2. ASYMMETRIES IN THE EXCHANGE RATE PASS-THROUGH INTO ROMANIAN PRICE INDICES[1]

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Abstract

The article examines the asymmetries of the exchange rate pass-through (ERPT) into import, producer and consumer price indices for the Romanian economy. Using three econometric methods naturally equipped to capture various types of asymmetries (MS-VAR, TAR and SETAR), important asymmetries with respect to sign and size of the exchange rate, size of inflation and time period have been detected.

Keywords: exchange rate, pass-through, import prices, producer prices, consumer prices, vector autoregression, asymmetries, MS-VAR, TAR, SETAR

JEL Classification: C32, E31, E52, F31, O52

1. Introduction

In Cozmâncă and Manea (2009), applying the methodology developed by McCarthy (2000), we determined the size and described the dynamics of the exchange rate pass-through (ERPT) into the Romanian price indices. The econometric methods employed were RVARS (on different price indices and/or on a rolling window) and Sign-restriction VARs. Employing the same economic methodology, but different econometric method, this paper investigates the asymmetries in the ERPT. The method of choice is Markov Switching VAR in different specifications (MS-VAR, TAR and SETAR), as various facets of the phenomenon are probed. The most important sources of asymmetries investigated regard time dynamics, sign and size of movements in the exchange rate and the size of the monthly inflation rate.

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[1] *The authors are very grateful to the excellent comments they received from Moisă Altăr, Ciprian Necula and Răzvan Stanca. All remaining errors are entirely the authors' responsibility. The views expressed in this paper are those of the individual authors and do not necessarily reflect the position of the National Bank of Romania, RBS or the Academy of Economic Studies.*

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2. The economic framework

Although many articles consider that the degree of pass-through is not affected by the direction of the change in the exchange rate, there could be cases in which pass-through may vary depending on whether the importer's currency is appreciating or depreciating or on how big or small are the movements of the exchange rate.

Pollard and Coughlin (2004) present the pricing decisions taken by exporters in the context of exchange rate changes. Thus, when production is realized only with domestic inputs, in the context of the depreciation of home's currency (the importer's currency), a foreign firm will have to take two main decisions: on the one hand to reduce its mark-up in order to keep the home currency price of its product (no pass-through), and, on the another hand, to maintain its mark-up by rising the home currency price to cover the entire depreciation (in this case will probably lose some market share) (complete pass-through). Another decision will be a combination of these two (partial pass-through). In the first case of no pass-through, the sales of the foreign firm abroad will be maintained, but its revenues will decline, implying a decline in its profits. In the case of complete pass-through, the prices will remain unchanged, but sales in the home country will decline, which will result in a drop in revenue and, consequently, in profit. The size of the decline in profit is determined by the elasticity of demand for that certain good in the home country. In the case of partial pass-through, both the received price and the sales will drop. In the case of the depreciation of the home currency, the negative consequences on the profits could be diminished by using both foreign and local inputs in production.

On the other hand, the appreciation of the home currency has a positive impact for the foreign firm: the firm may increase its mark-up by keeping the prices constant (no pass-through) or may chose to increase market share by cutting the prices in accordance with the appreciation (complete pass-through) or some combination of both. While in the case of no pass-through, the prices rise and the quantity remains unchanged, in the case of complete pass-through the opposite occurs. In the case of partial pass-through, both elements increase. In all these cases, the profit will rise, but this will depend on the elasticity of demand for that certain good in the home country.

Pollard and Coughlin (2004) present the main explanations for asymmetric pass-through.

A first explanation could reside in the firms purpose to maintain the *market share*. One possibility is that the firms to maintain their prices constant in the face of exchange rate fluctuations, that imply profits decline during periods of exchange rate appreciation and profits increase during periods of depreciation. In this case, pricing to market implies symmetric pass-through. Another possibility is that the firm will adjust their mark-ups. Thus, an appreciation of the importing country's currency will give the foreign firms the opportunity to lower the import prices and thus to rise their market share, while keeping their mark-ups constant. On the contrary, in order to reserve their market share in the case of the depreciation, the firms will have to absorb a part of the inflationary impact that will determine a decline in their mark-ups. Given the fact that the foreign firms' actions are restricted by the size of their mark-ups, the pass-through will be higher for appreciation than for depreciation. Thus, the pass-through will be asymmetric.

Another explanation for asymmetries in pass-through focuses on *production switching*, namely on the fact that foreign firms will tend to switch towards inputs produced in their own countries when the exchange rate appreciates and inversely when the exchange rate depreciates. Thus, in the case of depreciation, foreign firms will use imported inputs, implying no pass-through.

The *binding quantity constraints* refers to the incapacity of exporting firms to rise the production in the importing country due to capacity constrains in their distribution network or due to trade restrictions. When the importer's currency depreciates the revenues expressed in foreign currency decline. In this context the foreign firm could increase sales up to the capacity constraints limit, as an alternative to increase prices. In the case of appreciation, the revenues expressed in foreign currency will increase. In this context, the exporter will maintain the price level intact. Thus, the ERPT is higher in the case of depreciation than in the case of appreciation of the exchange rate.

Menu costs together with the type of price invoicing which is followed determine the asymmetry with respect to the size of exchange rate change. The cost of changing prices enlarges the probability that firms will adjust the invoice price only if the modify in the exchange rate is above some threshold. The direction of the asymmetry in pass-through will depend on the currency of invoice. Thus, when imports are invoiced in the importer's currency, a small change in the exchange rate will not determine the adjustment of local prices and the foreign firm will absorb the modification in the exchange rate through the price it receives (expressed in its currency) - in this case pass-through is zero. But if the change in the exchange rate is significant, the foreign firm will adjust local prices. While in the case of partial pass-through both local currency prices and foreign currency prices will change, in the case of complete pass-through foreign currency prices will not change. Therefore, with invoicing in the importer's currency, pass-through will be larger when exchange rate changes are large than when they are small. When imports are invoiced in the exporter's currency the pass-through will be complete (will fully determine the local prices) at a small change in the exchange rate. The exporters adjust the foreign currency prices when the exchange rate change is large, thus dropping the amount of pass-through. Thus, in the case of exporter's currency invoicing the pass-through is greater when exchange rate changes are small.

3. Econometric methodology

A popular method for determining asymmetries is by using Markov Switching models. This class of models have been proposed by Goldfeld and Quandt (1973) in the form of switching regressions. Another step in Markov Switching models analysis is due to Hamilton (1989), which extended the methodology to the case of dependent data, specifically on autoregressions. Important contributions to the use of Markov Switching models combined with vector autoregression are due to Hamilton (1989) and Krolzig (1998). As data for emerging economies could present structural breaks or shifts, this class of models (Markov Switching Vector Autoregression - MS-VAR) is naturally equipped to capture the properties of the data used. As presented in Hamilton (1994)[2] the changing behaviour of variables could be explained by the fact that the process could be influenced by an unobservable random variable s_t^*, named *state* or *regime* that the process was in at the time *t*. As s_t^* takes only discrete values, the simplest time series model for a discrete-valued random variable is Markov chain. Considering s_t a random variable that can only take integer values $\{1,2,\dots,M\}$, the probability that s_t will be equal to some particular value *j* depends only on the most recent value s_{t-1}, thus the process will follow an M-state Markov chain with transition probabilities $\{p_{ij}\}_{i,j=1,2,\dots M}$. The transition probabilities p_{ij} give the probability that state *i* will be followed by state *j*.

$$P\{s_t = j \mid s_{t-1} = i, s_{t-2} = k, \dots\} = P\{s_t = j \mid s_{t-1} = i\} = p_{ij} \quad \textbf{(1)}$$

$$p_{i1} + p_{i2} + \dots + p_{iM} = 1 \quad \textbf{(2)}$$

The transition matrix P $(M \times M)$ is:

$$P = \begin{bmatrix} p_{11} & p_{21} & \cdots & p_{M1} \\ p_{12} & p_{22} & \cdots & p_{M2} \\ \vdots & \vdots & \vdots & \vdots \\ p_{1M} & p_{2M} & \cdots & p_{MM} \end{bmatrix} \quad \textbf{(3)}$$

