5. SHOCK-DEPENDENT EXCHANGE RATE PASS-THROUGH INTO DIFFERENT MEASURES OF PRICE INDICES IN THE CASE OF ROMANIA

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Abstract

The paper presents a new research direction in quantifying the exchange rate pass-through (ERPT) coefficient. Innovations brought to the standard approach refer to incorporating changes in economic conditions behind currency movements. Before applying the new methodology, fluctuations of the transmission magnitude are illustrated through a time-varying coefficient regression. At the same time, by estimating an asymmetric error correction model, different responses of the price indices according to the sign of the exchange rate movements are captured. In order to quantify the transmission mechanism in the context of shocks, a sign and zero restrictions Bayesian VAR is estimated. Empirical evidence show that shock-dependent transmission is heterogeneous. The highest values of the ERPT coefficient result when the exchange rate movements are caused by a monetary policy shock. Nevertheless, this shock has a reduced contribution in explaining the exchange rate dynamics in the case of Romanian economy.

Keywords: exchange rate pass-through, asymmetries, macroeconomic shocks, sign and zero restrictions Bayesian VAR

JEL Classification: C11, C22, E31, E52, F31

1. Introduction

Exchange rate fluctuations have generated along time an increased interest in understanding their impact on various price indices. In the context of maintaining price stability, quantifying the transmission of nominal exchange rate movements is also imposed. Studying this phenomenon is therefore essential when elaborating economic policies. In this regard, quantifying both the potential asymmetries of the exchange rate pass-through into price indices and time variability is highly relevant, especially for policymakers. Recently, the importance of shocks in explaining movements across the exchange rate has gained momentum in the economic literature, which led to estimating exchange rate pass-through coefficients in the context of various economic shocks.

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This paper provides an analysis of the exchange rate pass-through into different measures of Romanian price indices. In order to bring innovation to previous empirical evidence, shock-dependent exchange rate pass-through (ERPT) is examined. As shown in Section 2, most papers in the related literature focus on the traditional ERPT coefficient and at the current juncture there is scarce information regarding the size of the ERPT conditional on the shocks leading to changes in the exchange rate. In this context, this paper aims to enrich evidence for the Romanian economy using the latest trends in terms of ERPT calculations. In order to make a clear statement that such coefficients are relevant, Section 3 illustrates the existence of asymmetries and of time variability of the pass-through coefficient. Section 4 provides empirical evidence for the shock dependent ERPT in the case of Romania, while Section 5 contains the concluding remarks.

2. Literature Review

Literature on exchange rate pass-through is a vast one, and a large number of econometric models for quantifying the role played by this variable in explaining annual inflation rate dynamics have already been developed. Overall, the theoretical background confirms the existence of asymmetries regarding the exchange rate pass-through into different price indices, as well as a various magnitude conditional on different factors. For instance, Colicev *et al.* (2019) find that a large and unexpected currency shock has an immediate pass-through into consumer prices. Nagengast *et al*. (2020) highlight a high ERPT conditional on prices for consumers with increased demand elasticities. By contrast, Osbat *et al*. (2021) argue that higher market concentration decreases the ERPT. Apart from such structural characteristics, also country specific and regionwide components matter when accounting for the ERPT, as suggested by Leiva *et al.* (2022).

Most papers in the related literature consider the exchange rate movements to be caused by exogenous forces. This assumption is specific to the standard approach of quantifying the exchange rate pass-through into different measures of price indices. It implies that the ERPT magnitude modifies based on structural causes, such as the market structure or the composition of exports or imports. However, these estimations fail to relate very well fluctuations of the short-run pass-through coefficient due to the fact that causes that led to exchange rate fluctuations are not taken into consideration.

Given the standard approach caveats, a new direction of quantifying this phenomenon has recently been developed. Shambaugh (2008) illustrates the variability of exchange rate pass-through coefficients in the context of various shocks which led to exchange rate movements. Moreover, given empirical evidence from Forbes and Nenova (2016), prices react differently according to the macroeconomic shocks which lead to exchange rate movements. Comunale (2017) confirms the shock dependence of exchange rate in the case of the Euro Zone countries. Additionally, she suggests that monetary policy shocks, quantified by interest rates, lead to the highest exchange rate pass-through coefficients. Those coefficients are computed as the cumulative impulse response of the price variable to exchange rate shocks divided by the cumulative impulse response of exchange rate to specific shocks. The same author (Comunale, 2020) argues in favour of a shock-dependent ERPT as price setters may react differently to the exchange rate movements triggered by different economic shocks. Furthermore, Forbes *et al.* (2020) explain that the prevalence of different shocks can help explain the variation in ERPT across countries. Castro and Nino (2018) also find that ERPT is nonlinear and shock-dependent. As regards the role played by different shocks, Khotulev (2020), Ortega and Osbat (2020), Ha *et al.* (2020) highlight that the monetary policy ones are associated with the highest ERPT. By contrast, while they agree on the shock-dependence nature of the ERPT, An *et al.* (2021) find that the exogenous exchange rate shocks remain the most important driver of exchange rate fluctuations.

