) are replaced by the following equations:

$$z_{u(t)} = \theta_u + \rho z_{u(t-1)} + \varepsilon_t \tag{14}$$

$$z_{l(t)} = \theta_l + \rho z_{l(t-1)} + \varrho_t \tag{15}$$

in which ρ is the autoregressive parameter and θ_u and θ_l are the intercepts of the corresponding models. The parameter ρ is common to both equations, because the series z_l is obtained by downward displacement of the series z_u.

In the alternative specification outlined by equations (14) and (15), the credibility conditions are satisfied when $\theta_u > 0$ (absence of inflationary bias in the monetary policy), $\theta_l < 0$ (absence of deflationary bias in the monetary policy), and $|\rho| < 1$ (mean reversion of the stochastic processes).[9]

[9] The constant terms θ are related to the unconditional mean (μ) of $z_{(t)}$ by the equation $\theta = \mu(1-\rho)$, with $\theta = 0 \rightarrow E(z) = \mu = 0$, that is, when θ is equal to zero, $z_{(t)}$ has a null unconditional mean.

Inflation credibility is defined as the probability of a positive parameter (θ_u) in equation (14) at each point in time:

$$Pr\left(\theta_{u(t)} > 0 \middle| z_{u(t)}, z_{u(t-1)}, \dots, z_{u(2)}, z_{u(1)}\right) \quad (16)$$

In contrast, deflationary credibility is defined as the probability of a negative parameter (θ_l) in equation (15) at each point in time:

$$Pr\left(\theta_{l(t)} < 0 \middle| z_{u(t)}, z_{u(t-1)}, \dots, z_{u(2)}, z_{u(1)}\right) \quad (17)$$

4. Econometric Approach, Sample and Treatment of the Database, and the Relationship between Credibility and Macroeconomic and Financial Variables

4.1 Econometric Approach

The Kalman filter is an estimation method based on regression estimates for each period based on estimates from the previous period and data regarding the current period. In other words, the resulting estimates consider both historical and contemporaneous data. The Kalman filter was used by Demir and Yigit (2008) and Biefang-Frisancho et al. (2011) in similar contexts.

Basically, Kalman filtering consists of the following: (i) a measurement equation, which describes how the observed data are generated based on the state variables, that is, it relates the vector of observations with the vector of states, the explanatory variable, and the measurement error, and (ii) a transition equation, which describes the evolution of the set of state variables. Kalman filtering is a recursive method that estimates the state variables in period t based on contemporaneous information. A conditional function of maximum likelihood is used to update the information for each period.[10]

This article uses a first-order autoregressive model (AR(1)) to estimate the variables $z_{u(t)}$ and $z_{l(t)}$. Using the Kalman filter, the parameters θ_u and θ_l can be estimated in such a way that different values are obtained for them for each moment in the sample, allowing inflation credibility and deflationary credibility, respectively, to be studied based on the evolution of the parameters over time. It is worth stressing that the time series of the estimated parameters are constructed based on filtered estimates of the parameters, which

[10] For additional detail about the process of Kalman filtering, see Hamilton (1994).

are based on the set of information available in each period. Thus, the following system is estimated:

$$z_t = \theta_t + \rho_t z_{t-1} + \varepsilon_t$$

$$\theta_t = \theta_{t-1} + \eta_t \tag{18}$$

$$\rho_t = \rho_{t-1} + \zeta_t$$

Because Kalman filtering is used to estimate the system described in (18), the above equations should be rewritten as follows:

$$\text{Measurement equation: } z_t = \beta_t x_t + \varepsilon_t \tag{19}$$

$$\text{Transition equation: } \beta_t = F\beta_{t-1} + \varrho_t \tag{20}$$

in which F is the matrix of parameters, β_t is the vector of parameters, and η_t, ζ_t, ε_t, and ϱ_t are normally distributed white noise.

Equations (19) and (20) also can be represented in matrix form:

$$[z_t] = [\,\theta_t \quad \rho_t] \begin{bmatrix} 1 \\ z_{t-1} \end{bmatrix} + [\varepsilon_t] \tag{21}$$

$$\begin{bmatrix} \theta_t \\ \rho_t \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \theta_{t-1} \\ \rho_{t-1} \end{bmatrix} + \begin{bmatrix} \eta_t \\ \zeta_t \end{bmatrix} \tag{22}$$

4.2 Sample and Treatment of the Database

To estimate the monetary policy's credibility, we use the annual inflation target, inflation target minimum, and inflation target maximum, one measure of inflation expectation collected via survey, as well as the breakeven inflation expectation implicit in the yield curves of Brazilian government bonds.

In order to reflect the expectations from surveys, we estimate the Focus survey inflation expectation in 12 months for the 2-year forward rate[11], using the time series presented in the BCB's Focus Report[12] and available in the Market Expectations System in the BCB's website. This series represents the consensus from survey participants and

[11] In the case of survey-based inflation expectations, the 2-year forward rate denotes the expected variation of the consumer price index (IPCA) between the second-year and the third-year during the year ahead. In this process, we constructed fixed horizon forecasts, for 2 and 3 year horizons, using a linear interpolation of calendar year inflation expectations from the Focus survey at the end of each month.

[12] See Marques (2013) for further details.

is used by market agents, specialized media, and the BCB itself to monitor inflation expectations.

The inflation expectation derived from the yield curves of government bonds is called breakeven inflation. For the purposes of comparison with the inflation expectation reported in the Focus survey, we calculate breakeven inflation in 12 months for the 2-year forward rate[13], at the end of each month, considering the yield curve of fixed-rate government bonds (LTN and NTN-F) with the corresponding rate for inflation-indexed government bonds (NTN-B). We estimate the yield curves by use of the Svensson (1994) model and indicative rates from the Brazilian Financial and Capital Markets Association (ANBIMA), which reflect daily negotiated prices of these bonds in the secondary market for Brazilian government bonds.

