FUNDAÇÃO GETULIO VARGAS
ESCOLA DE ECONOMIA DE SÃO PAULO

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MONETARY POLICY AND STOCK MARKET BUBBLES:
THE BRAZILIAN CATCH 22

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Dissertação apresentada à Escola de Economia de São Paulo da Fundação Getulio Vargas, como requisito para a obtenção do título de Mestre em Economia.

Área de concentração: Macroeconomia Financeira

Orientador: Prof. Dr. Rogério Mori

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Dedicado aos meus pais Vera e John.

ABSTRACT

This paper estimates the response of stock prices to monetary policy shocks following the framework set by Gali and Gambetti (2015) using data for Brazil. In doing so, a time-varying coefficient VAR is used for both quarterly and monthly data, separately. The evidence indicates continual periods in which stock prices respond positively to monetary policy contractions, siding with the initial finding by Gali and Gambetti (2015). However, such results is in stark opposition to commonly held "Leaning Against the Wind" approach to monetary policy and bubbles. The time-varying nature of the bubble component is further verified in subsamples representing Brasils different political-economic periods. Brazil potentially finds itself in a Catch 22: monetary policy tightening, aimed at stabilizing inflation, can lead to protracted periods of soaring stock prices.

Keywords: Monetary Policy, Bubbles, Rational Asset Price Bubbles, Time-Varying Coefficient SVar, Brazil.

RESUMO

Este artigo estima a resposta dos preços de ações a choques de política monetária seguindo o *framework* desenvolvido por Gali e Gambetti (2015) usando dados para o Brasil. Utiliza-se um *Time-Varying Coefficient Structural VAR* com dados trimestrais e mensais, separadamente. As evidências indicam períodos contínuos em que os preços de ações respondem positivamente às contrações da política monetária, alinhando-se com a constatação inicial de Gali e Gambetti (2015). No entanto, tais resultados estão em total oposição à abordagem comumente defendida *Leaning Against the Wind* para a política monetária e bolhas. A natureza variável no tempo do componente bolha é verificada em subamostras que representam os diferentes períodos político-econômicos do Brasil. O Brasil potencialmente se encontra em um Catch 22: o aperto da política monetária, com o objetivo de estabilizar a inflação, pode levar a períodos prolongados de alta dos preços das ações.

Palavras-chave: Política Monetária, Bolhas, *Rational Asset Price Bubbles*, *Time-Varying Coefficient Structural VAR*, Brasil.

SUMMARY

1 INTRODUCTION AND LITERATURE REVIEW

Following the 2008-2009 financial crisis Monetary Policy has taken centers stage alongside low interest rates as a measure to reduce the output gap. The consensus was, or still is, that Central Banks should focus on stabilizing inflation and reducing the output gap. That is, following a postulated Taylor Rule and optimal behavior. Alongside this conventional view, and possibly a consequence of the bubble driven crisis, advocates for the use of monetary policy to dampen Asset price Bubbles has gained mainstream support. Despite the position of grand importance that monetary policy has taken there is little agreement regarding the role of banks in stabilizing economies and the appropriate tools which should be used.

Bernanke and Gertler (2000) advocate for the consensus and advise against monetary policy intervention aimed at dampening prices. The Inflation targeting approach guarantees that the Central Bank acts against inflationary and deflationary pressures and steers the economy close to its fundamentals. A bubble bursting approach places monetary policy without a clear rule as it is unclear whether price hikes are driven by fundamentals, irrationality, or both. On that note, monetary policy should only target asset prices when these exert inflationary or deflationary pressures. Inflation-targeting provides macroeconomic stability and a clear direction for dealing with asset prices: interest rates will increase as a response to asset price booms and fall during burst. Such discipline may curb potential financial panics without the need of preemptive monetary action.

The following year Bernanke and Gertler (2001) offer a complementary and concise analysis contributions to the previous work by the authors, described above. The paper considers the same model developed by the authors previously but considered a different criterion for evaluating the effectiveness of the policy regimes. The policy regimes are tested against 3 disturbances: Bubble Shocks (Only), Technology innovations (Only) and, lastly, Bubble and technology combined. Additionally, the Policy commitment is varied from accommodative to aggressive. The results from the simulations show that the scenarios where the Central Bank had an aggressive commitment to inflation rate targeted dominated the instances where an accommodative approached was adopted – even when faced only Bubble Shocks. The results show that the reduction in output-gap which would occur from the response to a Bubble shock would be outweighed by the increase inflation variability. Such findings reinforce the authors previous contributions and reinforce the position that, for plausible parameters values, Central Banks should not respond to asset price.

Basile and Joyce (2001) analyses data across stock and house markets in Japan seeking insights for the behavior and evolution of bubbles using Granger-Causality tests. Evidence was found to substantiate that a positive cross-market causal relationship concerning bubbles, meaning a price increase in one market causes the other market to have price hikes. Causal links were also found between monetary, bank lending and output variables. Most importantly, however, is that the past behavior of the Bubble positively impacted the its size today, meaning that once a Bubble starts its increasing hard to stop it. These findings add new dimensions to the discussion on policy treatment of bubbles and encourages the current paper to look beyond the United States.

Cecchetti et al (2002) builds on the works of Bernanke and Gertler (2000), specifically on the conclusion that interest rates should only respond to asset price increases when inflationary pressures arise as consequence. The main contribution is non-prescriptive and conciliatory: inflation-targeting is deemed a narrow view on modern macroeconomic dynamics and Central Banks should include several categories of asset prices into their decision rules, if not only for informational purposes.

Borio and Lowe (2002) follow suit with Cecchetti et al (2002) by encouraging monetary policy to consider a more wholistic rule for interest rates. More specifically it is pointed out that interest rates should consider: 1) unwinding financial imbalances which can be disguised during period of economic prosperity (such as rapid credit expansion and rapid capital accumulation); 2) Supply-side dynamics (including the behavior of firms, the labor market and expectations of inflation) during periods of sustained low-inflation; 3) Anchors for achieving financial and monetary stability regardless the of the size of financial stress. Hence, establishing a policy rule solely on inflation-targeting might be practical but lead to short-sighted decision with undesirable consequences.

Posen (2006) argues that the Monetary Policy should not be a used to “Burst Bubbles” in a similarly named article “Why Central Banks Should Not Burst Bubble”. Throughout the article it is convened that the Bubbles “arise out of some combination of irrational exuberance, technological jumps, and financial deregulation” and that the costs associated to an increase in interest rates surpasses the benefits of preemptive measures. The macro-economic damages caused by a bursting bubble is a consequence of the financial systems stability and structure. Central Banks should guarantee that the financial markets are robust enough to withstand bubble bursting with limited negative transmission.

Woodford (2012) eloquently addresses commentators and critics calling for alternatives to the perceived “code of conduct” by which monetary policy is caried out. In particular he

addresses the need for a flexible approach to inflation targeting and the wows that policy makers should have acted faster and more intrusively to guarantee financial stability when faced with the 2007-2009 financial crisis. Throughout the paper a straightforward macroeconomic model is developed where monetary policies rules can be studied and made flexible. The author discusses the possibility of a flexible inflation rate targeting regime where central banks and policy makers should observe and react to financial market instabilities. Considering the new guidance, Central Banks could increase interest rates in response to an increase in asset price volatile and preemptive dampen an asset price bubble. Such conduct would be permissible even in cases where the interest rate retraction would mean an increase in output and price gap in the short-term as it is deemed less harmful than the consequences of a new financial downturn. The conclusion clearly sides with “leaning against the wind” policies, as was the sentiment following the financial crisis, and, most importantly, calls for greater flexibility in the conduct of monetary policy, especially in times of great volatility and uncertainty when macroprudential measures cannot support macro stability.

When it comes to Stock Market Bubbles a “Leaning Against the Wind” view holds that interest rates must increase to reduce the size of the asset price bubble. Additionally, Borde and Landon-Lane (2013) provide evidence in favor the existence of a relationship between “loose” monetary policy and asset price bubbles.

Conversely, Gali (2014) sets theoretical grounds for questioning the conventional view on the relationship between asset price and interest rates. Gali (2014) explores the possible underpinnings of “leaning against the wind” policies by establishing a Rational Price Bubble framework and, in doing so, analyses the dynamic in an initial partial equilibrium model and a general equilibrium framework. Both models lend the same conclusions regarding the relationship between interest rates and the role of monetary policy. Regarding the former, Monetary policy cannot influence the existence (or lack thereof) of Bubbles but can impact their short-term behavior, fluctuation and volatility. It follows that, a hike in interest rates in response to an Asset Price Bubble may sharply increase the volatility of stock prices and their so-called bubble component. As for the role of monetary policy, the optimal conduct should balance stabilization of current aggregate demand, calling for a positive interest rate response, and the bubble itself (or future aggregate demand), pushing for a negative in interest rates. The key here, is the size of the average size of the bubble: if sufficiently large the wows with stabilizing the bubble will dominate and prompt the central bank to lower interest rates to dampen a growing bubble. In closing Gali warrants for more research on the relationship and

impact of interest bubbles and interest rates as the proposed theoretical framework points to the a "potential important missing link in the case for "leaning against the wind" policies".

Gali and Gambetti (2015) set out to provide evidence to Gali's 2014 framework and dynamic relationships, described above. Fundamentally, this follow-up contribution sought to assess the "conventional view" empirically. The authors focus on quarterly US data GDP, GDP deflator, S&P500, Federal Fund Rate, dividends and commodity price index) and estimate a Vector Autoregression model with time-varying coefficients (TVC-Var) – allowing for the changing dynamic between interest rates, fundamental and bubble components. The baseline model and specification – not using contemporaneous response of monetary policy to asset prices, point to periods of stock price increases in response to monetary policy tightening. Thus, providing evidence against the "leaning against the wind" policies, as an increase in interest rates would lead to amplified bubbles. To further validate their finding, the authors address alternative explanations (principally the endogenous response to equity premium to monetary policy) and contemporaneous response of interest rates to stock prices and calls into question their validity in the analysis at hand. In concluding, the authors contribute evidence that warrants further study in the impacts of monetary policy in dealing with asset price bubbles and questions the prevailing dogma of "leaning against the wind".

Brunnermeier and Julliard (2016) carry out a similar study, including house-prices, with findings that point to the existence of Rational price bubbles. At a moment when interest rates are historically low across the globe and economies there are signs of new Stock Market bubbles, Central Banks find themselves victims of a Catch 22.

Blot, Hubert and Labondance (2017) investigates both methods for identifying Bubbly markets and the impacts of monetary policy on the found Bubble. The lack of consensus regarding models for identifying bubbles point to a model-averaging approach as the appropriate procedure. The impact of monetary policy was found to be asymmetrical: 1) decreases in interest rates, or a monetary policy expansion, contributed to price increases and expanded the bubble; 2) increases in interest rates generated no significant price movement or reduction in bubble size. Similar results are found when analyzing European Stock markets. The lack of symmetry in Bubble-behavior reinforces the potential Catch 22.

