sciendo
Proceedings of the 5th International Conference on Economics and Social Sciences (2022), ISSN 2704-6524, pp. 255-264

The 5th International Conference on Economics and Social Sciences
Fostering recovery through metaverse business modelling
June 16-17, 2022
Bucharest University of Economic Studies, Romania

Smooth Transition Approach for Monetary Policy Shocks over the Business Cycle

Georgiana PLEȘA[1]

DOI: 10.24789788367405072-023

Abstract

The empirical assessment of the monetary policy shocks represents an area of interest widely studied among macroeconomic research papers due to the implications for both central bank and economic agents, respectively. Given the fact that the economies are characterized by asymmetries over the business cycles, it becomes challenging for the monetary policy authorities to ensure price and financial stability. The method proposed in this paper is a Bayesian Smooth Transition Vector Autoregressive model (STVAR) that allows for nonlinearity via a two regime-dependent model. This dependence is defined by a logistic function to switch between cyclical positions when the economy is "overheated" (i.e., positive output gap) and periods when the actual output is below potential output (i.e., negative output gap). To assess the effects of a contractionary monetary policy shock on the economic activity, we use the real economic growth and inflation, all variables at a quarterly basis. The transmission mechanism is presented in this paper into a comparative analysis between three Central and Eastern European countries classified as emerging markets (Czech Republic, Poland, and Romania). Results suggest that a contractionary monetary policy shock that, according to the literature, is expected to decrease the gross domestic product and lower inflation produces different effects over the business cycle and across distinct states. Subsequently, the estimated effects of the shock are gradually dissipated in the medium term.

Keywords: monetary policy, smooth transition, regime switching.

JEL Classification: E52, E30, E32, E42.

1. Introduction

The monetary policy transmission mechanism represents an area of interest widely studied among economic research papers. To the extent that monetary policy shocks are essential for policy analysis, especially in times marked by uncertainty and data revisions, the key empirical question of this paper is how the effects of these shocks vary over the business cycles. The answer to this research problem is

[1] Bucharest University of Economic Studies, Bucharest, Romania, georgiana.plesa@fin.ase.ro.

important not only for policymakers to maintain price stability and sustainable economic growth, but also for economic agents to form their decisions. The objective of monetary policy is to stabilize the domestic economy by reducing the variability of prices and output growth. Changes in interest rates affect consumers directly through the cost of borrowing, while stable prices and steady real economic growth ease the economic and financial planning (Cecchetti, 2000).

Most empirical research papers assess the interaction between monetary policy and macroeconomic variables in a linear setup. According to economic theory, a contractionary monetary policy shock depresses economic activity and increases inflation, producing effects in the same direction, similar to a supply shock. The vector autoregressive multivariate models, estimated via classical econometric techniques or Bayesian inference are widely used to investigate the interactions between macroeconomic variables and the effects of shocks using impulse response functions. However, nonlinear models, such as regime-switching ones, highlight the existence of asymmetries in the transmission mechanism of shocks. This class of models permits the assessment of this mechanism that depends on the regime, on the subject to structural changes. These shifts could be abrupt (e.g. Markov-Switching, Threshold models) or gradual which are referred to as smooth regime switches or transition models. In this paper, we implement a Smooth Transition Vector Autoregressive model (STVAR) using the Markov Chain Monte Carlo method, more specifically the Metropolis Hasting algorithm, following a method similar to Auerbach & Gorodnichenko (2010) and Gefang & Strachan (2010).

The rest of the paper is structured as follows: the next section presents a survey of the literature, followed by the aim of the paper. Then, we present the methodology of the STVAR model implemented in this study and the framework of data introduced. Section 5 presents the results, and the last section concludes.