Considering a random vector ξ_t $(M \times 1)$ for which its jth element is equal to 1 when $s_t = j$ and it is equal to 0, otherwise, it results the following Markov chain representation:

$$\xi_t = \begin{cases} (1, & 0, & 0, & \dots & 0)' & when\ s_t = 1 \\ (0, & 1, & 0, & \dots & 0)' & when\ s_t = 2 \\ & & \vdots & & & \vdots \\ (0, & 0, & 0, & \dots & 1)' & when\ s_t = M \end{cases} \quad \textbf{(4)}$$

Thus, the conditional expectation of ξ_{t+1} is given by the *i*th column of the matrix P and in addition, when $s_t = i$ the vector ξ_t corresponds to the ith column of $I_M(M \times M)$identity matrix, the conditional expectation could be expressed as $P\xi_t$. And from the Markov property in eq. (1) it results:

$$E(\xi_{t+1} \mid s_t = i) = \begin{bmatrix} p_{i1} \\ p_{i2} \\ \vdots \\ p_{iN} \end{bmatrix} \quad \textbf{(5)}$$

[2] *The theoretical framework presented is that of Hamilton (1994).*

$$E(\xi_{t+1}|\,\xi_t) = P\xi_t$$
$$E(\xi_{t+1}|\,\xi_t, \xi_{t-1}, \dots) = P\xi_t$$

The eq. (5) can be expressed as a first-order vector autoregression for ξ_t, where the innovation v_t is a martingale difference sequence, with average zero.

$$\begin{aligned} \xi_{t+1} &= P\xi_t + v_{t+1} \\ v_{t+1} &\equiv \xi_{t+1} - E(\xi_{t+1}|\,\xi_t, \xi_{t-1}, \dots) \end{aligned} \qquad \textbf{(6)}$$

Essential properties of theoretical MS-VAR models are that of ergodicity and irreducibility. Thus, according to Hamilton (1994), an M-state Markov chain is said to be reducible if there exists a method to mark the states (a method to decide which cell to be state 1, state 2 and so on) such that the transition matrix to be written in the following form:

$$P = \begin{bmatrix} B & C \\ 0 & D \end{bmatrix} \qquad \textbf{(7)}$$

where: B is a $(K \times K)$ matrix for some $1 \leq K < M$. Thus, P is upper block-triangular. Therefore, once the process enters a state j, such that $j \leq K$, there is no possibility of ever returning to one of the states $K+1, K+2, \dots M$. In such a case it is said that the state *j* is an *absorbing state* and the Markov chain is *reducible*. Otherwise, it is name *irreducible*.

For an M-state irreducible Markov chain with transition matrix P, if the one of the eigenvalues of P is unity and all that all other eigenvalues of P are inside the unit circle, the Markov chain is *ergodic*.

Krolzig (1998) considers a generalization of the basic finite order VAR model of order p. In the generalization of the mean-adjusted VAR(p) model, Krolzig (1998) considers Markov-Switching vector autoregressions of order p and M regimes:

$$(y_t - \mu(s_t)) = A_1(s_t)\,(y_{t-1} - \mu(s_{t-1})) + \dots + A_p(s_t)\,(y_{t-p} - \mu(s_{t-p})) + e_t \qquad \textbf{(8)}$$

where: $e_t \sim NID\,(0, \Sigma(s_t))$ and $\mu(s_t), A_1(s_t), \dots, A_p(s_t), \Sigma(s_t)$ are parameter shift functions describing the dependence of the parameters $\mu, A_1, \dots, A_p, \Sigma$ on the realized regime s_t.

Model (8) presents an immediate one-time jump in the process mean after a change in the regime. There could be the case in which the mean smoothly approaches to a new level after the transition from one state to another. In this case, the regime-dependent intercept term $\alpha(s_t)$ could be used. From eq. (8), considering expression $\mu = (\mathrm{I_n} - A_1 - A_2 - \dots - A_p)^{-1}\,\alpha$, it results:

$$y_t = \alpha\,(s_t) + A_1(s_t)\,y_{t-1} + \dots + A_p(s_t)\,y_{t-p} + e_t \qquad \textbf{(9)}$$

The following table presents the types of Markov-Switching vector autoregressive models.

Table 1

Markov-Switching Vector Autoregressive Models

		MSM μ varying	MSI Specification μ invariant	 α varying	 α invariant
A_j invariant	Σ invariant	MSM - VAR	linear MVAR	MSI - VAR	linear VAR
	Σ varying	MSMH - VAR	MSM-MVAR	MSIH - VAR	MSH-VAR
A_j varying	Σ invariant	MSMA - VAR	MSA-MVAR	MSIA - VAR	MSA-VAR
	Σ varying	MSMAH - VAR	MSAH-MVAR	MSIAH - VAR	MSAH-VAR

Source: Krolzig (1998).

According to Krolzig (1998), the mean-adjusted form (8) and the intercept form (9) of the MS(M)-VAR model are not equal as while a permanent regime shift in the mean $\mu(s_t)$ causes an instant jump of the observed time series vector onto its new level, the dynamic response to a once-and-for-all regime shift in the intercept term $\alpha\ (s_t)$ is the same to an equivalent shock in the white noise e_t.

The MS-VAR models differ in their assumptions concerning the stochastic process generating the regime. A special case is that in which *the mixture of normal distributions model* is characterized by serially independently distributed regimes (Hamilton(1994)). In this case the density of y_t conditional on the random variable s_t which takes the value *j* is:

$$f(y_t|\ s_t = j;\ \theta) = \frac{1}{\sqrt{2\pi\sigma_j}} \exp\left\{\frac{-(y_t - \mu)^2}{2\sigma_j^2}\right\} \quad \textbf{(10)}$$

for $j = 1,2,3,\dots, M$. θ is a vector of population parameters that include $\mu_1, \dots, \mu_M$ and $\sigma_1^2, \dots, \sigma_M^2$. The unobserved regime $\{s_t\}$ is generated by a probability distribution, for which the unconditional probability that s_t takes on the value *j* is denoted π_j, these probabilities also being included in θ.

$$P\{s_t = j;\ \theta\} = \pi_j$$
$$\theta \equiv (\mu_1, \dots, \mu_M, \sigma_1^2, \dots, \sigma_M^2, \pi_1, \dots, \pi_M)' \quad \textbf{(11)}$$

Considering the conditional probability of an event A given an event B, we can write *the joint density-distribution function of* y_t *and* s_t.

$$P\{A|B\} = \frac{P\{A\ and\ B\}}{P\{B\}}$$
$$P\{A\ and\ B\} = P\{A|B\} \cdot P\{B\} \quad \textbf{(12)}$$
$$p(y_t, s_t = j;\ \theta) = f(y_t|\ s_t = j;\ \theta) \cdot P\{s_t = j;\ \theta\}$$

Replacing in this expression eq. (10) and (11), it results:

$$p(y_t, s_t = j; \theta) = \frac{\pi_j}{\sqrt{2\pi\sigma_j}} \exp\left\{\frac{-(y_t - \mu)^2}{2\sigma_j^2}\right\} \quad \textbf{(13)}$$

The *unconditional density of* y_t will be given by the following sum:

$$f(y_t; \theta) = \sum_{j=1}^{M} p(y_t, s_t = j; \theta) \quad \textbf{(14)}$$

In the context of s_t being distributed iid across different data y_t, the *log likelihood* for the observed data can be calculated as:

$$\mathcal{L}(\theta) = \sum_{t=1}^{T} log f(y_t; \theta) \quad \textbf{(15)}$$

From the definition of the conditional probability it also results that:

$$P\{s_t = j \mid y_t; \theta\} = \frac{p(y_t, s_t = j; \theta)}{f(y_t; \theta)} = \frac{\pi_j \cdot f(y_t \mid s_t = j; \theta)}{f(y_t; \theta)} \quad \textbf{(16)}$$

