ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Procedia Economics and Finance 5 (2013) 562 – 570

Procedia
Economics and Finance

www.elsevier.com/locate/procedia

International Conference on Applied Economics (ICOAE) 2013

Relationships between Effective and Expected Interest Rates as a Transmission Mechanism for Monetary Policy: Evidence on the Brazilian Economy using MS-models and a Bayesian VAR

Ricardo Ramalhete Moreira[a]*, Chukiat Chaiboonsri[b], Prasert Chaitip[c]

[a]*Professor at the Espírito Santo Federal University, Brazil.*
[b]*Professor at the Chiang Mai University, Thailand.*
[c]*Professor at the Chiang Mai University, Thailand.*

Abstract

This work applies *Markov-switching models* and a *Bayesian VAR* in order to verify empirical relationships between expected and effective short term interest rates in Brazil. The main results corroborate the theoretical idea according to which the Central Bank can smooth adjustments of effective short term interest rates, given that these last ones have effects on expected short term rates, thereby influencing long term interest rates, which are fundamental for controlling output activity and price changes. Besides, the MS-models show that these empirical relationships are more significant under a "higher response regime". At last, the BVAR test yields impulse-response functions showing that shocks in expected rates have more persistent impacts on effective rates than what is observed from the opposite direction. This evidence gives support for the idea of a transparent and predictable monetary policy in Brazil.

Selection and/or peer-review under responsibility of the Organising Committee of ICOAE 2013

Keywords: **Interest rates; MS-models; BVAR; Brazil.**

---

* Corresponding author. Tel.: +55 27 4009 26 12.
E-mail address: ramalhete.s@gmail.com.

Selection and/or peer-review under responsibility of the Organising Committee of ICOAE 2013
doi:10.1016/S2212-5671(13)00066-X

1. Introduction

The relationship between the effective short term interest rate and expectations regarding the future short term interest rate is an important transmission mechanism for monetary policy (Woodford, 2003). In New-Keynesian models investment decisions are determined by changes in long term interest rates, which, in their turn, depend on the weighted mean associated with the current interest rate and expected future short term interest rates for all possible maturities. This method of measuring the long term interest rate is known as *expectation hypothesis of the term structure of interest rates,* and it can be expressed by:

$$(1)\; L_{t,t+n} = \alpha_0 i_t + E_t[\sum_{g=1}^{n} \alpha_g i_{t+g}] + u_t$$

Where $L_{t,t+n}$ is the long term interest rate of a relevant bond with maturity from period t to period t+n; i_t and i_{t+g} are, respectively, the current short term interest rate and expected future short term interest rates for period t+1 to t+n; α (from α_0 to α_g) is a parameter and u_t is a shock expressing variations of the risk premium that investors require to accept long term bonds instead of short term ones.

Given that the long term interest rate is formed in such a way, the monetary policy's efficiency depends on the Central Bank's ability in affecting expectations regarding future short term interest rates in the required direction, so that targets can be attained with lower social costs (Levin, Wieland and Williams, 1999; Rotemberg and Woodford, 1999; Rudebusch, 2006). According to Woodford (2003), the higher the Central Bank's commitment with an inertial instrument rule the higher the causality between current adjustments of interest rates and expectations on future adjustments, thereby moving the long term interest rate without requiring expressive volatility of the short term interest rate. A *forward-looking Taylor rule*, by incorporating *inertial behavior for short term interest rates*, can show the transmission mechanism under analysis when iterating for one period ahead, such as:

$$(2)\; E_t[i_{t+1}] = \rho(i_t) + (1-\rho)\left[E_t(i^n{}_{t+1}) + \sum_{j=0}^{n} m_{-j}\pi^*{}_{t-j} + E_t\sum_{j=1}^{n}\phi_j\pi^*{}_{t+j} + \sum_{j=0}^{n} n_{-j}y_{t-j} + E_t\sum_{j=1}^{n}\kappa_j y_{t+j} \right]$$