2. Problem Statement

The data-driven economic mechanisms are often time-varying such that a specific model could perform better in some periods and worse in others, resulting in a non-linear (e.g., state-dependent) evaluating and forecasting performance. Our focus on nonlinearities related to the monetary policy transmission mechanism is justified by two important stylized facts. First, macroeconomic time series display asymmetric behaviour over the business cycles (see, among others, Lo, Piger, 2005). Second, monetary policy features non-identical dynamics in boom and bust periods. The literature presents different exhibitions of asymmetry, in the direction and the size of monetary policy action; or asymmetry related to the business cycles phases (Weisse, 1999; Lo, Piger, 2005).

In the first instance, Taylor (1993) specified a monetary policy rule where the short-term interest rate increases if the inflation is above the target and the actual output is above the potential output. The effects usually appear with a delay, because policymakers tend to smooth adjustments according to expected future movements in inflation and output gaps. The original version of the Taylor rule has been modified in many ways, to incorporate nonlinearities and to indicate asymmetric preferences of the central bank. However, studying a Taylor rule could also require expert judgment and rational forward-looking behaviour. Thus, a straightforward framework to study the interaction between monetary policy and economic data series is represented by vector autoregressive models. Additionally, Bayesian methods improved upon frequentist ones because this approach allows incorporating prior information about the parameters into posterior probability statements (Miranda-Agrippino, Rico, 2018).

Regime–switching models have received attention over the last years aimed at measuring, testing, and forecasting the economic variables. Among others, the seminal work for these is related to Chan and Tong's (1986) for threshold autoregressive models (TAR), Hamilton's (1989) for Markov-switching regime, and Teräsvirta's (1994) in the case of smooth transition models. For the last class of models, which is the one implemented in this research study, there are two different perspectives for state indicator. This could be defined either as logistic function (LSTAR) or exponential function (ESTAR). But, given the fact that there are findings for identification and estimation issues that make ESTAR models unsuitable for econometric modelling (Buncic, 2019), we prefer the logistic approach to control for the smoothness of the transition function. Among others, the LSTAR approach is implemented by Teräsvirta (1994), Lopes & Salazar (2006), and Dijk et al. (2002).

Within the literature that employs a regime-switching type of nonlinearity of effects of monetary policy during recessions and expansion, Peersman & Smets (2002) use multivariate extensions of Markov-Switching regressions allowing one to endogenously determine the phase of the economy and test the existence of different effects in the two states. The results estimated suggest that, on average, the short-term interest rate movements have significantly larger effects on output growth in recession than in boom periods. Bruns & Piffer (2021) prove similar conclusions by extending the smooth transition vector autoregression model to allow for identification under external instruments and sign restriction.

After years of empirical research and methodological advances, there is still uncertainty around the effects of monetary policy. The magnitude and the sign of the responses depend on the dataset, identification strategy, model specification, and also on the sample period. Hence, imperfect and asymmetric information or price rigidities are some of the reasons that increases in short-term interest rates could lead to countercyclical responses entitled „puzzles". This is equivalent to a short-term increase in output or prices in response to monetary contraction during recessions.

Bolboacă & Fisher (2019) investigate via a recursive identification the state-dependent effects on news shocks about technological information indicating that the probability of a regime switch is highly influenced by the news shocks. Moreover, the response to a news shock is larger in an expansion than in a recession, the intuition for those differences is related to increased uncertainty of the economic agents about what to expect when the economy is in recession.

A different strand of the research field investigates the relationship between monetary policy and uncertainty, arguing that the uncertainty shocks have been recently identified as one of the drivers of the business cycles. Therefore, some counterfactual simulations suggest that the effectiveness of monetary policy actions is more pronounced in expansions than in recessions (see Caggiano et al., 2017).

