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Exchange Rate Pass-Through to CEE Inflation: SVAR Approach

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Abstract

This paper examines exchange rate pass-through (ERPT) to prices in Central and Eastern European (CEE) countries, focusing on the Czech Republic, Poland, Hungary, and Romania. We employ a Structural Vector Autoregression (SVAR) model to analyse the transmission of exchange rate shocks to imported, producer, and consumer prices. Results indicate significant heterogeneity in ERPT across countries and price stages. While all countries exhibit higher pass-through for import prices, variations emerge in producer and consumer price responses. Monetary policy credibility and trade openness are found to influence ERPT dynamics. The findings highlight the importance of understanding ERPT for effective monetary policy in the region. Our results highlight the need for policymakers to consider the complex interplay between exchange rate fluctuations and domestic prices when formulating monetary policy strategies.

Keywords: exchange rate pass-through, Central and Eastern Europe, SVAR, price transmission

JEL classification: E31, F31, F41

Introduction

Exchange rate pass-through (ERPT), defined as the extent to which changes in the exchange rate are transmitted to domestic prices, is a pivotal factor influencing monetary policy decisions. It quantifies the degree to which fluctuations in a country's currency value impact its inflation rate. This relationship is especially pronounced in small, open economies heavily reliant on imports and exports, such as those in Central and Eastern Europe (CEE). These economies often act as price-takers in global markets, absorbing external price pressures directly through their exchange rates. The importance of understanding ERPT has surged in recent years due to several factors. Firstly, the increased volatility of exchange rates in emerging markets has amplified the potential impact on domestic price levels. Secondly, the global economy has experienced periods of elevated energy costs, which, combined with exchange rate movements, have exerted significant inflationary pressures. Thirdly, the persistence of inflation above central bank targets in many economies has heightened the need to accurately model the transmission of external shocks to domestic prices.

This study aims to estimate ERPT in four CEE countries: the Czech Republic, Poland, Hungary, and Romania. These economies share geographical proximity and have undergone similar economic transitions, yet they exhibit distinct economic structures and policy frameworks. Poland and Romania, while larger economies, have relatively lower levels of openness compared to the Czech Republic and Hungary. Consequently, the degree to which exchange rate fluctuations influence domestic prices is expected to vary across these countries.

Beyond the estimation of ERPT, this study aims to investigate the intricate relationship between exchange rates and different stages of the price formation process within the economy. Specifically, we focus on tracing the transmission channel from exchange rate fluctuations to imported prices, subsequently to producer prices, and ultimately to consumer prices. By examining these interconnections, we seek to understand the magnitude and speed of exchange rate pass-through at each stage of the pricing chain. This approach allows us to identify potential amplification or dampening effects as exchange rate movements propagate through the economy. Furthermore, we explore how variations in economic structure, trade openness, and monetary policy frameworks influence the strength and nature of these relationships across the four analyzed countries. The literature on ERPT in the CEE region often overlooks the nuanced impacts of recent structural economic shifts, particularly the heightened exchange rate volatility and inflationary pressures observed in recent years. Moreover, a significant portion of this literature concentrates on the aggregate ERPT effect, paying less attention to the differential pass-through across various price levels within the economy. This study aims to bridge these gaps by providing an updated analysis that captures the effects of recent economic changes and by examining the structural pass-through mechanisms within the CEE context.

To comprehensively analyze these complex dynamics, we employ a Structural Vector Autoregression (SVAR) model. The SVAR approach offers several advantages, including the ability to capture the simultaneous interactions among multiple economic variables, to identify structural shocks, and to quantify the dynamic responses of variables to these shocks. This methodological framework allows us to provide a more nuanced understanding of the ERPT mechanism and its implications for monetary policy.

This research contributes to the existing literature by providing empirical evidence on ERPT in a region characterized by significant economic transformation and integration into the global economy. Our findings should help policymakers and economic agents understand the potential inflationary consequences of exchange rate fluctuations and to contribute to the development of more effective monetary policy strategies.

The paper is composed of four sections, each contributing to a comprehensive understanding of ERPT. The initial section undertakes a thorough review of existing literature on ERPT, delving into key findings, methodological approaches, and identified research gaps within the field. This foundation establishes a contextual framework for the subsequent analysis. The second section shifts focus to the core determinants of ERPT, exploring the intricate relationship between trade openness, monetary policy credibility, and the transmission of exchange rate fluctuations to domestic prices. This section provides a theoretical underpinning for the empirical analysis that follows. The third section constitutes the empirical core of the paper. SVAR model is employed to rigorously examine the dynamic interplay between exchange rates and price levels across various economic sectors. This quantitative approach allows for a nuanced understanding of the speed and magnitude of ERPT. The concluding section synthesizes the key findings derived from the literature review and empirical analysis. It discusses the implications of the results for policymakers and economic agents, highlighting the significance of ERPT for macroeconomic stability. Additionally, the section identifies avenues for future research, suggesting potential extensions and refinements to the current study.

1. Related literature

There is a long-standing literature on ERPT, with a particular focus on advanced economies. However, with the growing importance of emerging countries, literature focusing on these countries has also been published. On the other hand, most of these studies are outdated and do not reflect the current changes in the world economy.

Mishkin (2008) explores the changing relationship between exchange rate fluctuations and inflation. Historically, a depreciation of a currency has been associated with higher inflation. However, the paper observes a weakening of this correlation in the period leading up to the start of the financial crisis in 2008. The paper delves into factors influencing ERPT, including globalisation, structural changes, and monetary policy. Increased global competition and trade integration may have dampened the inflationary impact of exchange rate movements. Shifts in economic structures, such as changes in import composition, can affect ERPT. Central bank actions and credibility can influence how exchange rate changes translate into price changes.

The paper concludes by emphasizing the importance of understanding ERPT dynamics for effective monetary policy. Central banks need to carefully assess the potential inflationary consequences of exchange rate fluctuations and adjust their policies accordingly.

