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A Note on the Nonlinearities of Brazilian Monetary Policy

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Abstract

This note analyzes the occurrence of asymmetry in Brazilian monetary policy considering distinct inflation levels. For this purpose, we use data with monthly frequency between 2003 and 2021 and a nonlinear Taylor rule. The results indicate that under the low inflation scenario, the impact of the deviation of inflation expectations to the target is statistically insignificant, revealing a preference by the monetary authority for price stability. Besides, there is a smoothing process in the conduction of Brazilian monetary policy, and the economic activity and the exchange rate are not statistically significant in the central bank reaction function during the period studied.

Keywords: monetary policy, interest rate, Nonlinear Taylor rule

1. Introduction

The interest rate is the main monetary policy instrument available to central banks. According to Dornbusch (2011), if correctly adjusted, monetary policy can balance the economy in the short run. A reduction in the basic interest rate tends to promote economic expansion, while an increase in this instrument has a contractionary effect on economic activity. In countries with inflation targets, monetary policy must ensure inflation control, currency stability, and the anchoring of expectations.

To contribute to the debate on how monetary policy should act, Taylor (1993) presents a reaction function for the US central bank, in which the interest rate is a function of the deviation of inflation from the target and the difference between the actual and potential product. This reaction function is known as Taylor's rule. In the following years, several studies show that this rule applies in several economies, with some modifications in some cases. Clarida, Galí and Gertler (1998 and 2000) include inflation expectations in the deviations from the inflation target and apply this modified Taylor rule in the US and a set of European and various other countries, including Brazil. The authors report an empirical regularity of the Taylor rule in explaining the dynamics of the interest rate, and the omission to observe it tends to cause problems in the conduction of monetary policy.

Additionally, Svensson (1998) shows that for open economies that are subject to external shocks, it is advisable to include other variables, such as the exchange rate, in the Taylor rule. Mishkin (2007) also defend the inclusion of this variable for emerging countries.

More recently, Caporale et al. (2018) show that Taylor's rule may present nonlinearities depending on some economic aspects. A possible explanation is an asymmetric behavior in several macroeconomic variables, whether arising from internal shocks (political crises, problems of institutional quality, internal market size, etc.) or external ones (fluctuations of commodity prices, contagion from international markets, foreign exchange crises, etc.). The authors estimate monetary policy rules with a threshold effect in five emerging economies[1] and report the existence of strong asymmetries in the response of monetary authorities both in magnitude and statistical significance in distinct inflation regimes. They conclude that a nonlinear Taylor rule with the exchange rate variable captures monetary policy movements more accurately.

Besides the study described above, there are several other examples and evidence of nonlinearities and threshold effects in the monetary authority's reaction function (Taylor & Davradakis, 2006; Surico, 2007; Cukierman & Muscatelli, 2008; Castro, 2011; Martin & Milas, 2013; Akdogan, 2015; Ahmad, 2016).

For the Brazilian economy, Aragón and Portugal (2010) estimate a nonlinear monetary policy for the period

from 2000 to 2007. They found evidence of an asymmetric preference in favor of above target inflation. Medeiros (2014) uses the inverse quantile regression method (IQR) to estimate the monetary authority's reaction function and report the prevalence of forward-looking rather than backward-looking expectations in determining the dynamics of the interest rate and the existence of nonlinearities over the quantiles analyzed. Olivindo (2020) employed the dynamic model averaging (DMA) strategy to investigate the nonlinearities of the reaction function of the Brazilian Central Bank (BCB) between 2003 and 2017. The evidence indicated changes in the conduction of monetary policy, which had a greater focus on stabilizing prices at the start of the period and relaxation of this policy during the period 2011-2016.

Fonseca, Oreiro, and Araújo (2018) use a Markov-switching vector autoregression model (MS-VAR) for the initial period after the adoption of the inflation targeting system in Brazil (2000-2013). The evidence found did not allow rejection of the hypothesis that the BCB's reaction function had a strong nonlinear component, with significance of 1%. The authors identified two distinct regimes: the first mainly in the period from 2000 to 2007 and the second from 2007 to 2013. Similar results are in Barbosa, Camelo, and João (2016).