Maximum likelihood (ML) estimation of the model is based on the implementation of the *Expectation Maximization (EM)* algorithm proposed by Hamilton as a special case of the EM principle developed by Dempster, Laird and Rubin (1977). Thus, Hamilton (1994) demonstrates that the maximum likelihood estimate $\hat{\theta}$ represents a solution to the following system of nonlinear equations, obtained from computing the FOC (First Order Conditions) for the Lagrangean of the log likelihood eq. (15).

$$\hat{\mu}_j = \frac{\sum_{t=1}^{T} y_t \cdot P\{s_t = j \mid y_t; \hat{\theta}\}}{\sum_{t=1}^{T} P\{s_t = j \mid y_t; \hat{\theta}\}} \quad for\ j = 1, 2, \dots, M \quad \textbf{(17)}$$

$$\hat{\sigma}_j^2 = \frac{\sum_{t=1}^{T} (y_t - \hat{\mu}_j)^2 \cdot P\{s_t = j \mid y_t; \hat{\theta}\}}{\sum_{t=1}^{T} P\{s_t = j \mid y_t; \hat{\theta}\}} \quad for\ j = 1, 2, \dots, M \quad \textbf{(18)}$$

$$\hat{\pi}_j = T^{-1} \sum_{t=1}^{T} P\{s_t = j \mid y_t; \hat{\theta}\} \quad for\ j = 1, 2, \dots, M \quad \textbf{(19)}$$

Due to the fact that eq. (17) - (19) are nonlinear, it is not possible to solve them analytically for $\hat{\theta}$ as a function of $\{y_1, y_2, \dots, y_T\}$. In this context the EM algorithm is employed. Thus, starting with an arbitrary initial value of θ, labelled $\theta^{(0)}$, the probability $P\{s_t = j \mid y_t; \theta^{(0)}\}$ is calculated from eq. (16). Then, by replacing the level of probability level in eq. (17) - (19), it results the values for $\hat{\mu}, \hat{\sigma}^2, \hat{\pi}$ from which a new estimate results $\theta^{(1)}$. This estimate is then replaced in eq. (16) and a new value for probability is obtained that will be replaced in eq. (17) - (19) in order to produce other values for $\hat{\mu}, \hat{\sigma}^2, \hat{\pi}$, that will generate a new θ. The iteration continues until the change between $\theta^{(m+1)}$ and $\theta^{(m)}$ is smaller than some specified convergence criterion.

4. Empirical analysis

Data description

The analysis is based on monthly data covering the period between 2000M01 and 2008M12.

The variables used are:

- WPI - US dollar based all Commodities Index - The source of data is IMF's International Financial Statistics (henceforth IFS). This is converted into a local currency index. The variable was seasonally adjusted using EViews 6.0 Census X12. Then it was normalized (considering 2000=100) and transformed into logarithm. (*l_wpi_u_sa_idx*);
- Output gap: The series was determined by applying Hodrick-Prescott Filter to monthly real GDP series. The monthly data were calculated by interpolating the quarterly seasonally adjusted[3] real GDP data (expressed in national currency) in logarithm through Chow-Lin method[4] using as indicator variable the industrial production. The Hodrick-Prescott Filter was applied on the series with additional twelve observations forecasted from a simple ARIMA model in order to avoid the end point problem. (*l_y_sa_yindcl_hpgap*);
- Nominal effective exchange rate: The RON nominal effective exchange rate was determined as a basket of two exchange rates, one against the EUR (70%) and the other against the USD (30%). The weights are that of EUR and USD-denominated transactions of Romania's international trading. The series was normalized (considering 2000=100) and transformed into logarithm. (*l_s_ef_sa_idx*);
- Import prices: The series used were unit value index (expressed in national currency), the source of the data being Eurostat. The series was normalized (considering 2000=100) and transformed into logarithm. (l_ivu_imp_t_sa_idx);
- Producer Price Index: The industry PPI index was used. The series was normalized (considering 2000=100) and transformed into logarithm. (l_ppi_n_sa_idx);
- Consumer Price Index: The CPI index published by Romanian National Institute of Statistics was used. The series was normalized (considering 2000=100) and transformed into logarithm (l_cpi_u_sa_idx).
- Short-term Interest Rate: computed as an arithmetic average of overnight tenor ROBID and ROBOR interest rates, the series was labelled ibon.

[3] The seasonal adjustment was made using Tramo/Seats method in Demetra 5.1.

[4] The program employed for interpolation is using Matlab R2008a, the source being Spain National Institute of Statistics (Quilis, 2004).

In order to assess the time series properties of the data unit root tests were completed. The Augmented Dickey Fuller (ADF) and the Phillips Perron (PP) tests indicate that commodities prices (l_wpi_u_sa_idx), nominal effective exchange rate (l_s_ef_sa_idx), import prices (l_ivu_imp_t_sa_idx), producer (l_ppi_n_d_idx) and consumer prices (l_cpi_u_sa_idx) are integrated of order one, I(1), while (by construction) the output gap (l_y_sa_yindcl_hpgap) is a stationary series. On the other hand, tests suggest that the short-term interest rate (ibon) is stationary, I(0).

Empirical results

Using the same data as in the previous sections of the paper, we estimated a MS-VAR belonging to the MSIAH type of model as introduced by Krolzig (1998). The program used for estimation is the Ox version 3.30 combined with the MSVAR module version 1.31k (from 2004) written by Hans Martin Krolzig.

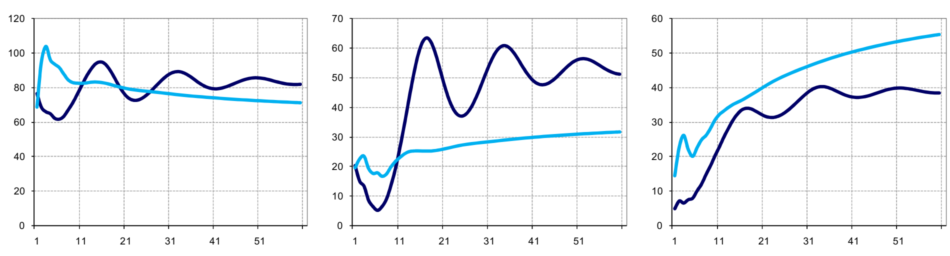
As the MS-VAR results cannot be easily interpreted, we have retrieved from the estimation program the coefficient and variance-covariance matrices for each regime (each being a VAR). These were used to compute the impulse response functions derived from the companion form VAR representation (eq. 20) combined with Cholesky identification of the shocks:

$$\xi_t = F^t \cdot C \cdot v_t \qquad \textbf{(20)}$$

The IRFs were computed using matrix operations in Microsoft Excel (for ease of use) - the matrices from the Ox program were exported in Excel form and thus they were easily linked with an IRF generating spreadsheet. The IRFs were accumulated and used to compute the pass-through coefficients for the price variables for each regime. It would have been very suggestive to be able to compute the confidence intervals for the ERPT albeit this was not possible due to the computational burden of bootstrapping each regime (as detailed in Ehrmann, Ellison and Valla (2001)), on one hand, and because the confidence intervals should have been reconstructed by dividing the confidence intervals of the accumulated IRFs for two variables (a price index and the exchange rate), on the other hand.

Figure 1

MSIAH MS-VAR model - ERPT into price indices for each of the two regimes s_t



The previous figure indicates similar pass-through for IVU prices in the two regimes and some marked differences regarding pass-through in the PPI and to a smaller extend into CPI. The first regime shows a pass-through higher for PPI and lower for CPI than the second regime. As the bulk of the observations in the second regime are concentrated at the beginning of the sample we can infer that the competition in the producer sector was relatively strong but its effects were overcompensated by an almost oligopolistic competition in the retail sector. The first regime (mostly concentrated in second part of the sample) points to a reversal compared to the second, the producer sector being more oligopolistic and the retail sector becoming more monopolistic. The next figures and Appendix 1 detail the MS-VAR estimation results and diagnostics tests. Figure 2 presents the variables used and the resulting regime probabilities. Figures 3 and 4 present the smooth and predicted errors in the model and the standard errors, on one hand and correlation and normality tests for the residuals, on the other hand. The figures indicate that the standard errors are not autocorrected and are normally distributed.