The model developed by Svensson (1994) is widely used in the market, and is currently estimated by central banks of various countries, including Belgium, France, Germany, Norway, Spain, Sweden, Switzerland, and Brazil.[14] It seeks to estimate yield curves in a smooth, flexible manner, adjusting a discount function for the bond's price and assuming the following parametric function for the bond's spot interest rate:

$$s_m = \beta_0 + \beta_1\left[1 - exp\left(-\frac{m}{\tau_1}\right)\right] + \beta_2\left\{\left[1 - exp\left(-\frac{m}{\tau_1}\right)\right]\left(-\frac{m}{\tau_1}\right)^{-1} - exp\left(-\frac{m}{\tau_1}\right)\right\} + \beta_3\left\{\left[1 - exp\left(-\frac{m}{\tau_2}\right)\right]\left(-\frac{m}{\tau_2}\right)^{-1} - exp\left(-\frac{m}{\tau_2}\right)\right\} \quad (23)$$

in which s is the bond's spot interest rate, m is the bond's time to maturity, and $\beta_0, \beta_1, \beta_2, \beta_3, \tau_1,$ and τ_2 are estimated parameters.

In this study, equation (23) is estimated by applying nonlinear conditional optimization, in which parameters τ_1 and τ_2 are constrained to be greater than zero. In addition, in an effort to mitigate problems of heteroskedasticity and more accurately estimates for the short-term rates, the squared estimation errors are weighted by the inverse of the bond's duration.[15]

[13] The 2-year forward rate is the future level of the 2-year zero-coupon rate that makes the investor indifferent between the 2-year and the 3-year bonds during the year ahead.

[14] The central banks of Finland and Italy use Nelson and Siegel's (1987) model, which gave rise to that of Svensson (1994) and is a simplified version of it.

[15] For further details about the yield curve estimation models, see the Bureau for International Settlements (2005) and Svensson (1994).

The two inflation expectation series used were collected or estimated on a monthly frequency and covered the period from January 2006[16] to July 2017, totaling 139 monthly observations for each series.

Table 1 presents the descriptive statistics for the two series of inflation expectations. The breakeven inflation expectation is the most volatile and dispersed, as evidenced by its higher standard deviation. The breakeven inflation expectation is also characterized by its greater mean and its leptokurtosis (a thick tail on the right side of the distribution).

Table 1 – Descriptive statistics for inflation expectations

Statistics / Expectation	Focus Survey	Breakeven Inflation
Mean	4.70	5.48
Median	4.53	5.51
Maximum	5.50	8.66
Minimum	3.99	3.62
Std. Dev.	0.44	0.84
Skewness	0.31	0.95
Kurtosis	1.75	5.47
Jarque-Bera	11.39	56.27
Prob (Jarque-Bera)	0.00	0.00
Observations	139	139

Notes: 2-year forward rates. Sample: January/2006 - July/2017.

Figure 1.1 shows that the Focus inflation expectation and the breakeven inflation expectation exhibit very strong adherence, which is reflected in the correlation of approximately 0.58. Figure 1.2, generated by the kernel density estimator, shows the greater volatility and dispersion of the breakeven inflation expectation, as well as its greater mean, kurtosis, and right-hand asymmetry.

[16] The year 2006 was selected as the initial date due to the low liquidity of inflation-indexed government bonds (NTN-B) in the previous years. Such low liquidity could generate undesirable distortion in the calculation of the breakeven inflation expectation. The changes in this liquidity over time were reported by Val et al. (2010).

Figure 1 – Historical series and probability density function of inflation expectation (2-year forward rate)

Fig. 1.1 Historial series

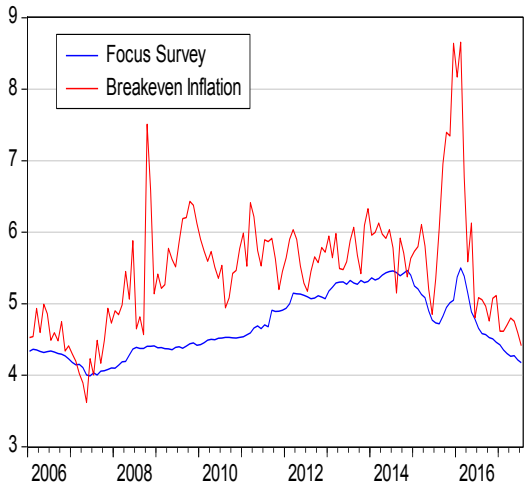
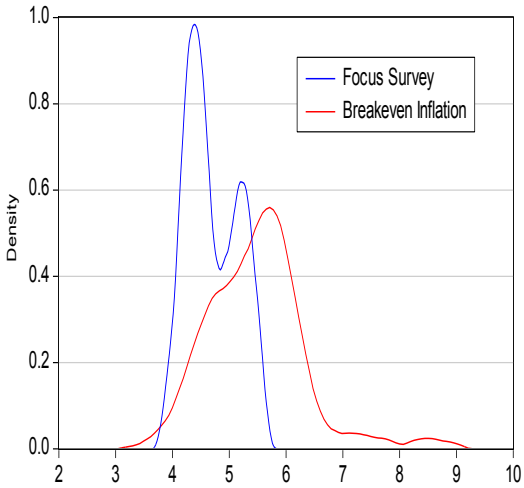


Fig. 1.2 Probability density function



4.3 The Relationship between Credibility and Macroeconomic and Financial Variables

From this point forward in this article, for the purpose of simplification, the measures of monetary policy's credibility estimated by means of yield curves and the Focus survey will be referred to as breakeven inflation credibility and Focus credibility, respectively.

Having identified and estimated the monetary policy's credibility based on two measures of inflation expectations, we explore the following relationships: (i) macroeconomic and financial variables that may explain the behavior of the estimated measures of credibility, and (ii) the joint dynamics and interrelationships between these credibility measures and macroeconomic/financial variables.

As previously mentioned, breakeven inflation credibility and Focus credibility are forward-looking indicators. Given that there is a relationship between these measures of credibility and expected inflation, we follow Carvalho and Minella (2012) in the identification of variables that are important in predicting the dynamics of these measures of credibility. The financial variables selected are the foreign exchange rate, R$/US$

(*dollar*) and the Emerging Markets Bond Index for Brazil, EMBI+BR (*embi*).[17] For macroeconomic variables, we select the unemployment rate (*unemp*) published by the Brazilian Institute of Geography and Statistics - IBGE, the IBC-BR economic activity index (*ibcbr*) published by the Central Bank of Brazil, and the monthly inflation rate (*ipca*) from the broad consumer price index published by the IBGE.