In the case of Romania, previous empirical evidence suggest the existence of asymmetries in the ERPT (Cozmâncă, 2010), as well as a decrease in the transmission coefficient based on various factors, such as: (i) globalization, (ii) consolidation of monetary policy credibility, (iii) macroeconomic framework characterized by a low annual inflation rate (Handoreanu, 2008, Murarașu and Stoian, 2015). Both Nalban (2015) and Gueorguiev (2003) find a declining ERPT along the distribution chain. However, at the current juncture, evidence during the COVID-19 pandemic and in the context of various economic shocks is rather scarce in the case of the Romanian economy.

3. Time Variability and Asymmetries of Exchange Rate Pass-through into Different Measures of Price Indices

3.1. Methodology and Data

In order to assess whether the exchange rate pass-through coefficients differ along time, a time-varying coefficient regression model is estimated. Generally, a state space one is used, which can be described as follows:

$$\pi_t = \beta_t^1 \cdot \pi_{t-1} + \beta_t^2 \cdot x_t + \beta_t^3 \cdot dl\_s\_ef_t + \varepsilon_t \qquad (1) \quad \text{Observation equation}$$

$$\beta_t^i = \beta_{t-1}^i + e_t^i\ ,\ VAR\left(e_t^i\right) = \sigma_i^2\ for\ i = \overline{1,3} \qquad (2) \quad \text{Transition equation}$$

In equation (1) above, π_t denotes the inflation rate of selected price index along the distribution chain (import deflator, domestic industrial producer price (IPP), consumer price index (CPI), net of direct effects of VAT changes and adjusted CORE2 index, excluding VAT changes). x_t represents an explanatory variable for each price index (foreign inflation in case of both the import deflator and the industrial producer prices; the industrial producer prices for consumer goods in case of both CPI and CORE), $dl\_s\_ef_t$ stands for the change in the nominal effective exchange rate[2]. As regards the transition equation (namely, equation 2), the model assumes time-varying parameters, β_t^i. e_t^i and ε_t are residual terms.

Estimations are made using quarterly data in case of the import deflator and monthly data for the three other price indices. The time span is common to all indices, namely quarter 1, 2002 – quarter 1, 2022. Data was seasonally adjusted using the X-13 ARIMA SEATS method. The above-mentioned equations embody the first difference of log data. A comprehensive table containing all variables considered and further details is available in Appendix A (Table A1).

[2] *Computed as a weighted average between EUR/RON and USD/RON exchange rates, according to the weights of the two currencies in Romania's foreign trade (73% in case of the EUR/RON exchange rate and 27% in case of the USD/RON exchange rate).*

Furthermore, in the context of potential sign asymmetries, an error correction model with asymmetries is estimated. The model also includes an indicator function (as suggested by Enders and Siklos, 2001):

$$\tau_t = \alpha_1 + \alpha_2 \cdot l\_s\_ef_t + \alpha_3 \cdot l\_x_t + \mathcal{E}_t \quad (3)$$

$$\pi_t = \beta_1 \cdot \pi_{t-1} + \beta_2 \cdot dl\_s\_ef_t \cdot 1\left(dl\_s\_ef_{t-1} > 0\right) + \beta_3 \cdot dl\_s\_ef_{t-1} \cdot 1\left(dl\_s\_ef_{t-1} \leq 0\right) +$$
$$+\beta_4 \cdot ecm_{t-1} + \beta_5 \cdot dl\_x_t + \vartheta_t \quad (4)$$

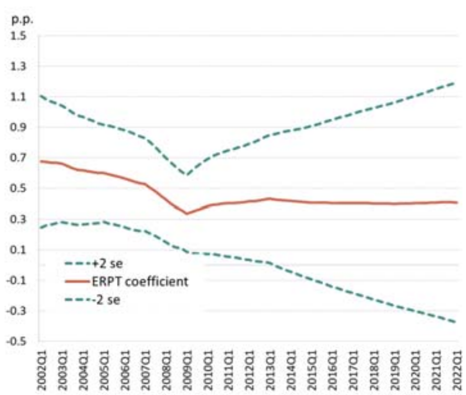
where: τ_t is the log level of the price index, while π_t is the inflation rate proxied by the first difference of log data. Similar to the previous model, l_x_t stands for the logarithm of the explanatory variable and dl_x_t for its related first difference (further described in the Appendix in case of each analysed price index). The indicator function for an appreciating domestic currency is denoted by $1\,(dl\_s\_ef_{t-1} \leq 0)$. In the case of an exchange rate depreciation, the sign inside the brackets is changed. Equation (4) contains the error correction term, ecm_{t-1}. The residuals are $\mathcal{E}_t$ and ϑ_t.

A more comprehensive explanation of the equations with the various price indices included is provided in Appendix B.

3.2 Results

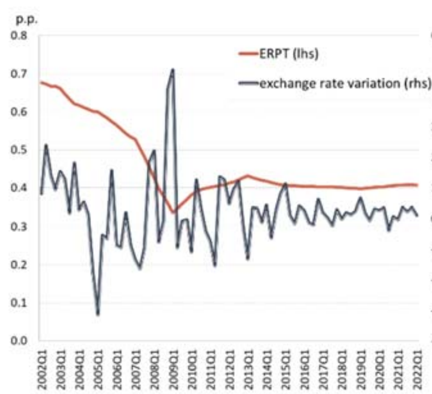
On the one hand, the time-varying coefficients model confirms that there has been a decline in the pass-through coefficient in the case of almost all analysed price indices. As for the import deflator, the quarterly ERPT coefficient varies between 68% (value reached in the first quarter of 2002) and 34% (first quarter of 2009) (Figures 1 and 2).