Beckers and Bernoth (2016) expand on the initial proposition of Gali and Gambetti (2015) by splitting the Bubble component in two: a risk premium and a mispricing component. Hence the Asset price is composed of three parts: a fundamental component, the risk premium aqnd the mispricing component. The authors follow a similar empirical work to Gali and Gambetti (2015) but, contradictory to the original work, find that an increase in interest rate

does in fact reduce the asset price – in great part due to the overreactions of the mispricing component. Hence, reducing the bubble size.

Svensson (2016) carries out a cost-benefit analysis, in line with Bernanke and Gertler (2000), of "leaning against the wind" (LATW) policies. The authors analyze the weakness and strengths arising from the adoption of the policies at hand, and how the economies fare during periods of normalcy and episodes of economic crisis. As discussed previously, LATW policies are substantiated by the claims of lower probability and absolute size of future economic crisis. Whereas the advocates of such policy emphasize the benefits, there is little quantifiable evidence of that greater macroeconomic stability is a consequence of retractive monetary policy. The author discusses three limitations of the LATW to contextualize its framework: 1) the probability of an economic crisis is correlated with the lagged growth of real debt of debt to GDP. A non-neutral monetary policy would, hence, increase the probability of crisis. 2) The policy rate-effect on the real debt to GDP ratio could be very small and of indefinite sign as interest rates have an impact on both numerator and denominator. 3) The correlation between size and magnitude of a crises and the previous growth rate of the debt to GDP ratio is derived from a reduced form model and does not consider underlying determinants (such as the nature of the shocks). More importantly, the author brings to light the costs of practicing LATW: the preemptive measure leads to an economy with ta greater out-put and unemployment gap in periods of stability. Logically, the total cost is amplified with the onset of the crisis. In establishing their framework Svensson takes a two-step approach, initially developing Benchmarks point associated to allegedly successes of LATW policies, and in a second moment, tests the robustness of the results. The overwhelming result is that the Costs of the adopted policies greatly outweigh their benefits, and more importantly, the breakeven point would be a crisis of more of them 5-40 standard errors. Hence, advocating against the use of "leaning against the wind" policies and calling for further studies regarding monetary policies.

Jianjun Miao, Zhouxiang Shen, and Pengfei Wang (2019), propose a self-titled comment to Gali's 2014 Rational Asset Price Bubble Framework. The comment comes as an alternative specification to the behavior of the agents in the dynamic equilibrium model and the nature of the innovation. The authors introduce learning as a selection device for choosing the particular state and subsequent equilibrium and focus their analysis on serially correlated bubble shocks. It is argued the 2014 paper focuses on a specific solution to the dynamic system (a backward-looking sunspot solution around a stable bubbly steady state), where the value of the preexisting bubble reacts only to its own innovations – in the absence of such impulses the size of the bubble is predefined and will increase with interest rates. In contrast to Gali, the authors

use a forward-looking minimal state variable (MSV) solution around an unstable bubbly state and, not surprisingly, find convergence with the postulates of "leaning against the wind" policies. That is, Asset price bubbles respond on impact to increases in interest rates, and constructionist monetary policy is indeed effective in dampening asset price bubbles. In closing, it is found that the sunspot solution proposed by Gali (2014) is not stable under learning and the monetary policy rule used, whereas as the conventional approach is E-stable. It should be noted, as underlined by the authors, the results are derived from an alternative specification of the 2014 framework using adaptive learning and serially correlated innovations. Therefore, prompting the importance the importance of more study and caution regarding monetary policy and asset prices.

Considering the discussions regarding monetary policy, the wide use of Quantitave and Qualitative Easing, the proximity to the Zero-Lower-Bound by many economies, and the recent trials of forward guidances, Ben Bernanke (2020) discusses a new toolset for monetary policy and evaluates their successes. The lecture explores alternative monetary policy tools yet focuses on forward guidance and quantitative easing as the prime recommendations, at different levels of the natural interest rates. While the lecture transmits an important and powerful message that the traditional tools will no longer be applicable as economies approach the zero lower-bound, Ben Bernanke establishes that the combination of Quantitative easing and forward guidances can provide up to 3% of policy space when the natural interest rate is between 2 and 3% (in line with the current estimates for the American natural rates). Below such interval, the afore mentioned showed to be less effective and should be used with other tools, such as an increase in inflation targeting. In closing, the author highlights the success of the new tool kit being trialed for monetary policy, emphasizes the intervals in which they are most efficient and, in the same light as the debate so-far, warrants discretion in their use.

There is no clear consensus regarding the role and responsibility of Monetary Policy when dealing with Bubbles and economic instabilities. A message, however, is clear: further research and evidence is required in the field of Bubbles, including identification, their behavior and how to treat them.

This paper focuses on the relationship between interest rates and asset prices, following the theoretical framework set forth in Gali (2014) and complemented empirically by Gali and Gambetti (2015). The debate on monetary policy as of late, has been focused on the United States of America and this study seeks to provide evidence of Rational Price Bubbles in Brazil.

The country at hand has a still very recent history of high interest rates, both real and nominal, high inflation, and a relative short track record, albeit effective, of inflation targeting

as a policy rule. Brazil's recent political landscape often shows signs of populism and adopts a rather loose fiscal policy rule. Combined with the still looming ghouls of high inflation and interest rates, the Brazilian Central Bank (BCB) operates under great scrutiny when establishing the federal base rate (Selic). In recent years, a likely consequence of inflations targeting, and the commodity cycles, interest and inflations rates have slowly decreased and stabilized. Concurrently, the Brazilian Financial Market has grown, especially in volumes of transactions, value, and number participants on either side, increasing the potential volatility and amounting great pressure to monetary policy decisions. Inflation-scare, a strong dependence on the export of commodities, a maturing financial market and historically low interest rates classify Brazil as a candidate for the study into the varying nature of the relation between asset prices and monetary policy.

Following this brief overview on the recent developments and discussions regarding monetary policy, this investigation comprises of five distinct parts: I. Theoretical Issues: covering the framework used throughout the study; II. The Empirical Model: section detailing the empirical strategy used provide evidence for the theoretical model. Both parts follow closely the writing of Gali and Gambetti (2015). III. Quarterly Data: exposes the first set of results using quarterly data for Brazil including the preliminary analyses, the Time Varying Coefficient SVARs impulse functions (TVC-SVAR IRF), subsamples and a note on significance. IV: Monthly Data: showcasing the results with monthly data, focusing on the time variation. V. Concluding Remarks: Summarizes the investigations findings and puts forth a conclusion.

2 THEORETICAL ISSUES

The theoretical framework developed by Gali and Gambetti (2015) and followed throughout the paper interprets the price of assets as the composite of two components:

$$Q_t = Q_t^F + Q_t^B$$

Where Q_t^F represents the "fundamental" component and Q_t^B the Bubble component. For simplification, Q_t^F is defined as the present discounted value of future dividends.

$$Q_t^F \equiv E_t \left\{ \sum_{k=1}^{\infty} \left(\prod_{k=1}^{n} \left(1/R_{t+j}\right) \right) D_{t+k} \right\}$$

The theoretical model provides the analytical basis for understanding how changes in interest rate (r_t) impact asset prices containing a Bubble component (Q_t^B). Log-linearizing the variables and combining their dynamic response to exogenous policy rate shock (ε_t^m):

$$\frac{\partial q_{t+k}}{\partial \varepsilon_t^m} = (1 - \gamma_{t-1}) \frac{\partial q_{t+k}^F}{\partial \varepsilon_t^m} + \gamma_{t-1} \frac{\partial q_{t+k}^B}{\partial \varepsilon_t^m}$$

Where $\gamma_{t-1} = Q_t^B / Q_t$ is the share of the Bubble component in the observed price in *t*.

Under the "conventional" view the exogenous interest rate shock should unambiguously reduce asset prices and suppress stock market bubbles. This is clear by analyzing the individual dynamic responses of the components:

$$\frac{\partial q_{t+k}^F}{\partial \varepsilon_t^m} < 0$$

$$\frac{\partial q_{t+k}^B}{\partial \varepsilon_t^m} \leq 0$$

Hence, the combined dynamic response:

$$\frac{\partial q_{t+k}}{\partial \varepsilon_t^m} < 0$$

The theory of *rational* asset price Bubbles, as argued by Gali (2014), indicates a different response. This is driven mainly by the Bubble component. In a rational expectation equilibrium, the following must be true (from the definition of Q_t^F):

$$Q_t R_t = E_t\{D_{t+1} + Q_{t+1}\}$$

Similarly, the following must also hold for the Fundamental and Bubble components, respectively:

$$Q_t^F R_t = E_t\{D_{t+1} + Q_{t+1}^F\}$$
$$Q_t^B{}_t R_t = E_t\{Q_{t+1}^B\}$$

The log-linear version of the Q_t^B becomes:

$$E_t\{\Delta q_{t+1}^B\} = r_t$$

Thus, an increase in interest rate will raise the expected growth of the Bubble component.

Interest rates may affect the Bubble component through a second channel. A systematic relationship can be shown to exist between the innovation in the bubble (deemed to be indeterminate) and the surprise component of the interest rate. This is done by evaluating the previous equation in *t – 1.*

$$\Delta q_t^B = r_{t-1} + \xi_t$$

Where:

$$\xi_t \equiv q_t^B - E_{t-1}\{q_t^B\};$$
$$E_{t-1}\{\xi_t\} = 0\ ;\ for\ all\ t;$$

The unanticipated changes to the size of the Bubble given by ξ_t is not necessarily correlated to fundamentals and, specially, changes in interest rate $(r_t - E_t\{r_t\})$. ξ_t takes the following form:

$$\xi_t = \psi_t(r_t - E_t\{r_t\}) + \xi_t^*$$

Where:

$$\psi_t \; is\; indeterminate\; in\; both\; size\; and\; sign;$$
$$\xi_t^* \; is\; a\; mean - zero\; martingale - difference\; process;$$
$$E_{t-1}\{\psi_t(r_t - E_t\{r_t\})\} = 0;$$
$$E_{t-1}\{\xi_t^*\psi_t(r_t - E_t r_t)\} = 0;$$

Regarding ψ_t: It is important to point out that neither the size, sign nor its relation with policy regimes is established by theory. Thus, the *contemporaneous impact* of changes in interest rate on the Bubble component in indeterminate.

The dynamic response function of the Bubble components to monetary policy shocks is given by:

$$\frac{\partial q_{t+k}^B}{\partial \varepsilon_t^m} = \begin{cases} \psi_t \frac{\partial r_t}{\partial \varepsilon_t^m}, & for\; k = 0 \\ \psi_t \frac{\partial r_t}{\partial \varepsilon_t^m} + \sum_{j=0}^{k-1} \frac{\partial r_{t+j}}{\partial \varepsilon_t^m}, & for\; k > 0 \end{cases}$$

Where:

$$\frac{\partial r_{t+k}}{\partial \varepsilon_t^m} > 0\,, for\; all\; k;$$

At the moment of the policy shock, the response of the Bubble component is indeterminate due to ψ_t. The long-run response will depend on the persistence of the interest rate response: Is the persistence of the real interest rate response is sufficient to compensate for the potential negative initial impact? The dynamic behavior of the Bubble and Fundamental components implies that the sign of the response of asset prices to the tightening of monetary policy is ambiguous.