Gurgel (2021) analyzes the existence of asymmetries in Brazilian monetary policy in the period 2003 to 2020, considering different levels of trade openness through a Taylor rule with a threshold effect. His results indicate that during the period of greater trade opening, the parameter of the deviation of inflation expectations from the target is statistically insignificant and in the opposite regime this parameter is positive and significant. The response to the output gap is positive and statistically significant in both trade regimes, with a greater response in the more open period.

Therefore, considering the possible asymmetries in the behavior of economic activity and the inflation dynamics, this study aims to contribute to this line of research by estimating a nonlinear reaction function of the BCB with the lagged level of inflation as a threshold variable, following Caporale et al. (2018), an exercise not yet conducted for Brazil.

In summary, we test the hypothesis that the deviations of inflation expectations to the target have tended to be statistically insignificant during periods of low inflation. On the other hand, in the context of high inflation, we expect a greater need for interventions by the monetary authority in response to this indicator. In this empirical exercise, we rely on monthly information from January 2003 to September 2021 and econometric models with a threshold effect in the presence of endogenous regressors, according to the model described by Caner and Hansen (2004).

Besides this introduction, the paper has three more sections. The second presents the methodological strategy; the third presents and discusses the results; and the fourth contains our final remarks.

2. Methodological Strategy

2.1 Data Base

Following Clarida, Galí and Gertler (1998, 2000) we use Taylor's rule with the deviation of the inflation expectation to the target, the output gap, the real exchange rate (Note 2) and the lags of the basic interest rate, to capture possible smoothing of monetary policy. We rely on monthly information between January 2003 (Note 3) and September 2021. Chart 1 summarizes the variables and their respective sources.

The Comprehensive Consumer Price Index (IPCA) and the inflation target are used to calculate the deviation of inflation. We use the average inflation expectation for the next 12 months, calculated by the Central Bank, as the variable denoting inflation expectations, while the inflation target is defined by the National Monetary Council (CMN). The deviation of expectations from the target is the difference between these two indicators. In turn, for the exchange rate variable, we use the variation of the real effective exchange rate indexed to the IPCA, made available by the Central Bank.

In line with the main studies conducted for Brazil, we use the SELIC rate, available in the Temporal Series Generation System of the Central Bank of Brazil (BCB-SGS), as the basic interest rate indicator. For the output gap, we use the Index of Economic Activity of the Central Bank (IBC-BR), subtracted from the values obtained by applying Hodrick-Prescott filtering.

Chart 1. Description of the variables used

Variable	Proxy	Data Source
Interest Rate	Annualized SELIC rate	BCB
Output Gap	Difference between the IBC-Br and its trend generated by the HP filter	BCB
Inflation	IPCA	BCB
Deviation of Expectations to the Target	Difference between the mean inflation rate (IPCA) for the ensuing 12 months and the inflation target	Focus Survey of the BCB
Nominal Exchange Rate	Nominal exchange rate	BCB
Real Effective Exchange Rate	Real effective exchange rate indexed by the IPCA	BCB

Source: Own elaboration.

2.2 Threshold-Augmented Taylor Rule

When applying models that involve forward-looking variables, it is necessary to use a strategy that considers the possible correlation between the endogenous explanatory variable and the error term, under penalty of obtaining spurious results. An important alternative in this sense is the generalized method of moments (GMM). Since our objective is to estimate a nonlinear forward-looking reaction function of the monetary authority, we follow the threshold model with endogenous variables by Caner and Hansen (2004).