Figure 1. Exchange Rate Pass-through into Import Deflator



Source: Author's calculations.

Figure 2. The Influence of Exchange Rate Volatility on the Pass-through Coefficient

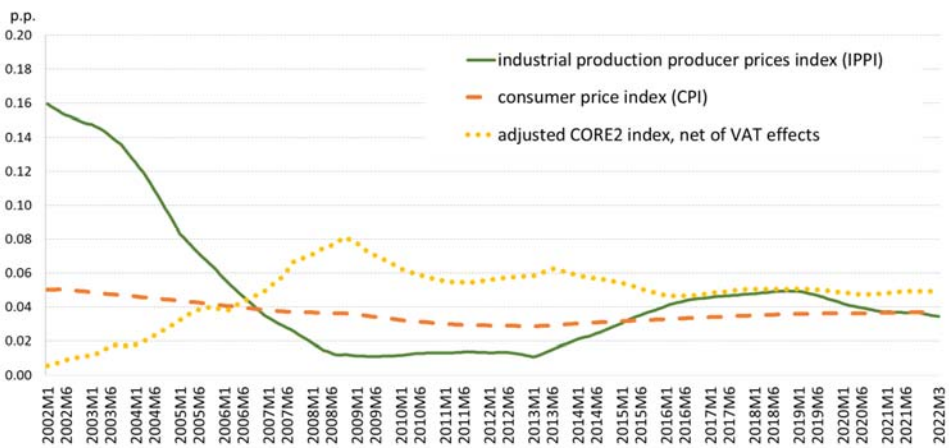


Source: Author's calculations.

In order to analyse the causes leading to fluctuations of the ERPT coefficients, influence factors found in related literature were taken into consideration. Under these circumstances, the impact of inflation environment was highlighted: the highest ERPT coefficients were obtained at the beginning of the sample, period characterised by high inflation rates. Moreover, changing the monetary policy strategy has also potentially contributed to the decline in the ERPT coefficient, in the context of the National Bank of Romania adopting the direct inflation targeting and, thus, consolidating the monetary policy credibility by better anchoring inflation expectations. Nevertheless, globalisation and domestic goods competitiveness relative to imported substitute goods is another factor: in 2007, Romania acceded to the European Union, with implications on foreign trade. Magnitude of the exchange rate movements matter as well. Figure 2 shows that the significant decline in the ERPT coefficient could be related to the high volatility of the exchange rate.

Empirical findings clearly suggest that the exchange rate pass-through into import deflator is time-varying. It is then questionable whether along the whole distribution chain the declining tendency of the transmission magnitude is present. Results confirm this hypothesis as well (Figure 3).

Figure 3. Exchange Rate Pass-through into IPPI, CPI and Adjusted CORE2



Source: Author’s calculations.

Figure 3 shows that ERPT into both industrial prices and consumer prices has declined, in contrast with the slightly increase into the adjusted CORE2 level. However, this phenomenon is explained by: *(i)* high persistence of core inflation, *(ii)* the existence and increase in the services directly indexed to exchange rate in the structure of this index.

On the other hand, the error correction model with asymmetries has also confirmed that ERPT is sensitive to the sign of the exchange rate movements. For instance, most price indices are more sensitive to an exchange rate depreciation. Yet, in the case of the import deflator, the ERPT coefficients do not differ significantly when accounting for the sign of the exchange rate movement. Instead, in the case of industrial production prices and CPI, the ERPT coefficient in case of an appreciation is not statistically significant (Table 1). This phenomenon is in line with the downward price rigidity: prices are stickier when the exchange rate appreciates.

Table 1. Results of the Error Correction Model

Dependent variable	Import deflator		IPP		CPI excluding VAT		Adjusted CORE2 excluding VAT	
Equation	**Long term relation**	**ECM model**	**Long term relation**	**ECM model**	**Long term relation**	**ECM model**	**Long term relation**	**ECM model**
Effective exchange rate	0.87***	-	0.63***	-	0.34***	-	0.24***	-
Persistence of price index	-	-	-	0.55***	-	0.75***	-	0.69***
Constant	-193.91***	-	-189.76***	-	-45.13***	-	-33.09***	-
Explanatory variable	0.17***	2.24***	0.25***	2.31***	0.71***	0.08**	0.52***	0.12***
Exchange rate depreciation	-	0.54***	-	0.15**	-	0.06*	-	0.10***
Exchange rate appreciation	-	0.59***	-	-0.02	-	-0.01	-	0.01
Error correction term	-	-1.67***	-	-0.07	-	0.00	-	-0.25***
Number of observations	89	88	89	87	89	87	89	87
R^2	0.98	0.58	0.98	0.77	0.99	0.90	0.99	0.93

*Note: The sample period spans from Q1, 2000 to Q1, 2022. All variables are expressed as logs. *, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.*

Source: author's calculations

4. Exchange Rate Pass-through in the Context of Economic Shocks

4.1. Methodology and Data

In order to study the magnitude of the nominal exchange rate pass-through into different measures of price indices for Romania, several Bayesian VAR models in which various price indices are alternatively introduced were estimated. As a prior, in line with Comunale's and Kunovac's (2017) estimations, the *Independent Normal Wishart* prior and a confidence band of 68% were chosen. As regards the number of lags, in line with the parsimony principle, a relatively reduced number of lags was chosen, namely 2 lags.