Zorzi, Hahn and Sanchez (2007) delve into the complexities of ERPT in emerging markets across Asia, Latin America, and Central and Eastern Europe with a VAR approach. The study acknowledges the unique challenges in estimating ERPT for these regions due to various factors, including active exchange rate policies, economic transformations, and macroeconomic instability. The study highlights the heterogeneity in ERPT across countries within these regions. While some countries exhibit significant ERPT, others display a more muted response in domestic prices to exchange rate fluctuations. The presence of a positive link between import openness and ERPT, while plausible theoretically, finds only weak empirical support.

According to Obstfeld and Rogoff (2005), the response of trade prices to exchange rate determines the potential change in the role of exchange rate in global current account effects, respectively its imbalances. Consistent with the theoretical assumptions, typical findings in the empirical literature (Campa and Goldberg, 2005) for developed countries show that ERPT lies in the interval <0;1> with the highest tending to be for import prices of goods, lower for producer prices and lowest for consumer prices. There are a number of explanations for this ranking within ERPT. Burstein et al. (2005) point out that imported goods reach consumers through wholesale and retail networks at prices affected by transportation, marketing and advertising costs, which partially dampens the impact of the exchange rate on the final price to consumers. The second explanation, according to Engel (2002), is that imported goods are intermediate goods in which the exchange rate is fully reflected, so that the pass-through is already complete when they enter the economy. Retail prices, on the other hand, are a combination of imported goods and domestic output, which is expressed in domestic currency. Moreover, retail prices are adjusted according to the exchange rate with a delay and with a given frequency.

Frimpong et al. (2014) conduct a meta-analysis synthesizes findings from 116 studies to examine the determinants of exchange rate pass-through (ERPT) in emerging markets. The study concludes that ERPT is significantly influenced by factors such as the level of economic development, monetary policy credibility, and exchange rate volatility. Notably, the authors find that ERPT has declined in recent decades, suggesting improved monetary policy frameworks and greater economic stability in emerging markets. The added value of this paper lies in its comprehensive overview of the ERPT literature, providing valuable insights for policymakers and researchers by identifying the key factors that affect the magnitude and dynamics of exchange rate pass-through in emerging economies.

Coricelli, Jazbec and Masten (2004) examine the relationship between the choice of exchange rate regime and inflationary performance in four countries that recently joined the EU: the Czech Republic, Hungary, Poland, and Slovenia. The study finds that the size of the pass-through effect and the importance of exchange rate shocks to overall inflationary performance vary across these countries. In particular, a perfect pass-through effect is associated with an accommodative exchange rate policy, which can become the most important source of inflationary pressures. The analysis suggests that for these four countries, an early adoption of the Euro can provide the most efficient framework for reducing inflation.

According to Jasova, Moessner and Takats (2016), it provides evidence for the conjecture that improving the monetary policy framework by fixing a nominal anchor leads to lower ERPT to consumer prices. This has been particularly confirmed for emerging countries in the last two decades. Thus, an important policy implication is that in countries where central bank credibility has been established, the exchange rate plays a key role in helping the economy counter a negative shock.

Carrière-Swallow et al. (2016) estimate ERPT for developed and emerging countries using the sample from 2000 to 2015. The paper's central argument is that a more credible monetary policy, characterized by well-anchored inflation expectations, is associated with a lower degree of ERPT to consumer prices. This suggests that central banks with strong reputations for achieving price stability can effectively mitigate the inflationary impact of exchange rate fluctuations. Within the CEE countries, they estimate ERPT over a one-year horizon as measured by the cumulative response of headline consumer prices to a one percent movement in the nominal effective exchange rate for the Czech Republic 0.13, Poland 0.21, Hungary 0.23 and Romania 0.25.

Ha et al. (2019) investigate the relationship between inflation and exchange rate movements, contingent on the nature of the underlying shocks. The authors use Factor-Augmented Vector Autoregression (FAVAR) models to compute seven shock-specific ERPT ratios for each country. Overall, domestic shocks are the main drivers of exchange rates in most of the developed and emerging samples examined. In particular, domestic shocks coming from monetary policy are accompanied by the largest ERPT on average. On the other hand, global shocks tend to have a smaller impact on the exchange rate and are associated with considerable heterogeneity of the estimated ERPT, depending on country specifics and the source of the shock.

Beirne and Bijsterbosch (2008) estimate the ERPT to consumer prices in Central and Eastern Europe using a multivariate cointegration approach and an impulse-response derivative of the Vector Error Correction Model (VECM). The results show an average ERPT of 0.5-0.6

but there are visible differences across countries according to their exchange rate regime. Countries with some form of fixed exchange rate exhibit higher ERPT, while those with floating exchange rates exhibit lower ERPT.

For the CEE region, Shevchuk (2022) finds that variability in consumer and producer prices is significantly influenced by external factors, including the German CPI and world oil prices, with varying impacts across different CEE countries. The findings reveal a sharp post-crisis increase in ERPT to consumer prices in Hungary, while a general strengthening of ERPT to producer prices is noted in most countries except the Czech Republic and Romania. The positive correlation between exchange rates and domestic prices supports the use of exchange rate appreciation as a potential anti-inflationary measure.

Most recently, Colak, Erden and Ozkan (2024) identify three key factors influencing ERPT: overall inflationary environment, exchange rate volatility, and openness. A positive relationship between average inflation and ERPT is observed in emerging economies, supporting existing hypotheses. The findings indicate that ERPT levels are generally low in advanced countries but higher in emerging economies, with significant changes observed after the global crisis. The analysis reveals the time-varying relevance of regressors, with significant coefficients for lagged inflation and exchange rates in emerging economies. The short-run ERPT is consistently significant in emerging economies, while it shows sparse relevance in developed economies over time.