Where $E_t[i_{t+1}]$ is the expected short term interest rate for period t+1, ρ is a smoothing coefficient (or inertial component); $E_t(i^n{}_{t+1})$ the expected equilibrium short term interest rate for period t+1; $\sum_{j=0}^{n} m_{-j}\pi^*{}_{t-j} + E_t\sum_{j=1}^{n}\phi_j\pi^*{}_{t+j}$ is the sum between, respectively, inflation deviations from period t to period t-n and expected inflation deviations from period t+1 to t+n; at last, $\sum_{j=0}^{n} n_{-j}y_{t-j} + E_t\sum_{j=1}^{n}\kappa_j y_{t+j}$ is the sum between, respectively, output gaps from period t to period t-n and expected output gaps from period t+1 to t+n. Moreover E_t means the expectation operator in period t.

The main goal of this work is to identify a transmission mechanism between i_t and $E_t[i_{t+1}]$, that is, to verify if by adjusting the current interest rate the Brazilian Central Bank is able to affect the expected short term interest rate. On the other hand, as the long term interest rate is determined through expectations regarding future short term rates (such as in 1), the verification of that transmission suggests additionally that the BCB is also able to change the term structure in Brazil.

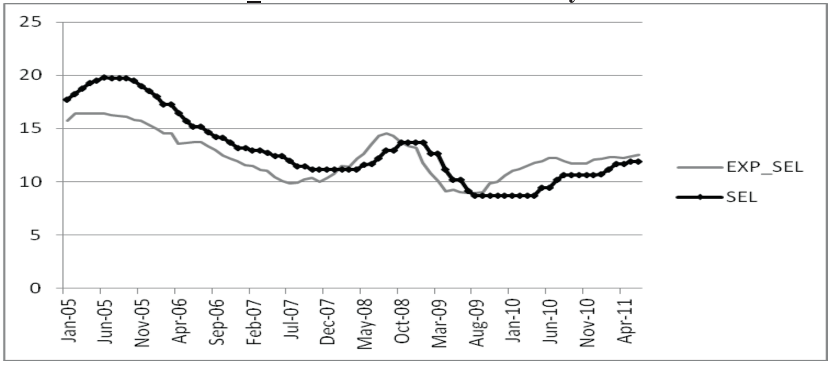
At an empirical level, Cook and Hahn (1989), Kuttner (2001) and Bauer (2011) are important references with regard to the verification of the term structure of interest rates in the United States, and in general they show that the FED's monetary policy affects interest rates in long terms.

On the other hand, specifically for the Brazilian economy, Guillen and Tabak (2009) test for the expectation hypothesis (EH) and attain, from 1995 to 2006, cointegration and causality evidences for short and long term interest rates. In their turn, De Mendonça and Simão Filho (2011) found a positive impact of instrument decisions on interest rates three months forward, thereby corroborating the related literature for Brazil.

2. Data and Methods

This work adopts two variables, that is, SEL = the *annual effective basic interest rate*, which is implemented by the Brazilian Central Bank as its main policy instrument; and EXP_SEL = *the annual expected basic interest rate for 12 months ahead*, which is collected by the BCB from the Focus, a research on the financial market's expectations. Both the monthly variables can be found in www.bcb.gov.br and were collected from January 2005 to June 2011. Their graphical behavior can be seen in Graph 1 below:

Graph 1 – Behavior of EXP_SEL and SEL from January 2005 to June 2011 in Brazil



Source: Own elaboration.

Some notes on the behavior of the variables seem to be appropriate and visually verifiable. From January 2005 to around July 2007 the variables present a co-movement of decrease, but from around August 2007 the expected short term interest rate begins an increasing process while the effective short term interest rate presents an inertial constancy up to around March 2008. The same occurs from August 2008: the expected short term rate has fallen, but the effective one begins to decrease only from around January 2009.

In its turn, the increasing movement of interest rates from the end of 2009 shows that the effective short term rate starts its path only after some months of expected rates' increases. All these movements suggest that the public's expectations regarding future instrument decisions take the Brazilian Central Bank's monetary policy rule into account, and that this last one has a predictable nature.