Generally, a VAR model with n endogenous variables, p lags and m exogenous variables can be written in a compact form as follows:

$$Y_t = A_1 * Y_{t-1} + A_2 * Y_{t-2} + \dots + A_p * Y_{t-p} + C * X_t + \varepsilon_t,\ with\ t = \overline{1,T}\ ,$$

where:

$Y_t = (Y_{1,t}, Y_{2,t}, \dots, Y_{n,t})$ is a $n\,x\,1$ vector of endogenous data

$A_1, A_2, \dots A_p$ are p matrices of dimension $n\,x\,n$

C is a $n\,x\,m$ matrix

$X_t = (X_{1,t}, X_{2,t}, \dots, X_{m,t})$ is a $m \, x \, 1$ vector of exogenous regressors

$\mathcal{E}_t = (\mathcal{E}_{1,t}, \mathcal{E}_{2,t}, \dots, \mathcal{E}_{n,t})$ is a $n \, x \, 1$ vector of residuals

Considering the fact that the purpose is investigating the exchange rate pass-through along the distribution chain, the analysed price indices are as follows: import deflator, industrial producer prices, CPI excluding VAT changes and last but not least the adjusted CORE2 index, excluding VAT changes. Frequency data was used and the reference period is Q2, 2000- Q1, 2022. As regards data transformations, despite the fact that in VAR models level data is accepted, the variables, excluding the output gap and the interest rate, were included as annualized quarterly variations. Data was seasonally adjusted.

In the model, the following shocks were introduced: *(i)* a demand shock (the output gap was used as a proxy), *(ii)* an inflationary shock (expressed according to the analysed price index), *(iii)* a monetary policy shock (quantified through the ROBOR3M interest rate), *(iv)* a supply shock (through the price of Brent oil) and *(v)* an own shock of the exchange rate (quantified by the influence of the NEER). The proposed identification scheme is one with sign and zero restrictions[3]. On the one hand, it is assured that the identification is according to the economic theory. For example, it is expected that a small and open economy such as Romania cannot have a significant impact on the international oil prices. On the other hand, in this manner an exogenous exchange rate shock can be isolated (Table 2).

Table 2. Proposed identification scheme

	NEER shock	Demand shock	Inflationary shock	Monetary policy shock	External supply shock
NEER	+	+	+	-	+
Output gap	0	+		-	-
Price index	0	+	+	-	+
ROBOR3M	0	+		+	
Brent oil	0	0	0	0	+

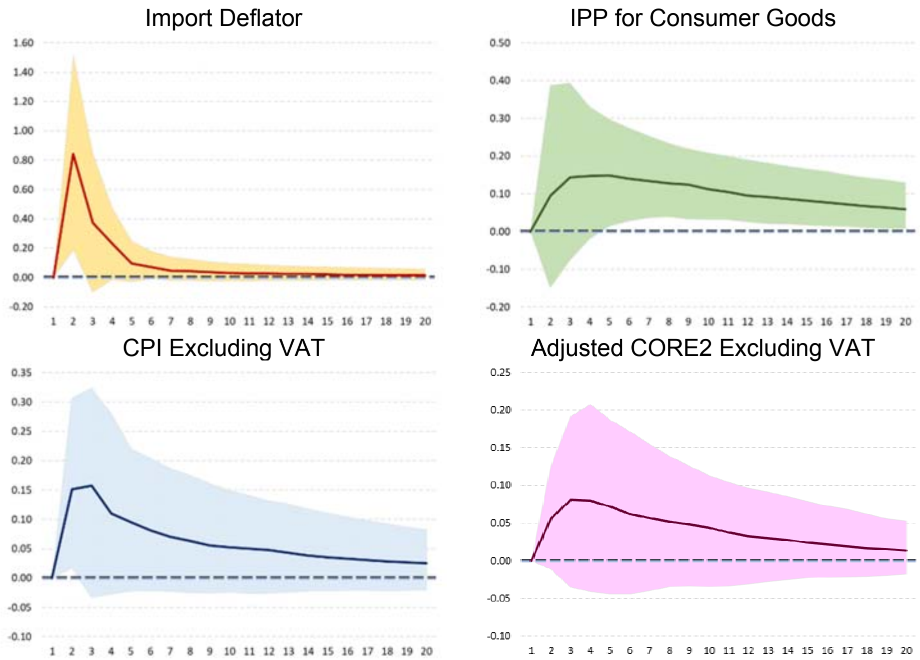
Source: *author's calculations*

4.2. Results

In a VAR model, impulse response functions are used to capture dynamic relations between variables. It is therefore an efficient tool in summarizing the information from the data by highlighting the response of a variable to a certain structural shock. In the context of this paper, the response of variables to an exchange rate shock is of general interest. It is noticed that economic theory is indeed respected: the depreciation of the national currency, resulting in an increase in the exchange rate, has the effect of exerting quite persistent inflationary pressures on the dynamics of selected price indices (Figure 4). The strongest response is obtained in the case of import prices and its magnitude gradually decreases along the distribution chain.

