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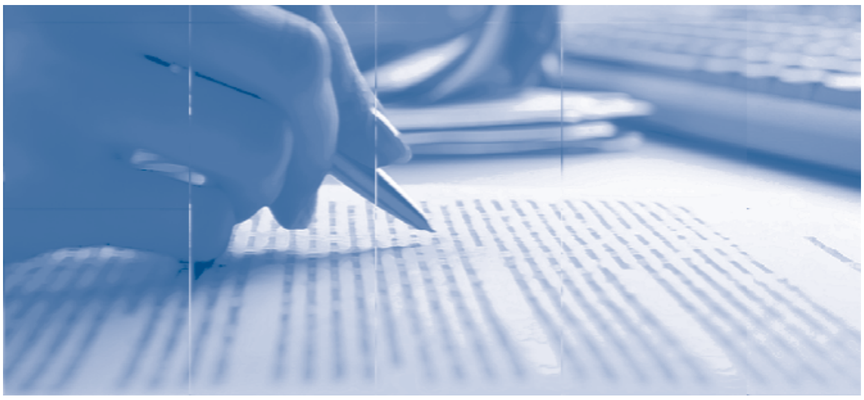

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Asymmetric Effects of Monetary Policy in the U.S. and Brazil

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Abstract

The Working Papers should not be reported as representing the views of the Banco Central do Brasil. The views expressed in the papers are those of the author(s) and do not necessarily reflect those of the Banco Central do Brasil.

We empirically test the effects of anticipated and unanticipated monetary policy shocks on the growth rate of real industrial production and explicitly test for different types of asymmetries in monetary policy implementation for two major international economies, the U.S. and Brazil. We depart from the conventional method of VAR analysis to estimate unanticipated monetary shocks and instead we use a combination of other methods. We first identify the Taylor rule that best describes the reaction of both central banks and then we test both forward looking linear and nonlinear models concluding that a Logistic Smooth Transition Autoregressive (LSTAR) forward looking model of the Taylor rule best describes the US FED Funds rate while a linear Taylor rule with the inclusion of a dummy variable best describes the reaction of the Central Bank of Brazil (BCB). We then use in-sample forecast errors in order to derive or identify the unexpected monetary shocks for both countries. In line with Cover (1992), we use these shocks to explore any asymmetries in the conduct of monetary policy on the growth rate of real industrial production. We also find asymmetries between anticipated and unanticipated monetary shocks as well as between effects of positive and negative shocks.

Keywords: Taylor rule, monetary policy, nonlinear effects, LSTAR
JEL code: E4, E52, E58

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1. Introduction

Numerous studies have dealt with the issue of the impact of monetary policy on real economic activity and this impact has been well established theoretically. Keynesian economics claim that an expansionary monetary policy i.e. a decrease in the short-term interest rate can affect long term rates, leading to increased investment and, ultimately, output. The channels for this outcome are the reduction of the cost of capital and liquidity increment. On the other hand, the seminal paper by Lucas (1972) proposes the neutrality of anticipated monetary policy, that is, only unanticipated changes in monetary policy can affect real production. Many researchers traced down empirically the effects of monetary policy innovations on the real economy (Bernake and Blinder 1992; Bernake and Boivin 2003; Bernake et al 2005; Uhlig 2005; Forni and Gambetti 2010). The majority of these studies confirm what Keynesian theory postulates. A contractionary monetary policy innovations lead to a decrease in real output.

In the Keynesian literature, there is no discussion on asymmetries in implementating monetary policy. Nonetheless, asymmetries may arise from: a) the phase of the business cycle; b) the type of monetary policy (contractionary versus expansionary); c) the relative size of the impact of the monetary intervention on the real economy; and d) whether monetary shocks are anticipated or not (Ravn and Sola 2006). In this paper we focus our empirical analysis in searching for differences in the effects from anticipated and unanticipated monetary shocks, as well as for possible asymmetric effects from positive versus negative unanticipated monetary policy shocks.

Under the assumption of sticky nominal wages (traditional Keynesian asymmetry), negative monetary shocks have greater real impact than positive monetary shocks. According to Ravn et al (1999), sticky nominal wages will render the aggregate supply curve convex. In the extreme case, the aggregate supply curve is vertical at the point where the nominal wage is in equilibrium. A positive monetary shock will increase aggregate demand along the vertical segment of the aggregate supply curve leaving real economy unchanged, at least in the short run. However, a negative monetary shock will depress the real economy as it moves the demand curve along the positively sloped segment of the supply curve.

The New Keynesian literature has attempted to provide more robust micro foundations to deal with this asymmetry (Ball and Romer (1990) and Ball and Mankiw (1994)). In an environment in which firms can costlessly set prices every two periods, but are subject to menu costs if they change prices between periods, negative monetary shocks affect real economy in the presence of inflation. The intuition behind this is that a decrease in aggregate demand caused by a contractionary monetary policy will not induce firms to change prices and take over the menu costs, as the relative price will decrease, partially offsetting in a degree the decrease of demand, due to inflationary pressures. On the other hand, positive monetary shocks will lead firms to adjust prices, and eventually take over the menu costs, because of the existence of inflation. This movement will not change the relative prices leading the positive monetary shock to neutrality. In models with menu costs (Blanchard and Kiyotaki (1987)), it may be optimal for firms to take over the associated menu costs in the event of large monetary policy shocks. Barro (1977) decomposes the monetary shocks into foreseen and unforeseen and, in a framework with rational expectations, concludes that only unexpected money growth can have real impact.