Therefore, to investigate the asymmetries in the behavior of the Brazilian monetary authority in distinct inflation regimes, we use an adaptation of the augmented nonlinear Taylor rule proposed by Caporale et al. (2018) (Note 4), described as follows:

$$\begin{aligned} i_t = \{&\rho_1^1 . i_{t-1} + \rho_2^1 . i_{t-2} + \rho_3^1 . i_{t-3} + \rho_4^1 . i_{t-4} + \beta^1[E(\pi_{t+1}|\Omega_{t+1}) - \pi^*] + \gamma^1[E(h_{t+1}|\Omega_{t+1})] + \\ &\mu^1 E(\theta_{t+1}|\Omega_{t+1})\}. I(\pi_{t-1} \leq \varphi) + \{\rho_1^2 . i_{t-1} + \rho_2^2 . i_{t-2} + \rho_3^2 . i_{t-3} + \rho_4^2 . i_{t-4} + \\ &\beta^2[E(\pi_{t+1}|\Omega_{t+1}) - \pi^*] + \gamma^2[E(h_{t+1}|\Omega_{t+1})] + \mu^2 E(\theta_{t+1}|\Omega_{t+1})\}. I(\pi_{t-1} > \varphi) \end{aligned} \quad (1)$$

Where: i_t is the current inflation rate; $E(\pi_{t+1}|\Omega_{t+1}) - \pi^*$ is the deviation of expected inflation to the respective target; $E(h_{t+1}|\Omega_{t+1})$ is the expected output gap (economic activity); $E(\theta_{t+1}|\Omega_{t+1})$ is the expected depreciation or appreciation of the real exchange rate; and I(.) is a dummy indicator function. Furthermore, lagged inflation, π_{t-1}, is the threshold variable, and φ is the threshold value. Finally, superscript 1 denotes the low inflation regime, $I(\pi_{t-1} \leq \varphi)$, while superscript 2 denotes the high inflation regime, $I(\pi_{t-1} > \varphi)$.

Considering the probable endogeneity of the model due to the presence of forward-looking indicators, we use the strategy proposed by Caner and Hansen (2004) to estimate equation (1). The estimation procedure consists of three steps: i) use a reduced-form regression to obtain a prediction (fit) of the endogenous variables that will be used in the next step; ii) apply the least squares method to estimate the threshold value and divide the sample according to Hansen (2000); and iii) employ the generalized method of moments (GMM) in each subsample to estimate the monetary authority's behavior in each regime. In the first step, 6 to 12 lags of the deviations of inflation expectations to the target, the output gap, and the real effective exchange rate are used as instruments.

3. Analysis and Discussion of the Results

We first performed two tests to verify the stationarity of the series:(i) the test of Kwiatkowski, Phillips, Schmidt and Shin (KPSS), whose null hypothesis is that all the series are stationary; and (ii) the augmented Dickey-Fuller test (ADF), in which the null hypothesis is the presence of a unit root. According to the results presented in Table 1, all the series are stationary at 5%.

Table 1. Results of the Unit Root Tests

VARIABLE	ADF	KPSS
Basic Interest Rate	-3.39	0.49*
	[-2.87]	[0.73]
Deviation of Expectations	-6.34	0.26
	[-2.87]	[0.46]
Output Gap	-5.85	0.03
	[-2.87]	[0.46]
Real Effective Exchange Rate	-10.65	0.40
	[-2.87]	[0.46]

Source: Critical value of the test at 5% significance in brackets. * All tests were conducted with intercept, except for the KPSS applied to the Basic Interest Rate, where both trend and intercept were used.

Table 2 shows the results of testing the null hypothesis of linearity against the alternative of a threshold model proposed by Hansen (1999). This hypothesis is rejected at the 5% level. Then, we tested the hypothesis of a threshold effect (two regimes) against the alternative of two threshold effects (three regimens), in which the former showed a better fit.

Table 2. Tests of Nonlinearities

Nonlinearity Test	F-Test Statistic	Critical Value
Linear model vs. Nonlinear model (2 regimes)	28.15*	23.70
Nonlinear model (2 regimes) vs. nonlinear model (3 regimes)	21.72	23.75

Source: Own elaboration. * Significant at 5%.

Therefore, the nonlinearity test indicated that the best specification was a nonlinear monetary policy rule with two inflation regimes. This result corroborates the findings of Fonseca, Oreiro, and Araújo (2018) and Gurgel (2021), who also indicated the better suitability of a nonlinear reaction function of the monetary authority in Brazil.

