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EXTERNAL SHOCKS PASS-THROUGH INTO SELECTED CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Abstract. The ongoing COVID-19 pandemic put further pressure on the economies, both at individual and global level and, amid already existing vulnerabilities, worsened the economic prospects. As a result of the negative effects of these tensions in tandem with global value chains disruptions, commodities' prices increased, leading to strong inflationary pressures around the globe. Given possible permanent effects on inflation expectations, it is therefore questionable how fast those prices are to be stabilized. In this context, this paper focuses on a group of 10 European countries, namely Czechia, Hungary, Poland, Romania, France, Germany, Italy, Spain, the Netherlands and the United Kingdom, in the period spanning from 2005 to 2020. By implementing a GVAR model, the study analyses the pass-through of the external shocks stemming mainly from the Euro Area and the US to the CEE region, comparing the responses obtained for these countries with the ones of the developed economies. Considering the strong trade relationships between the analysed countries, the considered transmission channel is the commercial one. The results indicate that a supply shock in the Euro Area has a significant negative impact on the selected CEE countries' economic growth, the offsetting factors not being strong enough to diminish the response.

Keywords: global vector autoregressive (GVAR), crisis, supply shocks, CEE region, trade chains.

JEL Classification: C32, E31, F16, F36, G01, O52.

Introduction

The international environment has become more fragile, amid the COVID-19 pandemic which heightened already existing vulnerabilities. Besides being a public health crisis, it has also severely affected economic activity. In 2020, most countries introduced lockdowns as a response to the pandemic, which led to deep GDP contractions. Furthermore, it has also led to significant reconfigurations of the labour market. At the current juncture, despite available

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vaccines to fight the pandemic, most countries still have difficulties in recovering from the damages already produced. Additional external shocks are not excluded as the emergence of new variants of the virus, possibly more contagious and resilient to existing vaccines is not ruled out.

To this adds recurrent significant geopolitical tensions and commercial and technological conflicts. Their exacerbation might lead to generalized protectionist measures. Negative effects of these tensions in tandem with global value chains disruptions caused by the pandemic are already visible on the international front. As a result, commodities' prices increased, leading to strong inflationary pressures around the globe. Given possible permanent effects on inflation expectations, it is therefore questionable how fast those prices are to be stabilized. Therefore, a potential inflationary shock has also to be considered, numerous central banks already taking decisions and adjusting their strategies in this regard, especially in emerging economies such as the Central and Eastern European (CEE) ones. However, the European Central Bank has repeatedly stated that the monetary conditions will be only gradually changed. Considering this, inflationary shocks stemming from the euro area core are the most relevant ones, especially in the short and medium term.

Risks to economic activity are not stemming just from the future evolution of the pandemic. They also relate to the energy shortages hindering economic recovery and possible increased volatility in the international financial markets. In case of this latter factor, relevant uncertainties stem from the geopolitical tensions generated by Russia, as well as from the Chinese financial market amid its biggest real estate player being on the brink of bankruptcy.

The outbreak of the COVID-19 pandemic meets all the criteria to be classified as a unique event in recent history. The unprecedented level of uncertainty stems from both the health sector - prevalence, degree of contagion, uncertain efficacy of treatments, the rapid discovery of a vaccine or effective treatment and its widespread application worldwide, the ability to absorb and accommodate medical systems facing flows of patients diagnosed with COVID-19, but also the dilemmas that currently characterize the global economy, such as the environment of low interest rates, the differences between temporary and permanent changes, potential bankruptcies of companies and their propagation effects, increasing global inequality and, of course, the emergence of new business models, adapted to this unforeseen situation. Thus, this situation has raised urgent questions about the impact of pandemics and the associated public health responses on the real economy. Decision makers are in unexplored territory, with little guidance on the expected economic consequences and how the crisis should be managed effectively.