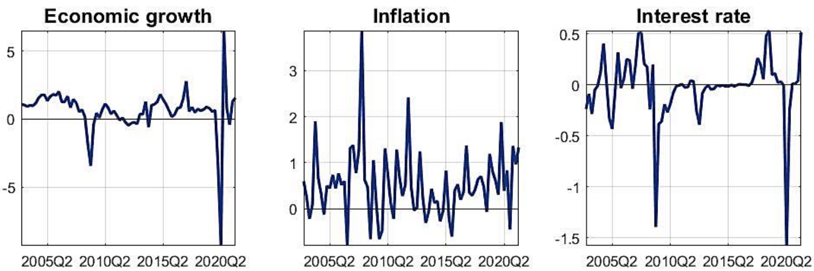
3. Research Questions / Aims of the Research

We contribute to the state of the art by studying whether the monetary policy of shocks produces effects conditioned by the state of the economy (expansion vs. recession). The analysis is conducted on three Central - Eastern European emerging markets that point out similar economic characteristics (Czech Republic, Romania, and Poland). To distinguish between periods that the economy is situated on expansionary or recessionary phases, we estimate the cyclical component of the economy via a classical Hodrick-Prescot filter. The regime-dependence is represented by a logistic function for switching between cyclical positions when the economy is "overheated" and periods when the actual output is below the potential output.

The results presented in this paper validate the hypothesis of the existence of asymmetric behaviour of the central bank over the business cycle. We also find some counterintuitive responses, defined by the literature as "economic puzzles", that could be potentially explained for example by the price rigidity. Moreover, these results could potentially indicate the need for another way of identification of shocks, such as sign restrictions (Uhlig, 2005) rather than the Cholesky decompositions. Also, we demonstrate that for the Czech Republic data, the hypothesis of nonnormality is rejected, therefore we did not perform impulse response functions.

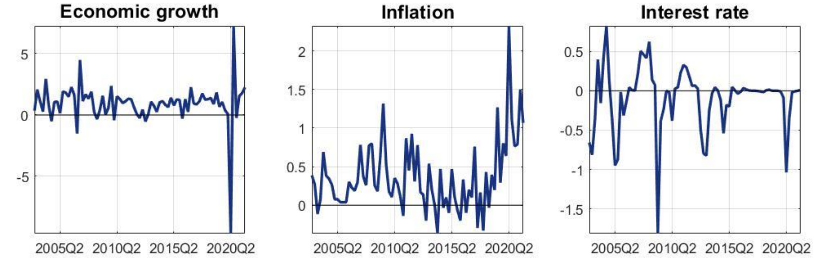
The quarterly dataset used in this paper is based on macroeconomic variables that are useful to be chosen when studying the possibility of nonlinearity of the business cycles. In this context, we use the short-term (3-months) interbank interest rates as a proxy for the monetary policy rate, introduced in absolute differences in the VAR model. Also, we include the economic growth calculated as a percentage change of real gross domestic product and a measure of core consumer prices inflation calculated from a harmonized index of consumer prices excluding food, energy, alcohol, and tobacco. All series are provided by the Eurostat database for the period 2003Q1-2021Q3. The evolutions are illustrated in Figure 1 to Figure 3.

Figure 1. The evolution of data series in period 2003Q1 – 2021Q3 for Czech-Republic



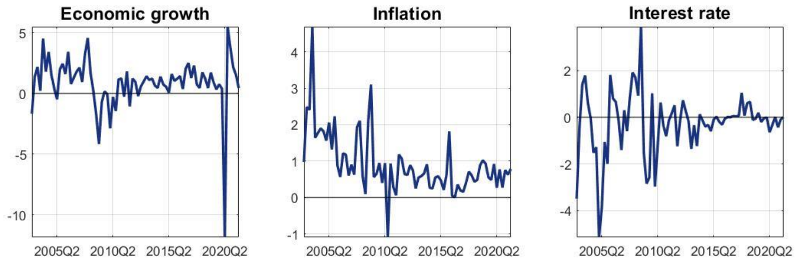
Source: Authors'calculations, data available on Eurostat.

Figure 2. The evolution of data series in period 2003Q1 – 2021Q3 for Poland



Source: Authors'calculations, data available on Eurostat

Figure 3. The evolution of data series in period 2003Q1 – 2021Q3 for Romania



Source: Authors'calculations, data available on Eurostat.