On the other hand, an alternative way of interpreting these relationships is as follows: given that the BCB's monetary policy is able in affecting the expected short term interest rate by a commitment with a dependent-path for effective rates, monetary authorities can smooth instrument adjustments so as to avoid interest rate volatility or a higher market uncertainty. Hence, expectations make a previous work for monetary policy by affecting the term structure even while the Central Bank does not still adjust its policy instrument.

Obviously, underlying the apparent co-movement between EXP_SEL and SEL there exist the public's and Central Bank's concerns on output and inflation cycles. Nevertheless, these are just preliminary remarks. Only by applying econometric methods more robust evidences and conclusions can be found.

Methodologically, this work implements *Augmented Dickey-Fuller and Phillips-Perron unit root tests*, *Granger causality test*, *Markov-Switching models* (see Hamilton, 1989) and a *Bayesian Vector Autoregressive (BVAR) model* (see Litterman, 1984), so as to test for predicted impulse-response functions between SEL and EXP_SEL.

MS-models

A classical example is Hamilton (1989), which studied the US business cycle by using a *Markov-Switching autoregressive model* on the quarterly percentage change in US real GNP from 1953 to 1984 with four lags:

$$(3)\ \Delta y_t - \mu(s_t) = \alpha_1 (\Delta y_{t-1} - \mu(s_{t-1})) + ... + \alpha_4 (\Delta y_{t-4} - \mu(s_{t-4})) + u_t$$

Given that u_t is a white noise shock and the mean μ switches from μ_1 to μ_2, where $\mu_1 < 0$ if $s_t = 1$ (an "economic contraction"); and $\mu_2 > 0$ is $s_t = 2$ (an "economic expansion").

BVAR model

The fundamental difference between a VAR model and a BVAR model is that the last one is estimated using Bayesian methods. In such a context, the parameters are regarded as random variables with prior probabilities (Chauvet and Potter, 2012). A standard Vector Autoregressive Vector can be defined broadly as:

$$(4)\ \Delta Y_t = A' x_t + u_t$$

Letting u_t be the disturbances vector which is uncorrelated with x_t. Another specification for (4) is:

$$(5)\ \Delta y = (I_M \otimes x)\alpha + u$$

Given that α = vec(A) and $u \sim N(0, \Theta \otimes I_T)$. And making the OLS of A:

$$(6)\quad \hat{A}' = [\textstyle\sum_{t=1}^{T} \Delta Y_t x_t'][\textstyle\sum_{t=1}^{T} x_t x_t']^{-1}$$

To estimate the priors, Koop and Korobilis (2010) suggest Minessota priors. According to Chauvet and Potter (2012), it implies that $\otimes$ is substituted by an estimation process, such as:

$$(7)\ \alpha \sim N(\underline{\alpha}_{nM}, \underline{V}_{nM})$$

From using Normal distribution:

$$(8)\ \alpha | y \sim N(\overline{\alpha}_{nM}, \overline{V}_{nM})$$

Regarding:

$$(9)\ \overline{V}_{nM} = [\underline{V_{nM}}^{-1} + \hat{\Theta}^{-1} \otimes (x'x))]^{-1}$$

And:

$$(10)\ \overline{\alpha}_{nM} = \overline{V}_{nM}[\underline{V_{nM}^{-1}\alpha_{nM}} + (\hat{\Theta}^{-1} \otimes x)'y]$$

Additionally, the prior $\overline{\alpha}_{nM}$ is regarded as zero and the variance-covariance matrix $\otimes$ is assumed to be diagonal (Chauvet and Potter, 2012).