2. Main drivers of exchange rate pass-through

Although the initial impact of exchange rate changes on inflation is typically visible very quickly within a few months, the time it takes for prices to adjust fully to the new exchange rate level can extend to several years. Moreover, as previous studies conclude, the effectiveness of ERPT varies over time and tends to decline as the economy develops. Therefore, any estimates must reflect the changing dynamics of the short- and long-term effects over time and the approach used in estimating should allow for time-varying sensitivities.

The characteristics of ERPT are influenced by several factors; however, previous studies (Frimpong et al., 2014; Carrière-Swallow et al., 2016) show that two factors in particular are key for emerging economies such as CEE countries:

(1) **The degree of the economy's openness to foreign exchange:** Countries that depend on foreign trade and imports of consumer goods tend to have a greater exposure to exchange rate risk, and any shock has a greater impact on price formation

in the economy. For instance, small open economies with a heavy reliance on imports are likely to experience a more pronounced ERPT to domestic prices. This is particularly evident in countries with a high import penetration ratio, where imported goods account for a significant portion of domestic consumption and production. Thus, the greater openness of the economy implies a stronger ERPT and vice versa.

(2) **Monetary policy credibility:** In economies where monetary policy is not credible and inflation expectations are not anchored, an exchange rate shock is likely to have a larger effect on inflation because producers and retailers are less likely to consider the shock temporary (Coulibaly and Kempf; 2010). Thus, price setters will be more likely to pass on the price shock to consumers. The low credibility of the monetary policy also usually leads to greater exchange rate volatility, which increases the cost of FX hedging, reducing the ability to defend against an exchange rate shock. At the same time, higher volatility increases retailers' sensitivity to price shocks and leads to a faster pass-through to consumers.

Beyond that, several other factors also affect ERPT, such as import composition, market structure or exchange rate regime. Beyond macroeconomic factors, ERPT is also affected at the firm level such as pricing-to-market behaviour, currency denomination of contracts and import share. At the same time, we have other factors such as global economic conditions, FX volatility or distribution channels.

Economies primarily importing raw materials or intermediate goods may experience a quicker and more direct pass-through compared to those importing finished consumer goods (Campa and Goldberg; 2005). This is because changes in the price of raw materials directly impact production costs, while the pass-through of price changes for finished goods might be delayed due to factors such as inventory adjustments and retailer pricing strategies.

The degree of competition within an industry can also significantly influence ERPT. In highly competitive markets, firms have limited pricing power and are more likely to pass through exchange rate fluctuations to consumers, to remain competitive. Conversely, firms operating in oligopolistic or monopolistic markets may have more discretion in adjusting prices, potentially leading to a slower or less complete pass-through. Additionally, the distribution of market power across different stages of the supply chain can impact the overall pass-through dynamics. For example, if import-competing firms possess significant market power, they may be able to absorb a portion of the exchange rate shock, mitigating the impact on consumer prices. However, if retailers or wholesalers have greater bargaining power, they may be able to shift a larger share of the ERPT to consumers.

The choice of exchange rate regime significantly influences ERPT. Fixed or managed exchange rate regimes often exhibit higher pass-through to maintain exchange rate stability. In contrast, countries with floating exchange rates may experience more flexible price adjustments. In particular, countries operating under a fixed exchange rate regime may find it difficult to insulate their economies from external shocks, leading to a more direct transmission of exchange rate fluctuations to domestic prices. This is because central banks under fixed exchange rate regimes often intervene in the foreign exchange market to maintain the exchange rate peg, which can limit the ability of monetary policy to respond to domestic economic conditions. On the other hand, countries with floating exchange rate regimes have more flexibility to adjust monetary policy in response to exchange rate shocks, which can help to mitigate the impact on domestic prices. However, the degree of exchange rate flexibility can vary across countries, and some countries may adopt intermediate exchange rate regimes that combine elements of both fixed and floating exchange rates. These hybrid regimes can present additional complexities in terms of ERPT dynamics.

Firms often engage in "pricing-to-market" strategies, adjusting export prices less than proportionately to exchange rates, changes to maintain market share or profit margins (Froot and Klemperer, 1989). This behaviour can dampen the pass-through of exchange rate changes to foreign consumers. As Campa and Goldberg (2005) argue, firms may strategically adjust their export prices to preserve market share or protect profit margins, in the face of exchange rate fluctuations. This pricing behaviour can contribute to incomplete pass-through, and influence the overall relationship between exchange rates and import prices.

The currency in which import and export contracts are denominated significantly impacts the timing and magnitude of ERPT. Firms with a substantial portion of contracts denominated in foreign currency may experience delayed or reduced pass-through effects (Goldberg and Knetter, 1997). For instance, if a firm has long-term contracts denominated in the foreign currency, it may be able to absorb exchange rate fluctuations in the short run, delaying the pass-through to domestic prices.

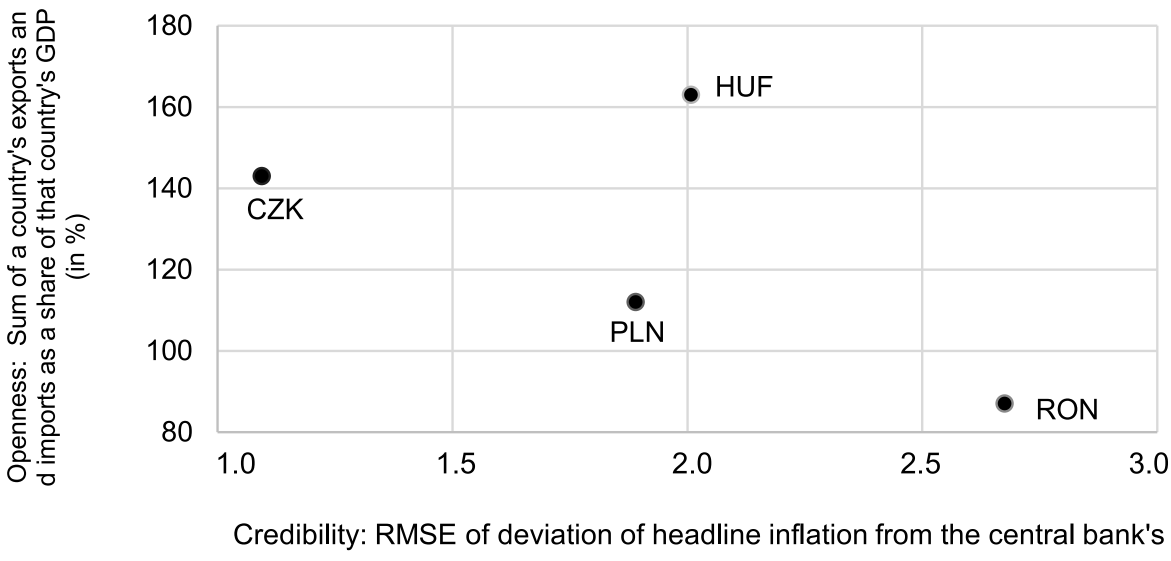
Firms with a higher import share are more exposed to exchange rate fluctuations and are likely to pass through changes in import prices to their output prices more rapidly (Dess et al.,, 2008). This is particularly relevant for firms operating in sectors with a high import content, such as manufacturing or assembly industries. A higher import share implies a greater reliance on imported inputs, making firms more vulnerable to exchange rate shocks and increasing the likelihood of passing through increased costs to consumers.