We test linearity versus nonlinearity by applying Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). According to Table 1, for the Czech Republic, it has been rejected the nonlinearity hypothesis in the vector autoregressive model. If we apply the methodology presented in the section above, the results are not conclusive. In the case of Poland, the values for linear and non-linear models are very close, even if the non-linear model is not recommended. Therefore, we will estimate the Smooth Transition Autoregressive model only for Poland and Romania.

Table 1. Lag length criteria (AIC and BIC) for non-linear model vs. linear model

Country	**Non-linear model**		**Linear model**	
	AIC	**BIC**	**AIC**	**BIC**
Czech - Republic	-3.4215	-3.2035	-2.7089	-2.6155
Poland	-3.2642	-3.0463	-3.0842	-2.9908
Romania	0.96747	1.1854	1.2458	1.3392

Source: Authors' contribution.

4. Research Methods

The methodology introduced in the following is closely related to the smooth transition vector autoregression model (STVAR) using Bayesian estimation techniques as in Auerbach & Gorodnichenko (2010) and Gefang & Strachan (2010). In this paper, the smooth regime-switching model allows for differentiated responses to monetary policy shocks across recession and expansion. We define these two regimes by the deviations of actual GDP from its potential, assessed by a logistic function $F(s_t)$. This can be interpreted as the probability of the underlying regime 2 (recession). The model specification for the vector of data Y_t is represented as

$$Y_t = \left(1 - F(s_{t-1})\right) \sum_{j=1}^{p} A_{1,j} Y_{t-j} + F(s_{t-1}) \sum_{j=1}^{p} A_{2,j} Y_{t-j} + \varepsilon_t \quad (1)$$

$$u_t \sim N(0, \Omega_t)$$

$$\Omega_t = \left(1 - F(s_{t-1})\right) \Omega_1 + F(s_{t-1}) \Omega_2 \quad (2)$$

$$F(s_t) = \frac{e^{-\gamma \hat{s}_t}}{1 + e^{-\gamma \hat{s}_t}},\ \gamma > 0,\ \ \hat{s}_t = \frac{s_t - \mu}{\sigma_s} \quad (3)$$

The nonlinear vector autoregressive process of order p allows for two types of difference in the propagation of structural shocks as in Auerbach and Gorodnichenko (2010): i) dynamic via differences in lag polynomials and ii) contemporaneous via differences in the matrix of covariances of disturbances. In other words, this basic specification of the nonlinear model could be set up as a weighted sum of two linear models with the estimated coefficients for the lagged variables (A_1, A_2) and the matrix of covariances of the residuals (Ω_1, Ω_2).

The regime-switching is assumed to be captured by the first order logistic smooth transition function $F(s_t)$, defined by the transition variable s_t, which is normalized so that γ is scale-invariant. Parameter $\gamma > 0$ determines the speed of the smooth transition. In this paper, for a smooth curvature, we calibrated it to 10 due to the Auerbach & Gorodnichenko (2010) findings suggesting that point estimates for γ to be above 5 and 10, so that the model to be best described by switching regimes at certain thresholds. When $\gamma \to \infty$, the transition logistic function becomes a Dirac function and the model converges to a two-regime threshold VAR. When $\gamma = 0$, $F(s_t)$ is constant, equal to 0.5 the model collapses to a linear VAR. This convention of non-negative γ, permits that the behavior of the system described the coefficients matrix A and covariance matrix of residuals Ω to be in a (sufficiently) deep recession (i.e. $F(s_t) \approx 1$) or being in a (sufficiently) deep expansion (i.e. $1 - F(s_t) \approx 1$).

The parameter estimates and their standard errors are computed using Monte Carlo Markov chain methods. Following Bayes' theorem, the prior is combined with the information contained in the data, as captured by the likelihood function to obtain the posterior probability distribution for the estimates.