Some of the variables must be adjusted before being used. Unemployment rate is seasonally adjusted by use of the X-12 method (Findley et al., 1998), and the stationary component of the IBC-BR (*ibcbr gap*) is estimated using the Hodrick-Prescott filter (Hodrick and Prescott, 1997). All of the financial and macroeconomic variables are tested for the presence of unit roots, with the unemployment rate (*unemp*), the foreign exchange rate (*dollar*) and the sovereign risk (*embi*) standing out due to the identification of non-stationarity[18] and, this way, are first-differenced. Finally, the independent variables are lagged relative to the dependent variable in order to mitigate problems related to endogeneity. In order to associate the behavior of the estimated measures of credibility with economic cycles, besides the macroeconomic variables, a dummy variable (*recession*) is created to indicate the periods of recession, as defined by the FGV Economic Cycle Dating Committee (CODACE). According to CODACE, the period under investigation included two periods of recession: (i) from the fourth quarter of 2008 through the first quarter of 2009, and (ii) from the second quarter of 2014 through the end of the period. To summarize, we investigate the following regressions:

$$cred_t = b_0 + b_1 cred_{t-1} + b_2 ipca_{t-1} + b_3 \Delta dollar_{t-1} + b_4 \Delta embi_{t-1} + b_5 ibcbrgap_{t-1} + e_t \quad (24)$$

$$cred_t = b_0 + b_1 cred_{t-1} + b_2 ipca_{t-1} + b_3 \Delta dollar_{t-1} + b_4 \Delta embi_{t-1} + b_6 \Delta unemp_{t-1} + e_t \quad (25)$$

$$cred_t = b_0 + b_1 cred_{t-1} + b_2 ipca_{t-1} + b_3 \Delta dollar_{t-1} + b_4 \Delta embi_{t-1} + b_7 recession + e_t \quad (26)$$

where $cred_t$ includes the breakeven inflation credibility or the Focus credibility, and e_t is the residual of the regression.

[17] The Emerging Markets Bond Index for Brazil (EMBI+BR) is defined as the average spread between the yields of Brazilian bonds and North American bonds negotiated in the international market.

[18] Stationarity is checked using the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests.

In an effort to evaluate the joint dynamics of the two measures of credibility, we also perform the Granger causality test[19] (Granger, 1969) to determine the informational utility and importance of the following: (i) macroeconomic and financial variables in relation to the measures of monetary-policy credibility, and (ii) of one measure of monetary-policy credibility relative to the other measure of monetary-policy credibility.

5. Results and Discussion

5.1 Credibility Indicators Previously Suggested in the Literature

Figures 2.1 through 2.4 show four indicators of the credibility of monetary policy previously suggested in the literature. The indices in figures 2.1 through 2.3, constructed based on the expectations of various agents, reveal the changes in credibility over time, while figure 2.4 also presents the monetary policy reputation series.

In order to associate the behavior of these measures of credibility with economic cycles, the gray areas in the figures indicate the quarters during which Brazil was in recession. We observe the following: (i) during the period between late 2008 and early 2009, the breakeven inflation credibility declined sharply and then recovered but the Focus credibility remained relatively stable, possibly due to the countercyclical and credit-expansion measures implemented by the Brazilian government during that period; (ii) during the period after the second semester of 2011 until the end of 2014, the Focus credibility progressively declined, reflecting the survey-based inflation expectation increasingly above the target, whereas the breakeven inflation credibility showed no clear pattern during the same period; (iii) since mid-2016, both credibility measures strongly recovered, as a consequence of inflation expectations decreasing towards the target.

The credibility indices shown in figure 2.4, which are constructed based on reputation measure and are entirely backward-looking, have high inertial weight. From late 2014 until 2016, monetary policy's reputation declined, due to observed inflation above the upper tolerance interval, and then recovered by the end of the sample. Because the credibility measures proposed by Mendonça and Souza (2009) are averages - simple and weighted - of this reputation, they slowly and with a lag reflect the reputation dynamics previously described.

[19] A time series *x* is said to Granger-cause time series *y* if the values of *x* can be shown to provide statistically significant information about the future values of *y*.

Figure 2 – Credibility indicators suggested in the literature

Fig. 2.1 – Cecchetti e Krause (2002)

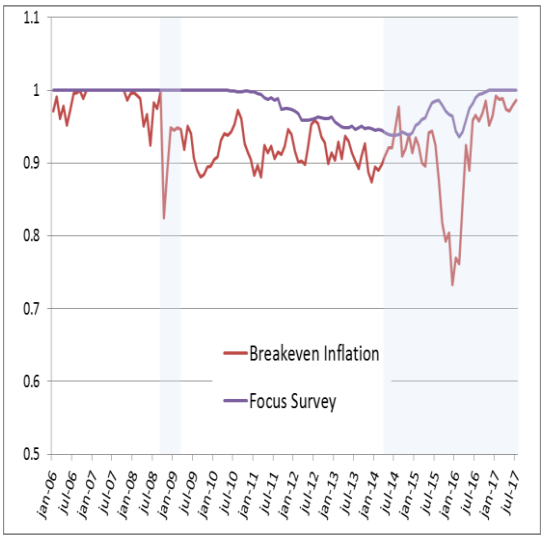


Fig. 2.2 – Sicsú (2002)

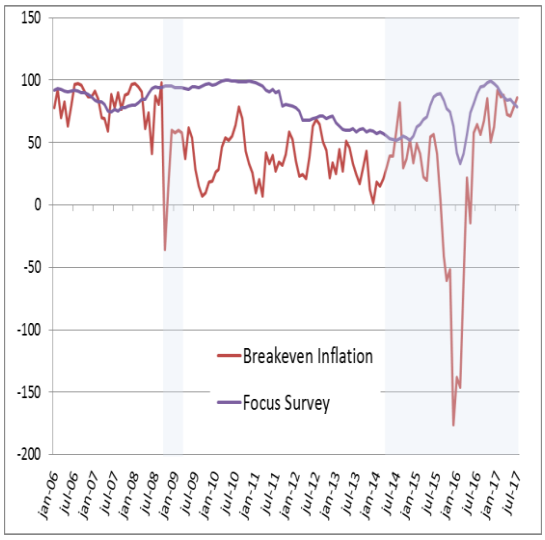


Fig. 2.3 – Mendonça (2004)