Figure 2

MSIAH MS -VAR model - Probabilities of the two regimes s_t

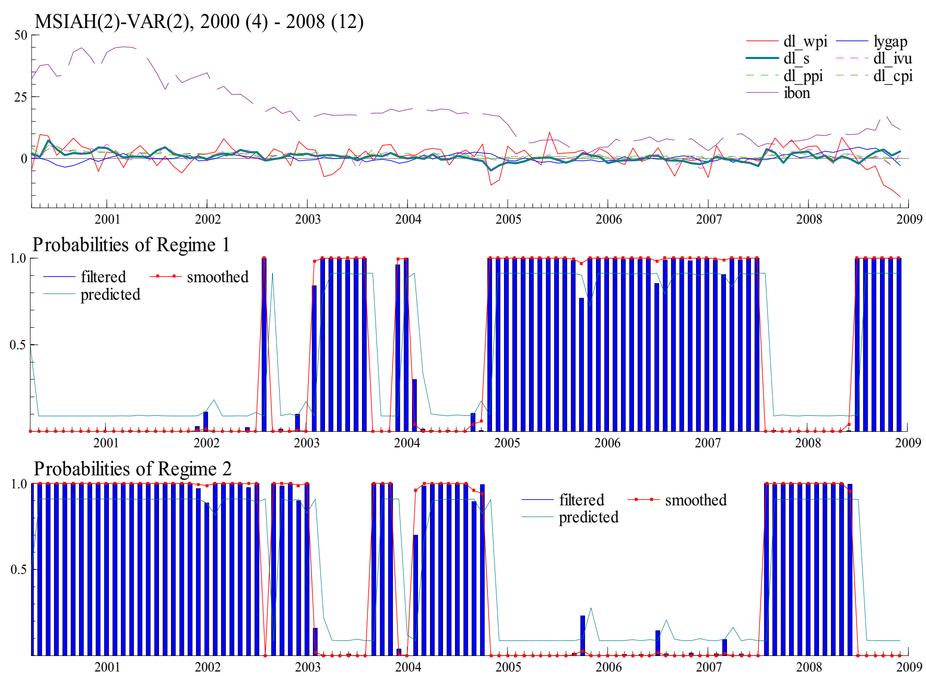


Figure 3

MSIAH MS -VAR model - Prediction error and Standard resids

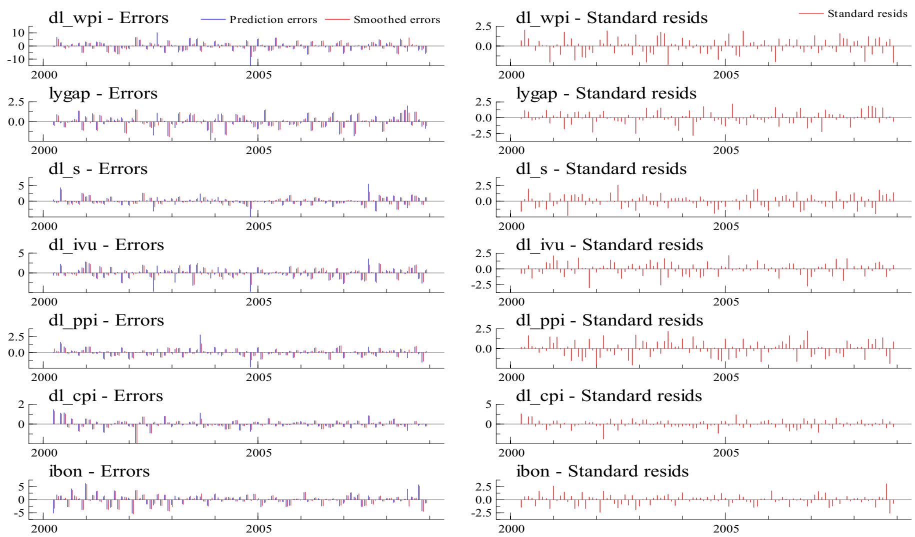


Figure 4

MSIAH MS -VAR model - Correlogram, Spectral density, Density and QQ Plot of standard resids

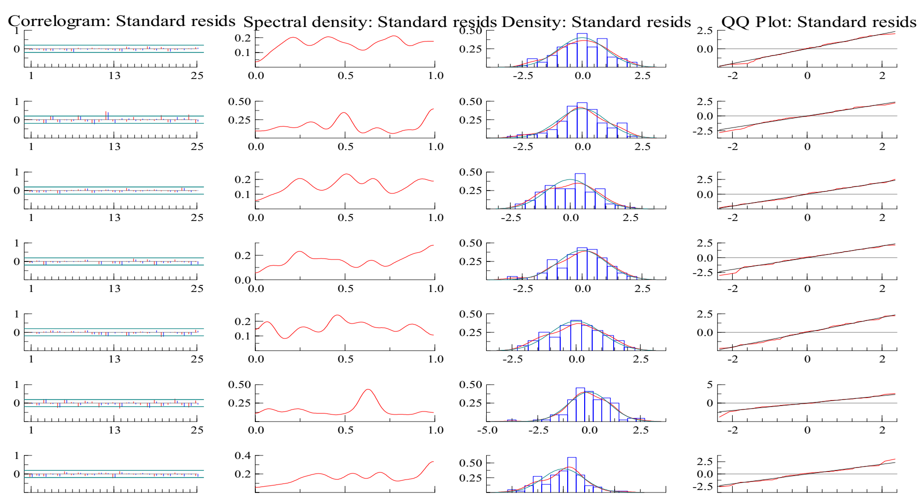


Figure 5 suggests that the model seems to capture well the data properties. The Figure 6 presents the model probabilities - the predicted h-step probabilities of each regime (almost 50%), the probability of duration and the cumulated probability of duration.

Figure 5

MSIAH MS -VAR model - Actual and fitted values

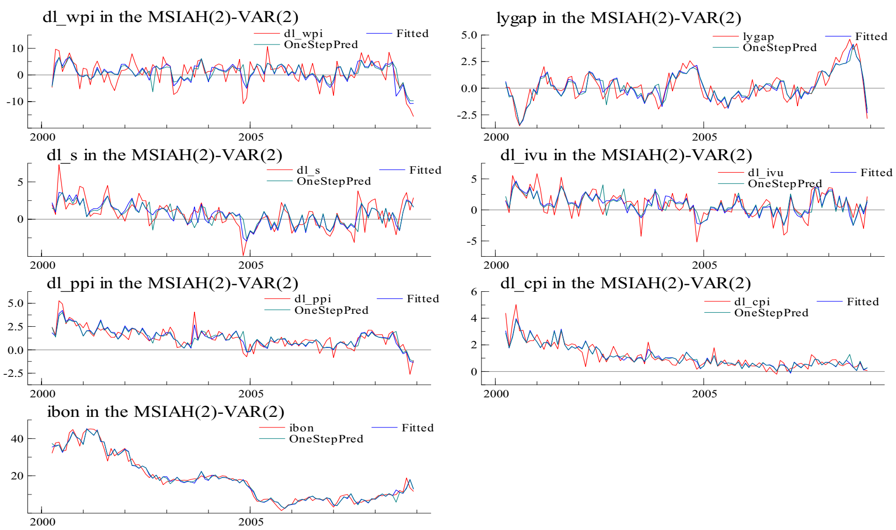
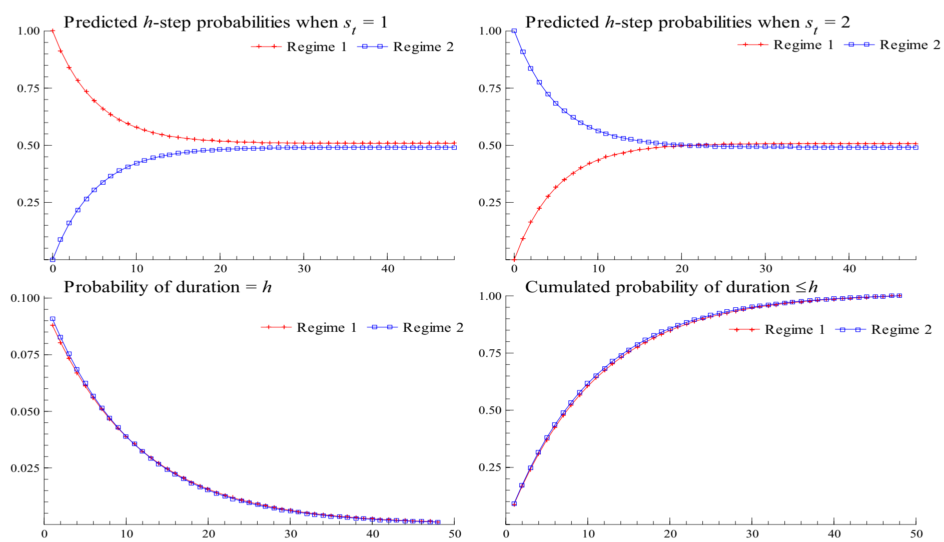