Regarding the Taylor rule used for extracting the unanticipated shocks, Taylor (1993) shows that there is a linear relationship between FED's interest rate, current inflation rate and output gap. He concludes that this is the rule the FED is following in order to set its interest rate. Clarida et al. (2000) suggests using a forward looking Taylor rule. The FED takes into account the expected inflation rate and output gap in order to set current interest rate. A further extension of the Taylor rule is to test whether a nonlinear Taylor rule best describes the decisions of the FED (Castro (2011)). The central bank may assign different weights to positive and negative inflation rate and to output gaps. Moreover, it probably will react differently if the inflation moves far away above its target than when it moves close to it.

In what follows, we try to find if there are asymmetries between unanticipated expansionary and unanticipated contractionary monetary policy in the U.S and Brazil with data spanning the period from 1980 to 2012. In doing so, we depart from conventional methods used so far in the literature. More specifically, we test whether the FED's and Central Bank of Brazil's (BCB) decisions are best described by a nonlinear Taylor rule. If this is true we then test whether it is better to use a Logistic Smooth Transition Autoregressive (LSTAR) or an Exponentially Smooth Transition Autoregressive (ESTAR) model, using the derived deviations from the in-sample forecasts to capture unanticipated positive and negative monetary shocks. We then run a regression with lags of these deviations as regressors and the industrial production index as the dependent variable. The results are rather interesting as they show statistically significant impact of both shocks as well as a larger impact of positive monetary shocks with respect to negative monetary shocks for the U.S. In the case of Brazil we confirm the conventional wisdom that positive monetary shocks (monetary contraction) have greater impact than negative monetary shocks (monetary expansions). To the best of our knowledge this is the first time that a Taylor's rule is used in order to extract the monetary shocks using nonlinear models. Furthermore, by using a Taylor's rule in order to identify the unexpected monetary shocks we avoid many simplistic assumptions (Choleski's orthogonalization) that we would have to impose in order to identify monetary shocks using a VAR analysis.

The rest of the paper is organized as follows: section 2 presents a brief literature of the asymmetric impact of monetary policy and on the Taylor rule. In section 3 data used are presented, section 4 analyses the model, section 5 presents the empirical results and section 6 concludes.

2. Literature Review

The empirical literature emphasizes on all types of asymmetries using a variety of models such as simultaneous equations, VAR and LSTVAR models and Markov switching models. Some empirical evidence supports the theoretical arguments raised above according to Keynessian, New Keynessian and Classical theory. Cover (1992), using quarterly data from the U.S. in a simultaneous equations framework, estimates a money supply process and an output equation. The results confirm the traditional Keynesian theory, that positive monetary shocks (an unexpected increase in interest rates) have greater impact on output than negative shocks (an unexpected decrease in interest rates). In the same vein, Delong and Summers (1988), using annual U.S. data, find that unanticipated negative monetary shocks have a larger impact than unanticipated positive shocks. Accordingly, Ravn and Sola (1999) find that in the U.S economy only small negative shocks have real effects. Thus, they conclude, there is evidence in favor of the asymmetry implied by menu costs models in environments with positive steady state inflation. The same results are obtained by Rhee and Rich (1995) and Karras and Stokes (1999) for European countries, implementing the method regarding asymmetry first introduced by Cover (1992).

Parker and Rothman (2004) using the interest rate as the basic variable and using data for the U.S. find no evidence in favor of monetary shock asymmetry in the pre-WW I subsample. For the interwar period they get results similar to Cover's (1992).

The no asymmetry findings are in line, according to the authors, with Ball and Mankiw (1994), because under a credible gold standard, agents do not expect persistent inflation. Belongia (1996) instead of the simple sum monetary aggregates uses a Divisia (Barnett (1980)) monetary aggregate. His study reveals that monetary neutrality may arise due to measurement errors of the traditional simple-sum monetary aggregates.

In all the above mentioned studies there is no use of the Taylor's rule in order to extract unanticipated monetary shocks, although there are many empirical studies asserting the statistically significance of various versions of the Taylor rule in reflecting the decisions of many central banks around the globe. Lately, nonlinear models of Taylor rule are attracting the interest. However, there are not many studies dealing with nonlinearities regarding Taylor rule. Petersen (2007) uses a logistic smooth transition regression model over the period 1985-2005 for the U.S. and finds evidence in support of nonlinearities. The FED reacts acutely when inflation reaches a specific threshold. Petersen (2007), however, does not use a forward looking Taylor rule.

On the other hand, Castro (2011) applies a smooth transition regression model over the period 1982-2007 for the U.S. and takes into account a forward looking Taylor rule, but he finds no evidence of non linearities in the behavior of the Federal Reserve Bank.

In the case of the Brazilian economy there are many studies which try to empirically estimate the relevant Taylor's rule. Some of these are Minella et al. (2002), Favero and Giavazzi (2002), Modenesi (2011) and Modenesi et al. (2013). Most of these studies find that the response of the BCB to inflation gap is more than one, reflecting a stabilizing monetary policy with respect to inflation targeting. On the other hand, there are no strong evidence of a reaction of the BCB with respect to the output gap. Nonetheless, all of the above studies, except of Modenesi et al. (2013), use a small number of observations, ranging from 28 to 71, whereas Modenesi et al. (2013) use 132 observations as we do in this paper. Our results, as it will be clear further on contradict those findings as we find a statistically significant response of the BCB with respect to the output gap. However, in our model, the reaction of the BCB to inflation gaps is not statistically significant. In relation to those studies, we differ because we use a more updated dataset (up to the end of 2012), and we test for a number of different specifications of Taylor rule, including a nonlinear functional form.