In conclusion, the behavior of asset prices discussed allows for the possibility that asset prices might increase in response to a tightening of monetary policy. As discussed, the principles conditions are: 1) ψ_t must not be "too" negative, 2) the real interest rate response should be persistent "enough" and 3) the relative size of the Bubble component (give by γ_t) is large "enough".

3 THE EMPIRICAL MODEL

The empirical model used, which will be detailed in the section, follows the framework of a Time-varying Coefficients Structural VAR (TVC-SVAR). That is, the model combines the frame TVC-VAR framework with variable choice and identification strategies present in SVAR.

A Time-varying coefficient framework is motivated by the dependence of the stock price response on the relative size of the bubble component. As noted in the theoretical model, the relative size of the eventual bubble component (γ_t) is likely to be time dependent and not previously established in literature.

The TVC-SVAR estimation includes GDP (y_t), GDP deflator (monthly variation in price levels – p_t), commodity price index ($p_t^c,$), the short-term nominal interest rate (controlled by the central bank – i_t), the stock index) and the corresponding dividend series (both adjusted for real terms – q_t and d_t respectively). Hence defining the vector

$$x_t \equiv [\Delta y_t, \Delta d_t, p_t, \Delta p_t^c, i_t, \Delta q_t]$$

and assuming the relationship between the variables and structural shock as the following autoregressive model with time-varying coefficients:

$$x_t = A_{0,t} + A_{1,t}x_{t-1} + A_{2,t}x_{t-2} + \cdots + A_{p,t}x_{t-p} + u_t$$

Where $\mathrm{A}_{0,\mathrm{t}}$ is the vector of time-varying intercepts and $A_{i,t}$ $(i = 1, \ldots, p)$ are the matrices of time-varying coefficients.

The vector of reduced form innovations (u_t) is assumed to follow a white noise Gaussian process with mean zero and covariance matrix $\sum_t$. The reduced form innovations is assumed to be a linear transformation of the underlying structural shocks (ε_t):

$$u_t \equiv S_t \varepsilon_t$$

Where $E\{\varepsilon_t \varepsilon'_t\} = I$ and $E\{\varepsilon_t \varepsilon'_{t-k}\} = 0$ (for all *t* and *k*). S_t is defined such that $S_t S'_t = \sum_t$.

The behavior of the parameters over time is assumed to be:

$$\theta_t = \theta_{t-1} + \omega_t$$

Where:

$$\theta_t = vec(A_t')$$
$$A_t = [A_{0,t}, A_{1,t}, A_{2,t}, \cdots, A_{p,t}]$$

Additionally, ω_t is white Gaussian process with mean zero and constant covariance Ω. The model for the behavior of $\sum_t$ through time is given by:

$$\textstyle\sum_t = F_t D_t F_t'$$

Where F is a lower triangular matrix with main diagonal of ones and D is a diagonal matrix. Additionally, it is assumed that:

$$log\sigma_t = log\sigma_{t-1} + \zeta_t$$
$$\phi_{i,t} = \phi_{i,t-1} + \nu_{i,t}, \qquad i = 1\ldots5$$

Where:

- σ_t is the vector containing diagonal elements of $D_t^{1/2}$;
- $\phi_{i,t}$ a column vector containing the nonzero elements of the row (i + 1) of F_t^{-1};
- ζ_t is white Gaussian process with mean zero and constant covariance Ξ;
- ν_t is white Gaussian process with mean zero and constant covariance Ψ;
- $\omega_t, \varepsilon_t, \zeta_t$ and $\nu_{i,t}$ are time independent (that is, $\nu_{i,t}$ is independent of $\nu_{i,j}$, for $i \neq j$) and mutually uncorrelated at all leads and lags.

So far, the construction has focused on characterizing the TVC-VAR, the structural identification of the model follows the proposals by Christiano, Eichenbaum and Evans (2005). Hence, it is assumed that:

- Monetary policy shock has no contemporaneous impact on GDP, dividends and inflation;
- The central bank does not respond contemporaneously to innovations in real stock prices.

The model is estimated using the framework proposed by Del Negro and Primiceri (2005).

4 QUARTERLY DATA

The study uses a combination of Brazil Time series data, Financial Indices and Commodity Price Index. The quarterly nominal GDP is obtained from the Brazilian Central Bank together with the monthly consumer price index (IPCA), the general market price index (IGPM) used as the implicit price deflator, and the annual federal fund rate (SELIC). The IBOVESPA (or IBOV) index was selected as the major asset price indicator. The corresponding dividend series was also included in the data set and model. Lastly, the World Bank Commodity Price index was used to adjust for the price puzzle. The GDP, IBOV and the dividend series were deflated to real terms using the IGPM.

In setting up the Model, Augmented Dickey Fuller tests were carried out to guaranty stationarity: Real GDP, IBOV, IBOV dividend and the commodity Price index are used in logarithmic form for and first difference, while SELIC and IPCA are not subject to any prior transformation. An extensity routine of Lag-Length tests concluded the need for a Lag-length of 2 for both the Constant and the time-varying-coefficients VAR. The Results are reported in the Appendix I. – III.

The baseline period ranges from the second quarter o 1998 (2Q1998) to the first quarter of 2020 (1Q2020), inclusively. It should be noted that 1999 marks the start of inflation targeting by the Brazilian Central and the beginning of lower and more stable inflation. Hence, the response of IPCA to the monetary policy shock can be subject to initial sample bias and, consequently, price-puzzle distortions. The baseline data range does not include 3 quarters of 2020 due to the onset of the Coronavirus and the economic detriments caused by the pandemic.

4.1 C-VAR IRFS

As a preliminary analysis a constant coefficient VAR (C-Var) was run, and the resulting Impulse response (IRFs) functions are reported in figure 1 (ranging from 1a. to 1h.). As described in section II. the graphed IRFs illustrate the path of each variable in the model in response to an exogenous interest rate shock in moment t=0. Thus, the behavior of the nominal and real interest rates in figures 1.a. and 1.b.

Fig. 1a. Nominal Interest Rate (Selic)

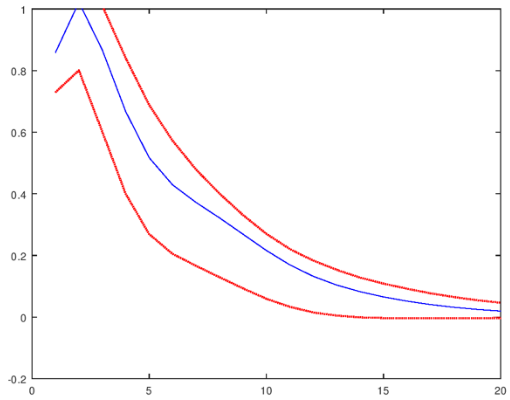


Fig. 1b. Real Interest Rate

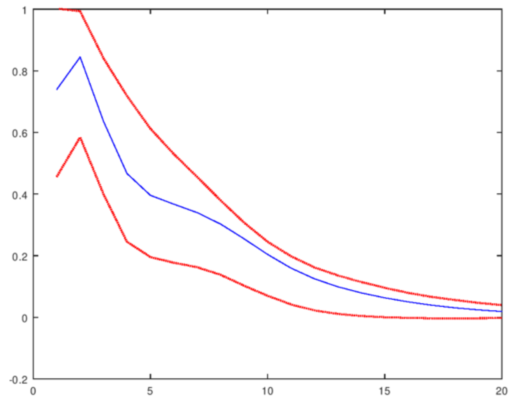


Fig. 1. Estimated Responses to Monetary Policy Shocks – C-Var

As it pertains to the strictly macroeconomic variables: GDP (2c.) and Consumer Price Index (2d.) behave according to previously and extensive documented literature. Following the shock in interest rates, GDP falls and later stabilizes. Whereas the consumer price index (IPCA) shows indications of the so-called price puzzle by failing to retreat when faced with an interest rate hike. The response of the IPCA can also be attributed to the respond of the fundamental asset price component or the IBOVESP (IBOV). It should be noted that the confidence interval for both the GDP and IPCA is very wide, making interpretations of the overall direction of the response tough.

Fig. 1c. GDP

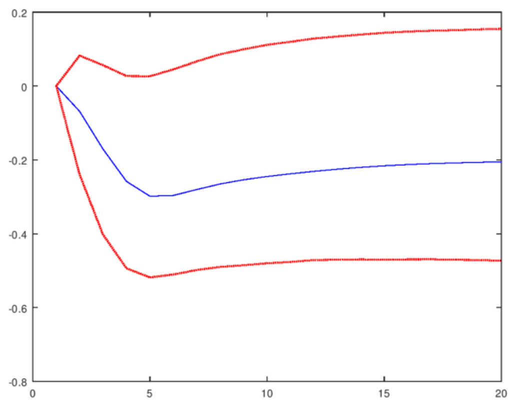


Fig. 1d. Consumer Price Index (IPCA)

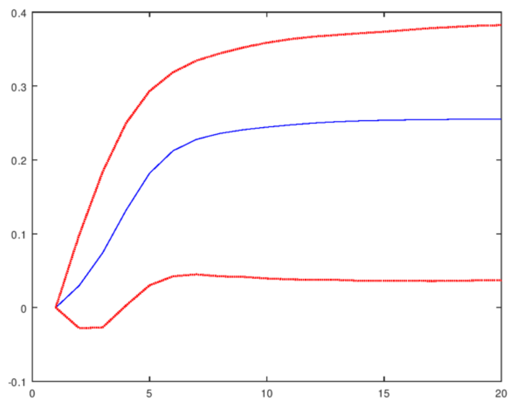


Fig. 1. Estimated Responses to Monetary Policy Shocks – C-Var

Figures 1e. to 1h. are the center pieces for the preliminary analyses and study, specially the resulting 1h. Comparing the trajectories of the Stock Price Index and the corresponding dividend series (IBOV and IBOV dividend henceforth), it is the different responses to the policy impact: both in the periods immediately the shock and the convergence in the long run. The IBOV retracts less drastically than the dividend series in the periods immediately after the interest rate increase and is shown to recover faster. Such distinct behaviors are a clear indication that Asset Prices are not fully comprehended by the dividend series alone.

Fig. 1e. Dividend Series (IBOV)

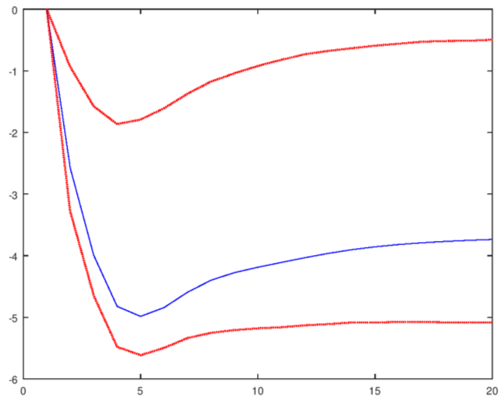


Fig. 1f. Stock Price Index (IBOV)

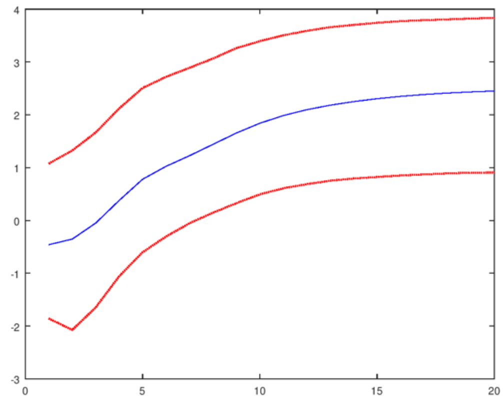


Fig. 1. Estimated Responses to Monetary Policy Shocks – C-Var

Lastly, the following IRFs build preliminary indications for the existence of a Bubble component, as hinted when comparing figures 1e. and 1f. above. Figure 1g. illustrates the response function of the Fundamental Component, that is the present value of the IBOV dividend IRFs. Most importantly, Figure 1h. compares the impulse functions of both the stock price index (Fig. 1f) with its fundamental component (Fig. 1g), and it is evident the existent of a significant and non-zero Bubble component. Such is positive and becomes increasingly so after one.