Under these circumstances, elevated uncertainties are associated with the rhythm of the economic activity recovery, both at the level of the Euro Area and the global one. The materialization of such risks, individually or cumulative, could lead to the exacerbations of disruptions of economic activity, with consequences for small and open economies, such as the CEE ones. Thus, these markets could be affected through various channels, in an already vulnerable context triggered by the flight to quality phenomenon, which might generate a significant outflow of investment from the emerging countries. In this context, the present paper aims at studying the pass-through of the external shocks stemming mainly from the Euro Area to a selected group of CEE countries that already joined the European Union but

not the monetary union, comparing the responses obtained for these countries with the ones of the developed European Economies. Therefore, the analysis focuses on 10 European countries, namely Czechia, Hungary, Poland, Romania, France, Germany, Italy, Spain, the Netherlands and the United Kingdom, in the period spanning from 2005 to 2020. This study is particularly relevant considering that although the 21st century has already been marked by a number of epidemics, none can be compared in magnitude and extent with the COVID-19 pandemic. A recent epidemiological episode worth mentioning was the outbreak of the SARS virus from 2002 to 2003, originating in China. However, this episode caused only 8,000 infections and 900 deaths, compared to 265 million SARS-CoV-2 infections and 5.2 million deaths by the beginning of December 2021. At the same time, it should be noted that at the time of the SARS virus, China's economy accounted for only 3% of the global economy, compared to 16% today. Thus, the immediate effects felt after the appearance of the first outbreak were felt much more strongly. Nevertheless, the paper complements the existing literature by studying the shocks transmission in a macroeconomic environment potentially vulnerable to a stagflation state, where the potential policy decisions have to be made with caution.

The rest of the paper is organised as follows. Section 1 details the relevant economic literature related to similar matters, while Section 2 summarises the most important transmission channels of external shocks for Romania, Poland, Hungary and Czechia, detailing the commercial channel, the financial channel and the labour migration channel during the analysed period. The COVID-19 pandemic is a clear example how a presumable local shock could have spill-over effects all around the globe. Given its severe implications on international trade, we focus on the trade channel. Furthermore, Sections 3 and 4 describe the GVAR Methodology and explain the implementation steps and the calibration of this model. Moreover, Section 4 details the constructed dataset and provides information regarding the 5 illustrates (space between 5 and illustrates) of the GVAR model, analysing and comparing the magnitude and the duration of the possible adverse effects on CEE countries of negative inflationary supply shocks from the Euro Area and the United States.

1. Literature review

The importance of the global financial cycle, the evolution of global commodity prices and lending conditions for emerging market economies (EME) is increasingly highlighted in literature. In a world where countries have become more interconnected as global value chains extend and financial markets are more integrated, the analysis of spillover effects has gained popularity. In this regard, an important number of studies in relevant literature explore the pass-through of external shocks to certain economies or regions by using a Global Vector Autoregressive (GVAR) model. Chudik and Pesaran (2014) survey the latest developments in GVAR modelling and show their widespread use. However, Kim (2013) brings critics to the use of such models, as generalized impulse response functions may lead to misleading economic inferences.

One research direction refers to quantifying the global financial cycle. Davis et al. (2021) find that the global financial cycle and commodity price factor account for half of the variance of gross flows in advanced countries and forty percent of the variance of gross flows in

emerging countries. By contrast, Cerutti et al. (2017) provide empirical evidence supporting the fact that the role of the global financial cycle is limited, smaller than typically implied in literature. Furthermore, Ha et al. (2020), despite confirming the importance of the global financial factor, find significant spillovers stemming from equity and house prices.