[3] *Restrictions based on working papers in which the exchange rate and dependencies among macroeconomic variables were analysed (Bobeica, Jarocinski, 2017; Forbes, 2017).*

Figure 4. Impulse Response Functions of Various Price Indices to an Exchange Rate Shock

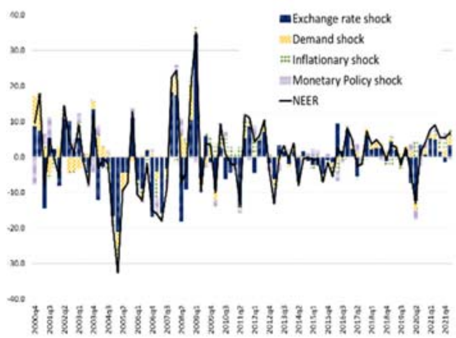


Source: Author's calculations.

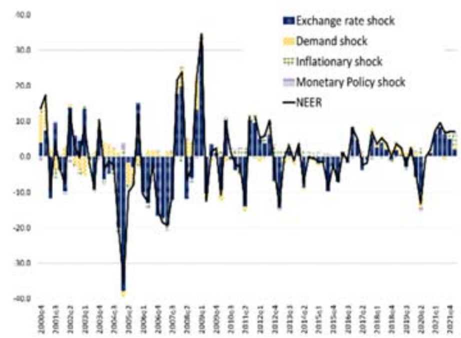
In order to quantify the shock-dependent ERPT coefficients, impulse response functions are necessary. However, in order to be able to compute a total coefficient that quantifies the exchange rate pass-through, the share in which different shocks explain this variable's movements is important. From this point of view, the historical decomposition of the exchange rate is proposed, based on a backward iteration in order to highlight how much each shock contributes to the exchange rate variation. Under this framework, it is noticed that the nominal effective exchange rate dynamics is mostly explained by its own shocks. However, when the model accounts for the import deflator or the industrial producer prices, the exerted inflationary pressures have a relatively important contribution in explaining exchange rate fluctuations (Figure 5). In the case of aggregate demand, the opening of the output gap leads to an important contribution to the exchange rate. Regarding the contribution of the ROBOR3M interest rate in explaining the exchange rate variations, these shocks have a higher impact in the context of a key interest rate modification. Hence, it was concluded that there was a correlation between the National Bank of Romania's decision to modify the monetary policy interest rate and the degree in which this particular shock explains the exchange rate variations.

Table 5. Historical decomposition of exchange rate movements given various price indices

(a) import deflator

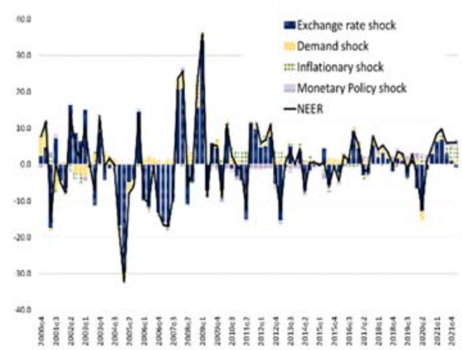


(b) IPP for consumer goods



(c) CPI excluding VAT

(d) adjusted CORE2 excluding VAT



Source: author's calculations

Given the estimated impulse reaction functions and the historical decomposition, the shock-dependent exchange rate pass-through can be computed, using the following formula:

$$ERPT_i = \frac{cumulative\ impulse\ respose\ of\ the\ price\ variable\ to\ exchange\ rate\ shocks}{cumulative\ impulse\ response\ of\ exchange\ rate\ to\ \boldsymbol{shock_i}}$$

In order to compute the total pass-through coefficient, a weighted average is used. The weighting scheme is according to the average contributions of the shocks explaining exchange rate movements given the historical decomposition:

$ERPT_{total} = \sum_{i=1}^{n} ERPT_i * \Theta_i$, where: $ERPT_i$ is the pass-through coefficient in the context of shock *i* and Θ_i represents the average contribution of shock *i* in explaining the exchange rate dynamics.

Taking into consideration the above-mentioned equations, results are summarized in Table 3.

Table 3. ERPT into Different Measures of Price Indices in One Year

Macroeconomic shock	Import deflator		IPP for consumer goods		CPI excluding VAT		adjusted CORE2 excluding VAT	
	$ERPT_i$	θ_i	$ERPT_i$	θ_i	$ERPT_i$	θ_i	$ERPT_i$	θ_i
Exchange rate shock	0.44	0.51	0.1	0.63	0.13	0.62	0.09	0.57
Demand shock	0.44	0.16	0.15	0.19	0.19	0.14	0.2	0.17
Inflationary shock	0.77	0.18	0.31	0.13	0.16	0.16	0.12	0.15
Monetary policy shock	-1.04	0.15	-2.93	0.05	-0.46	0.09	-0.12	0.11
TOTAL	0.59		0.29		0.17		0.12	

Source: author's calculations

Given these results, empirical findings suggest that the magnitude of the exchange rate pass-through in the context of various shocks is heterogeneous. The shock leading to the highest value of the ERPT coefficient is the monetary policy one, followed by the inflationary and demand shocks.