Global economic conditions, such as commodity price shocks, financial market volatility, and trade tensions, can exert significant influence on ERPT (Devereux and Engel, 2003). For example, a surge in commodity prices can increase production costs for firms, leading to higher output prices even in the absence of exchange rate changes. Similarly, financial market volatility can create uncertainty and affect firms' pricing decisions. Trade tensions, including tariffs and trade restrictions, can disrupt supply chains and lead to price adjustments. Increased exchange rate volatility can amplify ERPT, as firms may adjust prices more frequently to hedge against exchange rate risk. However, the relationship between volatility and pass-through is complex and depends on other factors, such as market structure, firm characteristics, and monetary policy.

The structure of distribution channels, including the number of intermediaries and the degree of competition, can influence the speed and extent of pass-through from import prices to consumer prices. Longer and more complex distribution channels may lead to delayed pass-through due to factors such as inventory management, markups, and transportation costs.

By considering these factors, in conjunction with specific country characteristics and economic conditions, researchers can gain a deeper understanding of the complex mechanisms driving ERPT.

Chart 1: Economy openness and monetary policy credibility



Source: Macrobond, author calculations

With a focus on main factors, to measure the openness of the economy, the sum of exports and imports relative to a country's GDP can be tracked. Monetary policy credibility can be expressed as the deviation of headline inflation from the central bank's target. In this simplified view of the economies under study in the CEE region (Chart 1), we see that the Czech Republic should benefit from the highest monetary policy credibility within the region. On the other hand, in terms of foreign trade, it is the second most open economy within the sample under study. Thus, the Czech Republic should have a relatively high ERPT due to the high openness of the economy. Poland ranks in the middle of the ranking of these two metrics and thus ERPT should be rather average within the region. On the other hand, Hungary is by far the most open economy in CEE and also has relatively low monetary policy credibility, indicating the highest ERPT. Compared to the Czech Republic, Romania is at the other end of the spectrum. It is by far the least open economy and at the same time the lowest monetary policy credibility, which should still indicate a relatively high ERPT.

In addition to differences in the ERPT across countries, it can also be assumed that there is an asymmetry in the response of inflation to exchange rate shocks within a particular economy. Normally, there is less pass-through in the case of currency appreciation than in the case of currency depreciation. This stems from downward price rigidity, given that price-setters may be less willing to cut prices and more open to raising prices with the incentive to increase margins at the same time.

3. Exchange rate pass-through estimation: SVAR approach

For the ERPT analysis, a Structural Vector Autoregressive (SVAR) model is estimated for the CEE countries. SVAR models (Forni et al.,.; 2019) offer several advantages for the purpose of this study. Unlike reduced-form VAR, SVAR models allow for the identification of structural economic shocks, which are crucial for isolating the causal impact of exchange rate fluctuations on domestic price levels. Given that ERPT is inherently a structural phenomenon, understanding the propagation of exogenous exchange rate shocks is paramount. A key advantage of the SVAR approach in this context is its ability to disentangle the effects of various economic shocks, particularly supply and demand-side disturbances. This is highly relevant for ERPT analysis, as exchange rate movements can be driven by both supply and demand forces, each with potentially distinct implications for domestic prices. The complexities of ERPT necessitate a modeling framework that can address the identification problem. SVAR models, through the imposition of structural restrictions, enable us to identify the contemporaneous relationships between variables and thus isolate the impact of exchange rate shocks from other confounding factors. Given the policy implications of ERPT for monetary authorities in the CEE region, the SVAR model provides a robust framework for evaluating the effects of exchange rate fluctuations on inflation. This allows for a more informed assessment of the potential consequences of different exchange rate policies and their impact on price stability. To identify the structural shocks, this study uses a Cholesky decomposition.

The goal is to estimate the sensitivity of price chains in the economy to exchange rate movements. The benchmark model contains seven variables including oil price, money supply, nominal effective trade-weighted exchange rate, output gap, import price index, producer price index, and consumer price index. The oil price is included in the models to capture supply side, while the output gap reflects the demand side. The money supply side represents the effect of monetary policy on the overall price level in the economy. The nominal effective trade-weighted exchange rate in the model represents the exchange rate as it best reflects the domestic economy's relationship with foreign economies and has a direct effect on import prices from abroad. To differentiate ERPT in different segments of the economy along the pricing chain, three price sectors, import price index, producer price index and consumer price index, are included in the model, assuming that import prices are the most sensitive, and CPI have the least sensitivity to the change in NEER.