Relating to the theoretical model, Figure 1h points to the response of Bubble component $q^B_{t+k} = q_{t+k} - q^F_{t+k}$ being positive and increasing over time. Hence, it serves as initial evidence for the existence of a time varying Rational Asset Price Bubble component and a non-negligeable correspondence with interest rate increases.

Fig. 1g. Fundamental Component

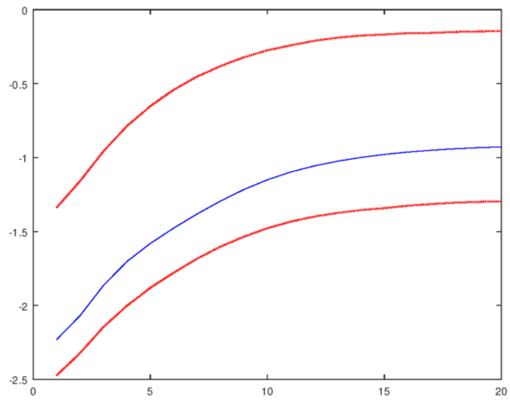


Fig. 1h. Price minus Fundamental Component

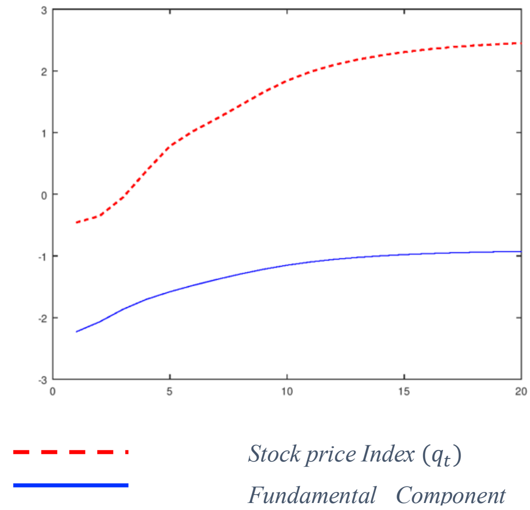


Fig. 1. Estimated Responses to Monetary Policy Shocks – C-Var

4.2 TVC-SVAR IRFS

The preliminary findings point to the existence of a significant Rational Asset Price Bubble component. Furthermore, the bubble component's response, to monetary policy contractions, was shown to be positive at impact and increases over time. This subsection focuses on the time-varying responses of the variables to increases in interest rates. In doing so, the Impulse Response functions (IRFs) of the Time-Varying Coefficients SVAR (TVC-SVAR) are reported in figure 2 (2a. to 2g.). It should be noted that the Z-axis is the magnitude of the response (equivalent to the Y-axis of figure.1), the Y-axis is the time-periods after the shock (similar to the X-axis of the previous sections) and the X-axis corresponds to the multiple years for which the TVC-SVar was calculated. Figures 2a. through to 2g. can be thought of as a compilation of impulse response functions forming the surfaces presented below.

Figures 2a. and 2b. show the interest rate paths for different time periods from the moment of the exogenous interest rate shock. It is not surprising that the behavior of both nominal and real interest rates does not show signs of varying over time and, consequentially, follows a similar overall path to figures 1a. and 1b. above.

Fig. 2a. Nominal Interest Rate (Selic)

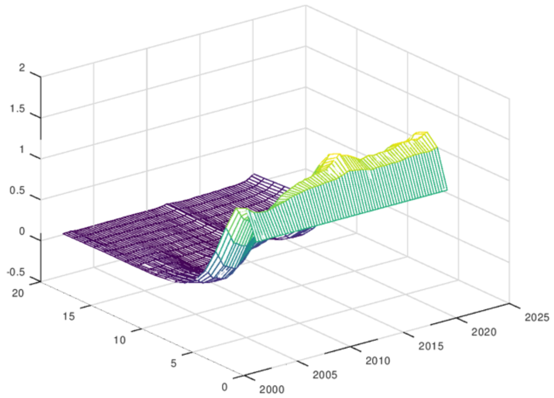


Fig. 2b. Real Interest Rate

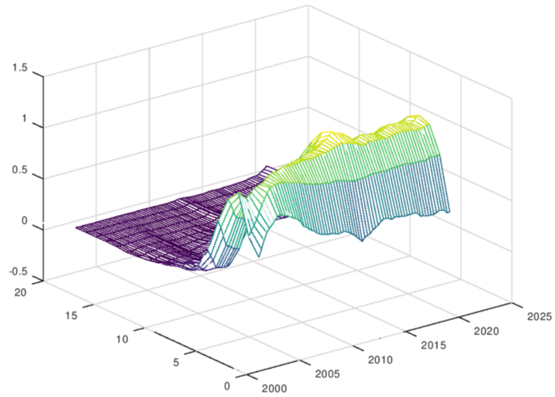


Fig. 2. Estimated Responses to Monetary Policy Shocks – TVC-SVar

The following 2 panels illustrate the time-varying behavior of the Brazilian GDP (Fig. 2c.) and the Consumer Prince Index (IPCA; Fig. 2d.). The GDP shows a consistent trajectory over the periods: declining immediately after monetary tightening and recovering over time. As per the IPCA, figure 2d. shows an overall decline over time. It should be noted that, as mentioned previously, the IPCA data set includes the early periods of inflation targeting in Brazil leading to initial sample-bias and the presence of the so-called price-puzzle. Such, in combination with the reliance on commodities, in the foreign market, can lead to a distorted analyses regarding inflation.. Here, the Consumer Price Index IRFs are reported but are not the principal concern of the investigation.

Fig. 2c. GDP

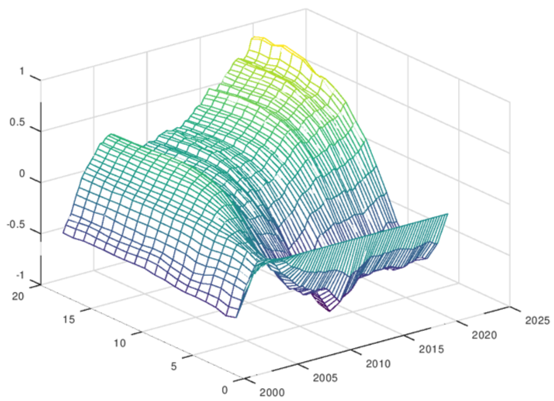


Fig. 2d. Consumer Price Index (IPCA)

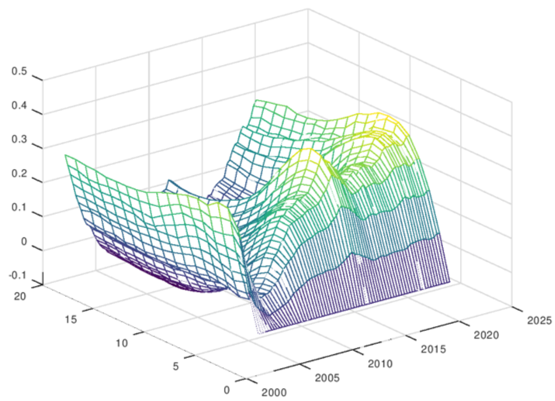


Fig. 2. Estimated Responses to Monetary Policy Shocks – TVC-SVar

The time varying IRFs for Stock price Index (IBOV; Fig. 2f) and its corresponding dividend series (Fig. 2e) are shown below. The dividend series displays an overall similar path

across the periods, declining on impact and recovering after approximately 5 periods of decline. It can observe that the perseverance of the initial contraction varies, reaching the lowest points between 2015 and 2020. The IBOV, on the other hand, displays a change in behavior towards the policy contraction as shown in Figure 2f. below. Until 2010, the stock prices can be seen to decline on impact and follow a path upwards to recovery in the following time periods. Such is consistent with an economy in the absence of bubbles and in line with the convention, or "leaning against the wind", approach to monetary policy. However, from 2010 to 1Q2020, the initial decline becomes a rapid increase in asset price. The changing behavior of asset prices and the contrasting responses between the stock prices and the corresponding dividend series points to the existence of a non-negligible time varying Bubble Component.

Fig. 2e. Dividend Series (IBOV)

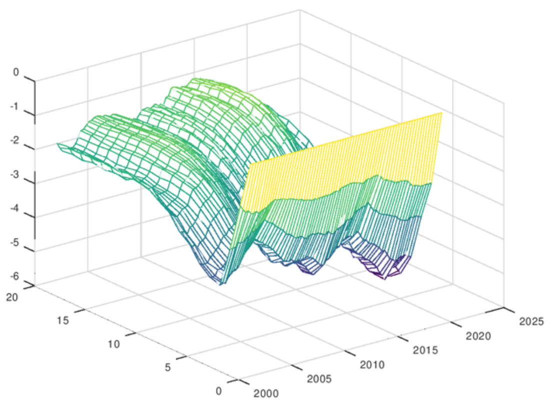


Fig. 2f. Stock Price Index (IBOV)

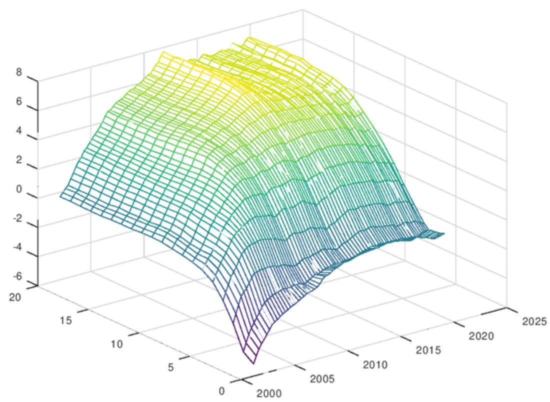


Fig. 2. Estimated Responses to Monetary Policy Shocks – TVC-SVar

In further contrast to the response function of stock prices, the fundamental component (shown in figure 2g.) has changed little over time and has an overall behavior similar its constant VAR counterpart (figure 1g.). The Gap in responses between Asset prices and the fundamental component is shown in Figure 2h. Similarly, to Figure 2f. it must be noted that only in the years prior to 2010 does the gap decrease with the interest rate contraction. For the rest of the sample (i.e. 1Q2020 to 1Q2020) the gap is positive and increasing. This is consistent with the rational bubble framework described in section I and stands in opposition with the belief that monetary tightening is beneficial in combating Asset price Bubbles.