As expected, the transmission along the distribution chain is declining. These results provide an overview of the exchange rate pass-through phenomenon. Empirical findings point to differences of this variable's transmission magnitude. For example, in the context of a monetary policy shock, an increase in the ERPT coefficient is anticipated.

As compared to the standard approach, slightly lower ERPT coefficients are obtained by using the shock-based methodology. Nalban (2015) finds the long-run ERPT into producer prices to be about 0.5 and the one corresponding to CPI around 0.3. These figures are also confirmed by Gueorguiev (2003). Handoreanu (2008) shows that increased monetary credibility in Romania led to the lowering of the exchange rate and suggests an ERPT of 0.25 in the case of CPI. At the same time, Murarasu and Stoian (2015) confirm the decrease in the ERPT coefficient. In the case of the import deflator, ERPT in 2014 is evaluated at 0.56, decreasing from 0.76 in 2000. The results in the case of industrial producer prices are also consistent with the ones obtained in this manuscript, namely around 0.3. Yet, in the case of the CPI and adjusted CORE2 indices the authors find slightly higher values of the ERPT (0.35 and 0.25, respectively). Mention should be made that the reference period of these estimations is 2000-2014, whereas the current analysis consists of more recent data and embodies factors reducing the ERPT coefficients, such as increased globalization and a higher credibility of monetary policy.

4.3. Testing Robustness

In order to check the obtained results, testing their robustness is required. In this matter, the estimation of new Bayesian VAR models was proposed. Differences from the previous models refer to: *(i)* introducing more variables in the model – three price indices at a time instead of estimating one model for each price index, *(ii)* eliminating zero restrictions and last but not least *(iii)* drastically reducing sign restrictions – keeping just the sign restriction corresponding to the response of the exchange rate to the shocks within the model.

As regards impulse reaction functions, the responses highlighted in the first models are confirmed. A positive shock in the exchange rate leads to inflationary pressures in the case of all selected price indices. Yet, as compared to the baseline model presented in the previous section, the responses are not statistically significant. More details are available in

Appendix C. Furthermore, as for the historical decomposition, shocks explaining exchange rate movements are more proportionally distributed.

Table 4. Results of the robustness models as compared to the baseline specification

ERPT values	Baseline model	Robustness model
ERPT for import deflator	0.59	0.69
ERPT for IPP	0.29	0.27
ERPT for CPI	0.17	0.16
ERPT for adjusted CORE2	0.12	0.12

Source: author's calculations

When computing shock-dependent ERPT coefficients, it is worth noticing that exchange rate pass-through into industrial producer prices, CPI and the adjusted CORE2 prices has similar values to the ones obtained in the first estimated models (Table 4). However, there is a discrepancy as regards the ERPT coefficient in the case of import deflator dynamics. According to the baseline specification of the BVAR model as shown in sub-section 4.2, the ERPT into the import deflator after one year is evaluated at 59%, whereas the robustness model points to an ERPT of 69%. This value is closer to the results in the related literature[4] and to the ones obtained in the first part of the paper. It is therefore highlighted a possible undervaluation of the ERPT coefficient in the context of imposing an identification scheme with sign and zero restrictions.

5. Conclusions

Quantifying the magnitude of the ERPT in the context of macroeconomic shocks is relevant to both economic policy makers and to economic agents. It facilitates the understanding of existent fluctuations and asymmetries regarding the impact of exchange rate on price indices. In this paper, after highlighting the time-varying nature and existing asymmetries in terms of the transmission of exchange rate movements into price indices, a shock-dependent ERPT is computed. Empirical findings confirm results in the related literature: ERPT has declined over time. The estimated time-varying regression models point to the largest values of the ERPT in the case of almost all analysed price indices at the beginning of the sample, namely 2002. The adjusted CORE2 index makes an exception, as the ERPT is evaluated to follow a slightly upward trajectory, in line with the increase in services directly indexed to the exchange rate.

At the same time, empirical evidence points to sign asymmetries, as a higher response was found in the case of exchange rate increases. Therefore, possible downward price rigidities are highlighted. As regards the magnitude of the ERPT, similar to findings in the related literature, the ERPT decreases along the distribution chain.