Figure 6

MSIAH MS -VAR model - Model probabilities



Threshold vector autoregressive (TAR or TVAR)

The threshold autoregressive (TAR) models were first presented by Tong & Lim (1980), being one class of non-linear autoregressive models. In contrast to Markov Switching models, in the case of TAR models the state variable is supposed to be known and observable. A general TAR model, that permits the existence of more than two regimes and more than one lag, may be written as:

$$y_t = \sum_{j=1}^{J} I_t^{(j)} (\phi_0^{(j)} + \sum_{i=1}^{p1} \phi_1^{(j)} y_{t-1} + u_t^{(j)}, r_{j-1} \leq z_{t-d} \leq r_j \quad \textbf{(21)}$$

where $I_t^{(j)}$ is an indicator function for the *jth* regime taking the value one if the underlying variable is in state j and zero otherwise. z_{t-d} is an observed variable that determines the switching point and $u_t^{(j)}$ is zero-mean independently and identically distributed error process. The TAR approach considers the $\mathbf{y}$ variable in one regime or another, given the value of z and there are discrete transitions between the regimes, in contrast with the Markov Switching approach, where the variable $\mathbf{y}$ is in both regimes with some probability at each point in time. Thus, for a given threshold r, the "probability" of the unobservable regime $s_t = 1$ is given by:

$$P\left\{s_t = 1 | \left\{s_{t-j}\right\}_{j=1}^{\infty}, \left\{y_{t-j}\right\}_{j=1}^{\infty}\right\} = I\left\{z_{t-d} \leq r\right\} = \begin{cases} 1 & if\ z_{t-d} \leq r \\ 0 & if\ z_{t-d} > r \end{cases} \quad \textbf{(22)}$$

Using the corresponding VAR version of TAR (TVAR), we will discuss the nature and extent of ERPT to price indices. We considered four different threshold variables that identify two different regimes. As in the previous section, the program used for estimation is the Ox version 3.30 combined with the MSVAR module version 1.31k from 2004 written by Krolzig (1998). We will present the evolution of the ERPT into the three price indices. The Ox outputs, including: prediction error and standard residuals, the correlogram, spectral density, density and QQ Plot of standard residuals and actual and fitted values are presented in Appendixes 2 to 5.

Time asymmetry

The first threshold variable considered is a *time variable* for which the indicator function takes value one for the period 2000M02 - 2003M12 (regime 2) and value zero for the period 2004M01-2008M12 (regime 1).

According to Figure 8, the ERPT into all price indices (import, producer and consumer price index) is lower for the second than for the first regime. However, the difference between the two regimes ERPT increases along the distribution chain. Thus, after 24 months the ERPT into import prices was 95% during the first part of the data sample (regime 2) and 78% in the second part of the data sample, the difference being of 17 percentage points. On the other hand, the difference of ERPT between the two regimes increases for producer and consumer prices. Thus, after two years the difference of ERPT between the two regimes is 26 percentage points (40% versus 14%) for producer price index and 35 percentage points (46% versus 11%) for consumer price index.

Figure 7

TVAR (Time asymmetry) - Probabilities of the two regimes s_t

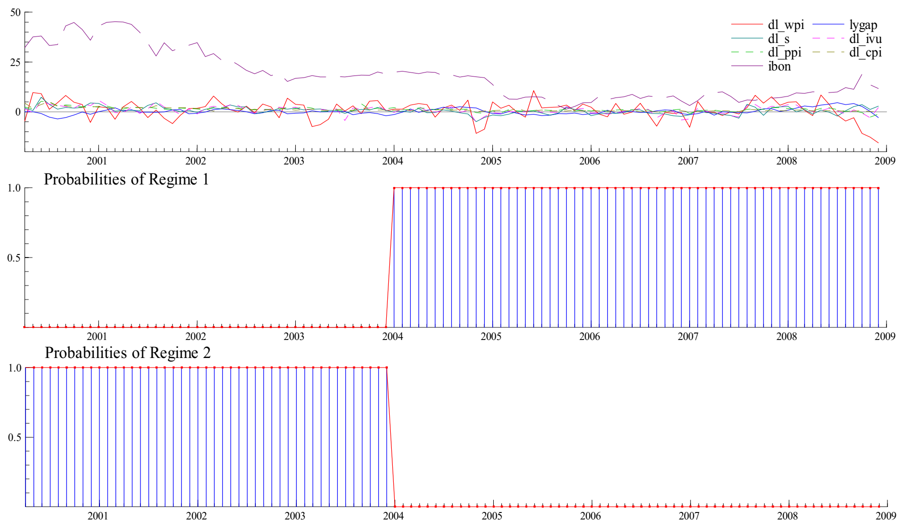
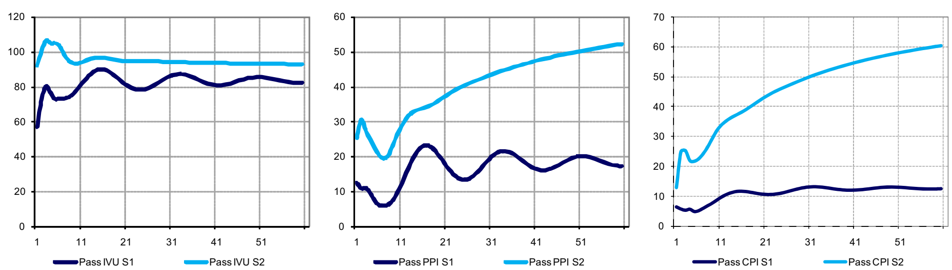


Figure 8

TVAR (Time asymmetry) - ERPT into price indices for each of the two regimes s_t



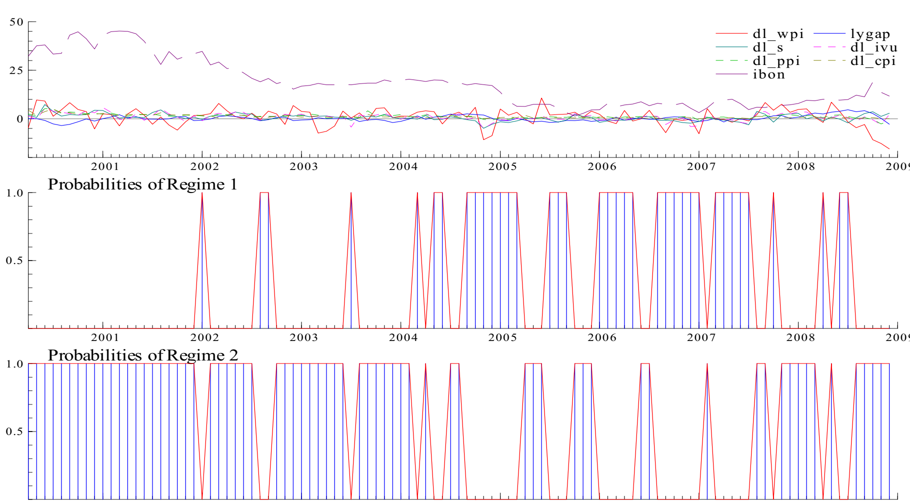
Sign of the exchange rate change asymmetry

The second threshold variable accounts the *difference between exchange rate appreciation and depreciation*. Thus, the indicator function takes value one in the case of a monthly increase (depreciation) of exchange rate and value zero in the case of a monthly decline of the exchange rate (appreciation). Thus, the first regime groups the appreciation episodes, while the second regime the ones of depreciation.