The method by Caner and Hansen (2004) provides the estimate of the threshold value and the other parameters of the model, presented in Table 3. The null hypothesis that the instruments are valid was not rejected by the J-test. The results are reported in Table 3. The threshold value for lagged inflation is 5.61%, and the subsamples of high and low inflation regimes contained 103 and 110 observations, respectively. Figure 1 plots the path of inflation, the estimated threshold, inflation target and its upper and lower bands. It is worth noting initially that the estimated threshold proved to be higher than the upper band of the inflation target throughout the entire sample considered.

The high inflation regime observed at the start of the sample can be explained by the uncertainty of economic agents regarding the first Lula administration, the resulting sharp devaluation of the exchange rate and the repercussions of the electricity crisis in 2001. However, the initial mistrust in the leftist Lula was allayed when the government adopted orthodox measures, demonstrating a commitment to the inflation target. That scenario held sway until the middle of 2014. At the end of 2014, inflation rises due to the fiscal crisis and a change in the conduction of Brazilian monetary policy (Olivindo, 2020). This gets worse in 2015 and 2016 with the process of impeaching President Dilma Rousseff. The focus of the new government's monetary policy returns to price stabilization and a commitment to fiscal adjustments was announced, bringing inflation closer to the target. This situation lasted until 2020, with the Covid-19 pandemic and uncertainties related to the conduction of fiscal and monetary policy in reaction to the crisis characterized by a conflict between expansionary fiscal policy and restrictive monetary policy, the latter determined by the Central Bank, which gained legal autonomy in 2021.

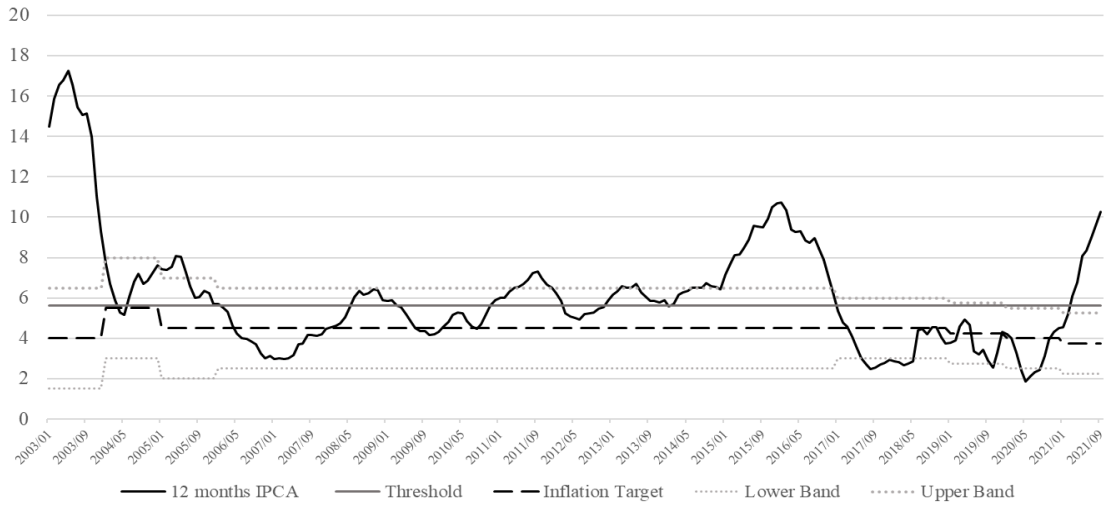

Figure 1. Evolution of 12 months IPCA, estimated threshold, inflation target and its upper and lower bands

In general, the results confirmed our working hypothesis, i.e., in a low inflation setting, the monetary authority would tend not to respond to fluctuations of the deviations of inflation expectations to the target, due to the

conjuncture of tame inflation. In contrast, in the high inflation regime, the central bank's response would become statistically significant, with a preference for price stability, as highlighted by Cukierman and Muscatelli (2008). In this circumstance, the results indicated that an increase of 1 percentage point of the deviation of the inflation expectation is associated with an average 0.48 p.p. increase in the basic interest rate in the month.