3. Results

MS-models (I and II)

As the series SEL and EXP_SEL have unit root in level, this work uses them in log difference. Then *Dickey-Fuller* and *Phillips-Perron* tests show that LD(SEL) and LD(EXP_SEL) are both stationary (Table 1 in Appendix), letting LD be the operator of log difference. The Granger-causality tests (Table 2 in Appendix), in their turn, indentify statistical significance for a mutual causality between the two variables under the time sample. It means that changes in the Brazilian effective short term interest rate are followed, with time lags, by changes in expected short term interest rates, and this causality also occurs from the contrary direction, that is, changes in the expected one cause, with time lags, changes in the effective one.

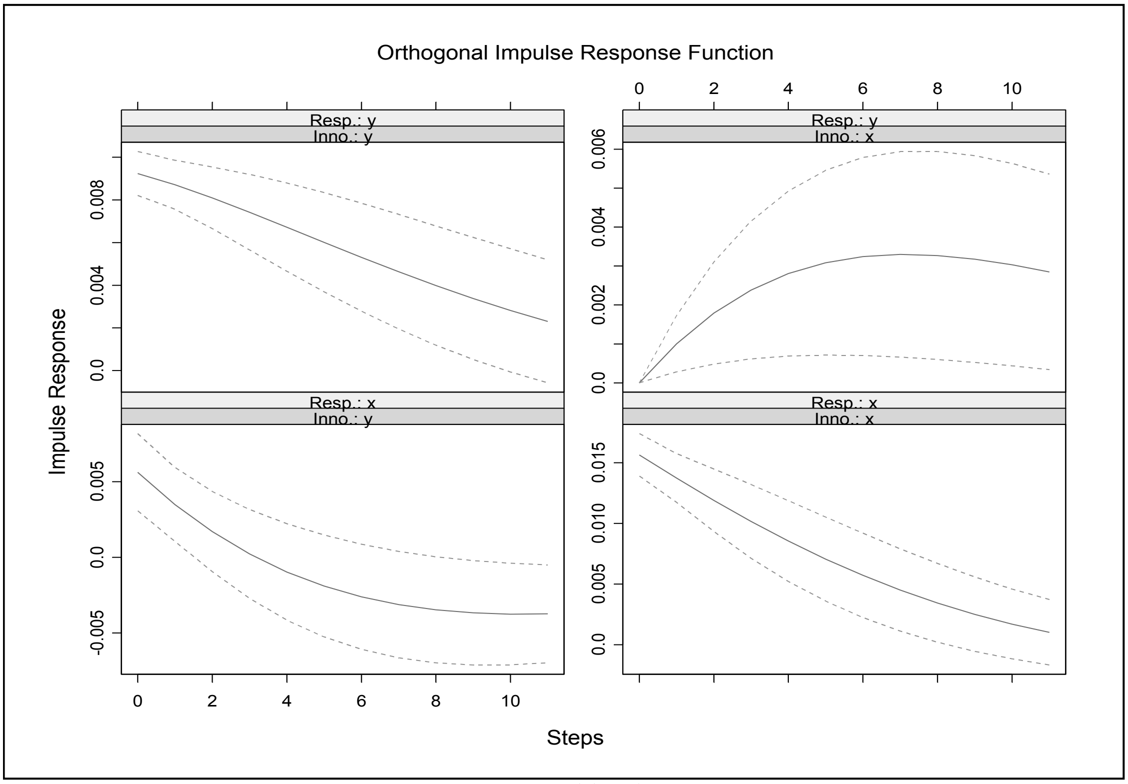
In order to verify if these causal relationships present switching-parameters or different regimes, we test for two bivariate MS-models, namely *MS-model I*, which is specified as y = f(x), by letting y = LD(SEL) and x = LD(EXP_SEL); and *MS-model II*, specified as x = f(y). The main statistics of these MS-models can be observed respectively in Table 3 and 4 (Appendix). With regard to *MS-model I*, two regimes were estimated, but only one has statistical significance, with a response coefficient at 0.79; on the other hand, with regard to *MS-model II* both the regimes presented statistical significance: in the first one, the coefficient response is 0.32, and in the second one 0.37.