An analysis of Figure 10 indicates a significant difference regarding the behaviour of importers comparing to that of producers and retailers. Therefore, the behaviour of local importers seems to be opportunistic, the figure suggesting a higher pass-through for an exchange rate depreciation than that of an appreciation. This could indicate a widely used pricing strategy of local importers which regards depreciation as a reason for price increases. Thus, after 24 months, the ERPT in the first regime (of appreciation) is 60%, while in the second regime (of depreciation) is 78%. On the other hand, the pass-through of exchange rate appreciation is higher than that of depreciation in the case of producer and consumer price indices. An explanation of this behaviour may be the fact that domestic producers and retailers are trying to maintain their *market share*. Consequently, the appreciation regime will represent a good opportunity to increase market share, while keeping their mark-ups, while in the case of depreciation regime, the firms absorb a part of the inflationary impact, this implying the decline of their mark-ups. Another explanation would be that in periods of exchange rate depreciation, the firms will increase the weight of local products (inputs for producers and goods for the retailers) in the detriment of the foreign ones that become more expensive. The opposite occurs in the context of exchange rate appreciation when the foreign products become cheaper. Thus, after 24 months, while in the first regime the ERPT into produce prices was 61% and into consumer prices was 59%, during the second regime the ERPT was 11%, respectively 32%. Moreover, during both regimes the ERPT increases along the time horizon.

Figure 9

TVAR (Exchange rate appreciation - depreciation) - Probabilities of the two regimes s_t



Size of the exchange rate change asymmetry

Another threshold variable used refers to the *magnitude of monthly change in exchange rate* (depreciation or appreciation) in order to examine whether the effects of exchange rates on price indices differ during periods of *big* versus *small* changes in exchange rates. Hence, in the first regime we considered a monthly change (depreciation or appreciation) lower than 1.3%, while the second regime we considered a monthly depreciation/appreciation higher than 1.3%. Thus, the threshold chosen was $\mp$1.3%, so that the sample data of the two regimes to be equilibrated.

Figure 10

TVAR (Exchange rate appreciation - depreciation) - ERPT into price indices for each of the two regimes s_t

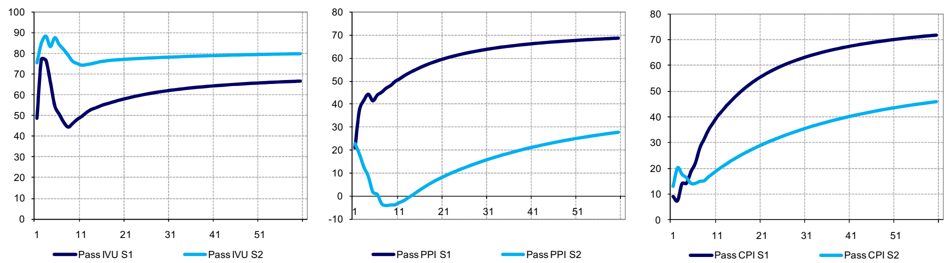
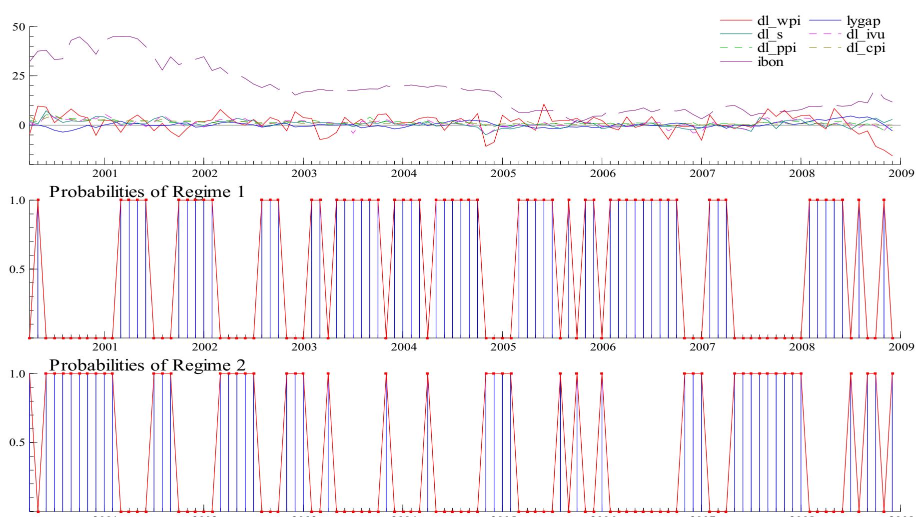


Figure 11 shows the periods in which each of the two regimes occurs. Thus, the first regime includes periods of *small* changes in exchange rate, while the second one includes periods of *large* changes.

Figure 11

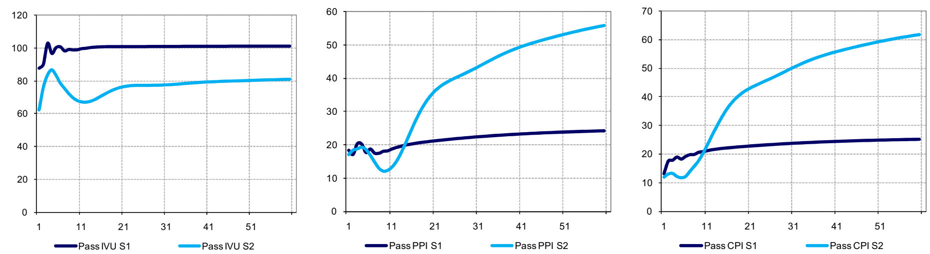
TVAR (magnitude of monthly change in exchange rate) - Probabilities of the two regimes s_t



Analyzing Figure 12 it results a significant difference regarding the behaviour of importers comparing to that of local producers and retailers. Thus, the pass-through into import price index is greater when exchange rate changes are small, a possible explanation being that the *imports are invoiced in the exporter's currency*.

Figure 12

TVAR (magnitude of monthly change in exchange rate) - ERPT into price indices for each of the two regimes



In this context a small change in the exchange rate has no effect on price received by the exporters (the invoice price), but completely affects the local import prices – the pass-through is complete. When the exchange rate change is large the exporter adjusts the foreign prices, dropping the amount of pass-through. On the other hand, during the first thirteen months for producers and during the first ten months for retailers, the pass-through is greater when the changes of exchange rate are small, as it is easier to pass a smaller change in the exchange rate into prices so that the sales will not be very much affected. But after this time span, pass-through becomes greater when exchange rate changes are large than when they are small, probably due to the fact that both producers and retailers pass the large exchange rate shock gradually. Thus the ERPT into producer and consumer prices increases during the second regime and remains almost constant during the first regime.

Size of the monthly inflation asymmetry

Another variable considered is the *magnitude of the monthly increase of the inflation*. The threshold chosen was 1%. Thus, when the monthly inflation rate is higher than 1%, the indicator function will take value 1, otherwise will take value zero. The Figure 13 suggests that the first regime is that of *low inflation* (below 1%), while the second one is occurring when the *inflation is high* (above 1%). Analyzing the Figure 14, it can be seen that the exchange rate pass-throughs into all price indices are lower in the low inflation regime, this being in line with the hypothesis put forward in Taylor (2000) regarding the asymmetric effects of exchange rates during periods of high and low inflation.