According to Anaya et al. (2017), one of the key factors in explaining the global cycle is the USA monetary policy, which is transmitted through international capital flows. In their study, the authors empirically investigate whether the 2008–2014 unconventionally monetary policy of Fed influences financial conditions in EMEs and whether shocks are transmitted through capital flows. Anaya et al. (2017) remarks that an USA unconventional monetary policy shock significantly intensifies capital flows from the USA to EMEs for almost two quarters. The increase in capital inflows is accompanied by a persistent increase of more real and financial variables in EMEs. Furthermore, it is shown that, by average, EMEs, react through a monetary policy easing as a response to the expansionary shock stemming from the USA. Results are also confirmed by Miranda-Agrippino and Rey (2020) highlighting that US monetary policy shocks induce strong co-movements in the international financial variables that characterize the global financial cycle. Miranda-Agrippino et al. (2020) shows that US monetary policy shocks affect the global economy primarily through their effects on integrated financial markets, global asset prices and capital flows. The authors also analyse spillovers from the Chinese monetary policy, yet the transmission channel in this case is of a different nature, namely through effects on international trade and the commodity price factor.

According to Anaya et al. (2017), USA's central bank, namely the Federal Reserve, Fed, has engaged in several unconventional monetary policy measures, especially through large-scale financial asset purchase programs, widely known as "quantitative easing". At the same time, Anaya et al. (2017) highlight that the evolution of large and volatile capital flows in EMEs have generated a debate over the determinants and consequences of these cross-border flows.

Rey (2018) and Passari and Rey (2015) intensively analyse the importance of cross-border capital flows and the link with the global financial cycle. The global financial cycle is described by the existence of common tendencies in gross capital flows, in lending conditions and in the worldwide evolution of commodities prices. Rey (2018) considers that a key factor of this global cycle is monetary policy in the USA, which is globally transmitted through capital flows. As a consequence, the author claims that, in this case, the classical trilemma between independent monetary policy, free capital mobility and a fixed exchange rate is reduced to a dilemma: even if exchange rates are floating, an opened capital account restricts the monetary policy independence. Passari and Rey (2015) offer empirical evidence regarding the existence of a global financial cycle. The authors demonstrate that prices of stocks and other risky assets, as well as the size of credit, the degree of indebtedness and gross capital flows worldwide are interconnected with a global component. In line with the idea of a dilemma, correlations between countries do not vary systematically depending on the exchange rate regime.

Bruno and Shin (2015) and Rey (2018) present empirical proof according to which, until the Financial Crisis, international bank flows represented an important transmission channel

of the USA monetary policy to EMEs and, therefore, an important part of the global financial cycle. Therefore, Shin (2014) refers to the period of mid-1990 until the Financial Crisis as the first phasis of "global liquidity". Garcia et al. (2021) also confirm that bank-to-bank transmission remains one of the most relevant in terms of financial spillovers. Another important channel of external shocks pass-through, yet with effects rather on economic activity as a whole, refer to foreign direct investment, likely to generate valuable productivity spillover gains (Demena & Murshed, 2018).

The increasing importance associated to external shocks pass-through into emerging economies has encouraged both researchers and economic policy makers to make a greater effort to understand relevant transmission channels of financial institutions' policies (International Monetary Fund [IMF], 2013). Studies argue that, in particular, global financial conditions and economic growth are driven by a global financial cycle which, in turn, seems to be largely driven by the monetary policy in the USA (Rey, 2018; Bekaert et al., 2013).

Georgiadis (2016) evaluates the global contagion effects of shocks induced by Fed monetary policy decisions using a GVAR model. As a result, the author realises that effects generated by the monetary policy in USA are substantial; actually, in case of many economies, the spillover effects are larger than effects generated in the USA. Moreover, it is common knowledge that the magnitude of contagion effects depends on a series of country characteristics, such as the degree of financial integration, the degree of trade openness, the exchange rate regime, industry structure, development of the financial market and the stickiness of labour market (Rey & Martin, 2006; Cavallo & Frankel, 2008; Calvo et al., 2008; Edwards, 2007a, 2007b; Milesi-Ferretti & Tille, 2011; Broda, 2001; Edwards & Levy Yeyati, 2005). For instance, economies which are more integrated in global capital markets, have a lower integration in international trade, are characterized by a more rigid labour market and by domestic financial markets less developed, and are affected to a larger extent by spillover effects. Furthermore, it seems that there are some differences between the determinants of the magnitude of effects in advanced economies and other types of economies. In special, advanced economies limiting the exchange rate flexibility experiment larger contagion effects; in turn, less developed economies and more financially open have larger spillover effects.