To sum up, there is evidence regarding the existence of asymmetries and a time-varying nature of the ERPT into Romanian price indices. In this context, the novel shock-based

[4] *Cozmâncă (2010) indicates a one-year exchange rate pass-through into import deflator of approximately 74%.*

approach is relevant. In light of this methodology, results show that the transmission of the exchange rate movements is highly heterogeneous, as the ERPT coefficients depend on the composition of economic shocks underlying the movement in the exchange rate. Empirical evidence show that the monetary policy shock leads to the highest ERPT coefficient in spite of a weak degree in explaining nominal exchange rate dynamics. Exchange rate dynamics is mainly explained by its own shocks. Applying this methodology leads to slightly lower results of the ERPT as compared to figures from the related literature. For instance, the import deflator is evaluated at around 0.6 in one year, whereas other papers find an ERPT of more than 0.7. In the case of producer price index, results point to an ERPT of 0.3 in one year, at the lower bound of the interval found in other studies. Furthermore, the decline in ERPT along the distribution chain is confirmed, as the shock-dependent ERPT into CPI is evaluated at 0.17 and in the adjusted CORE2 at 0.12 in one year after the exchange rate movement. In the case of these prices, the ERPT coefficients are in line with those found in the related literature.

The obtained results provide a new perspective to the understanding of the exchange rate pass-through into various price indices from Romania. These findings contribute to the ERPT literature in the case of Romanian price indices as this approach is a novel one and has been mostly applied to a limited number of countries. However, as recent studies also recommend, the contextual ERPT is complementary to the one computed in line with the standard approach, in which the exchange rate is considered to have moved due to exogenous reasons. Exchange rate is influenced by a series of factors which cannot be captured in the context of only some shocks included in the model. In this regard, an important limitation of the shock-dependent approach is that it is very difficult to find a robust characterization of the shocks driving the exchange rate movements. Furthermore, without information regarding the future structure of shocks, it is difficult to estimate the pass-through coefficient which will be recorded in the next periods only by taking into consideration historical data. Another limitation of the model refers to potential distortions of estimates caused by imposed sign and zero restrictions. As highlighted by the robustness model, different values of the ERPT coefficient can be obtained according to the proposed identification scheme, which might become misleading. Given these limitations, future research might focus on estimating the ERPT coefficients using a narrative sign approach. At the same time, current estimations might be extended towards the case of Central and Eastern European countries in order to provide a comparison between ERPT coefficients in Romania and other countries in the region. Nevertheless, the model may be extended to study the effects of exchange rate movements on other relevant macroeconomic variables.

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Appendix A

Table A1. Data Description

Symbol	Variable name	Transformations	Frequency	Time period
l_s_ef	log of effective exchange rate	weighted average*, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
dl_s_ef	first difference of the log of effective exchange rate	first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022
l_p_m	log of import deflator	X13 seasonal adjustment, 2010=100, logarithm	quarterly	Q1, 2000 - Q1, 2022
dl_p_m	first difference of the log of import deflator	first difference of logarithm	quarterly	Q2, 2000 - Q1, 2022
l_ppi	log of total domestic industrial production price index	X13 seasonal adjustment, 2010=100, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
dl_ppi	first difference of the log of total domestic industrial producer price index	first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022
l_ppi_cg	log of domestic industrial producer price of consumer goods index	X13 seasonal adjustment, 2010=100, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
dl_ppi_cg	first difference of the log of domestic industrial producer price of consumer goods index	first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022
l_cpi_xvat	log of consumer price index excluding VAT changes	2010=100, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
dl_cpi_xvat	first difference of the log of consumer price index excluding VAT changes	first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022
l_core3_xvat	log of adjusted core 2 index excluding VAT changes	2010=100, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
dl_core3_xvat	first difference of the log of adjusted core 2 index excluding VAT changes	first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022
dl_cpi_star	first difference of the log of foreign price index	weighted average**, X13 seasonal adjustment, logarithm, first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022

l_oil_brent	log of brent oil price index	X13 seasonal adjustment, 2010=100, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
dl_oil_brent	first difference of the log of brent oil price index	first difference of logarithm	monthly, quarterly	Q2, 2000 - Q1, 2022
l_ulc_pr	log of unit labour costs for the private sector	X13 seasonal adjustment, logarithm	monthly, quarterly	Q1, 2000 - Q1, 2022
l_y_gap	log of the output gap	Kalman filter, logarithm	quarterly	Q1, 2000 - Q1, 2022
robor3m	3 months inter-banking interest rate	-	monthly, quarterly	Q1, 2000 - Q1, 2022

Note: quarterly frequency was obtained as a mean of the monthly data; data source: Eurostat, NBR, National Institute of Statistics.

* *Computed as a weighted average between the EUR/RON exchange rate (weight of 73%) and the USD/RON exchange rate (27%).*

** *Computed as a weighted average between the EA HICP (weight of 73%) and USA CPI (27%).*

Appendix B

B1. Equations considered within the time-varying parameters model

$dl\_p\_m_t = \beta_t^1 \cdot dl\_p\_m_{t-1} + \beta_t^2 \cdot dl\_s\_ef_t + \beta_t^3 \cdot dl\_cpi\_star_t + \varepsilon_t$

$dl\_ppi_t = \beta_t^1 \cdot dl\_ppi_{t-1} + \beta_t^2 \cdot dl\_s\_ef_t + \beta_t^3 \cdot dl\_cpi\_star_t + \varepsilon_t$

$dl\_cpi\_xvat_t = \beta_t^1 \cdot dl\_cpi\_xvat_{t-1} + \beta_t^2 \cdot dl\_s\_ef_t + \beta_t^3 \cdot dl\_ppi\_cg_t + \varepsilon_t$