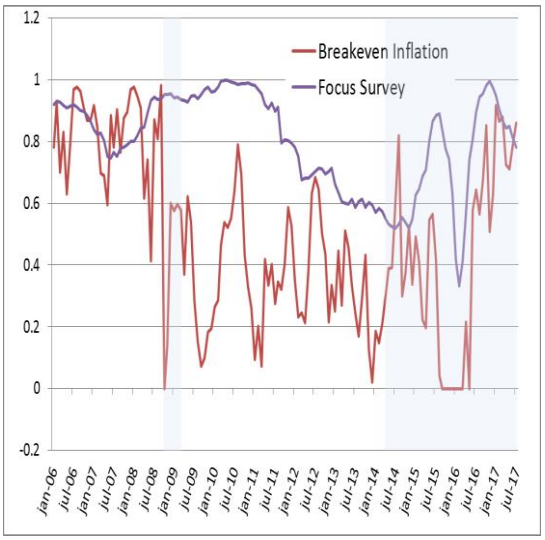
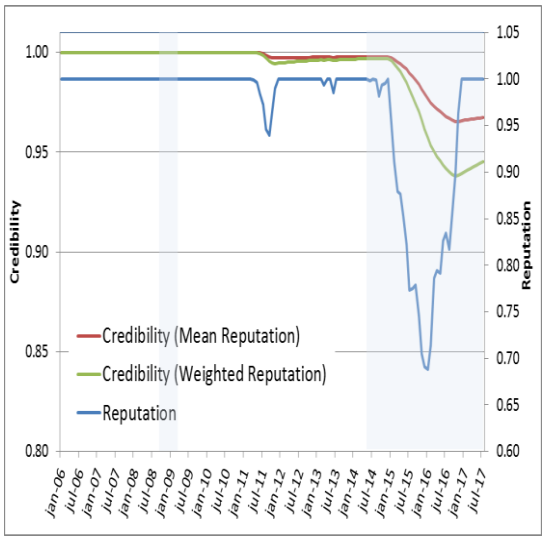


Fig. 2.4 – Mendonça and Souza (2009)



5.2 Svensson's Test and the Probabilistic Framework

In this study, we consider only inflationary credibility, disregarding the calculation of deflationary credibility, for the following reasons: (i) during the sample period, real interest rates were closer to the minimum real interest rates consistent with the inflation target, raising questions only regarding inflationary monetary policies; (ii) inflation expectations were above the minimum inflation target throughout the sample period; (iii) the observed inflation was not below the minimum inflation target during the entire sample period (excepting June and July, 2017).

Figure 3.1 shows the forecasts of 2-year forward inflation rate represented by the two measures of inflation expectation (Focus survey and breakeven inflation) relative to the inflation target tolerance intervals in effect between January 2006 and July 2017. The breakeven inflation expectation is consistently higher than the other measure based on the Focus survey and exceeds the inflation target upper tolerance interval in mid-2008, at the most critical point in the subprime mortgage crisis, and then more markedly from early 2014 until mid-2016. The inflation expectation published in the Focus Report remained inside the tolerance intervals along the entire sample. As previously mentioned, the breakeven inflation expectation is positively correlated with the inflation expectation from the Focus survey but more volatile. One of the reasons for this greater volatility is the existence of time-varying risks in the yield curves.[20]

Figure 3.2 shows the minimum and maximum real interest rates consistent with the inflation target, inflation target minimum (CMmin), and inflation target maximum (CMmax), calculated by use of Svensson's test (1993) and equations (7) and (8). The breaches of CMmin by the real interest rates that correspond to breakeven inflation expectation and Focus inflation expectation indicate inflation expectations above the inflation target ceiling. Recall that CMmin is defined as the difference between the nominal interest rate (LTN and NTN-F bonds) and the upper inflation tolerance interval π_{max}.

[20] Vicente and Graminho (2015) decomposed breakeven inflation in Brazil as follows: breakeven inflation = inflation expectation + inflation risk premium – liquidity premium + convexity. Estimates based on data from January 2006 through September 2013 show that the liquidity premium and convexity have very small values, less than 1 basis point for a 12-month horizon, and therefore can be ignored. These same estimates show a mean inflation risk premium of 0.20% with a standard deviation of 0.46%.

Figure 3 – Inflation forecasts (2-year forward rate) from two measures of expectations and min-max real interest rates

Fig. 3.1 – Inflation expectations and inflation target tolerance intervals

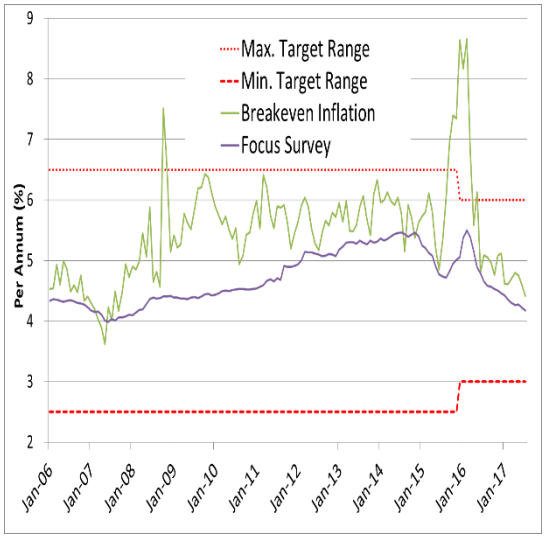
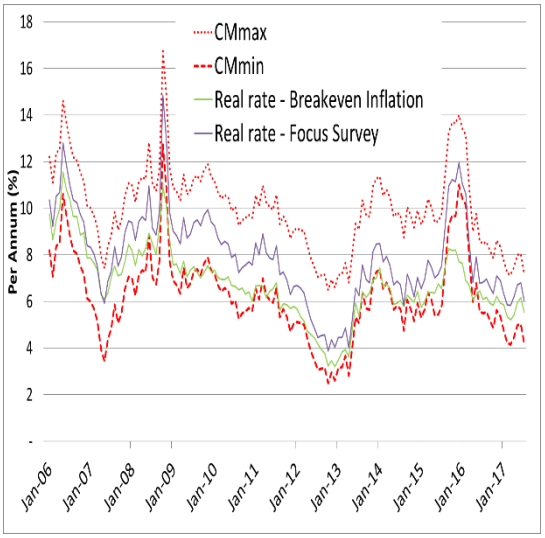