The reduced form of the VAR model can be written as

$$A(L)_{yt} = \alpha + \varepsilon_t \tag{4.1}$$

where y_t represents a vector of endogenous variables at time t. $A(L)$ is the matrix polynomial of the lag operator L which represents the coefficients of the lagged values of the endogenous variables. Effectively, it captures how past values of the y variables influence their current values. α is a vector of constant terms, representing the deterministic component of the model. ε_t is a vector of reduced-form error terms, at time t.

The reduced-form error terms in the SVAR model, denoted by ε_t, represent the unexplained portion of the variation in the endogenous variables after accounting for their lagged values and any deterministic components. These error terms are assumed to be serially uncorrelated, implying that there is no systematic pattern in their values over time. However, they are typically correlated with each other, reflecting the contemporaneous relationships between the variables in the system. The error terms are linear combinations of the underlying structural shocks, which are the unobserved economic forces driving the dynamics of the model. By imposing identifying restrictions on the contemporaneous relationships, the SVAR model aims to disentangle these structural shocks from the observed error terms, allowing for the analysis of their individual effects on the variables.

To capture the interaction between endogenous variables, it is necessary to identify the structural form of the VAR model (SVAR). A structural model can be identified when at least it can be established $(k^2-k) / 2$ restrictions, where k is the number of endogenous variables. This is done using recursive variable ordering, i.e. Choleski decomposition.

The ordering (4.2) reflects the structure of the domestic economy and follows McCarthy (2007) approach. The price of oil (*oil*) is first in the order, with the assumption that the economy is a price-taker and is not able to influence the price of oil in global markets, while having an impact on all other variables in the model. The economic activity, represented by the output gap (*gap*) in the model, responds only with a lag to the monetary shock ($m1$), while the exchange rate (*neer*) responds to both monetary and real shocks in the economy. In this case, the output gap is calculated using a production function approach, outsourced from OECD estimates. The last four variables represent the price chain in the economy, where the exchange rate affects all prices immediately through a pass-through effect. Subsequently, the exchange rate directly affects import prices (*imp*), which are passed through to industrial producer prices (*ppi*), and then enter the consumer price index (*cpi*).

$$\begin{pmatrix} e_t^{\mathrm{oil}} \\ e_t^{\mathrm{m1}} \\ e_t^{\mathrm{gap}} \\ e_t^{\mathrm{neer}} \\ e_t^{\mathrm{imp}} \\ e_t^{\mathrm{ppi}} \\ e_t^{\mathrm{cpi}} \end{pmatrix} = \begin{pmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & 0 & 0 \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & 0 & 0 \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} & 0 \\ S_{71} & S_{72} & S_{73} & S_{74} & S_{75} & S_{76} & S_{77} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil} \\ \varepsilon_t^{m1} \\ \varepsilon_t^{gap} \\ \varepsilon_t^{neer} \\ \varepsilon_t^{imp} \\ \varepsilon_t^{ppi} \\ \varepsilon_t^{cpi} \end{pmatrix} \tag{4.2}$$

Quarterly data from 2009:1 to 2024:2 is used to estimate the model, implying a sample size of 62 observations (Table 1). The time series are seasonally adjusted where necessary. A unit root test is performed to assess the properties of the used time series. The results of the Augmented Dickey Fuller (ADF) test and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test show that alltime series are integrated of order one, I(1), in line with other studies (Table 1). Thus, for the purposes of model estimation, time series employed in the form of first differences of logarithms to ensure stationarity and to facilitate interpretation of the estimated ERPT. In the context of a system of this magnitude, it is crucial to consider parameter parsimony. Adopting the methodology of Ivanov and Killian (2005), the Akaike Information Criterion (AIC) was employed to ascertain the optimal lag length, which was determined to be five lags. This is consistent with the literature and economic logic. Subsequently, the impulse response function is estimated to calculate the ERPT. All shocks are normalized to the single-percentage response of *imp*, *ppi,* and *cpi* to impulse of *neer*.

To assess the adequacy of the SVAR model (Lütkepohl, 2005), we conducted a series of diagnostic tests (Table 2). The Lagrange Multiplier (LM) test is employed to assess the presence of serial correlation in the residuals, a crucial assumption for model validity. To comprehensively evaluate the potential for serial correlation, the LM test is conducted at both individual lags (h-time lag) and jointly across multiple lags (1: h time lag). The h-time lag allows for the detection of serial correlation at specific lags, while the 1: h time lag offers a broader perspective by examining the joint significance of serial correlation up to a certain lag order.

The LM test statistic (Greene, 2019) for the h-time lag is given by:

$$LM_h = TR^2 \tag{4.3}$$

where T represents the number of observations, R^2 is the coefficient of determination from the auxiliary regression of the residuals on the lagged residuals up to lag h.

The LM test for serial correlation revealed no significant evidence of autocorrelation in the residuals (Table 2), suggesting that the model captures the dynamic relationships between the variables effectively. The joint LM test for serial correlation in SVAR models often encounters degrees of freedom limitations, particularly with larger systems and limited sample sizes. This test assesses the null hypothesis of no serial correlation at lag h (h-time lag) for individual lags. It also assesses the null hypothesis of no serial correlation at lags 1 to h (1: h time lag) testing for serial correlation across all variables in the system up to lag h. As the number of lags included in the joint test increases, the number of parameters to be estimated grows rapidly. When the required parameters exceed the available degrees of freedom, we cannot reliably compute the test statistic and p-value. However, the individual lag tests and limited results of the joint test can still provide valuable information about the presence of serial correlation at specific lags.

Additionally, the Jarque-Bera test for normality confirmed that the residuals are approximately normally distributed, a crucial assumption for valid inference in SVAR models. To further validate the model, we inspected residual plots for any signs of autocorrelation or heteroscedasticity. These plots did not reveal any obvious patterns, reinforcing the findings from the LM test and suggesting that the model is adequately specified. Standard heteroscedasticity tests are not applicable to our SVAR model due to restrictions in the estimation process, and we rely on visual inspection of residuals and utilize heteroscedasticity-consistent standard errors to ensure robust inference. Overall, the diagnostic tests provide enough evidence that the estimated SVAR models are well-specified and do not suffer from misspecification issues that could bias the results.