Fig. 2g. Fundamental Component

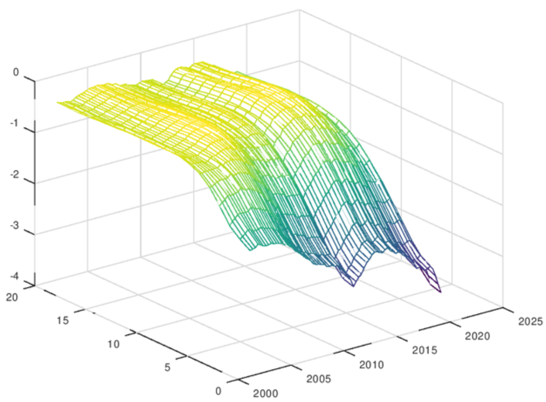


Fig. 2h. Price minus Fundamental Component

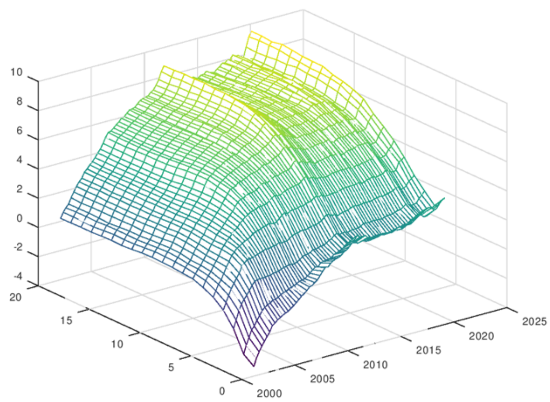


Fig. 2. Estimated Responses to Monetary Policy Shocks – TVC-SVar

4.3 SIGNIFICANCE

Having established the existence of the Bubble component and its time dependent response to monetary policy tightening, Figure 3 (below) offers an alternative view on the impulse response function reported in Figure 2h. It shows the evolution over time (starting from the policy shock) of the impact of interest rate increases on the log deviations between the IBOV and its fundamental component. The separate lines represent the different time horizons, and it becomes clear that there is a change in response between around 2008 and 2010, when the deviation is positive across all time horizons.

Fig. 3. $q^B_{t+k} = q_{t+k} - q^F_{t+k}$ responses for different periods

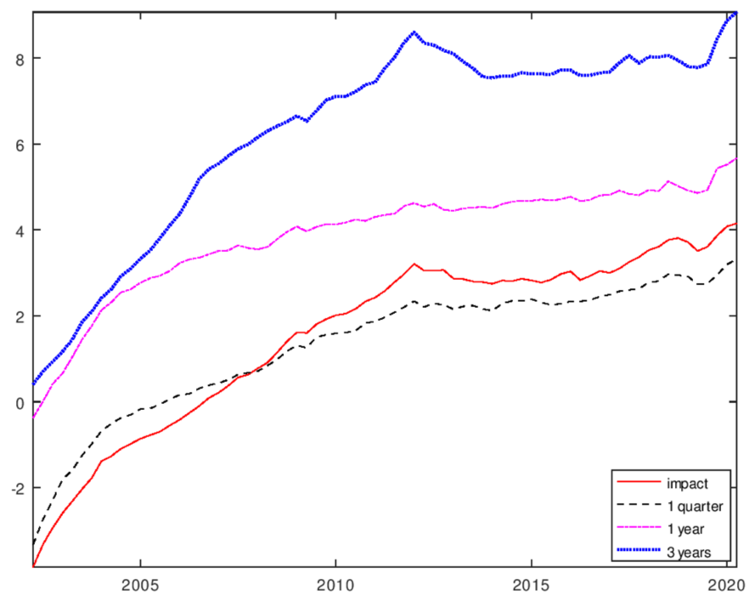
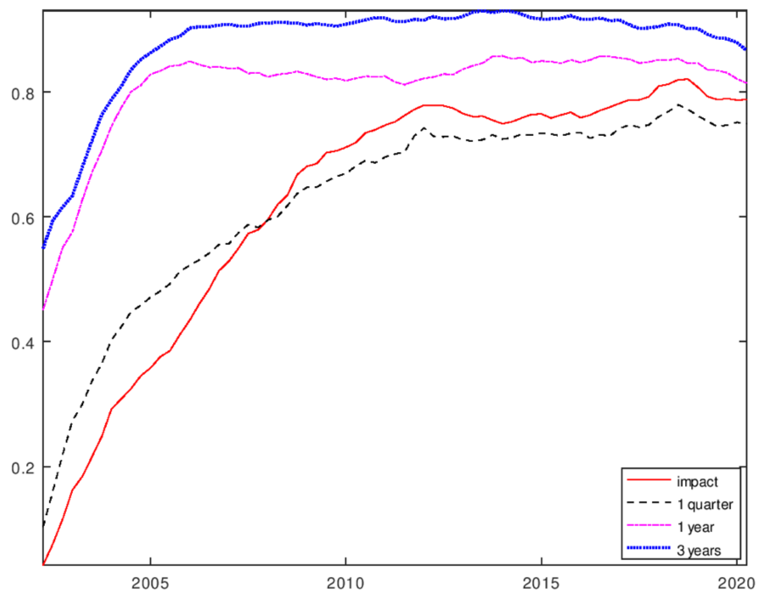


Figure 4 reports the probability of a positive deviation from fundamentals at selected time horizons, in a format like figure 3 above. At time periods furthest away from the shock (1 and 3 years) positive gap in over consistently over 50% and nearing 100%. More importantly, between 2008 and 2010 the probability of a positive gap is consistently over 60% for all time periods. Thus, underlying the significance of the results for Brazil so-far.

Fig. 4. Probability of a positive $q^B_{t+k} = q_{t+k} - q^F_{t+k}$ response



4.4 SUBSAMPLES

Figures 5 (5a. through to 5e.) illustrates the different the bubble component response by portraying the average IRFs for the IBOV and its fundamental component at selected periods in the sample. Given how the political scenario in Brazil is often volatile and how it steers the county's perception and macro-stability, four subsamples with that in mind. Figure 5a. encompasses a period of relative stability (both politically and economically) from 2003 to the end of 2009. The IRFs show an initial negative gap between price and fundamentals, and the smallest deviation across the 20 periods. Figure 5b. on the other hand features a period of economic uncertain, between 1Q2010 and 2Q2014 for Brazil and late repercussions of 2008-2009 financial crisis. The gap response of both variables considered can be seen to change and as a result the Bubble component at impact is positive increasing across the time horizon. Figure 5c. covers a sample ranging from 3Q2014 to 3Q2016 riddled by doubtful economic decisions and the conclusion of successful impeachment proceeding. Across such subsample the gap between the response function is greatest on average. Figure 5d. captures the horizon from 4Q2016 to 4Q2017, featuring an interim government in Brazil and a recuring attempt to calm market sentiments and internal instabilities (for example, the trucker's strike). The isolated IRF for the period shows a greater gap when compared to the previous periods in both the initial overshooting and the long term-divergence. Lastly, Figure 5e. portrays a period from 1Q2018 to 1Q2020, characterized by the election of a far-right president, political uncertainty, and tentative implementation of market-oriented policies. The initial overshooting of price over fundamentals is smaller, when compared to figures 5c and 5d., and the inclination of the Asset Price IRFs is smaller in the subsequent periods. The different subsamples and varying behaviors of the IRFs is further evidence of the Rational Asset Price Bubbles and its volatile behavior, specially as it pertains monetary policy.

Fig. 5a. 1Q2003 – 4Q2009

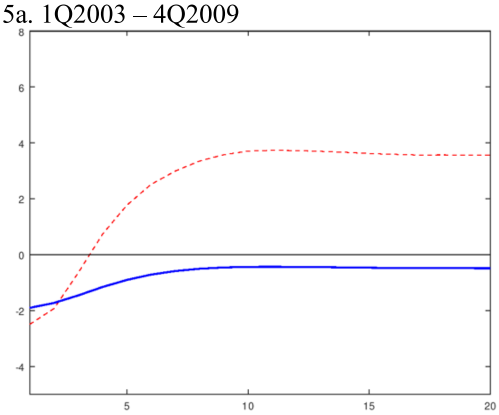


Fig. 5b. 1Q2010 – 2Q2014

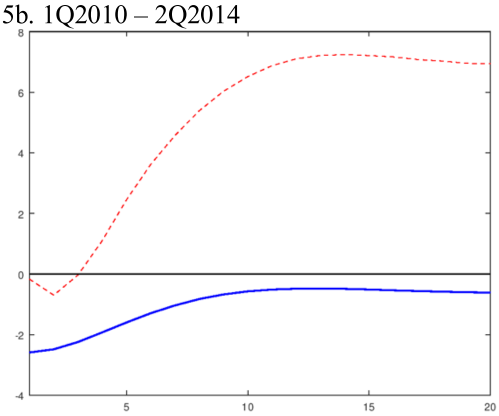


Fig. 5c. 3Q2014 – 3Q2016

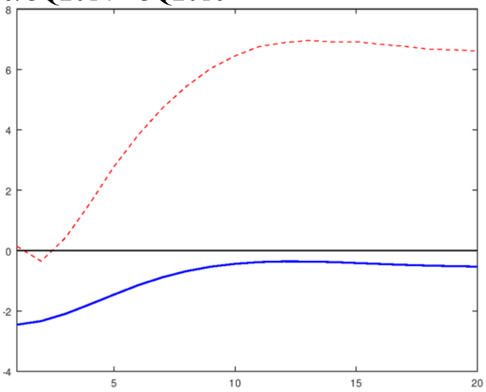


Fig. 5d. 4Q2016 – 4Q2017

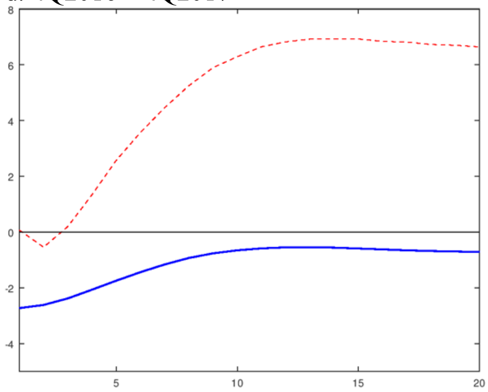
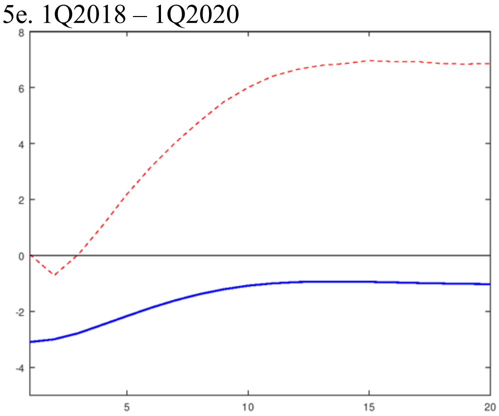