Fig. 3.2 – Estimated CM_{Max}, CM_{Min} and real interest rates



After the z_u series are constructed based on the (2-year forward) expected real interest rates (Focus survey and breakeven inflation), equation (18) is estimated. For these two inflation expectations, the z_u series was estimated by Kalman filtering, decomposing the series at intercept θ_t and at the first-order autoregressive coefficient ρ_t, both varying over time.

Table 2 shows the coefficients estimated by means of Kalman filtering, in their final filtered states. For the two estimates, the autoregressive coefficients are statistically significant at the 10% level. Breakeven inflation credibility has a more persistent estimated series comparing to the Focus-based series.

Table 2 – Estimations by Kalman filter

State Space - Kalman Filter		
Variable	Focus Survey Final State	Breakeven Inflation Final State
θ	0.8697*	0.1187
ρ	0.5357*	0.8979*

Note: * indicates significance at the 10% level.

One limitation of Svensson's test is that it does not allow for a quantitative evaluation of the credibility of a monetary policy. In the next graphs, this limitation is overcome by inflation credibility being estimated via Kalman filtering.

Based on real interest rate estimates from the yield curve, figure 4.1 shows the credibility, the corresponding θ_t parameter, and its 95% confidence interval, and figure 4.2 shows the real interest rate, the minimum real interest rate consistent with the inflation target (CMmin from equation (7)), and the auxiliary variable z_u (from equation (9)).

Figures 4.1 and 4.2 can be interpreted jointly. Four clear shifts in inflation credibility can be observed: (i) decline in mid-2008, at the most critical point in the subprime mortgage crisis in the U.S., with a resulting negative $z_{u,t}$; (ii) relative stability from early 2009 through mid-2015; (iii) severe drop by the end of 2015, with the $z_{u,t}$ series again reaching negative values (as a consequence of real interest rates falling below the minimum real interest rate compatible with the inflation target); and (iv) recovery from mid-2016 until the end of the sample.

Figure 4 – Breakeven inflation credibility

Fig. 4.1 – Estimated breakeven inflation credibility and thetas

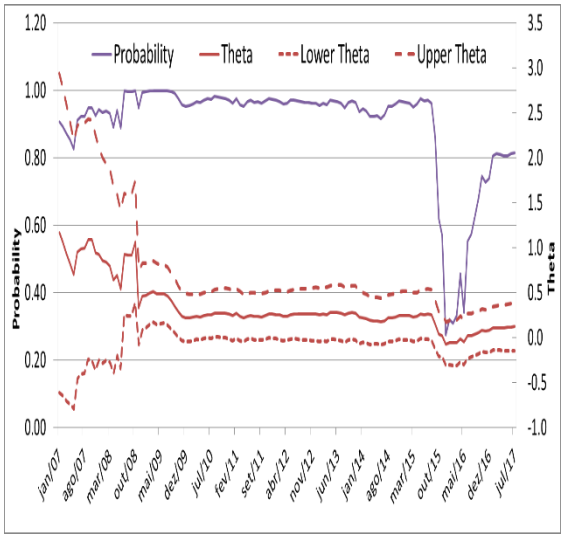
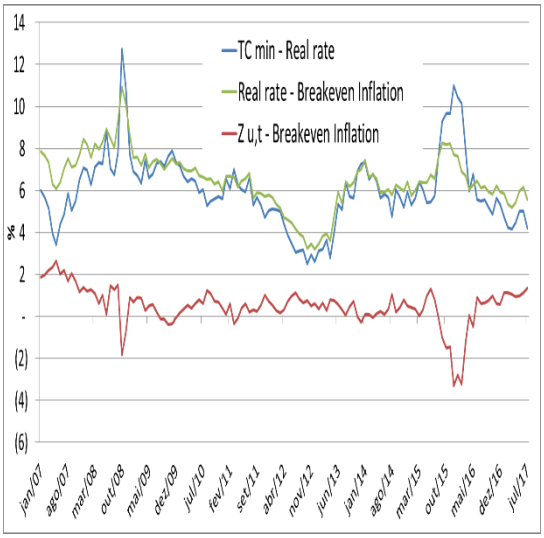


Fig. 4.2 – Estimated TC_{Min}, real interest rate and Z_u using breakeven inflation



Note: Probability in the left panel refers to the conditional probability of inflation to be inside the tolerance intervals based on the respective breakeven inflation expectation.

Based on real interest rate estimates from the Focus survey, figure 5.1 shows the inflation credibility, the corresponding θ_t, and its 95% confidence interval, and figure 5.2 shows the real interest rate, the minimum real interest rate consistent with the inflation target (CMmin from equation (7)), and the auxiliary variable z_u (from equation (9)).

The credibility based on the Focus survey remained high all over the sample, suggesting that the survey-based inflation expectations were properly anchored along the investigated period; and for the considered (medium-term) forecast horizon (i.e., 2-year forward rate). The real interest rates remained above the minimum real interest rate compatible with the inflation target and, as a consequence, $z_{u,t}$ showed only positive values. The main deterioration of the Focus credibility, in terms of the minimum $z_{u,t}$, occurred by late 2015, followed by a steady recovery until the end of the sample.