Figure 13

TVAR (magnitude of monthly inflation) - Probabilities of the two regimes s_t

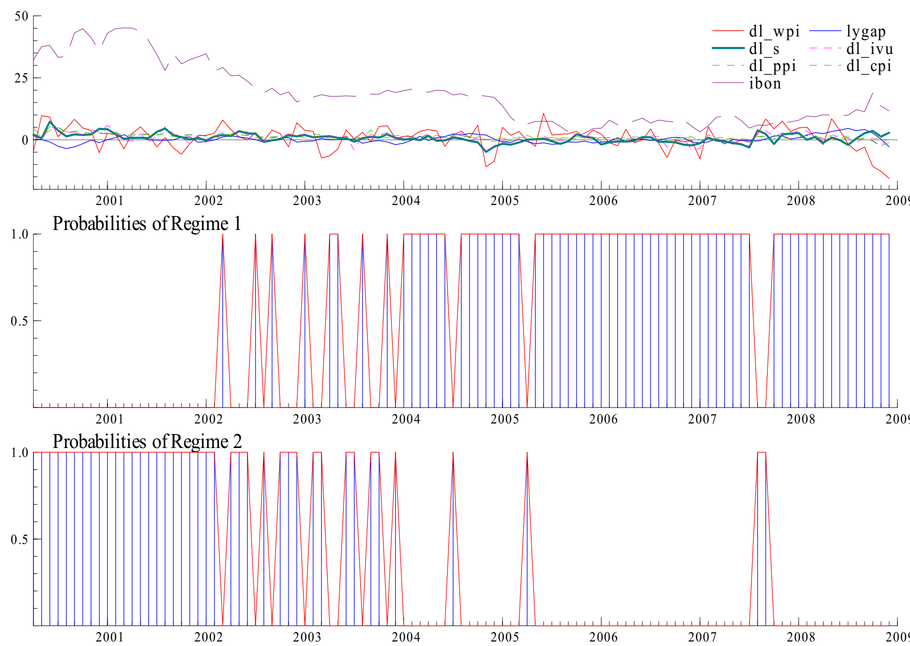
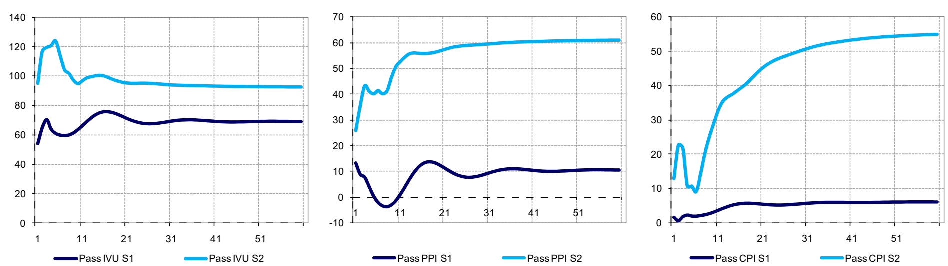


Figure 14

TVAR model (magnitude of monthly inflation) - ERPT into price indices for each of the two regimes



Self-exciting threshold autoregressive (SETAR)

In the self-exciting threshold autoregressive SETAR model, the regime-generating process is not assumed to be exogenous, but linked to the lagged endogenous variable y_{t-d}. Thus, in eq. (21) the variable z_{t-d} is replaced by y_{t-d}. Thus, for a given threshold r, the probability of the unobservable regime $s_t = 1$ is given by

$$P\left\{s_t = 1 \mid \{s_{t-j}\}_{j=1}^{\infty}, \{y_{t-j}\}_{j=1}^{\infty}\right\} = I\{y_{t-d} \le r\} = \begin{cases} 1 & if\ y_{t-d} \le r \\ 0 & if\ y_{t-d} > r \end{cases}$$

Using the same program as in previous sessions we estimated a SETAR model. Based on this we determined the ERPTto price indices. We considered two different threshold variables that identify two different regimes. The Ox outputs, including: prediction error and standard residuals, correlogram, spectral density, density and QQ Plot of standard residuals and actual and fitted values are presented in Appendixes 6 and 7.

Threshold variable: Exchange rate

The first threshold variable considered is the *monthly change in exchange rate*. The value of the threshold was estimated to be 0.88957 percent. As a result, the high regime (the second one) was identified as the one in which the exchange rate increases are higher than 0.88957%. The Figure 15 presents the periods in which the each of the two regimes take place, while the Figure 16 presents the threshold variable shifting from one regime to another. The Figure 17 suggest that the ERPT into all price indices are higher in the second regime than in the first one, suggesting that a depreciation higher than 0.88957% will be more likely to be passed into prices.

Figure 15

SETAR (exchange rate threshold variable) - Probabilities of the two regimes s_t

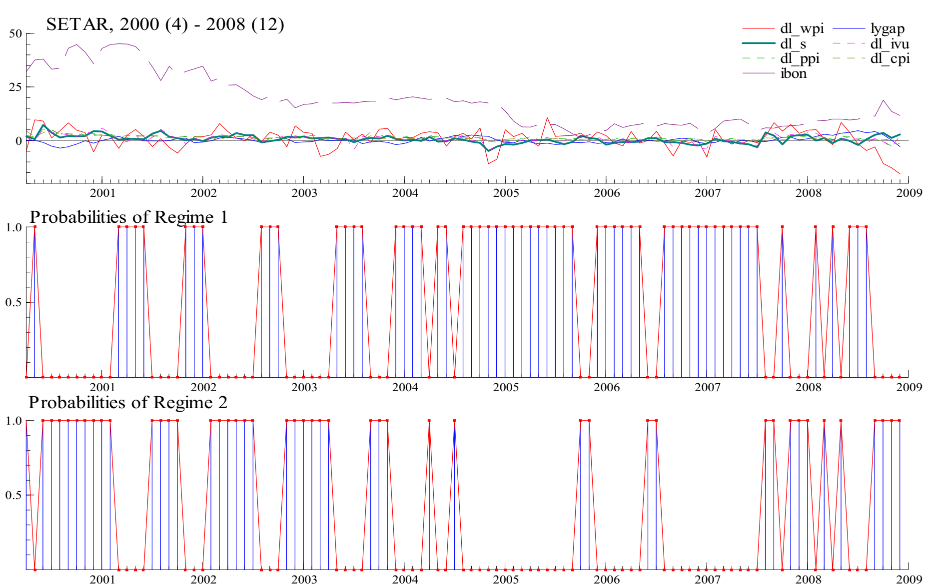


Figure 16

SETAR (exchange rate threshold variable) - Estimated threshold

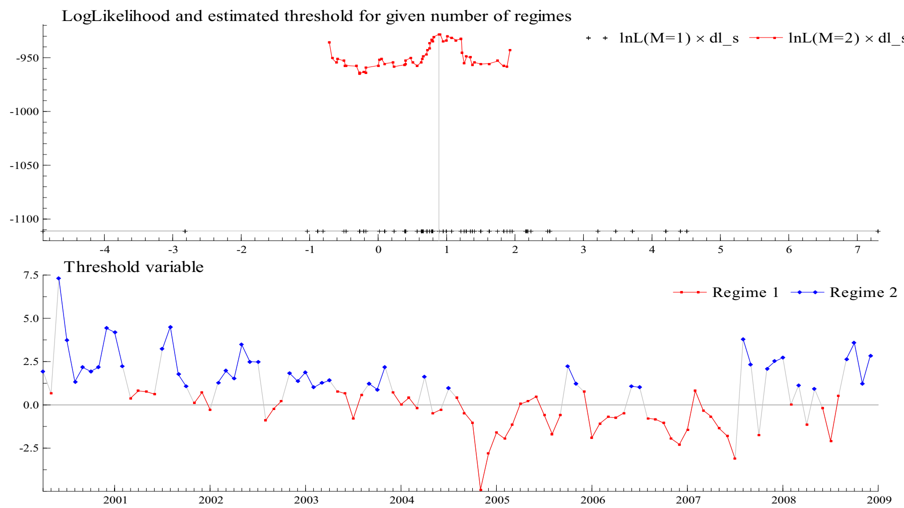
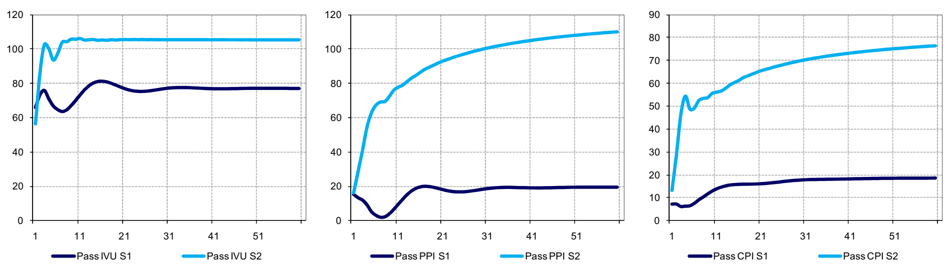