Fig. 5e. 1Q2018 – 1Q2020



5 MONTHLY DATA

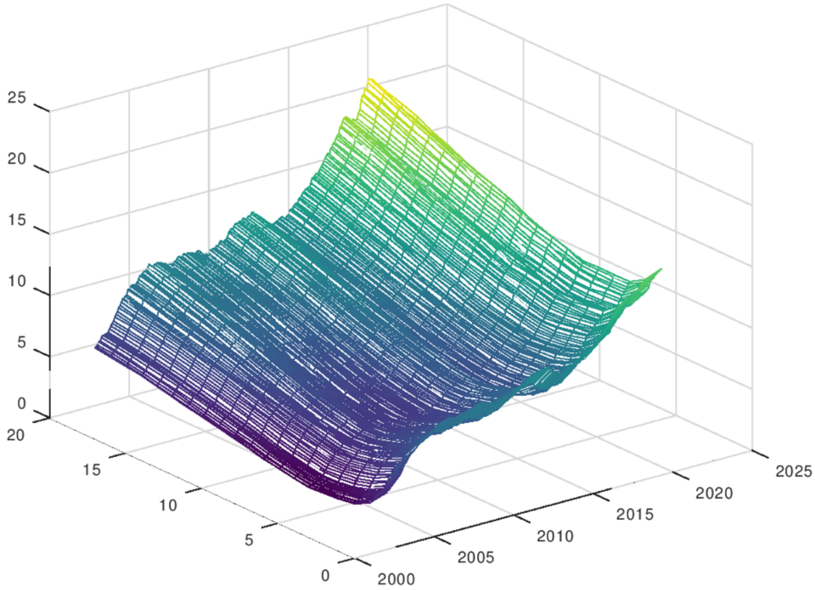
So-far the investigation has established the variability in response of asset prices the monetary policy, indicating the existence of a non-negligible and positive bubble component from around 2008 to the remainder of the sample. The purpose of this section is to further confirm and explore the findings using monthly data for Brazil. The motivation here is to increase degrees of freedom of the empirical investigation and to explore the time-variability at a higher frequency.

Except for the Gross domestic product (GDP), the variable used were strictly the same as before. The consumer price index (IPCA), the annual federal fund rate (SELIC), the asset price market indicator (IBOV) and its corresponding dividend series, previously been used as quarterly aggregates, were now studied in monthly frequency. The series were, as before, deflated using the monthly general market index (IGPM). Per completion, monthly figures of World Bank Commodity Index were added. For the so-called monthly GDP, the monthly industrial survey data (PIM; henceforth referred to as GDP) was used as its widely considered a monthly proxy for the quarterly GDP and shows strong correlation with gross domestic product. The baseline period continues to range from June 1998 (6M1998) to the March 2020 (3M2020), inclusively.

Similarly, to the model with Quarterly data, during the initial setup the Augmented Dickey Fuller tests were applied to confirm stationarity: Real GDP, IBOV, IBOV dividend and the commodity Price index are used in log for and first difference, while SELIC and IPCA are not transformed. Lag-Length tests indicate a sufficient Lag-length of 3 for both the Constant and the time-varying-coefficients VAR. The Results are reported in the Appendix IV. – VI.

Figure 6, below, shows the gap in response between Price and the fundamental component, also referred to as Bubble component, for monthly data. The figure certifies the robustness of the divergence in response to exogenous tightening of monetary policy. Akin to figure 2h, there is a non-negligeable and positive gap in response which widens over time. The full set of results for this section, including the constant coefficient IRF, the remaining time varying coefficients IRFs, Significance results and Subsample analyses can be found in Appendix VII. – X.

Fig. 6. Price Minus Fundamental Component for Monthly Data



6 CONCLUDING REMARKS

As explored in the opening section, there is much debate, little consensus, and less evidence regarding the role and impacts of monetary with regards to asset price bubbles. This paper applied the framework of Rational Asset price Bubbles set forth by Gali (2014) and empirically illustrated by Gali and Gambetti (2015), to quarterly and monthly data for Brazil.

The so-called “conventional view” or “Leaning against the wind” (LATW) holds that the tightening of policy rates would suppress asset prices and avoid, even revert, a price hike. It follows, logically, that monetary policy could, and it argued by the supporters of LATW that should, be used to prevent asset price bubbles. However, there is little evidence to support such claim and shown by Gali and Gambetti (2015), using American quarterly data, there is strong evidence that monetary tightening can lead to an increase in asset prices. Using data for Brazil and acknowledging its rich recent-history of political and economic volatility, this investigation finds that the response of the bubble component is significant, time variable and increasing with time. Thus, siding with the original findings by Gali and Gambetti (2015) and further questioning the long-held convention that monetary policy contractions is both appropriate and effective for deflating asset price bubbles.

Brazil has history of staggering high inflation, crippling real interest rates, which was partly eased by the adoption of inflation-targeting and monetary stabilization. More recently, it has reaped the benefits of an expanding financial market and less volatile foreign exchange rates while failing to stabilize its often-populist fiscal policy and government spending. Pressing inflation, loose fiscal policies and a volatile asset market, places Brazil in possible Catch 22 with regards to monetary policy: interest rates increases aimed at bringing inflation closer to target levels can lead, as shown throughout this paper, to exuberant volatility and inflation of asset price bubbles.

REFERENCES

BERNANKE, BEN, S; MARK GERTLER. "Monetary policy and asset price volatility," **Proceedings, Federal Reserve Bank of Kansas City**, pages 77-128, 1999.

BERNANKE, BEN, S; MARK GERTLER. "Should Central Banks Respond to Movements in Asset Prices?" **American Economic Review**, 91 (2): 253-257. 2001.

BASILE, AMY; JOYCE, JOSEPH P. Asset bubbles, monetary policy and bank lending in Japan: an empirical investigation, **Applied Economics**, 33:13, 1737-1744, DOI: 10.1080/00036840010018621, 2001.

HUNTER; WILLIAM C.; GEORGE C KAUFMAN; MICHAEL POMERLEANO. (eds.) Asset Price Bubbles: Implications for Monetary, Regulatory, and International Policies." Cambridge, MA: **MIT Press**, 2002.

BORIO, CLAUDIO E.V.; LOWE PHILIP WILLIAM, Asset Prices, Financial and Monetary Stability: Exploring the Nexus (July 2002). **BIS Working Paper No. 114**, Available at SSRN: https://ssrn.com/abstract=846305 or http://dx.doi.org/10.2139/ssrn.846305 , 2002

POSEN, ADAM S., Why Central Banks Should Not Burst Bubbles (January 2006). **Institute for International Economics Working Paper No. 06-1**, Available at SSRN: https://ssrn.com/abstract=880450 or http://dx.doi.org/10.2139/ssrn.880450 , 2006.

JULLIARD, CHRISTIAN; BRUNNERMEIER, MARKUS KONRAD, Money Illusion and Housing Frenzies (December 2006). **NBER Working Paper No. w12810**, Available at SSRN: https://ssrn.com/abstract=955243, 2006.

GALÍ, JORDI; GAMBETTI, LUCA. "On the Sources of the Great Moderation." **American Economic Journal: Macroeconomics**, 1 (1): 26-57. DOI: 10.1257/mac.1.1.26, 2009.

WOODFORD, MICHAEL, "Inflation Targeting and Financial Stability," **Sveriges Riksbank Economic Review**, 2012:1, 2012.

GALÍ, JORDI; GAMBETTI, LUCA. "Monetary Policy and Rational Asset Price Bubbles." **American Economic Review**, 104 (3): 721-52. DOI: 10.1257/aer.104.3.721, 2014.

GALÍ, JORDI; GAMBETTI, LUCA. "The Effects of Monetary Policy on Stock Market Bubbles: Some Evidence." **American Economic Journal: Macroeconomics**, 7 (1): 233-57, 2015.

BENJAMIN BECKER; KERSTIN BERNOTH. "Monetary Policy and Mispricing in Stock Markets," **Discussion Papers of DIW Berlin 1605**, DIW Berlin, German Institute for Economic Research, 2016.

SVENSSON, LARS. "Cost-Benefit Analysis of Leaning Against the Wind: Are Costs Larger Also with Less Effective Macroprudential Policy?," **IMF Working Papers, vol 16(3)**, 2016.

MIAO, JIANJUN; ZHOUXIANG, SHEN; PENGFEI, WANG. "Monetary Policy and Rational Asset Price Bubbles: Comment." **American Economic Review**, 109 (5): 1969-90, 2019.

BERNANKE, BEN S. "The New Tools of Monetary Policy." **American Economic Review**, 110 (4): 943-83.DOI: 10.1257/aer.110.4.943, 2020.

APPENDIX A. QUARTELY DATA SPECIFICATION.

I. Augmented Dickey Fuller tests for Stationarity

Real GDP

Null Hypothesis: D(Y_REAL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.056528	0.0000
Test critical values:	1% level	-3.508326	
	5% level	-2.895512	
	10% level	-2.584952	

*MacKinnon (1996) one-sided p-values.

Consumer Price Index

Null Hypothesis: P has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.525801	0.0000
Test critical values:	1% level	-3.507394	
	5% level	-2.895109	
	10% level	-2.584738	

*MacKinnon (1996) one-sided p-values.

Interest Rate (Selic - %p.a.)

Null Hypothesis: I___4189 has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.839341	0.0001
Test critical values:	1% level	-3.509281	
	5% level	-2.895924	
	10% level	-2.585172	

*MacKinnon (1996) one-sided p-values.

Commodity Price Index

Null Hypothesis: D(PC) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.763726	0.0000
Test critical values:	1% level	-3.509281	
	5% level	-2.895924	
	10% level	-2.585172	

*MacKinnon (1996) one-sided p-values.

Real Stock Market Price Index (IBOVESPA)

Null Hypothesis: D(Q_REAL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.671739	0.0000
Test critical values:	1% level	-3.508326	
	5% level	-2.895512	
	10% level	-2.584952	

*MacKinnon (1996) one-sided p-values.

Real Stock Market (IBOVESPA) Dividend Series

Null Hypothesis: D(DT_REAL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.580912	0.0000
Test critical values:	1% level	-3.504727	
	5% level	-2.893956	
	10% level	-2.584126	

*MacKinnon (1996) one-sided p-values.

II. Lag-Length Criteria

VAR Lag Order Selection Criteria
Endogenous variables: Y_REAL P DT_REAL PC I___4189 Q_REAL
Exogenous variables: C
Date: 06/06/21 Time: 17:49
Sample: 6/01/1998 3/01/2020
Included observations: 84

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1964.596	NA	9.59e+12	46.91895	47.09258	46.98875
1	-1465.410	915.1750	1.56e+08	35.89071	37.10611*	36.37929*
2	-1419.913	76.91091*	1.26e+08*	35.66460*	37.92178	36.57197
3	-1390.717	45.18444	1.53e+08	35.82659	39.12556	37.15275
4	-1363.157	38.71527	2.00e+08	36.02755	40.36829	37.77249

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

III. Residual Tests

VAR Residual Heteroskedasticity Tests (Levels and Squares)
Date: 05/26/21 Time: 22:54
Sample: 6/01/1998 3/01/2020
Included observations: 83

Joint test:

Chi-sq	df	Prob.
1068.147	1008	0.0920

VAR Residual Serial Correlation LM Tests
Date: 05/26/21 Time: 22:55
Sample: 6/01/1998 3/01/2020
Included observations: 83

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	42.86224	36	0.2005	1.212382	(36, 209.2)	0.2033
2	40.62774	36	0.2738	1.143341	(36, 209.2)	0.2770
3	48.17000	36	0.0845	1.379140	(36, 209.2)	0.0863
4	53.05527	36	0.0333	1.536122	(36, 209.2)	0.0342

APPENDIX B. MONTHLY DATA SPECIFICATION.