Figure 5 – Credibility from the Focus survey

Fig. 5.1 – Estimated Focus survey credibility and thetas

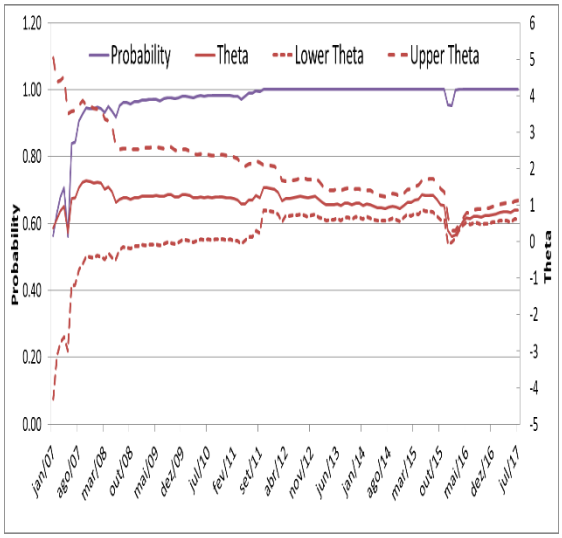
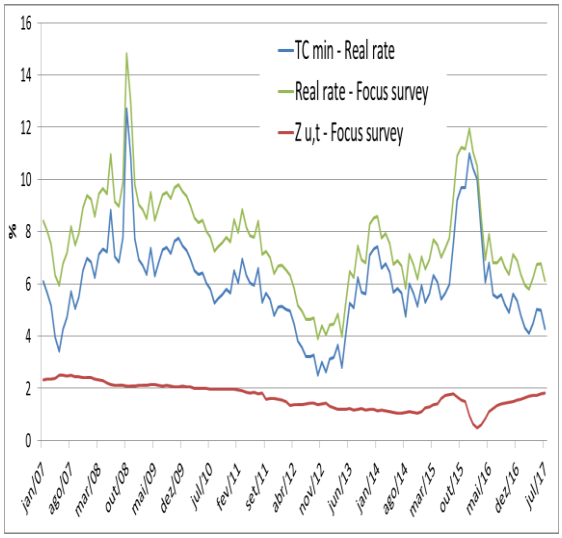


Fig. 5.2 – Estimated TC_{Min}, real interest rate and Z_u using Focus survey



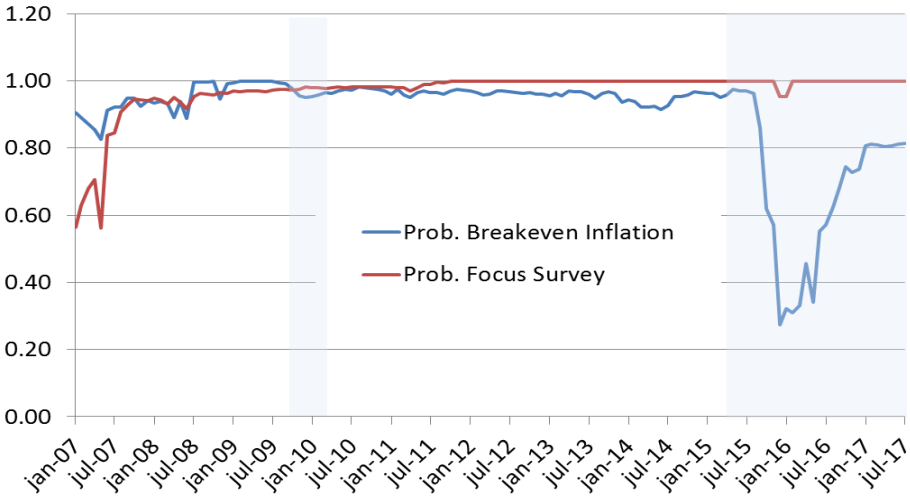
Note: Probability in the left panel refers to the conditional probability of inflation to be inside the tolerance intervals based on the respective Focus survey inflation expectation.

Figure 6 shows the measures of monetary-policy credibility based on breakeven inflation expectation and Focus inflation expectation; the quarters during which Brazil was in recession are indicated by gray shading.

In the first recessionary period, largely a consequence of the U.S. subprime mortgage crisis, there was no significant impact in credibility; not even after a few months.[21] Later, during 2010-2015, both credibility measures remained at high levels.

However, in the second recessionary period, there was a decline in both measures of credibility by the end of 2015. The Focus credibility showed a small impact, with a rapid recovery, whereas credibility based on the breakeven inflation tumbled from a figure above 0.9 to levels below 0.3 in just a few months, slowly improving afterwards.

Figure 6 – Estimation of breakeven inflation and Focus survey credibilities



Theoretically, differences in the magnitude of the credibility estimates should be viewed as natural. Different economic agents may have different expectations regarding inflation, which will affect their expectations regarding real interest rates and their perceived credibility of the monetary policy. As pointed out by Biefang-Frisancho et al. (2011), the fact that there are various methods of measuring inflation expectations and that they focus on various social groups may tell us that one monetary policy is more credible to some groups than to other groups.

[21] A possible explanation could be the wide confidence bands (in the beginning of the sample) for the theta parameter estimated with the Kalman filter.

This heterogeneity of the expectations of the various market agents may be a result of biased inflation expectations. Such bias is not a reason to forgo using these expectations: *"In brief, just because some expectations are wrong does not seem a very good reason for excluding them if we wish to measure credibility. On the contrary, it threatens to prejudge the issue"* (Biefang-Frisancho et al., 2011).

Furthermore, the yield curves and measures derived from them, such as breakeven inflation, may incorporate time-varying risks that uniquely affect breakeven inflation credibility. Breakeven inflation credibility experienced high volatility between August 2008 and March 2009, including the most acute portion of the U.S. subprime mortgage crisis. During this period, the 2-year nominal forward interest rate increased more than the respective inflation expectation augment, resulting in an increase of the inflation risk premium.[22]

The decline in monetary-policy credibility observed in 2015 was characterized by alterations in inflation expectations, in great part, due to adjustments in administered prices and depreciation of the Brazilian real throughout 2015, directly affecting the IPCA inflation observed in 2015, as well as inflation forecasts for the following year.

In other words, economic agents did not perceive at the time the BCB as implementing an appropriate monetary policy to offset inflationary pressures. Credibility only began to improve again in mid-2016 when the new governor of the BCB began his term with a clear objective of reducing inflation; with the help of fiscal measures designed to control the future trajectory of public debt.

In next section, we seek to quantify the influence of inflation and other financial and macroeconomic variables on monetary-policy credibility.