The log-likelihood function that has to be maximized is:

$$\log L(\theta) = constant - \frac{T}{2}\log|\Omega_t| - \frac{1}{2}\sum_{t=1}^{T} \varepsilon_t' \ \Omega_t^{-1} \varepsilon_t \quad (4)$$

Where the vector of

$$\varepsilon_t = Y_t - \left(1 - F(s_{t-1})\right) \sum_{j=1}^{p} A_{1,j} Y_{t-j} - F(s_{t-1}) \sum_{j=1}^{p} A_{2,j} Y_{t-j}\ . \quad (5)$$

Conditional on γ, Ω_1 ,Ω_2, the coefficients can be estimated by minimizing $\frac{1}{2}\sum_{t=1}^{T} \varepsilon_t' \ \Omega_t^{-1} \varepsilon_t$. If we note

$$W_t = \left[\left(1 - F(s_{t-1})\right) Y_{t-1} \ \ F(s_{t-1}) \ Y_{t-1} \ \dots \left(1 - F(s_{t-1})\right) Y_{t-p} \quad F(s_{t-1}) \ Y_{t-p}\ \right]$$

It can be proved that the first-order condition with respect to A is given by the representation

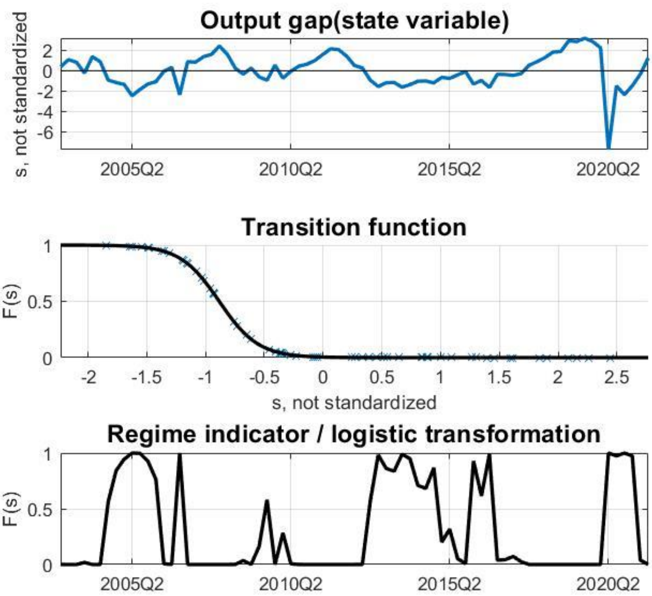
$$vecA' = (\sum_{t=1}^{T}[\,\Omega_t^{-1} \otimes W_t' W_t]\,)^{-1}\, vec\,(\sum_{t=1}^{T} W_t' Y_t \Omega_t^{-1}) \qquad (6)$$

To ensure positive definiteness of the variance-covariance matrix, we estimate the alternative vector $\Psi = [chol(\Omega_1), chol\,(\Omega_2), A_{1,j}, A_{2,j}]$. To compute the posterior estimates we implement the Markov Chain Monte Carlo (MCMC) simulation via Metropolis- Hasting algorithm using MATLAB R2018a software.