Table 1: List of variables and tests of stationarity

		ADF				KPSS			
		Level		First Difference		Level		First Difference	
Variable	**Description**	**t-Stat**	**Prob.**	**t-Stat**	**Prob.**	**t-Stat**	**Prob**	**t-Stat**	**Prob**
CPI_CZK	Index, 2009=100	2.451	1.000	–4.593	0.000	2.706	1.000	–5.708	0.000
CPI_HUF	Index, 2009=100	2.250	1.000	–2.130	0.033	2.193	1.000	–2.855	0.057
CPI_PLN	Index, 2009=100	2.271	1.000	–2.103	0.035	2.209	1.000	–3.071	0.034
CPI_RON	Index, 2009=100	2.192	1.000	–2.539	0.012	2.227	1.000	–3.767	0.005
GAP_CZK	OECD calc.	–1.792	0.381	–3.801	0.000	–2.567	0.105	–3.423	0.014
GAP_HUF	OECD calc.	–1.901	0.330	–3.793	0.000	–2.192	0.211	–3.464	0.013
GAP_PLN	OECD calc.	–2.466	0.129	–3.032	0.003	–2.527	0.114	–3.070	0.034
GAP_ROM	OECD calc.	–1.944	0.311	–3.569	0.001	–3.076	0.034	–2.926	0.048
IMP_CZK	Index, 2009=100	–1.437	0.558	–4.168	0.000	–0.755	0.824	–4.476	0.001
IMP_HUF	Index, 2009=100	–0.372	0.907	–2.692	0.008	–0.315	0.916	–2.848	0.058
IMP_PLN	Index, 2009=100	–1.167	0.683	–2.522	0.013	–1.097	0.712	–2.596	0.099
IMP_RON	Index, 2009=100	–0.515	0.880	–2.957	0.004	0.250	0.974	–3.479	0.012
M1_CZK	Volume, LCYbn	–0.434	0.896	–1.976	0.047	–0.259	0.924	–3.181	0.026
M1_HUF	Volume, LCYbn	–0.003	0.954	–2.738	0.007	0.161	0.968	–3.824	0.005
M1_PLN	Volume, LCYbn	0.277	0.975	–2.399	0.017	0.363	0.980	–3.257	0.022
M1_RON	Volume, LCYbn	0.782	0.993	–1.905	0.055	0.991	0.996	–2.936	0.047
NEER_CZK	BIS, 2020=100	–0.971	0.758	–6.059	0.000	–1.044	0.732	–6.094	0.000
NEER_HUF	BIS, 2020=100	–1.709	0.421	–6.189	0.000	–0.327	0.914	–9.018	0.000
NEER_PLN	BIS, 2020=100	–2.353	0.160	–6.484	0.000	–2.561	0.107	–6.392	0.000
NEER_RON	BIS, 2020=100	–2.791	0.066	–6.756	0.000	–2.283	0.181	–7.030	0.000
PPI_CZK	Index, 2021=100	–1.779	0.387	–5.813	0.000	0.532	0.987	–4.249	0.001
PPI_HUF	Index, 2009=100	0.404	0.982	–3.854	0.000	1.051	0.997	–2.458	0.131
PPI_PLN	Index, 2009=100	0.944	0.996	–2.177	0.030	–0.262	0.924	–2.382	0.151
PPI_RON	Index, 2021=100	–0.346	0.911	–2.270	0.024	0.073	0.961	–3.470	0.012
OIL	USD/barrel	0.005	0.955	–3.185	0.002	–2.122	0.237	–5.816	0.000

Source: Authors' own elaboration

Table 2: Examination of error terms of the model: non-autocorrelation and normal distribution

		***p*-value**			
LM-test	**Lag**	**CZK**	**PLN**	**HUF**	**RON**
h-time lag	1	0.503	0.933	0.503	0.271
	2	0.185	0.329	0.559	0.806
	3	0.969	0.957	0.268	0.571
	4	0.730	0.661	0.209	0.136
	5	0.884	0.083	0.703	0.541
	6	0.936	0.292	0.694	0.762
1:h time lag	1	0.503	0.933	0.503	0.271
	2	0.981	0.168	NA	NA
	3	NA	NA	NA	NA
	4	NA	NA	NA	NA
	5	NA	NA	NA	NA
	6	NA	NA	NA	NA
Jarque–Bera	Joint	0.477	0.719	0.944	0.554

Source: Authors' own elaboration

Table 3 presents the coefficients of the estimated SVAR model, corresponding to the structure of the domestic economy and ordering (4.2). Each column represents a different country (CZK, PLN, HUF, RON), and the rows correspond to the estimated coefficients for each variable in the system. These coefficients capture the dynamic relationships between the endogenous variables, reflecting how past values of the variables influence their current values. Alongside the coefficients, the table provides the standard errors and p-values, allowing for an assessment of the statistical significance of each estimated relationship. The high log-likelihood values across all countries indicate a good fit of the model to the data.