Finally, to the best of our knowledge there are not many studies considering asymmetric effects of the monetary policy for Brazil. The study of Aragon and Portugal

(2009), is an example of asymmetric analysis. Using a Markov switching model they find that the real effects of negative monetary shocks are larger than those of positive shocks in an expansion. Their results contradict conventional theory that positive monetary shocks (monetary contraction) have larger impact than negative monetary shocks (monetary expansion).

3. The Data

We use monthly frequency data over the period 1981:1-2011:4, for the U.S, and from 2001:10 to 2012:12, for Brazil. The variables used for the U.S are: the effective Federal Reserve funds interest rate (monthly average), the annualized core inflation rate of the consumer price index (CPI, base year 1982=100), the annualized growth of the industrial production index, and the output gap computed as the percentage deviation of the log industrial production index from its Hodrick-Prescott trend. U.S data were retrieved from FRED, the economics database of the Federal Reserve Bank of St. Louis. For robustness checks we also use the NBER's recession indicators for the U.S. The variables for Brazil are the Selic nominal interest rate (which is the Brazilian basic interest rate), the core inflation rate, the annual change of the industrial production index, the real interest rate which is computed from the Selic subtracted by the core inflation. Finally, we use the output gap computed as the percentage deviation of the log industrial production index from its Hodrick-Prescott trend. Brazilian data were retrieved from the Brazilian central bank[4].

In order to avoid spurious regression, we employ three different unit root tests: a) an augmented Dickey-Fuller test, b) a KPSS test where the null hypothesis is stationarity and finally c) an Elliott-Rothenberg-Stock test. In Table 1 we present the results of these unit root tests for U.S data and we conclude that the inflation rate and the annual change of the industrial production index are stationary, while the effective federal reserve funds interest rate is non-stationary. The ADF test is not conclusive for stationarity of the interest rate. Thus we proceeded based on the other two tests. By definition the output gap is stationary. For the rest of the empirical section we use the first differences of the interest rate unless otherwise stated. In the case of the Brazilian data[5], the core inflation, the real interest rate and the annual change of the industrial production index as well as the output gap are stationary, while the nominal interest rate

[4] The data can be retrieved at http://www.bcb.gov.br/?serietemp.

(Selic) is non-stationary, thus we use first differences. In Tables 2a and 2b, we present the descriptive statistics of the series.

4. Empirical Model

4.1 Taylor's Rule

As it was previously mentioned, we first test for nonlinearity of the Taylor rule. For that, we start by estimating a linear version of the Taylor rule for both the U.S. and Brazil. The resulting disturbance errors are used to test the null of linearity. Following Castro (2011), we first estimate a forward-looking and a backward-looking linear Taylor rule for both countries. For each country we select the model that has the best fit in terms of minimizing the Akaike information criterion. The forward-looking linear model that also has been estimated by Orphanides (2004), Castro (2010) and Qin and Enders (2007) is of the form:

$$i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1-\rho_1-\rho_2)(\alpha + \beta\pi_{t+i} + \delta y_{t+i}) + \varepsilon_t \qquad (1)$$

where i_t, is the interest rate, π_{t+i}, is the future core inflation rate and y_{t+i}, is the future output gap. The error, ε_t, is assumed to reflect other factors that affect the interest rate in both countries during the month and is assumed to be identically and independently distributed following a white noise process, $\varepsilon_t \sim iid(0,\sigma^2)$. Parameters $\rho_1, \rho_2 \in [0,1)$ measure the degree of partial adjustment of the interest rate. The parameters β and δ reflect the responsiveness of the monetary policy to the interest rate and output gap respectively.

The classical backwards Taylor rule model is of the form:

$$\mathrm{i}_t = \rho_1 \mathrm{i}_{t-1} + \rho_2 \mathrm{i}_{t-2} + (1-\rho_1-\rho_2)(\alpha + \beta\pi_{t-i} + \delta y_{t-i}) + \varepsilon_t \qquad (2)$$

where i_t, is the interest rate, π_{t-i}, is the core inflation rate in the past and y_{t-i}, is the output gap in the past. The error, ε_t, is assumed to reflect other factors that affect the interest rate in both countries during the month and is assumed to be identically and independently distributed following a white noise process, $\varepsilon_t \sim iid(0,\sigma^2)$. The ρ_1, ρ_2 is

[5] Unit root test results for the Brazilian data are available upon request.