[22] We follow the assumption of Vicente and Graminho (2015), who estimated inflation expectations based on expectations from the BCB Focus Report's survey.

5.3 The Relationship between Credibility and Macroeconomic/Financial Variables

In table 3, the estimated coefficients for the financial and macroeconomic variables in equations (24), (25) and (26) are reported in columns (a), (b), and (c), respectively. In all regressions, only the autoregressive coefficient and the intercept are statistically significant; suggesting that monetary-policy credibility is relatively persistent and not influenced by financial or macroeconomic variables (e.g., economic cycles).

Table 3 – Credibility of monetary policy and macroeconomic/financial variables

	Breakeven inflation credibility						**Focus survey credibility**					
Regressors	(a)		(b)		(c)		(a)		(b)		(c)	
intercept	0.08887	**	0.09672	*	0.10547	*	0.10163	*	0.10328		0.10358	*
credibility (-1)	0.91745	***	0.90672	***	0.90181	***	0.89333	***	0.89153	***	0.89048	***
IPCA (-1)	-0.02605		-0.01971		-0.02090		0.00588		0.00553		0.00574	
Δ dollar (-1)	-0.08727		-0.06947		-0.06142		-0.00510		-0.00626		-0.00708	
Δ embi (-1)	-0.00014		-0.00013		-0.00012		0.00002		0.00002		0.00002	
ibc-br gap (-1)	0.00244						0.00035					
Δ unemp (-1)			-0.04385						0.00692			
dummy recession					-0.01560						0.00245	
Adjusted R^2	0.8924		0.8919		0.8924		0.9044		0.9044		0.9044	
Observations	137		137		137		137		137		137	

Notes: Sample from March 2006 to July 2017. OLS regressions (Newey-West HAC standard errors) from equations (24), (25) and (26), where: *dummy recession* identifies months of economic recessions in Brazil, *unemp* is the seasonally adjusted unemployment rate, *ibc-br gap* is the (HP filtered) gap of the economic activity index, *dollar* is the foreign exchange rate (R$/US$), *embi* is the Emerging Markets Bond Index - Brazil (EMBI+BR) and *IPCA* is the inflation rate from the Brazilian Broad Consumer Prices Index. The significance levels of 1%, 5% and 10% are indicated, respectively, by ***, ** and *.

Interesting questions regarding the setting of inflation expectations can be answered from the results reported in table 3 and the variables selected. Does a deterioration of monetary-policy credibility increase sovereign risk or *vice versa*? Is a current increase in inflation important for forecasting monetary-policy credibility?

Appendix B shows the results of the Granger causality test performed to help answering these questions. Breakeven inflation credibility indeed helps predicting the considered macroeconomic/financial variables (excepting the economic activity gap). Furthermore, the exchange rate and the sovereign risk Granger-cause the credibility measure based on breakeven inflation.

This bi-directional causality involving breakeven inflation credibility and the financial variables can possibly be related to the risk premium embedded in the breakeven inflation dynamics.

On the other hand, the Granger-causality tests based on the Focus survey credibility indicate no rejection of the null hypothesis in all cases (i.e., no causality). With regard to the joint dynamics of the monetary-policy credibility measures, the results indicate no causal relationship between the breakeven inflation credibility and the Focus survey credibility (in any direction).

6. Conclusions

In this study, we have estimated the credibility of Brazilian monetary policy in the inflation-targeting regime of 2006 through 2017. We have used two measures of inflation expectations: one from the BCB Focus survey and other based on the yield curves of Brazilian government bonds. Via Kalman filtering, we have estimated inflation-target credibility over time and quantitatively evaluated the consistency of the inflation-targeting monetary policy.

One of the limitations of our methodology arises due to the direct manner in which the monetary-policy credibility is evaluated, which makes impossible the explicit identification of the source of variation in credibility. Variation may result from monetary policy tactics or instruments or adverse economic shocks. Macroeconomic and financial variables are incorporated, in sections 4.3 and 5.3 of this article, in an effort to overcome this limitation.

The results of this study indicates four main shifts in breakeven inflation credibility: (i) decline in mid-2008, during the U.S. subprime mortgage crisis; (ii) relative stability from early 2009 through mid-2015; (iii) severe drop by the end of 2015, as a consequence of real interest rates falling below the minimum rate compatible with the inflation target; and (iv) recovery from mid-2016 until the end of the sample.

On the other hand, the Focus survey credibility, overall, remained at high levels, suggesting that survey-based inflation expectations were properly anchored along the considered sample and for the considered medium/long term horizon. The main deterioration of the Focus survey credibility, since 2010, occurred by late 2015, followed by a steady recovery until the end of the sample.

The decline in both monetary-policy credibilities observed in 2015 was characterized by shifts in inflation expectations, greatly due to changes in administered prices and depreciations of the foreign exchange rate (R$/US$) throughout 2015, directly affecting the IPCA inflation observed in 2015 as well as inflation forecasts for the following year. In other words, economic agents did not perceive (at the time) the BCB as implementing an appropriate monetary policy to offset inflationary pressures. Credibility only began to improve again in mid-2016 when the new governor of the BCB began his term with a clear objective of reducing inflation towards the target; with the help of fiscal measures announced by the federal government to control the future trajectory of public debt.

By associating the measures of monetary-policy credibility with macroeconomic and financial variables, we have found that credibility is relatively persistent and seems not to be influenced by short-run movements of the considered financial and macroeconomic variables; including economic cycles.

Granger causality tests indicate that breakeven inflation credibility helps predicting financial and macroeconomic variables (except economic activity gap). Moreover, the foreign exchange rate and the sovereign risk Granger-cause the credibility measure based on breakeven inflation; probably due to risk premium issues. On the other hand, there is no Granger causality, in any direction, involving the Focus survey credibility and the macroeconomic/financial variables.

With regard to the joint dynamics of both credibility measures, the Granger-causality tests indicate no causal relationship in any direction, i.e., neither the breakeven inflation credibility Granger-causes the Focus survey credibility nor the opposite.

As points of future study in this area, we suggest the implementation of new methods, such as the Bayesian setup, that can capture the variation in inflation credibility over time. Furthermore, the analysis could be expanded to additional countries, aiming at an intertemporal comparison of the credibility dynamics of various central banks.