Table 3. Results of monetary policy rule with Threshold

Variables	Low Inflation Regime <5.61 (110 Obs.)		High Inflation Regime ≥ 5.61 (103 Obs.)	
	Coefficient	Standard Error	Coefficient	Standard Error
Deviation of Expectations	-0.13	0.17	0.48*	0.16
Output Gap	15.56	10.79	-7.21	9.61
Real Effective Exchange Rate	-0.001	0.003	-0.005	0.003
Interest $Rate_{t-1}$	0.15	0.12	0.56*	0.09
Interest $Rate_{t-2}$	0.80*	0.08	0.33*	0.10
Interest $Rate_{t-3}$	0.30*	0.08	0.41*	0.10
Interest $Rate_{t-4}$	-0.29*	0.10	-0.35*	0.11
J-Test	11.13	Critical Value	15.51	

Note. *Significant at 5%. Instruments: 6 to 12 lags of deviation of inflation expectations to the target, the output gap, and the real effective exchange rate.

Most of the autoregressive terms, or smoothing indicators, are statistically significant in both regimes and with cumulative effects of around 0.81p.p. in the low-inflation regime and 0.95 p.p.in the high-inflation situation. The high smoothing values suggest a commitment by the monetary authority not to alter the interest rate abruptly. Similar results have been reported by other authors, such as Souza Júnior and Caetano (2014), Olivindo (2020) and Gurgel (2021).

The non-statistical significance of the exchange rate parameters shows that there is no evidence of an exchange rate pass-through effect, at least in a contemporary way. In the case of the output gap, our results are like those of Aragón and Portugal (2010), who did not find evidence of nonlinear responses of the interest rate to deviations of the output gap for Brazil. This evidence should be analyzed with caution, as it may be affected by the type of filter used, as highlighted by Hamilton (2018). Future research could test alternative measures for this indicator.

To evaluate the robustness of the results, we test three alternative formulations of the monetary policy rule with a threshold based on the literature. The first specification, in line with Christiano, Eichenbaum and Evans (1996), add the commodity price index, as reported in Table 4. Next, we add a fiscal variable, the primary result (% of GDP), as suggested by Dornbush (1998) and Pires (2008). The result is shown in Table 5. Finally, we use both variables (commodity price index and primary result). The results are reported in Table 6 (Note 5).

Table 4. Robustness test considering Commodity Price Index

Variables	Low Inflation Regime <5.61 (110 Obs.)		High Inflation Regime ≥ 5.61 (103 Obs.)	
	Coefficient	Standard Error	Coefficient	Standard Error
Deviation of Expectations	-0.05	0.18	0.48*	0.16
Output Gap	21.70	11.14	-10.42	9.93
Real Effective Exchange Rate	-0.001	0.003	-0.006	0.003
Interest $Rate_{t-1}$	0.14	0.12	0.58*	0.10
Interest $Rate_{t-2}$	0.78*	0.08	0.31*	0.11
Interest $Rate_{t-3}$	0.28*	0.09	0.41*	0.10
Interest $Rate_{t-4*}$	-0.24*	0.10	-0.35*	0.12
Commodity	-0.04	0.02	0.03	0.04
J-Test	9.07	Critical Value	15.51	

Source: Own elaboration. *Significant at 5%.

These modifications did not significantly change the initial results. The estimated threshold value varies between 5.61 and 5.85. In general, in the low-inflation regime, the effect of the deviation from inflation expectations is statistically null, the smoothing in the conduct of monetary policy in Brazil remains, and the coefficients of the

output gap and the exchange rate are statistically insignificant in both regimes. Finally, the additional variables are not statistically significant in the exercises performed.

In summary, the evidence of this exercise supports the importance of using nonlinear versions of the monetary policy rules in emerging countries, as advocated by Caporale et al. (2018). Moreover, the results confirm that the Central Bank of Brazil has asymmetric behavior in response to deviations of inflation from the target, with significant responses only in high-inflation settings. Finnaly, it is worth noting that during the investigated period, the Brazilian economy was subject to changes in monetary regime, as highlighted by Fonseca et al. (2018) and Barros and Lima (2018), which may pose a limitation to the conducted analysis.