5. Findings

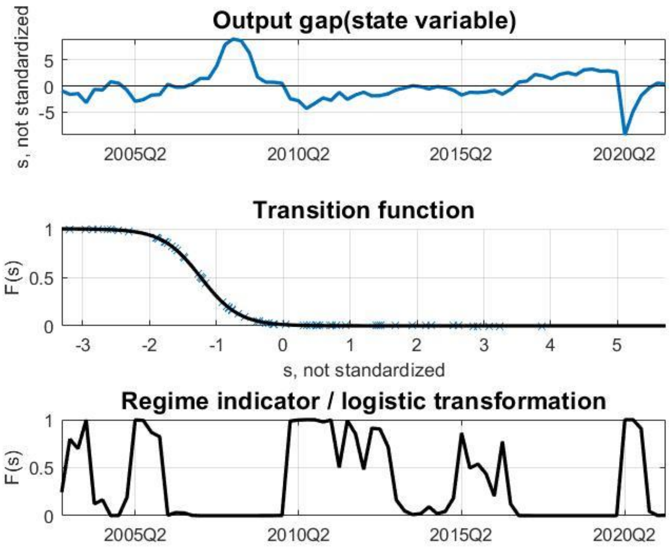
As we mentioned before, we identify the transition between the two distinct phases of the business cycle, recession, and the expansion using a state variable given by the output gap, calculated by a simple Hodrick - Prescott filter. The transition between these two distinct economic regimes is smooth, as a result of logistic indicator function $\boldsymbol{F(s_t)}$. In the last representation of Figure 4 and Figure 5 it is drawn the regime indicator, meaning that for a level of 1, there is a 100% probability for the economy to be situated in periods with negative output gap (as we can see the outbreak of COVID-19 pandemic crises in 2020, that generated significant drops in output, both for Poland and Romania).

Figure 4. The state variable and the transition function for Poland



Source: Authors' contribution.

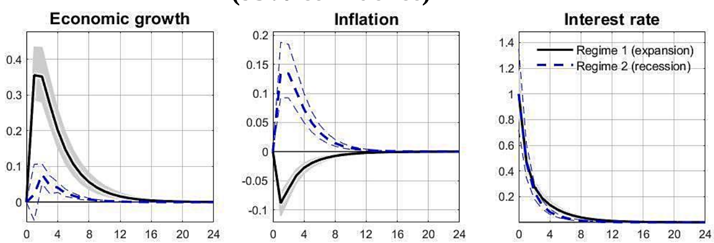
Figure 5. The state variable and the transition function for Romania



Source: Authors' contribution.

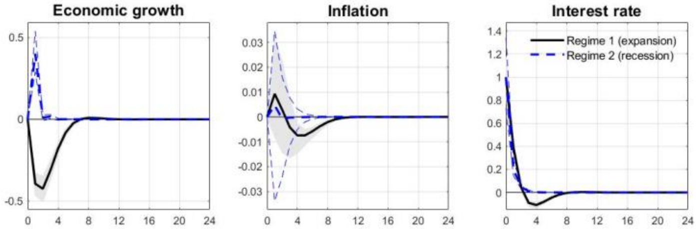
Following an increase of one standard deviation in the short-term interest rate, the responses of the shock in output and inflation are represented in Figure 6 and Figure 7. In the case of Poland, we can see results that are in line with economic theory only regarding inflation in Regime 1 (expansion). Most exactly, an increase in interest rate, decreases inflation with about 0.05 percentage points when economy is above its potential. For the recession case, we can observe a"price puzzle" that is potentially explained by the nominal price rigidities or other factors that are not quantified in this research study. The economic growth seems to be positively driven by a monetary policy shock in expansion, while for the second regime, the results are not significant at 95% confidence level.

Figure 6. Impulse responses functions of monetary policy shock for Poland (95% confidence)



Source: Authors' contribution.

Figure 7. Impulse responses functions of monetary policy shock for Romania (95% confidence)



Source: Authors' contribution.

As for Romania, an increase in the interest rate depresses economic activity in expansion by almost 0.5 percentage points, while for prices, the results don't put forward economic interpretation due to the fact that there are outside of confidence interval. Also, the estimated effects of the shock are gradually dissipated in the medium-term. A better way to address these issues is a different calibration of parameters or the identification of business cycles phases by a multivariate, much complex filter.

6. Conclusions

This paper attempts to assess the monetary policy mechanism from the perspective of a smooth transmission of shocks at the macroeconomic level. This analysis is developed for the CEE countries that have similar characteristics in terms of the business cycle. The method introduced in this study is widely used among research papers and it is based on the Bayesian Smooth Transition Vector Autoregressive model (STVAR) that allows for nonlinearity via a two regime-dependent model.