It means that by analyzing effects of Brazilian expected short term interest rates on effective short term rates there exists only one statistical regime (i.e. the parameter does not present a switching process); however, when analyzing effects of effective short term interest rates on expected short term rates there exist two statistical regimes. The first one can be defined as a “lower response regime” (0.32), while the second one can be defined as a “higher response regime” (0.37). In economic terms, this kind of a higher response regime could be associated with recession cases or with periods of higher uncertainty in the financial markets, when expectations become more volatile. Nevertheless, this work does not have the goal of identifying exact historical periods in which a regime of higher (and of lower) response occurs.

BVAR model

The BVAR yields dynamic and probabilistic relationships between LD(SEL) and LD(EXP_SEL), so that it is possible to verify the nature of the time-varying response of both the variables facing shocks from each other. The estimated BVAR has one lag and its main statistics can be found in Table 5 (Appendix). The Graph 2 below shows the impulse-response functions estimated from the BVAR:

Graph 2 – Impulse-response functions from the estimated BVAR. y = LD(SEL); x = LD(EXP_SEL)



Source: Own elaboration.

The first evidence is that positive shocks (innovations) in x (=LD(EXP_SEL)) have persistent positive effects on y (=LD(SEL)), even after ten months from the initial shock. One possible hypothesis for explaining this result is the existence of a transparent and predictable monetary policy in Brazil under the time sample. Indeed, the Brazilian inflation targeting regime yields information useful in teaching how the BCB works and reacts to macroeconomic fluctuations, so that its future instrument adjustments become more predictable from the public's expectations. There exist several studies on the monetary policy rule under the Brazilian inflation targeting regime (see, for instance, Minella et. al. 2003; Holland, 2005; Barbosa and Soares, 2006; and Moreira, 2012).

On the other hand, positive shocks in y (=LD(SEL)) have initial (i.e. until around the second month after the shock) positive effects on the expected short term interest rate (x), thereby corroborating the hypothesis of a predictable smoothing or inertial monetary policy in Brazil. It means that, when the BCB increases its basic short term interest rate, the public expects it to increase again periods ahead, then generating positive responses of the expected short term interest rate.

Nevertheless, from around the second month to the tenth month after the shock, the expected short term interest rate stays below its normal value. A possible hypothesis for explaining this evidence is that the initial positive shock in y (=LD(SEL)) affects negatively output activity and so inflation dynamics, so that after some months expected interest rates decrease.

4. Concluding remarks

The Brazilian Central Bank, under an inflation targeting regime, has worked to create a predictable monetary policy associated with two main gains:

a) a commitment with a gradual or inertial monetary policy rule has been translated into an empirical positive causality from current interest rate adjustments to expected interest rates in the same direction (at least in the first months), thereby moving the term structure in a counter-cyclical way;

b) since 1999, years of Central Banking under inflation targeting yielded information useful in teaching how Brazilian monetary authorities react to macroeconomic fluctuations, so that there exist empirical evidences on the anticipation – in Granger sense – from expected short term interest rates to the effective one, denoting an underlying predictable monetary policy.

5. References

Barbosa F. H., Soares J. J., 2006. The Taylor's rule in Brazil: 1999-2005. *Proceedings of the 34th Brazilian Economics Meeting*, Brazil, 2006, pp. 1-19.

Bauer, M., 2011. What moves the interest rate term structure?. *FRBSF Economic Letter*, November, 2011.

Chauvet, M., Potter, S., 2012. Forecasting Output. *Handbook of Economic Forecasting*, Vol.2.

Cook, T., Hahn, T., 1989. Federal Reserve Information and the Behavior of Interest Rates. *Journal of Monetary Economics*, 24:331-351.

De Mendonça, H. F., Simão Filho, J., 2011. Transparência do Banco Central e Mercado Financeiro: evidências para o caso brasileiro. *Revista Brasileira de Finanças*, v. 9, p. 51-67, 2011.

Guillen, O. T., Tabak, B. M., 2009. Characterising the Brazilian term structure of interest rates. *International Journal of Monetary Economics and Finance*, v. 2, p. 103, 2009.