Table 5. Robustness test considering Primary Result (% of GDP)

Variables	Low Inflation Regime <5.85 (119 Obs.)		High Inflation Regime ≥ 5.85 (94 Obs.)	
	Coefficient	Standard Error	Coefficient	Standard Error
Deviation of Expectations	-0.19	0.20	0.48*	0.17
Output Gap	16.2	11.90	-4.42	9.54
Real Effective Exchange Rate	-0.002	0.003	-0.006	0.004
Interest $Rate_{t-1}$	0.12	0.13	0.51*	0.10
Interest $Rate_{t-2}$	0.74*	0.09	0.45*	0.11
Interest $Rate_{t-3}$	0.32*	0.09	0.35*	0.10
Interest $Rate_{t-4*}$	-0.24*	0.11	-0.34*	0.12
Primary Result	-0.02	0.02	-0.02	0.03
J-Test	12.33	Critical Value	15.51	

Source: Own elaboration. *Significant at 5%.

Table 6. Robustness test considering a combination of Commodity Price Index and Primary Result (% of GDP)

Variables	Low Inflation Regime <5.61 (110 Obs.)		High Inflation Regime ≥ 5.61 (103 Obs.)	
	Coefficient	Standard Error	Coeficientes	Coefficient
Deviation of Expectations	-0.09	0.22	0.49*	0.17
Output Gap	20.78	12.39	-7.05	9.89
Real Effective Exchange Rate	-0.001	0.003	-0.006	0.004
Interest $Rate_{t-1}$	0.14	0.12	0.56*	0.10
Interest $Rate_{t-2}$	0.78*	0.08	0.33*	0.11
Interest $Rate_{t-3}$	0.28	0.89	0.41	0.97
Interest $Rate_{t-4}$	-0.24*	0.10	-0.34*	0.12
Commodity	-0.04	0.02	0.03	0.04
Primary Result	-0.005	0.02	-0.02	0.03
J-Test	11.13	Critical Value	15.51	

Source: Own elaboration. *Significant at 5%.

4. Final Considerations

We analyze the presence of asymmetries in the reaction function of the Brazilian monetary authority considering distinct inflation regimes. For that purpose, we use nonlinear Taylor's rules with lagged inflation as a threshold variable, as previously done by Caporale et al. (2018).

The results show the existence of asymmetries in the responses of monetary policy that in the low-inflation regime, the monetary authority's response to deviations of inflation expectations to the target is statistically nil, while in the high-inflation regime, this variable has a positive and statistically significant effect on the interest rate in all the models.

The evidence also points to a tendency of smoothing in the monetary authority's decisions, since the estimated cumulative autoregressive components are significant and fluctuated between 0.81 in the low-inflation regime and 0.95 in the high-inflation setting. The parameters of the output gap and the exchange rate are not statistically significant in the Brazilian monetary rule.

Finally, this study, along with that of Caporale et al. (2018), indicates the importance of using nonlinear models

to estimate the monetary policy rules in emerging economies.

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Notes

Note 1. Indonesia, Israel, South Korea, Thailand, and Turkey.

Note 2. The exchange rate is used as an instrument. Various authors have used the (variation) of the real exchange rate, such as Bonomo and Brito (2001) and Barbosa, Camelo, and João (2016), or the nominal exchange rate, as in the case of Belaisch (2003). Therefore, we decided to estimate four models with these variables, in level and variation rate (first difference). The results were practically identical with these two variables, and the results with the real exchange rate are presented. The similarity of the results with the different

exchange rates was not surprising, given the high correlation coefficient (around 0.84) between these variables.

Note 3. We chose the sample period in function of the availability of data for the economic activity variable, the Economic Activity Index of the Central Bank (IBC-Br), which is only available starting in January 2003.

Note 4. The preliminary analysis of the correlogram and the residuals indicated that the use of four lags was necessary to prevent serial autocorrelation.

Note 5. The commodity price index, debt/GDP ratio of the general government (%) and primary result in relation to GDP (%) were obtained from the Time Series Generation System of the Brazilian Central Bank.