the degree of partial adjustment of the interest rate, $\rho_1, \rho_2 \in [0,1)$. The coefficients β and δ reflect the responsiveness of policy to interest rate and output gap respectively. Next, using Terasverta's (1998) methodology, described in the next section, we test the null hypothesis of linearity against the alternative of nonlinearity. If we reject the null hypothesis, we proceed by estimating a nonlinear Taylor rule of a Smooth Transition Model (STAR) form:

$$i_t = a'X_t + \beta' X_t \Theta(\gamma, c, s_t) + \varepsilon_t \qquad (3)$$

where X_t is the vector of explanatory variables, α' and β' are the parameter vectors, ε_t is the error term which is identically and independently distributed following a white noise process, $\varepsilon_t \sim iid(0, \sigma^2)$ and $\Theta(\gamma, c, s_t)$ is a transition function that can take a logistic or an exponential form as follows:

$$\Theta(\gamma, c, s_t) = [1 + \exp(-\gamma(s_t - c))]^{-1} \qquad (4)$$

and

$$\Theta(\gamma, c, s_t) = [1 - \exp[-\gamma(s_t - c)^2], \qquad \gamma > 0 \qquad (5)$$

where γ is the smoothness parameter. Equation (4) is the logistic (LSTAR) and (5) is the exponential (ESTAR) transition function. In the logistic transition function, as γ tends to zero or to infinity, the LSTAR model becomes a linear function since the value of $\Theta(\gamma, c, s_t)$ reduces to a scalar. The same holds for the ESTAR model as γ tends to infinity. The parameter c determines where the transition takes place and the transition variable s_t determines the level at which the model changes behavior. In our model, several lags of the inflation rate and output gap are alternatively tested as transition variables.

The $\Theta(\gamma, c, s_t)$ is a monotonic function which takes values between zero and one. As the transition variable drifts away from the parameter c, Θ converges to one and the estimated parameters of the independent variables take the value of α plus β[6]. The slope of this adjustment is being determined by the γ parameter. For large values of γ the

[6] α and β are elements of vectors α' and β' respectively.

adjustment is sharp. All the values of the $\Theta(\gamma, c, s_t)$ are simultaneously estimated by the model along with the other parameters.

4.2 Unanticipated Monetary Shocks

Following Cover (1992), we extract the residuals from the best fitted model and we decompose them in two series according to their sign: a positive and a negative shock time series. These residual series are the difference between the actual FED's interest rate and the one expected by the model and thus they represent the unanticipated monetary policy shocks. The series of the negative monetary shocks equals the monetary policy shock if the latter is negative otherwise it is equal to zero. This means that the expected interest rate is higher than the one actually implemented by the FED. Thus, the actual monetary policy is less contractionary than expected and we can interpret this as a positive monetary shock. The series of the positive sign monetary shocks equals the monetary policy shock if this is positive and otherwise it is equal to zero and being interpreted as an actual FED's interest rate higher than the one expected thus interpreted as a negative monetary policy shock. By this discrimination we test for the presence of possible asymmetries between positive and negative monetary shocks. Formally:

$$MSN_t = -1/2\,[|MS_t| - MS_t] \qquad (6)$$

$MSP_t = 1/2\,[|MS_t| + MS_t]$,

where MS_t is the monetary policy shock extracted as described above and MSN_t and MSP_t are the series of the negative and positive monetary policy shocks respectively.

5. Empirical Results

The results from the estimation of the linear Taylor rule for the U.S. and Brazil are presented in Tables 3a and 3b respectively. In these Tables we present the four best estimated models for each country. For comparison we estimated a number of models for both countries, all of which contained alternative lags and leads. In the case of U.S, the best fit model is a forward looking Taylor's rule with 3 leads (model 1). All reported results for the U.S. indicate that during the examined period, the estimated response to the output gap, δ, is statistically significant in all four models having also the expected sign. In a positive output gap the FED reacts by increasing the interest rate trying to defuse inflationary pressure and stabilize the economy. The estimated response to inflation β, is only statistically significant in the three month forecasting window. Also, the estimated sign contradicts the expected one by the Taylor rule indicating that an increase of the inflation leads to a decrease of the federal funds rate. Both estimates are below unity meaning that the FED is not performing a stabilizing policy.

In the case of Brazil, the best fit model is a backward looking Taylor's rule with 2 lags. As it is seen in Table 3b, the estimated model with the lowest AIC and Schwartz criteria value is model 2 which includes the second lag of both the core inflation and of the output gap. The estimated response of inflation is not statistically significant whereas the response of output is statistically significant and well beyond unity. These results reflect the sensitivity of the Brazilian Central bank to a stabilization policy in the case where industrial production is below its trend. In models 3 and 4 of Table 3b, we used a dummy variable for the period from 2008:10 to 2010:03 because as it is evident from Figure 1 the output gap exhibits a large drop during this period. This is also confirmed by the results[7] of a Chow test that we run for this period. As model 2 has the lowest AIC and Schwarz value we neglect the rest of the models.

The next step is to test for the possible presence of nonlinearities. If we find evidence in support of nonlinearities then we can also estimate the nonlinear Taylor rule in a maximum likelihood framework. First, we test whether a nonlinear model best describes the FED's decisions. This means that we have to test the null hypothesis $H_0: \gamma = 0$, the linearity assumption against the alternative $H_1: \gamma \neq 0$ ($\gamma > 0$ in the case of an ESTAR model) of nonlinearity for Equation 2. A Lagrange Multiplier test (LM) is not appropriate for this since under the null hypothesis $\beta = 0$, β is unidentified. For this reason we follow Terasverta (1998) who uses a third order Taylor's expansion around the null hypothesis to approximate the transition function. The estimated auxiliary regression is of the form:

$$\varepsilon_t^* = \delta_0 X_t + \delta_1 X_t s_t + \delta_2 X_t s_t^2 + \delta_3 X_t s_t^3 + e_t \qquad (7)$$

where ε_t^* is the disturbance term from the linear Equation (1) above. As the minimized value of the AIC is used to select the best fit model for the U.S. economy the residuals from Model 1 in Table 3a below are used and for the Brazilian economy the residuals from Model 2 in Table 3b below in order to test the null hypothesis of linearity.