IV. Augmented Dickey Fuller tests for Stationarity – Monthly Data

Real GDP (Monthly Industrial Production Survey)

Null Hypothesis: D(Y_REAL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.657694	0.0000
Test critical values:	1% level	-3.505595	
	5% level	-2.894332	
	10% level	-2.584325	

*MacKinnon (1996) one-sided p-values.

Consumer Price Index

Null Hypothesis: P has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.722407	0.0000
Test critical values:	1% level	-3.503879	
	5% level	-2.893589	
	10% level	-2.583931	

*MacKinnon (1996) one-sided p-values.

Interest Rate (Selic - %p.a.)

Null Hypothesis: D(I___4189) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.10533	0.0001
Test critical values:	1% level	-3.505595	
	5% level	-2.894332	
	10% level	-2.584325	

*MacKinnon (1996) one-sided p-values.

Commodity Price Index

Null Hypothesis: D(PC) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.555817	0.0000
Test critical values:	1% level	-3.505595	
	5% level	-2.894332	
	10% level	-2.584325	

*MacKinnon (1996) one-sided p-values.

Real Stock Market Price Index (IBOVESPA)

Null Hypothesis: D(Q_REAL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.872097	0.0000
Test critical values:	1% level	-3.504727	
	5% level	-2.893956	
	10% level	-2.584126	

*MacKinnon (1996) one-sided p-values.

Real Stock Market (IBOVESPA) Dividend Series

Null Hypothesis: D(DT_REAL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.83096	0.0000
Test critical values:	1% level	-3.455387	
	5% level	-2.872455	
	10% level	-2.572660	

*MacKinnon (1996) one-sided p-values.

V. Lag-Length Criteria – Monthly Data

VAR Lag Order Selection Criteria
Endogenous variables: Y_REAL P DT_REAL PC I Q_REAL
Exogenous variables: C
Date: 06/06/21 Time: 22:11
Sample: 1998M06 2020M03
Included observations: 250

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3145.039	NA	3572.594	25.20831	25.29282	25.24232
1	-1012.578	4145.503	0.000186	8.436625	9.028231	8.674729
2	-785.0293	431.4326	4.02e-05	6.904234	8.002930*	7.346427*
3	-748.5758	67.36601	4.01e-05*	6.900607*	8.506393	7.546889
4	-720.6315	50.29973	4.28e-05	6.965052	9.077929	7.815423
5	-680.8001	69.78471	4.17e-05	6.934401	9.554368	7.988861
6	-657.8199	39.15829	4.65e-05	7.038559	10.16562	8.297108
7	-623.6286	56.62080	4.76e-05	7.053029	10.68718	8.515667
8	-599.9953	38.00234	5.30e-05	7.151962	11.29320	8.818689
9	-561.7157	59.71619*	5.28e-05	7.133725	11.78205	9.004541
10	-533.9060	42.04827	5.73e-05	7.199248	12.35467	9.274153
11	-504.8713	42.50676	6.18e-05	7.254970	12.91748	9.533964
12	-474.6824	42.74746	6.63e-05	7.301459	13.47106	9.784542

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

VI. Residual Tests – Monthly Data

VAR Residual Heteroskedasticity Tests (Levels and Squares)
Date: 06/06/21 Time: 22:10
Sample: 1998M06 2020M03
Included observations: 249

Joint test:

Chi-sq	df	Prob.
3075.839	3024	0.2510

VAR Residual Serial Correlation LM Tests
Date: 06/06/21 Time: 22:09
Sample: 1998M06 2020M03
Included observations: 249

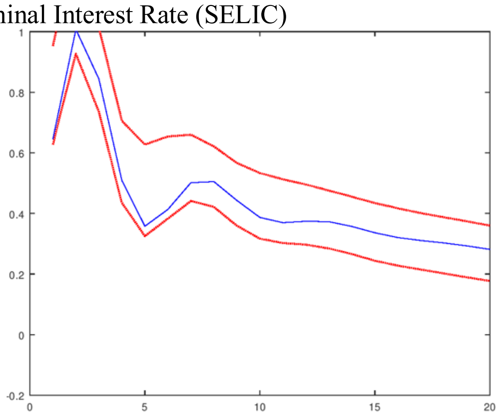
Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	46.38681	36	0.1151	1.299155	(36, 727.3)	0.1153
2	39.76384	36	0.3061	1.108674	(36, 727.3)	0.3064
3	33.46624	36	0.5897	0.929117	(36, 727.3)	0.5900
4	50.30199	36	0.0571	1.412558	(36, 727.3)	0.0572
5	36.88937	36	0.4276	1.026529	(36, 727.3)	0.4279
6	55.46561	36	0.0201	1.563036	(36, 727.3)	0.0202
7	29.12247	36	0.7849	0.806149	(36, 727.3)	0.7851
8	39.56666	36	0.3138	1.103029	(36, 727.3)	0.3141
9	45.27173	36	0.1383	1.266966	(36, 727.3)	0.1385
10	45.49051	36	0.1335	1.273277	(36, 727.3)	0.1337
11	38.29240	36	0.3658	1.066584	(36, 727.3)	0.3662
12	37.62398	36	0.3947	1.047492	(36, 727.3)	0.3951

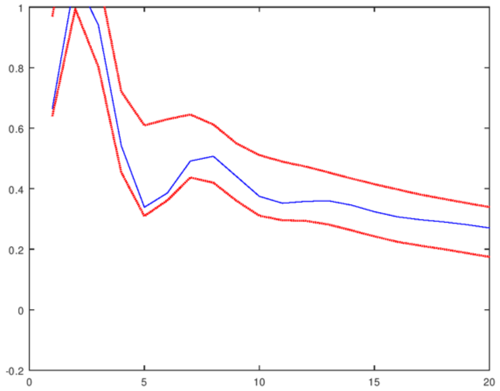
APPENDIX C. MONTHLY DATA RESULTS.

VII. C-Var IRFs – Monthly Data

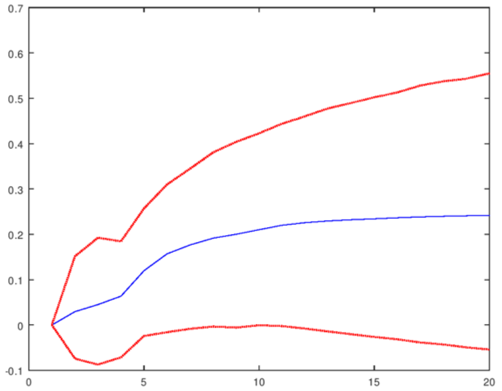
Nominal Interest Rate (SELIC)



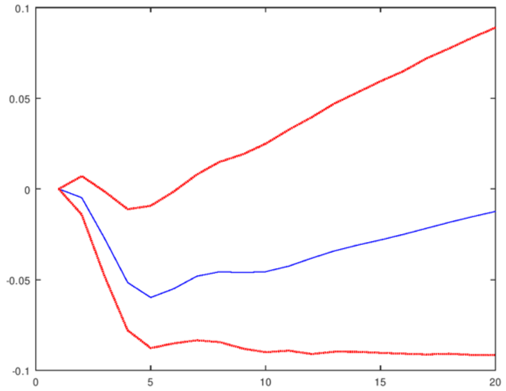
Real Interest Rate



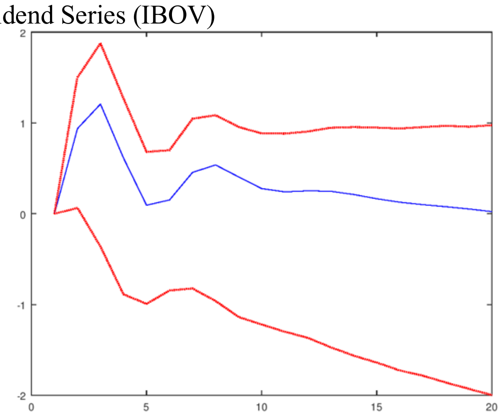
GDP



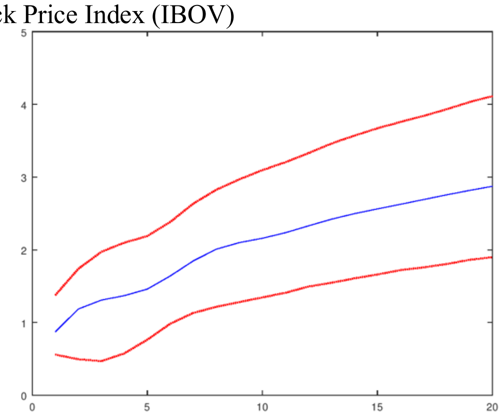
Consumer Price Index



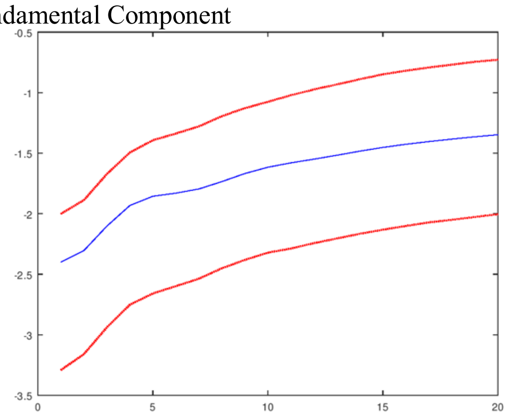
Dividend Series (IBOV)



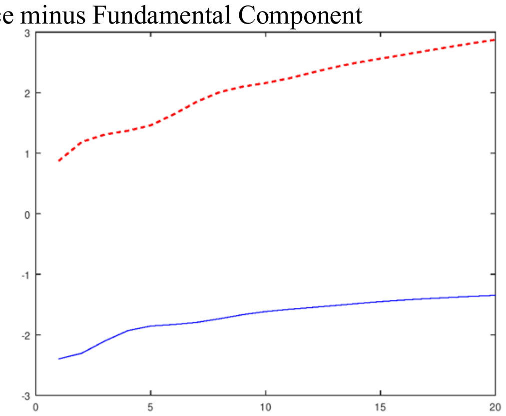
Stock Price Index (IBOV)