Finally, we emphasize the importance of the monetary authority estimating, analyzing, and maintaining its credibility, which is an indication of the performance of its duties, at a high level. As Bernanke (2003) stated, *"certainly, in general, the greater the inherited credibility of the central bank, the less restrictive need be the guidelines, targets, or the like that form the central bank's communication strategy. But credibility is not a permanent characteristic of a central bank; it must be continuously earned."*

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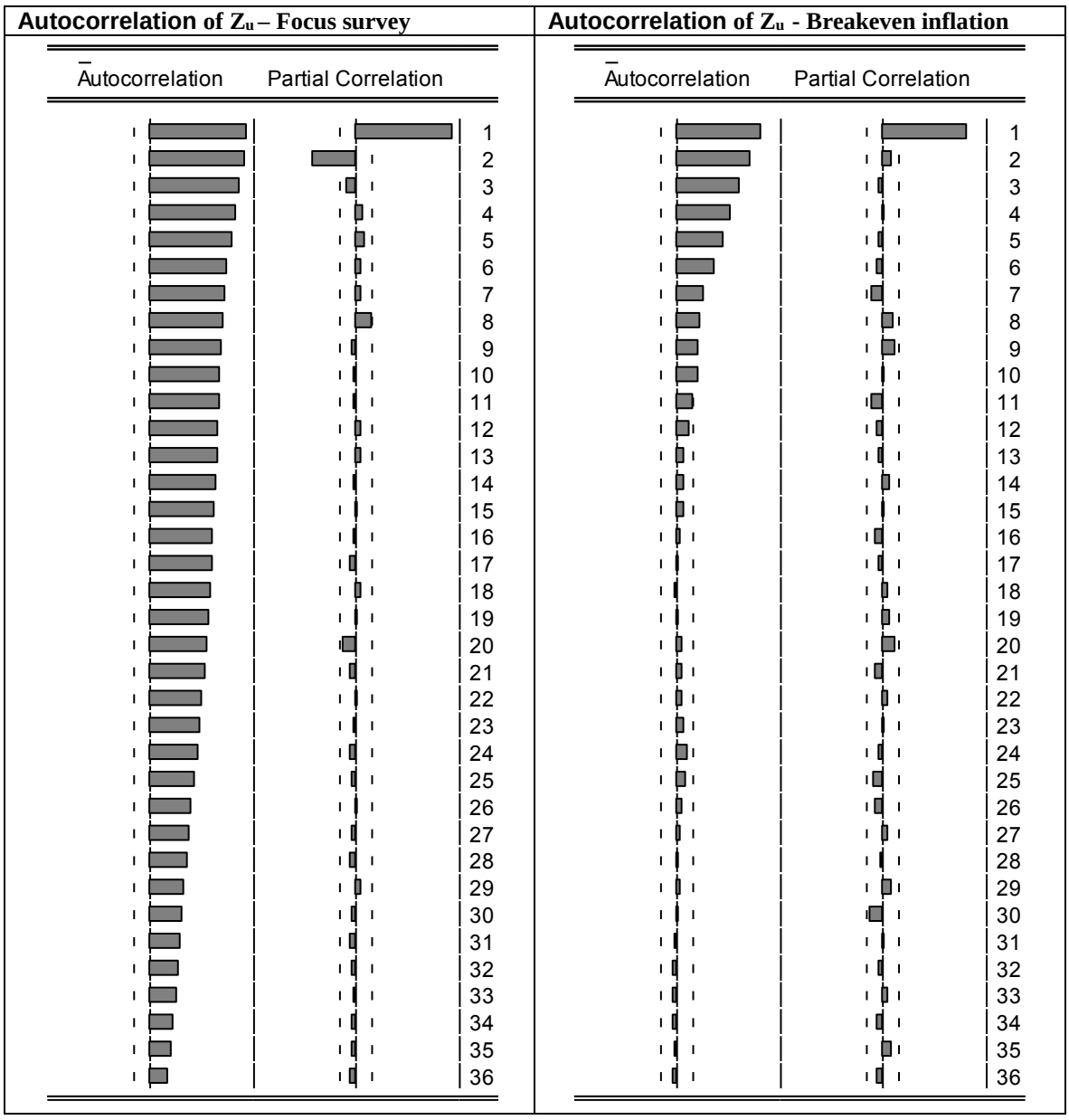
Appendix A

Table A.1 – Autocorrelation of Z_u series



Appendix B

Table B.1 – Granger causality of estimated credibilities and macroeconomic/financial variables

Variable	Null Hypothesis	Variable	Probability	
cred_breakeven	does not Granger cause	cred_focus	0.875	
cred_focus	does not Granger cause	cred_breakeven	0.342	
Δ unemp	does not Granger cause	cred_focus	0.998	
cred_focus	does not Granger cause	Δ unemp	0.254	
Δ dollar	does not Granger cause	cred_focus	0.912	
cred_focus	does not Granger cause	Δ dollar	0.322	
Δ embi	does not Granger cause	cred_focus	0.597	
cred_focus	does not Granger cause	Δ embi	0.961	
IPCA	does not Granger cause	cred_focus	0.894	
cred_focus	does not Granger cause	IPCA	0.179	
ibc-br gap	does not Granger cause	cred_focus	0.735	
cred_focus	does not Granger cause	ibc-br gap	0.710	
Δ unemp	does not Granger cause	cred_breakeven	0.183	
cred_breakeven	does not Granger cause	Δ unemp	0.036	**
Δ dollar	does not Granger cause	cred_breakeven	0.001	***
cred_breakeven	does not Granger cause	Δ dollar	0.048	**
Δ embi	does not Granger cause	cred_breakeven	0.000	***
cred_breakeven	does not Granger cause	Δ embi	0.070	*
IPCA	does not Granger cause	cred_breakeven	0.337	
cred_breakeven	does not Granger cause	IPCA	0.026	**
ibc-br gap	does not Granger cause	cred_breakeven	0.879	
cred_breakeven	does not Granger cause	ibc-br gap	0.842	

Note: ***, ** and * indicate rejection of the null hypothesis of the Granger-causality test (3 lags) at 1%, 5% and 10% levels, respectively.