The preliminary results reject the hypothesis on nonlinearity for the Czech Republic economy, therefore, this specification of the model is not appropriate to be applied in this case. Consequently, we estimate the impulse responses of the monetary policy shock for Romania and Poland. We obtain results that are in line with economic theory (i.e., an increase in interest rate depress economic activity and diminish inflation) only in expansion regime for inflation in Poland. Similarly, in an expansion regime, the economic growth is decreased in Romania's case. Also, there are shreds of evidence of "price puzzles", possibly explained by the factors that are not incorporated in this study. These findings could be a starting point for further developments in the area by including other variables and recalibrating the model.

References

[1] Auerbach, A.J., Gorodnichenko, Y. (2010). Measuring the output responses to fiscal policy, *NBER Working Paper Series*, No. 16311.

[2] Bolboacă, M., Fischer, S. (2019). *News shocks: Different effects in boom and recession? Working Paper*, No. 19.01, Swiss National Bank, Study Center Gerzensee.

[3] Bruns, M., Piffer, M. (2021). *Monetary policy shocks over the business cycle: Extending the Smooth Transition framework*, University of East Anglia School of Economics Working Paper Series 2021-07, School of Economics, University of East Anglia, Norwich, UK.

[4] Caggiano, G., Castelnuovo, E., Nodari, G. (2017). Uncertainty and monetary policy in good and bad times: A replication of the VAR investigation by Bloom (2009). CESifo Working Paper, No. 6630.

[5] Cecchetti, S.G. (2000). Making monetary policy: objectives and rules, *Oxford Review of Economic Policy*, 16(4), pp. 43-59.

[6] Chan, K.S., Tong, H. (1986). On estimating thresholds in autoregressive models, *Journal of Time Series Analysis*, 7(3), pp. 179-190.

[7] Dijk, D.V., Teräsvirta, T., Franses, P.H. (2002). Smooth transition autoregressive models: a survey of recent developments, *Econometric Reviews*, 21(1), pp. 1-47.

[8] Gefang, D., Strachan, R. (2010). Nonlinear impacts of international business cycles on the UK: a Bayesian smooth transition VAR approach, *Studies in Nonlinear Dynamics and Econometrics*, 14(1), pp. 1-33.

[9] Hamilton, J.D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycles, *Econometrica*, 57, pp. 357-384.

[10] Lo, M.C., Piger, J. (2005). Is the response of output to monetary policy asymmetric? Evidence from a regime-switching coefficients model, *Journal of Money, Credit and Banking*, 37(5), pp. 865-886.

[11] Lopes, H.F., Salazar, E. (2006). Bayesian model uncertainty in smooth transition autoregressions, *Journal of Time Series Analysis*, 27 (1), pp. 99-117.

[12] Peersman, G., Smets, F. (2002). Are the effects of monetary policy in the Euro Area greater in recessions than in booms? In L. Mahadeva and P. Sinclair (Eds.), *Conference on Transmission Mechanism of Monetary Policy*, pp. 28-48. Cambridge University Press.

[13] Uhlig, H. (2005). What are the effects of monetary policy on output? results from an agnostic identification procedure, *Journal of Monetary Economics*, 52(2), pp. 381–419.

[14] Taylor, J.B. (1993). Discretion versus policy rules in practice, *Carnegie-Rochester Conference Series on Public Policy*, 39, pp. 195-214.

[15] Teräsvirta, T. (1994). Specification, estimation, and evaluation of smooth transition autoregressive models, *Journal of the American Statistical Association*, 89(425), pp. 208-218.

[16] Weisse, C.L. (1999). The asymmetric effects of monetary policy: A nonlinear vector autoregression approach, *Journal of Money, Credit and Banking*, 31(1), pp. 85-108.