[7] The results of the Chow test are available upon request

The null hypothesis of linearity becomes, $H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$, against the alternative H_1 that at least one δ is different from zero. The resulting distribution is a X^2 and if the calculated value of TR^2 (or the value of the *F*-test) exceeds the critical value we reject the null hypothesis of linearity in favor of the alternative of nonlinearity. The *F*-tests results are presented in Tables 4a and 4b below for the U.S. and the Brazilian economy respectively. The results indicate rejection of the null hypothesis of linearity in favor of the alternative one for the case of the U.S. but we are unable to reject of the null hypothesis of linearity for the Brazilian economy (we use an 1% level of significance). As a linear Taylor's rule model best describes the Brazilian economy we stick to model 2 of Table 3b which is a backward looking Taylor rule model.

We then run 288[8] different models in order to estimate the nonlinear Taylor's rule for the U.S. and based on the minimized AIC criterion we select the best three in terms of fit and we present them in Table 5a. For the U.S. economy the three models are: Model 1, with 4 lags for both independent variables -inflation and output gap-, Model 2, with five and two lags respectively and Model 3 with eleven and four lags respectively. The errors used next in this paper are extracted from Model 1 of Table 5 as this has the lowest AIC. In all these three models the nonlinear part of the equation is statistically significant. The results indicate that there is a reaction of the FED when there is a deviation from the inflation target which is approximately 4.3 (π_t) in the first two models and approximately 5 (π_t) in the last one. The estimated parameters of inflation and output gap are above unity, in absolute values, indicating a stabilizing policy from the FED. However, the inflation coefficient is negative which contradicts the sign expected by the Taylor rule.

In the linear part of the model, which applies to periods when the inflation is close to the FED's implicit target, the reaction of the FED with respect to these variables is moderate and in many cases statistically insignificant. In order to get a better understanding about the estimation of the theta parameter, in Figure 1, it is presented the estimated theta parameter against the dummy variable of the U.S. business cycle provided by the NBER. A value of 1 represents a contractionary period, while a value of 0 is an expansionary period. As it can be easily seen the nonlinear Model 1

[8] The number of models corresponds to all different combinations of leads of inflation and output gap during a year in monthly basis (12*12) as well as the number of lags of the dependent variable (1 and 2).

(from Table 5a) can accommodate the responses of the FED in all contractionary periods except for the recession in the start of 2000 (bubble crisis).

The final step is to estimate the impact of the unexpected monetary policy shocks and to test for the presence of possible asymmetries stemming from the sign of the shock (that is positive versus negative shocks). Furthermore, we also test for any differences in impacts between unexpected monetary shocks and real interest rates on the real economy for both countries.

In doing so, we follow Cover (1992) and we run a simple OLS regression for both countries with the annual change of industrial production index as the dependent variable and as explanatory variables we use the lags of the unanticipated shocks and also lagged values of the interest rate as well as the annual change of inflation. As it was explained previously, we interpret the residuals from the selected Taylor rule for each country (Tables 5a and 3b for the U.S. and Brazil respectively) of the nonlinear Taylor rule as the unanticipated monetary policy shocks and we decompose these shocks in positive and negative ones according to Equation (6). Next, we try to estimate any possible contemporaneous and lagged effects from the unanticipated positive and negative monetary policy shocks on the industrial production index. The results are presented in Tables 6a and 6b for the U.S. and Brazil respectively.

In the first two Models of Table 6a, we test the impact of unexpected positive and negative monetary policy shocks taking into account only contemporaneous effects (Model 1) and both contemporaneous and lagged effects (Model 2). In Model 2, where the lagged effects are included, both positive in sign and negative in sign monetary shocks are highly statistically significant, both are above unity and have the expected negative sign. The interpretation of the signs of the coefficients is that, for example, if expected interest rate is lower than the actual interest rate (negative monetary policy shock) then we expect a negative effect on the industrial production index and vice versa. We do not detect any asymmetries stemming from the sign of the shocks since when we test these coefficients for equality all the relevant Wald test statistics are insignificant. On the other hand, in Model 1, in which no lagged effects were taken into account, both positive and negative monetary shocks are statistically insignificant. Finally, it is evident from all models and especially from the last two Models, 3 and 4 that only unanticipated monetary policy shocks have statistically significant effects on the industrial production index. This result confirms what would be expected by Neo-Classical theory.

As it is clear from Model 1 of Table 6b only the unanticipated positive monetary shock has a large negative impact on the year change of the industrial production index of Brazil while the unanticipated negative monetary shock and the real interest rate do not have any statistically significant impact. In all the regressions we run, the negative monetary shock didn't have any statistically significant impact. These results are in line with the theoretical concept of a convex aggregate supply, in which theoretical models, only positive unexpected shocks (contractionary monetary policy) have a large impact on the real economy. On the other hand, negative monetary shocks (expansionary monetary policy) have a smaller impact than positive shocks or no impact at all. We also found a statistically significant difference between the impact of an unanticipated monetary shock and the real interest rate. Results confirm the theoretical predictions of Classical economists that only unanticipated shocks in monetary policy can have an impact on the real economy and not the anticipated monetary policy. In Model 2 of Table 6b, the coefficient of the lagged unanticipated shocks is larger than the coefficient of the real interest rate.