Fundamental Component

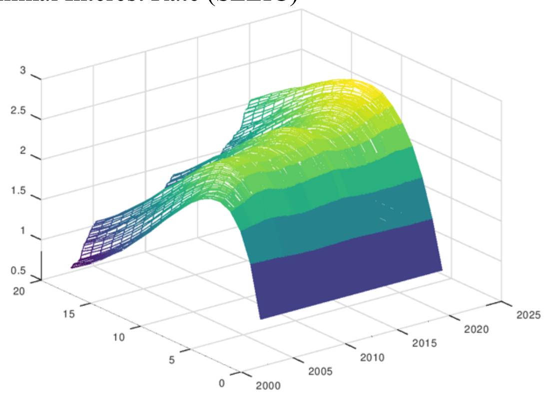


Price minus Fundamental Component

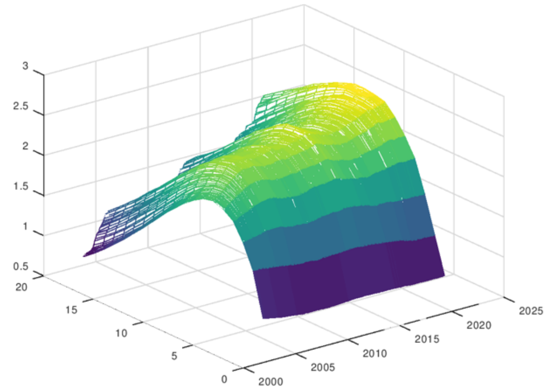


VIII. TVC-Var IRFs – Monthly Data

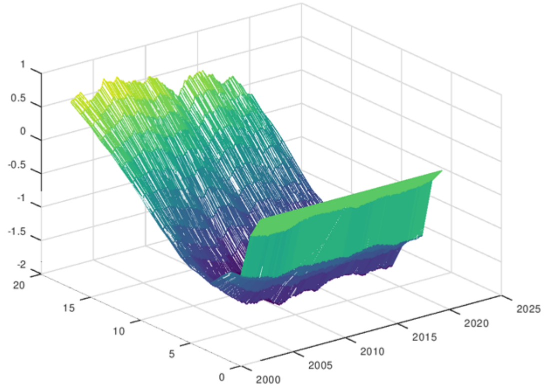
Nominal Interest Rate (SELIC)



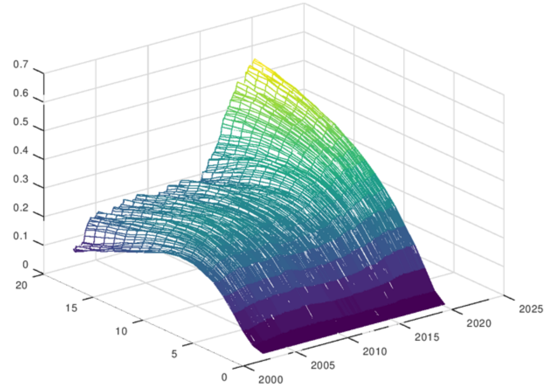
Real Interest Rate



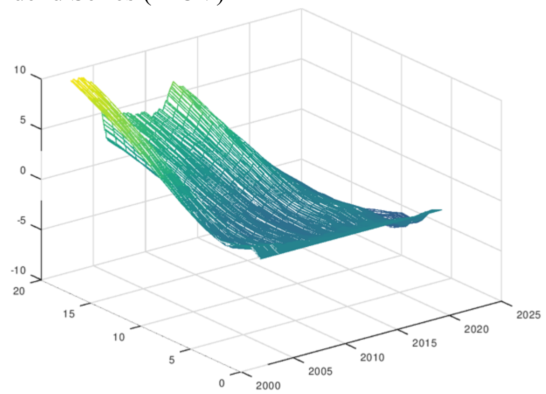
GDP



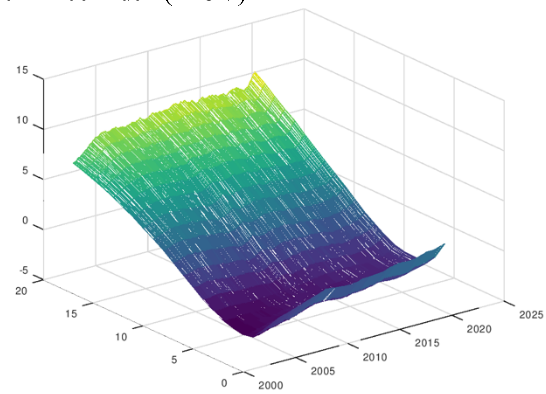
Consumer Price Index



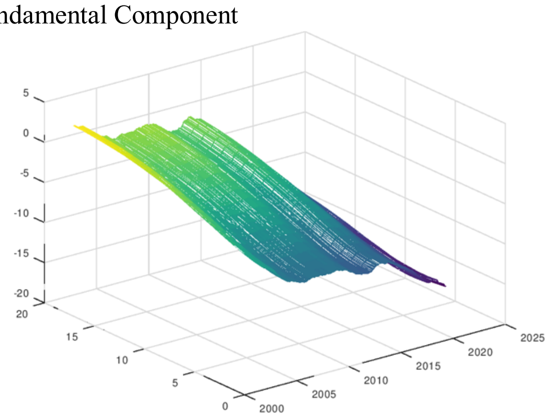
Dividend Series (IBOV)



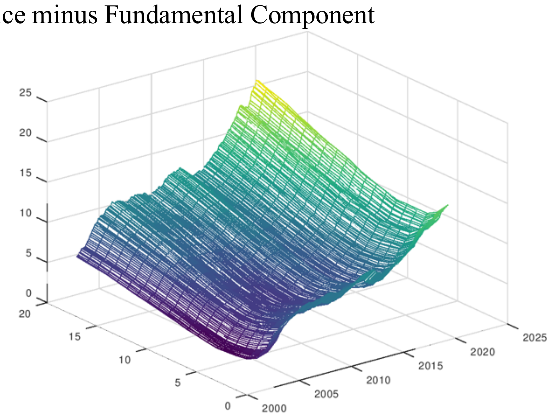
Stock Price Index (IBOV)



Fundamental Component

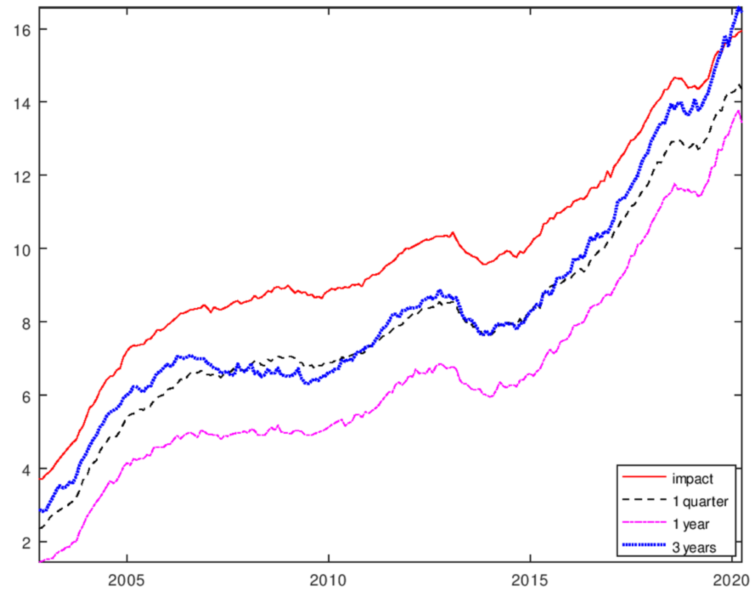


Price minus Fundamental Component

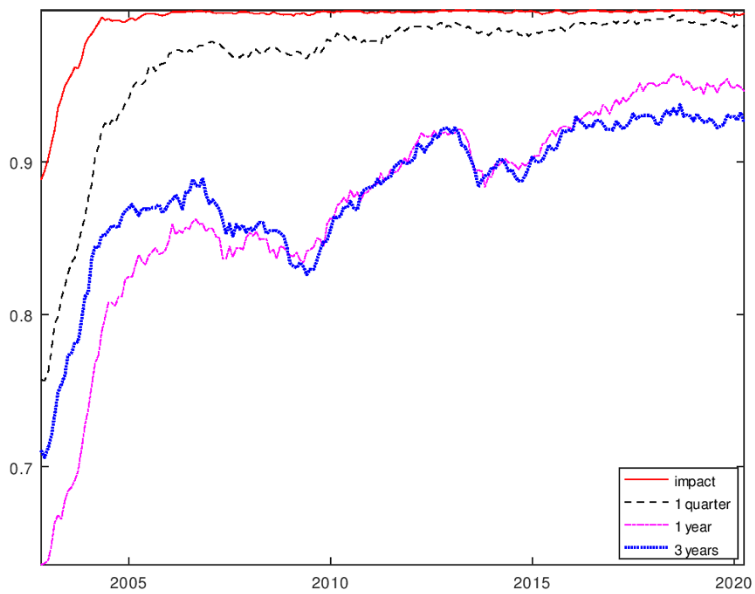


IX. Significance – Monthly Data

$q^B_{t+k} = q_{t+k} - q^F_{t+k}$ responses for different periods

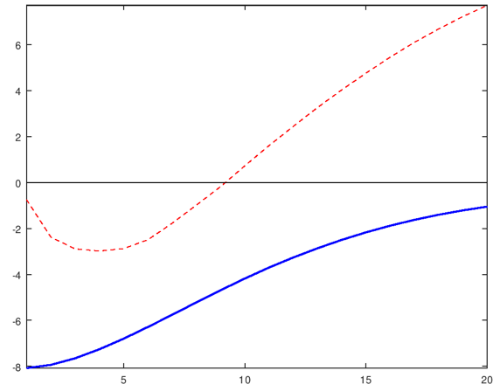


Probability of a positive $q^B_{t+k} = q_{t+k} - q^F_{t+k}$ response

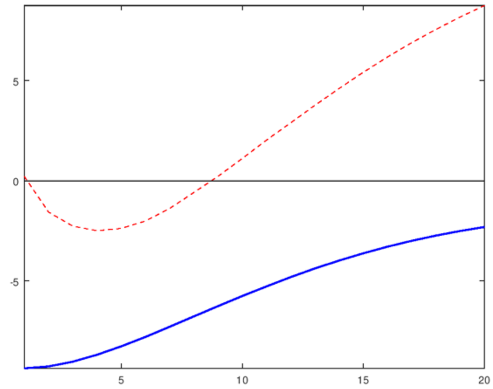


X. Subsamples – Monthly Data

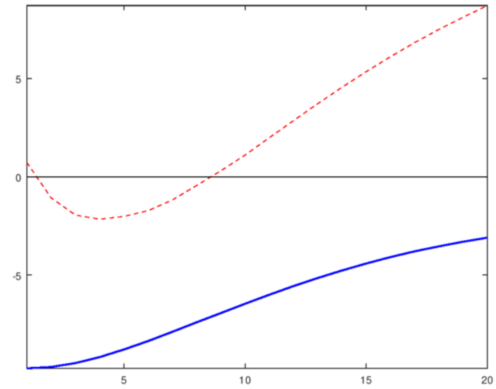
1M2003 – 12M2009



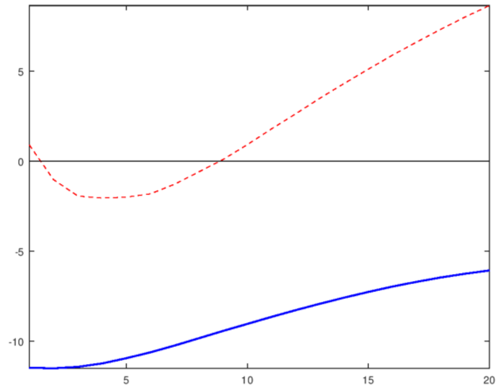
1M2010 – 6M2014



7M2014 – 9M2016



10M2016 – 12M2017



1M2018 – 3M2020