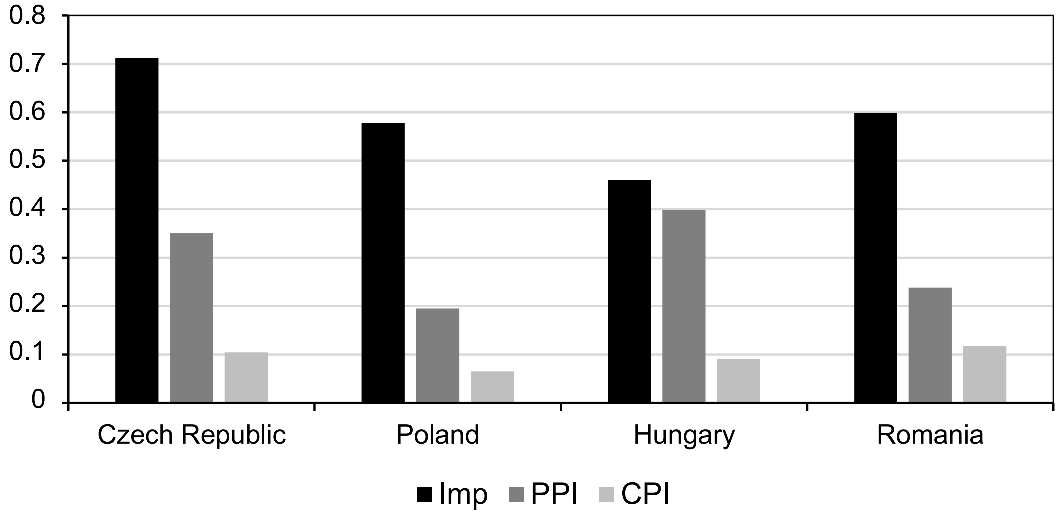
ERPT is calculated using the estimated SVAR model and the resulting impulse response functions. By summing the responses of import prices, producer prices, and consumer prices to the exchange rate shock over a specific period, we obtain the total pass-through effect. Chart 2 presents the main results of the estimated models and impulse response exercise. ERPT represents the cumulative response of import prices, industrial producer prices, and consumer price index to a one-percentage impulse in the nominal effective exchange rate after four quarters in the Czech Republic, Poland, Hungary, and Romania.

Table 3: Results of SVAR estimate

	CZK			PLN			HUF			RON		
	Coeff	Std. Error	Prob	Coeff	Std. Error	Prob	Coeff	Std. Error	Prob	Coeff	Std. Error	Prob
C(1)	−0.131	0.012	0.000	−1.584	0.148	0.000	0.171	0.016	0.000	0.154	0.015	0.000
C(2)	−1.033	0.902	0.253	−3.580	0.263	0.000	−1.369	1.033	0.185	3.666	1.013	0.000
C(3)	0.027	0.005	0.000	−0.008	0.004	0.040	−0.032	0.005	0.000	−0.028	0.005	0.000
C(4)	−0.025	0.005	0.000	0.038	0.005	0.000	0.011	0.002	0.000	0.004	0.001	0.000
C(5)	−0.023	0.003	0.000	−0.078	0.008	0.000	0.019	0.003	0.000	0.003	0.004	0.422
C(6)	−0.044	0.007	0.000	0.024	0.004	0.000	0.028	0.004	0.000	0.021	0.005	0.000
C(7)	−0.036	0.006	0.000	0.116	0.012	0.000	0.024	0.003	0.000	0.018	0.003	0.000
C(8)	6.712	0.634	0.000	2.992	0.280	0.000	7.666	0.724	0.000	7.126	0.673	0.000
C(9)	0.007	0.004	0.108	0.001	0.004	0.801	0.027	0.003	0.000	0.020	0.003	0.000
C(10)	0.014	0.004	0.001	−0.018	0.003	0.000	0.008	0.001	0.000	0.003	0.001	0.003
C(11)	−0.008	0.002	0.000	−0.003	0.002	0.234	−0.014	0.002	0.000	0.009	0.004	0.020
C(12)	−0.003	0.005	0.626	−0.021	0.003	0.000	−0.012	0.003	0.000	−0.003	0.005	0.554
C(13)	−0.002	0.005	0.688	−0.032	0.004	0.000	−0.009	0.002	0.000	0.001	0.002	0.579
C(14)	0.030	0.003	0.000	0.028	0.003	0.000	0.017	0.002	0.000	0.021	0.002	0.000
C(15)	−0.022	0.004	0.000	0.007	0.002	0.000	0.002	0.001	0.122	0.000	0.001	0.618
C(16)	−0.006	0.002	0.001	−0.007	0.002	0.002	−0.009	0.002	0.000	−0.011	0.003	0.002
C(17)	−0.038	0.004	0.000	−0.001	0.002	0.737	−0.010	0.003	0.000	−0.016	0.005	0.000
C(18)	−0.037	0.004	0.000	0.005	0.003	0.120	−0.007	0.002	0.000	−0.012	0.002	0.000
C(19)	0.021	0.002	0.000	0.013	0.001	0.000	−0.009	0.001	0.000	0.006	0.001	0.000
C(20)	−0.010	0.002	0.000	−0.002	0.002	0.317	−0.001	0.001	0.674	0.006	0.003	0.058
C(21)	0.011	0.002	0.000	0.007	0.002	0.002	−0.006	0.002	0.010	0.010	0.004	0.017
C(22)	0.013	0.002	0.000	0.013	0.003	0.000	−0.007	0.001	0.000	0.004	0.002	0.021
C(23)	0.011	0.001	0.000	0.016	0.002	0.000	−0.010	0.001	0.000	0.024	0.002	0.000
C(24)	0.007	0.001	0.000	0.016	0.002	0.000	−0.016	0.002	0.000	0.022	0.004	0.000
C(25)	0.004	0.001	0.000	0.018	0.002	0.000	−0.008	0.001	0.000	0.010	0.001	0.000
C(26)	0.005	0.000	0.000	0.004	0.000	0.000	0.004	0.000	0.000	0.021	0.002	0.000
C(27)	0.005	0.001	0.000	0.006	0.001	0.000	0.003	0.000	0.000	0.005	0.000	0.000
C(28)	−0.003	0.000	0.000	−0.002	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.000
Log likelihood	890.61			1080.04			1052.46			948.56		

Source: Authors' own elaboration

Chart 2: Estimates of Exchange Rate Pass-through by Individual Economy



Source: Authors' own elaboration

All analysed countries confirm the assumption of the highest pass-through for import prices and the lowest for the CPI. However, at first glance, different dynamics are evident across countries. The Czech Republic has the highest sensitivity of import prices to exchange rate movements in the CEE region. Thus, a 1% movement in the NEER translates into a 0.71pp annualised inflation rate over a one-year horizon. For industrial producer prices, ERPT falls to 0.35pp, and for consumer prices it is 0.10pp. As expected, Poland, being a significantly less open economy, shows a smaller ERPT in all price sectors. Import prices show a pass-through of 0.58pp, industrial producer prices 0.19pp, and consumer prices 0.06pp. Hungary, as the most open economy in the sample, shows a surprisingly low ERPT for import prices (0.46pp). On the other hand, the model indicates the highest pass-through within the region for industrial producer prices (0.40pp). Consumer prices, however, only increase by 0.09pp, which is the sample average. Romania, as the least advanced and open economy in the sample, shows the second highest ERPT for import prices (0.60pp). On the other hand, the pass-through for industrial producer prices (0.24pp) is lower than the Czech Republic and Hungary. However, the ERPT for consumer prices is the highest (0.12pp) within the CEE region.