Hamilton, J., 1989. A new approach to the economic analysis of nonstationary time series and business cycle. *Econometrica*, vol.57, no.2, 357-384.

Holland, M., 2005. Monetary and exchange rate policy in Brazil after inflation targeting. *Working Paper*, Berkeley: University of California.

Koop, G., Korobilis, D., 2009. Bayesian multivariate time series methods for empirical macroeconomics. *MPRA paper no. 20125*, University Library of Munich.

Kuttner, K. N., 2001. Monetary Policy Surprises and Interest Rates: Evidence from the Federal Funds Futures Market. *Journal of Monetary Economics*, 47: 527-544.

Levin, A. T., Natalucci, F. M., Piger, J. M., 2004. Explicit inflation objectives and macroeconomic outcomes. *Working Paper Series 383*, European Central Bank.

Litterman, R., 1984. Specifying VAR's for macroeconomic forecasting. *Federal Reserve Bank of Minneapolis Staff report no. 92*.

Minella, A., de Freitas, P.S., Goldfajn, I., Muinhos, M.K., 2003. Inflation targeting in Brazil: lessons and challenges. *BIS Papers, n° 19,* pp. 106-133.

Moreira, R. R., 2012. How the Brazilian Central Bank has reacted to the macroeconomic dynamics. *Working Paper no. 01*, Master in Economics Program, Espírito Santo Federal University, Brazil.

Rotemberg, J., Woodford, M., 1999. Interest Rate Rules in an Estimated Sticky Price Model. NBER Chapters, in: Monetary Policy Rules, pages 57-126 National Bureau of Economic Research, Inc.

Rudebusch, G. D., 2006. Monetary Policy Inertia: Fact or Fiction?. *International Journal of Central Banking*, vol. 2(4), December.

Woodford, M., 2003. Interest and Prices: Foundations of a Theory of Monetary Policy. Princeton University Press.

Appendix

Table 1. Augmented Dickey-Fuller (ADF) test and Phillips-Perron test

	ADF*		PP**	
	t-stat	*P-value*	*adj. t-stat*	*P-value*
LD(SEL)	-2.82	0.059	-6.32	0.000
LD(EXP_SEL)	-2.91	0.048	-4.85	0.000

(*) Maxlag = 11; exogenous: constant; (**) Using Bartlett kernel. Source: Own elaboration.

Table 2. Granger-causality test

Null hypothesis	F-stat	P-value
LD(SEL) does not Granger cause LD(EXP_SEL)	3.26	0.043
LD(EXP_SEL) does not Granger cause LD(SEL)	13.40	0.000

Note: 02 lags; Source: Own elaboration.

Table 3. MS-Model I: LD(SEL) = f(LD(EXP_SEL))

	Model's variance	Switching parameter	Std-error	P-value	Duration
State 1	0.0000	0.002	0.012	0.86	2.02 times
State 2	0.0003	0.799	0.210	0.00	2.16 times

Source: Own elaboration.

Table 4. MS-Model II: LD(EXP_SEL) = f(LD(SEL))

	Model's variance	Switching parameter	Std-error	P-value	Duration
State 1	0.0000	0.321	0.121	0.01	33.15 times
State 2	0.0003	0.370	0.183	0.05	27.56 times

Source: Own elaboration.

Table 5. Bayesian VAR main statistics: y = LD(SEL); x = LD(EXP_SEL)

	y	x
Intercept	0.0000	-0.0002
Std.error	0.0004	0.0007
t-stat	-0.1248	-0.2343
yLag1	0.9037	-0.1569
Std.error	0.0649	0.1169
t-stat	13.9216	-1.3424
xLag1	0.0642	0.8779
Std.error	0.0474	0.0854
t-stat	1.3533	10.2742

Regression Diagnostics:

Adj.R-squared: y = 0.87; x = 0.69

AIC = -763.45; BIC = -753.31

Dfreedom = 40

Source: Own elaboration.