Conclusions

In this paper we tried to identify any asymmetric impact of unanticipated monetary policy shocks on the real economy, as the latter is being described by the industrial production index. In doing so, we tested for the true Taylor's rule model for each economy under question and we used a nonlinear forward looking Taylor's rule in order to forecast the movements of the FED for U.S and a backward looking linear Taylor's rule for Brazil. Any deviation from these forecasts is assumed to be an unanticipated monetary policy shock. To the best of our knowledge this is the first time that a non linear Taylor's rule is used in order to identify the monetary shocks. Next, using a well-documented methodology (Cover 1992) we find a significant impact of these shocks on the real economy. In the case of U.S, only unanticipated monetary shocks appear to have statistically significant impact on the real economy confirming the expected results of the rational expectations theory. On the other hand, in the case of Brazil, we detected a significant impact of a positive monetary shock. Furthermore, the anticipated monetary policy has a much less significant impact than the impact of an unanticipated shock which is in line with the theory of rational expectations that only unanticipated monetary shocks can affect the real economy.

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Table 1. Unit Root Tests

	A. ADF Test				B. KPSS Test				C. Elliott et al. Test				
Variable	Level		1st Diff.		Level		1st Diff.		Level		1st Diff.		Decision
	Null Hypothesis: I(1)				Null Hypothesis: I(0)				Null Hypothesis: I(1)				
	Probability margin				LM-Stat				Test statistic				
π	0.000	***											I(0)
i	0.042	**	0.000	***	1.76	***	0.180		69.66		1.61	***	I(1)

The tests are done with an intercept.

, ** or *, denote a rejection of the null hypothesis at the 10%, 5% or 1% level.*

The 10%, 5% and 1% critical values for the KPSS tests are 0.347, 0.463 and 0.739 respectively.

The 10%, 5% and 1% critical values for the Elliot-Rothenberg-Stock tests are 4.45, 3.24 and 1.97 respectively.

Table 2a. Descriptive Statistics for U.S			
	Inflation	Fed Rate	Output Gap
Mean	2.26	5.31	-0.03
Median	2.06	5.26	0.01
Maximum	9.68	19.10	4.58
Minimum	-0.59	0.07	-7.09
Std. Dev.	1.59	3.51	1.57
Skewness	1.40	0.85	-0.74
Kurtosis	6.49	4.55	7.26
Observations	366	366	366

Table 2b. Descriptive Statistics for Brazil			
	Inflation	Selic	Output Gap
Mean	0.47	1.07	-0.001
Median	0.45	0.99	0.001
Maximum	1.00	2.08	0.07
Minimum	0.2	0.59	-0.17
Std. Dev.	0.15	0.31	0.04
Skewness	0.73	0.92	-1.7
Kurtosis	3.71	3.48	7.64
Observations	110	110	110

Table 3a. Best Estimated Linear Models for U.S				
	Model 1	Model 2	Model 3	Model 4
c	**0.027**	0.008	-0.005	-0.018
	[0.89]	[0.26]	[-0.13]	[-0.49]
i (-1)	**0.533**	0.533	0.534	0.534
	[10.56]**	[10.55]***	[5.78]***	[5.84]***
i (-2)	**-0.122**	-0.120	-0.122	-0.118
	[-2.45]**	[-2.42]**	[-1.05]	[-1.00]
π (3)	**-0.024**			
	[-2.10]**			
y (3)	**0.018**			
	[1.74]*			
π (6)		-0.016		
		[-1.29]		
y (6)		0.023		
		[2.14]**		
π (9)			-0.010	
			[-0.46]	
y (9)			0.026	
			[2.89]***	
π (12)				-0.003
				[-0.19]
y (12)				0.028
				[3.11]***
Observations:	**366**	366	366	366
R-squared:	**0.277**	0.275	0.275	0.276
AIC:	**0.553**	0.556	0.556	0.555
DW	**2.09**	2.08	2.08	2.08

*Note: *, ** and ***, denote a rejection of the null hypothesis at the 0.10, 0.05 and 0.01 levels respectively, t-statistics are in brackets. Robust standard errors with Newey-West/Barlett window were computed.*

Table 3b. Best Estimated Linear Models for Brazil				
	Model 1	**Model 2**	Model 3	Model 4
c	-0.08	**-0.10**	-0.06	-0.14
	[-1.47]	**[-2.20]****	[-1.34]	[-3.3]***
i (-1)	-0.49	**-0.51**	-0.48	-0.52
	[-6.58]***	**[-7.73]*****	[-6.50]***	[-7.86]***
π (1)	0.11		0.11	
	[1.00]		[0.95]	
y (1)	0.658		0.365	
	[2.05]**		[0.53]	
π (-2)		**0.142**		0.208
		[1.57]		[2.32]**
y (-2)		**1.63**		3.25
		[3.98]***		[4.12]***
Dummy*π (1)			0.038	
			[0.64]	
Dummy*y (1)			0.557	
			[0.74]	
Dummy*π (-2)				0.166
				[1.84]*
Dummy*y (-2)				-1.97
				[-2.33]**
Observations:	138	**140**	138	127
R-squared:	0.25	**0.30**	0.25	0.32
AIC:	-1.556	**-1.636**	-1.530	-1.567
Schwarz	-1.471	**-1.552**	-1.402	-1.433
DW	2.28	**2.33**	2.26	2.44