Figure 17

SETAR (exchange rate threshold variable) - ERPT into price indices for each of the two regimes



Threshold variable: Monthly inflation

The second threshold variable considered is *monthly inflation*, respectively the monthly change of consumer price index. The threshold level estimated by the model is 1.6904 percent. The high inflation regime in this case is observed when the monthly inflation rate is higher than 1.6904 percent. Thus, when the inflation exceeds the threshold of 1.6904 percent, the system enters into the second regime. This regime includes 24% of total observations and occurs mainly in the first part of the data sample. Figure 19 presents the threshold variable shifting from one regime to another. The Figure 20 suggest that in the high inflation regime the ERPT into all price indices are higher than in the low inflation regime, once again the Taylor's (2000) hypothesis of asymmetric effects of exchange rates during periods of high and low inflation being verified.

Figure 18

SETAR (CPI threshold variable) - Probabilities of the two regimes s_t

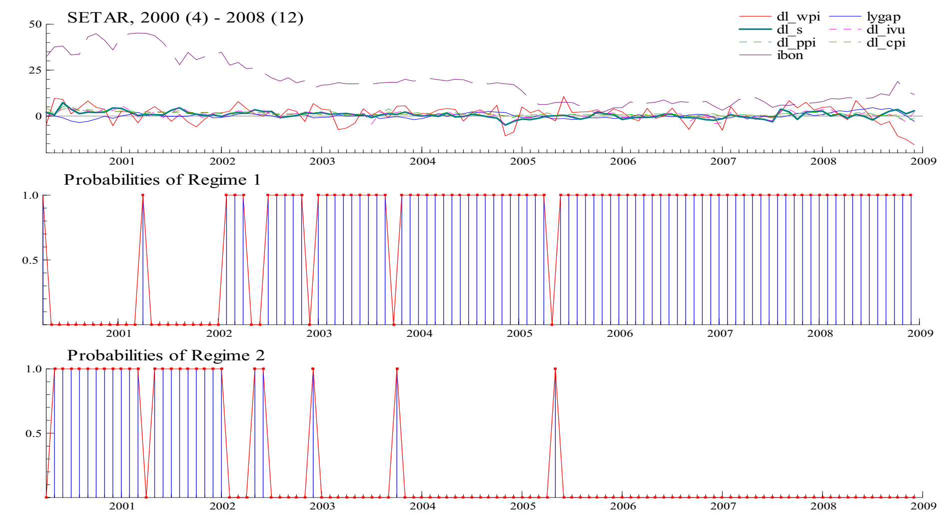


Figure 19

SETAR (CPI threshold variable) - Estimated threshold

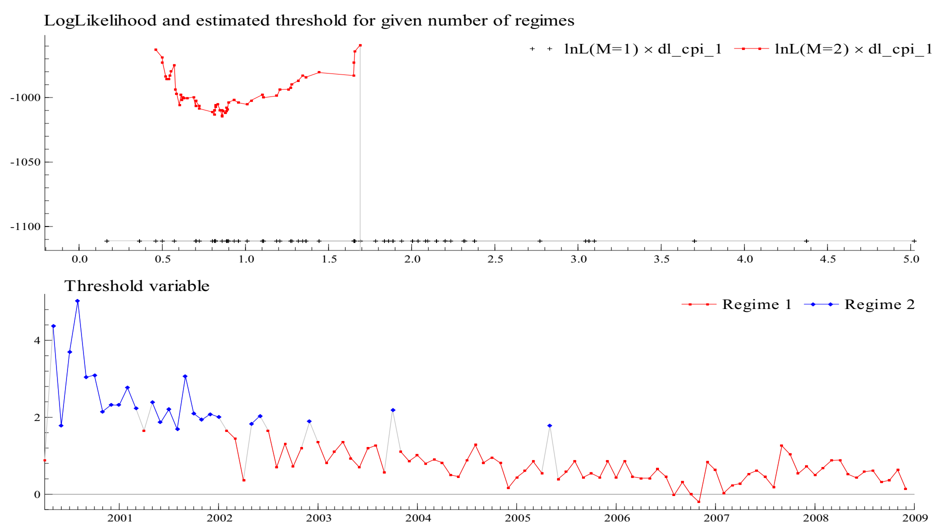
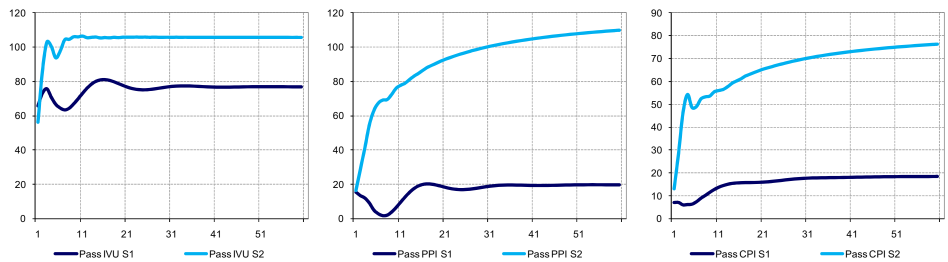


Figure 20

SETAR (CPI threshold variable) - ERPT into price indices for each of the two regimes



5. Conclusions

Using various MS-VAR models, we determined *important asymmetries* in the ERPT pertaining to different time periods, the sign and the size of the exchange rate change and the size of the monthly inflation.

Testing for *two different time periods* further supports the rolling window estimates (described in Cozmâncă and Manea (2009)) in indicating a decrease of the pass-through during time.

As for the *sign of the exchange rate movements*, the behaviour of local importers seems to be opportunistic, as a higher pass-through is apparent for exchange rate depreciation than in the case of an appreciation. This is in contrast with the behaviour of the local producers and retailers which are trying to maintain their *market share*; another explanation could be that during periods of exchange rate depreciation, the firms will increase the weight of local products (inputs for producers and goods for the retailers) to the detriment of foreign ones that are becoming more expensive.

Investigating the *threshold for the exchange rate shock* at which there is a change in the behaviour of the agents, it is clear that a relatively larger depreciation has a more pronounced effect on prices.

Regarding the *size of the exchange rate shock*, there seems also to exist a behavioural shift at the level of the importers, on one hand, and at the level of producers and retailers, on the other hand. Thus, the pass-through into import price index seems to be greater when exchange rate changes are small, a possible explanation being that the *imports are invoiced in the exporter's currency*. In this context a small change in the exchange rate has no effect on price received by the exporters (the invoice price), but completely affects the local import prices – the pass-through is complete. On the other hand, during the first thirteen months for producers and during the first ten months for retailers, the pass-through is greater when the changes of exchange rate are small, being easier to pass a lower modification of exchange rate into prices so that the sales will not be very much affected. But after this time span, pass-through becomes greater when exchange rate changes are large than when they are small, probably due to the fact that both producers and retailers pass the large exchange rate shock gradually.

If the *magnitude of the monthly increase of the inflation* is considered as a source of asymmetry, it appears that the ERPT into all price indices are lower for the low inflation regime, this being in line with the hypothesis put forward in Taylor (2000) regarding the asymmetric effects of exchange rates during periods of high and low inflation. This conclusion is further supported by the threshold value identified for the change in regime.

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7. Appendixes

The appendices of this paper are published as a separate pdf file on the website of the Romanian Journal of Economic Forecasting (rjef.ipe.ro).