Table 4: Variance decomposition

Imp	Period	CZK	PLN	HUF	RON
	1	57.36	50.71	50.31	67.92
	2	27.69	28.92	34.57	51.07
	4	21.56	12.75	14.40	28.22
	8	13.28	6.37	12.66	9.13

PPI	Period	CZK	PLN	HUF	RON
	1	28.02	12.66	31.22	18.17
	2	16.29	29.79	30.98	16.47
	4	11.51	42.89	11.98	17.70
	8	7.19	17.66	7.16	15.51

CPI	Period	CZK	PLN	HUF	RON
	1	0.08	0.00	2.77	3.41
	2	3.61	2.49	4.94	6.65
	4	10.69	10.13	10.28	11.17
	8	5.72	6.61	6.65	5.44

Source: Authors' own elaboration

An alternative view of the results shows the variance decomposition of the resulting SVAR models. The variance decomposition analysis, based on the historical data, (Table 4) reveals that exchange rate shocks have a significant impact on import prices, particularly in the short term. In the Czech Republic, for example, exchange rate shocks explain over 57.4% of the variation in import prices within the first quarter. However, the effect of the exchange rate on import prices halves in the second period and falls to 13.3% after two years. We see a similar trend in Hungary, while in Poland the exchange rate effect declines faster and explains only 6.4% of the variability after two years. In Romania, on the other hand, exchange rate explains 67.9% in the first period and 51% in the second, which is roughly double that of the other countries. However, in the subsequent periods, the explained variability decreases similarly to the other countries. In the case of industrial producer prices, the picture is more mixed. In the Czech Republic, Hungary, and Romania, the exchange rate effect is largest in the first period and declines thereafter, while it is visibly lower than in the case of import prices. In Poland, the exchange rate effect on PPI is particularly visible in the one-year horizon, which may be due to the less openness of the economy and the greater diversification of the internal market compared to other countries. In the case of consumer prices, the effect of the exchange rate is seen to be smallest, and all countries have the highest effect at one year horizon, in line with previous studies. However, in all cases it does not exceed 10.1-11.2% of the explained variability.

In conclusion, domestic factors, such as those captured by the output gap and monetary policy shocks, play a more substantial role in explaining the variation in PPI and CPI, particularly in the short term. Over time, the relative importance of exchange rate shocks and domestic factors changes. This suggests that, while exchange rate fluctuations have a significant initial effect on import prices, their influence weakens. These findings underscore the importance of considering both external and internal factors when analysing price dynamics in the region.

4. Concluding remarks

This study contributes to the growing body of literature on ERPT by examining its dynamics in four Central and Eastern European countries – the Czech Republic, Poland, Hungary, and Romania. Our findings highlight the significant heterogeneity in ERPT across countries and price stages, emphasizing the importance of considering country-specific factors. The results underscore the role of monetary policy credibility and trade openness in shaping ERPT patterns. A key finding is the substantial pass-through of exchange rate shocks to import prices, confirming the notion that these economies are price takers in global markets. However, the transmission to producer and consumer prices is more nuanced, with variations across countries. This suggests that domestic factors, such as pricing power, market structure, and consumer behaviour, play a crucial role in determining the overall impact of exchange rate fluctuations on inflation.

The CEE region is characterized by significant openness and price-taking from global markets. Moreover, the credibility of monetary policy does not reach the level of developed countries. These two factors thus indicate that ERPT is high in the CEE region in particular. The objective of this paper is to examine and estimate ERPT in the Czech Republic, Poland, Hungary, and Romania and across price sectors - import prices, industrial producer prices and consumer prices. A SVAR model incorporating global prices, domestic demand and supply side of the economy, exchange rate and the mentioned price sectors has been employed to estimate ERPT. The results confirm the hypothesis that import prices are most sensitive to exchange rate movements while consumer prices are the least sensitive. While import prices are directly influenced by the exchange rate, domestic pricing and other costs unrelated to goods prices enter into industrial producer prices and especially consumer prices. The country analysis shows that the Czech Republic has the highest sensitivity of import prices to exchange rate movements in the CEE region, but the sensitivity is relatively high for other countries in the sample. In the case of industrial producer prices, however, variation across the region is already visible. While Hungary shows the highest ERPT, Poland, on the other hand, indicates roughly half the sensitivity. In the case of consumer prices, the ERPT across the region is by far the lowest within price sectors. The highest exchange rate pass-through to prices was measured in Romania, medium in the Czech Republic and Hungary, and lowest in Poland within the CEE region.

The findings of this research have important implications for policymakers. Central banks in the region should carefully monitor exchange rate developments and their potential impact on inflation. Understanding the degree of pass-through at different price stages can inform monetary policy decisions and help mitigate inflationary pressures. Moreover, policies aimed at enhancing monetary policy credibility and promoting trade openness can contribute to a more stable macroeconomic environment.

Future research could explore the non-linear effects of exchange rate shocks on prices, considering factors such as financial development, exchange rate regimes, and global economic conditions. Additionally, investigating the role of supply-side factors, such as productivity and input costs, in shaping ERPT would provide further insights into the transmission mechanism.

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