*Note: *, ** and ***, denote a rejection of the null hypothesis at the 0.10, 0.05 and 0.01 levels respectively, t-statistics are in brackets. Robust standard errors with Newey-West/Barlett window were computed. y and π denotes the outputgap and the core inflation respectively. Dummy denotes the dummy variable taking the value of one from 2008:10 to 2010:03 and zero elsewhere. We run many tests and we present here those with the best values of the AIC and Schwartz criteria*

Table 4a. F-tests for linearity of Model 1 of table 3a

F-statistic:	4.45
Prob(F-stat):	0.000***

Note: as the inflation target seems to be of greater importance than the outputgap for the U.S economy, we use as a delay parameter the inflation. We run several tests using different lags each time for the inflation and in all tests the null hypothesis of linearity was rejected. We present above in table 4b the results of the test using one lag of the inflation as a delay parameter

Table 4b. F-tests for linearity of Model 2 of table 3b

F-statistic:	1.18
Prob(F-stat):	0.30

Table 5. Best Estimated of nonlinear Taylor rule models for U.S.

	Model 1		Model 2		Model 3	
	Coefficient	**Prob.**	Coefficient	Prob.	Coefficient	Prob.
c_1	**0.051**	**0.607**	0.033	0.602	0.009	0.836
ρ	**0.415*****	**0.000**	0.442***	0.000	0.388***	0.000
β	**-0.0352***	**0.0875**	-0.029	0.168	-0.018	0.315
γ	**0.0009**	**0.5078**	0.0123	0.443	0.0257**	0.017
c_2	**12.609*****	**0.0017**	11.639***	0.003	57.176***	0.007
b	**-1.828*****	**0.0022**	-1.917***	0.003	-11.090***	0.007
d	**1.957*****	**0.0002**	2.053***	0.001	5.9134***	0.003
γ	**1.110*****	**0.0000**	1.202**	0.016	2.36***	0.000
π_t	**4.35*****	**0.0000**	4.38***	0.000	5.19***	0.000
AIC	0.426		0.557		0.431	
Obs	366		366		366	

*Notes: Model 1 corresponds to 4 lags for the variables I and π, model 2 corresponds to 5 and 2 lags respectively and model 3 corresponds to 11 and 4 lags respectively. Significance level at which the null hypothesis is rejected: ***, 1%; **, 5%; *, 10%. γ is made dimension free by dividing it by the standard deviation of the inflation variable. The estimated equation is of the form:*

$$i_t = \rho_1 i_{t-1} + (1-\rho_1)(c_1 + \beta\pi_{t+i} + \gamma y_{t+i}) + (1-\rho_1)[1 + exp(-\gamma(s_t - c))]]^{-1}(c_2 + b\pi_{t+i} + dy_{t+i}) + \varepsilon_t$$

. π_τ is the target inflation.

Table 6a. Effects of Unanticipated Monetary shocks for the U.S.				
Equation	Model 1	Model 2	Model 3	Model 4
Dep. Var:	YCIP	YCIP	YCIP	YCIP
C	0.278	0.357	0.275	0.359
	(0.15)*	(0.13)***	(0.15)*	(0.13)***
Year Change IP(-1)	1.220	1.082	1.217	1.083
	(0.09)***	(0.08)***	(0.09)***	(0.08)***
Year Change IP(-2)	-0.280	-0.137	-0.278	-0.141
	(0.09)***	(0.08)*	(0.08)***	(0.07)*
RESP	0.597	-1.660		
	(0.39)	(0.63)***		
RESN	0.390	-1.906		
	(0.32)	(0.89)**		
FEDRATE	0.050	2.151	0.052	2.058
	(0.03)	(0.65)***	(0.03)	(0.56)***
INFLATION	-0.187	-0.375	-0.182	-0.364
	(0.07)***	(0.19)**	(0.07)**	(0.19)*
RESP(-1)		-0.966		
		(0.50)*		
RESP(-2)		-1.047		
		(0.55)*		
RESP(-3)		-0.563		
		(0.52)		
RESP(-4)		0.323		
		(0.54)		
RESN(-1)		-0.260		
		(0.58)		
RESN(-2)		-0.974		
		(0.55)*		
RESN(-3)		-0.711		
		(0.49)		
RESN(-4)		-0.153		
		(0.33)		
FEDRATE(-1)		-2.218		-2.130
		(0.92)**		(0.82)***
FEDRATE(-2)		0.882		0.807
		(0.68)		(0.62)
FEDRATE(-3)		-0.710		-0.471
		(0.64)		(0.60)
FEDRATE(-4)		-0.109		-0.265
		(0.40)		(0.39)
INFLATION (-1)		0.247		0.250
		(0.22)		(0.22)
INFLATION (-2)		-0.272		-0.301*
		(0.18)		(0.18)
INFLATION (-3)		0.145		0.145
		(0.21)		(0.21)
INFLATION (-4)		0.206		0.220
		(0.15)		(0.15)
RES			0.486	-1.700