$dl\_core3\_xvat_t = \beta_t^1 \cdot dl\_core3\_xvat_{t-1} + \beta_t^2 \cdot dl\_s\_ef_t + \beta_t^3 \cdot dl\_ppi\_cg_t + \varepsilon_t$

B2. Equations considered within the error correction model

$l\_p\_m_t = \alpha_1 + \alpha_2 \cdot l\_s\_ef_t + \alpha_3 \cdot l\_oil\_brent_t + \varepsilon_t$

$dl\_p\_m_t = \beta_1 \cdot 1\ (dl\_s\_ef_t > 0) \cdot dl\_s\_ef_t + \beta_2 \cdot 1\ (dl\_s\_ef_t \leq 0) \cdot dl\_s\_ef_t + \beta_3 \cdot ecm_{t-1} + \beta_4 \cdot dl\_cpi\_star_t + \vartheta_t$

$l\_ppi_t = \alpha_1 + \alpha_2 \cdot l\_s\_ef_t + \alpha_3 \cdot l\_oil\_brent_t + \alpha_4 \cdot l\_ulc\_pr_t + \varepsilon_t$

$dl\_ppi_t = \beta_1 \cdot dl\_ppi_{t-1} + \beta_2 \cdot 1\ (dl\_s\_ef_t > 0) \cdot dl\_s\_ef_t + \beta_3 \cdot 1\ (dl\_s\_ef_t \leq 0) \cdot dl\_s\_ef_t + \beta_4 \cdot ecm_{t-1} + \beta_5 \cdot dl\_cpi\_star_t + \vartheta_t$

$l\_cpi\_xvat_t = \alpha_1 + \alpha_2 \cdot l\_s\_ef_t + \alpha_3 \cdot l\_ppi_t + \varepsilon_t$

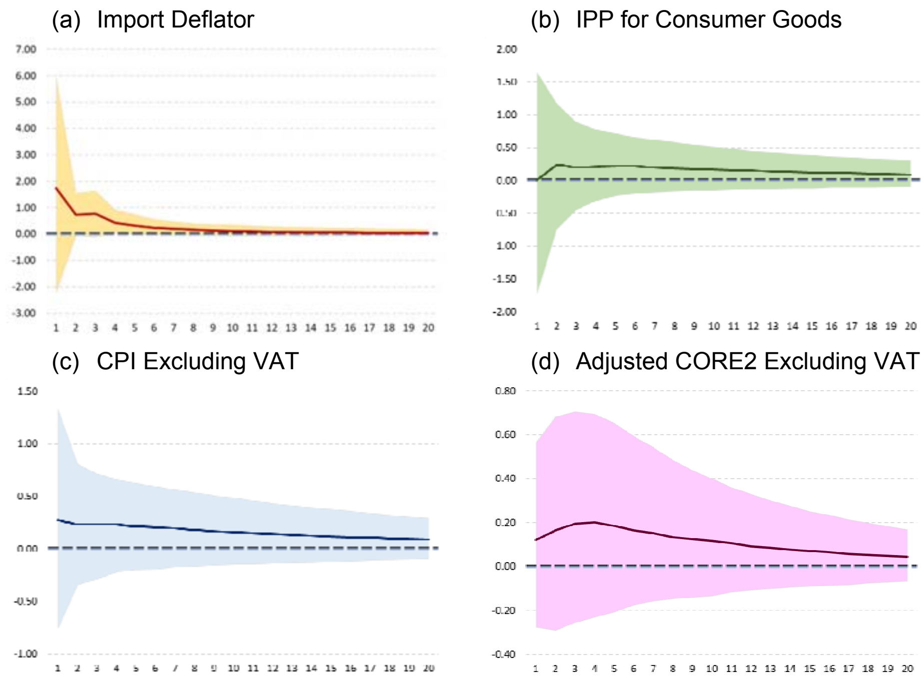
$dl\_cpi\_xvat_t = \beta_1 \cdot dl\_cpi\_xvat_{t-1} + \beta_2 \cdot 1\ (dl\_s\_ef_t > 0) \cdot dl\_s\_ef_t + \beta_3 \cdot 1\ (dl\_s\_ef_t \leq 0) \cdot dl\_s\_ef_t + \beta_4 \cdot ecm_{t-1} + \beta_5 \cdot dl\_ppi_t + \vartheta_t$

$l\_core3\_xvat_t = \alpha_1 + \alpha_2 \cdot l\_s\_ef_t + \alpha_3 \cdot l\_ppi\_cg_t + \varepsilon_t$

$dl\_core3\_xvat_t = \beta_1 \cdot dl\_core3\_xvat_{t-1} + \beta_2 \cdot 1\ (dl\_s\_ef_t > 0) \cdot dl\_s\_ef_t + \beta_3 \cdot 1\ (dl\_s\_ef_t \leq 0) \cdot dl\_s\_ef_t + \beta_4 \cdot ecm_{t-1} + \beta_5 \cdot dl\_ppi\_cg_t + \vartheta_t$

Appendix C

Figure A.1. Impulse Response Functions of Various Price Indices to an Exchange Rate Shock in the Robustness Models



Source: Author's calculations.