			(0.18)***	(0.61)***
RES(-1)				-0.532
Table 6a. Effects of Unanticipated Monetary shocks for the U.S. (cont)				
				(0.45)
RES(-2)				-0.891
				(0.31)***
RES(-3)				-0.739
				(0.40)*
RES(-4)				0.021
				(0.27)
Observations:	366	362	366	362
R-squared:	0.96	0.96	0.96	0.96
F-statistic:	1320.9***	405.5***	1588.7***	528.6***
DW	2.15	2.07	2.15	2.08
F-tests		Prob.	Prob.	Prob.
RESP=RESN		0.37		
Σ SGP = Σ SGN		0.39		
Σ RESP=Σ FEDRATE		0.001***		
Σ RESN=Σ FEDRATE		0.01**		
RES=FEDRATE			0.02**	
Σ RES=Σ FEDRATE				0.006***

*Notes: Robust standard errors with Newey-West/ Barlett window were computed and the respective standard errors are presented in parentheses; significance level at which the null hypothesis is rejected: ***, 1%; **, 5%; *, 10%. RESP are the monetary shocks with positive sign, thus negative monetary shocks, RESN are the monetary shocks with the negative sign, thus the positive monetary shocks, RES are unexpected monetary shocks.*

Table 6b. Effects of Unanticipated Monetary shocks for Brazil				
Equation	Model 1		Model 2	
Dep. Var:	YCIP		YCIP	
C	0.45		0.72	
	[0.58]		[1.01]	
Year Change IP(-1)	1.09		1.03	
	[7.05]***		[8.13]***	
Year Change IP(-2)	-0.2		-0.14	
	[1.29]		[-1.06]	
RESP(-1)	-10.24			
	[-2.24]**			
RESN (-1)	2.80			
	[0.57]			
RESN(-1)				
REAL INTEREST RATE			-0.69	
			[-1.76]*	
REAL INEREST RATE (-1)	0.11 [0.45]		0.48 [1.54]	
RES			2.11	
			(0.77)	
RES(-1)			-3.33	
			[-1.81]*	
				1
Observations:	121		127	
R-squared:	0.83		0.82	
DW	2.05		2.04	

*Notes: Robust standard errors with Newey-West/ Barlett window were computed and the respective t-statistics are presented in brackets; significance level at which the null hypothesis is rejected: ***, 1%; **, 5%; *, 10%. RESP are the monetary shocks with positive sign, thus negative monetary shocks, RESN are the monetary shocks with the negative sign, thus the positive monetary shocks, RES are unexpected monetary shocks.*

Figure 1. The output gap for the Brazilian Economy

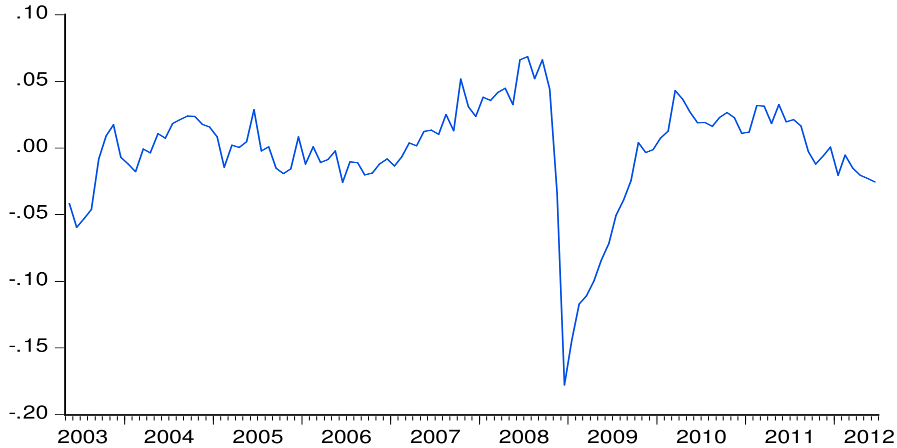
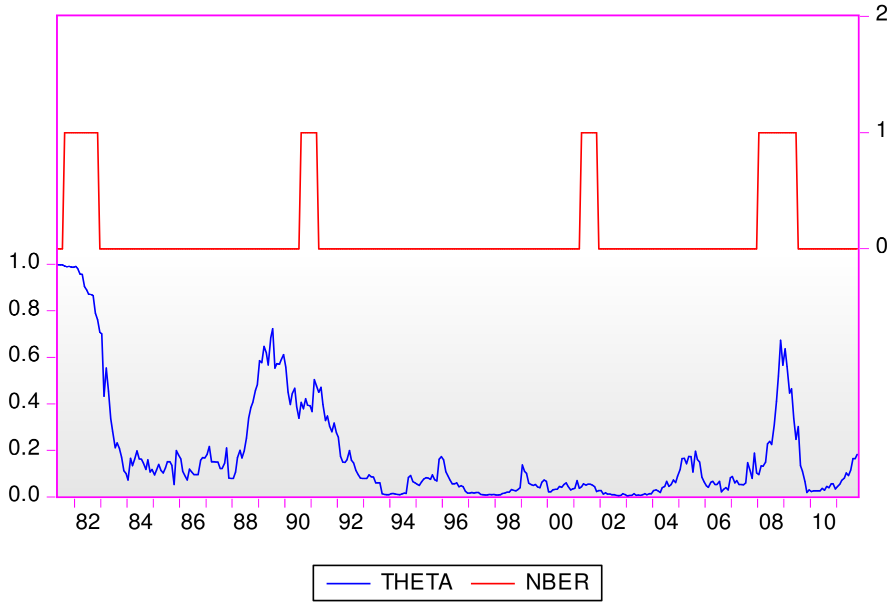


Figure 2. Theta parameter against NBER's expansion and contraction dates in U.S



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