While empirical evidence supports the idea of significant spillover effects stemming from monetary policy and financial shocks, in case of fiscal policy shocks, relevant literature finds rather little influence. While Belke and Osowski (2019) highlight moderate effects of fiscal policy shocks originating in Germany and France in case of euro area member countries and reduced spillovers in case of non-euro area countries, Cavallo and Ribba (2018) explain that fiscal policy turns out to be a minor driver of business cycle fluctuations.

As regards the CEE countries, Altăr et al. (2015) highlight a high degree of synchronization of the equity markets. The authors argue that while the equity markets of countries such as Romania, Hungary and Poland tend to overshoot the US equity shocks, the ones originating from the Euro Area have limited effects and do not get amplified over time. By contrast, Hung (2019) focuses on volatility spillovers from CEE countries and argues that the persistence of associated spillover effects is remarkable. Hung (2020) also finds that among CEE countries, the Czech market exerts a significant influence on the rest of foreign exchange markets.

El-Shagi and Tochkov (2022) find that monetary policy of the ECB has profound effects on CEE economies. Those results are just partly confirmed by Antal and Kaszab (2022), showing that the spillover effects of the ECB's expanded asset purchase program are more pronounced in case of sovereign bond yields when accounting for Czechia, Hungary, Poland and Romania. In case of these countries, such results are also supported by Falagiarda et al. (2015). Moder (2019) finds that spillovers from the ECB's non-standard monetary policy are mostly transmitted through the export channel.

In case of other types of external shocks, such as trade ones, Khan (2020) argues that trade spillovers on economic growth are significant across CEE countries. By using a GVAR model, the author shows that shocks originating from the Czech Republic, Poland and Slovakia play a greater role in the pass-through process. In terms of foreign direct investment, Szent-Ivanyi and Vigvari (2012) show that CEE countries experience productivity spillovers and the Czech Republic is evaluated to benefit from the largest effects.

At the current juncture, a hot topic in economic literature is the analysis of COVID effects. The pandemic has already struck a hard blow on the global economy. Its fast spread all around the globe had multiple socio-economic implications. From global value chains disruptions, to rising unemployment, the public health crisis brought significant reconfigurations to economic activity (e.g. Albu et al., 2020; Dimian et al., 2021; Umar et al., 2021). First papers on this topic addressed comparisons between various pandemics. For example, Jordà et al. (2022) compared different pandemics, showing that such episodes generate permanent reductions in the natural interest rate. Other research direction relates to the effectiveness of support measures introduced by authorities. While Cochrane (2020) and Huber et al. (2021) focused on the response of the Central Bank, Chudik et al. (2021) estimated a GVAR model in order to assess discretionary fiscal measures. After more data became available, spillover effects were also taken into consideration. For instance, Wang and Han (2021) analysed the implications of the COVID-19 induced slowdown in the USA economy for other countries. Empirical evidence shows that most countries were affected by the reduction in carbon and energy consumption in the USA. More recently, given the impressive economic recovery packages adopted at European level, the analyses of spillover effects currently focus on the *Next Generation EU* fund. Pfeiffer et al. (2021) highlight the existence of significant positive spillovers and argue that the total effect of the EU recovery funds could be up to one third larger when accounting from spillovers. At the same time, Picek (2020) admits the existence of significant spillover effects, yet conditional on the synchronization of European countries in terms of implementing investment projects. Furthermore, the same author shows that Northern and Western European countries could have a much higher spillover as compared to the one evaluated for Southern and Eastern European countries.

2. Transmission channels of external shocks: case of selected CEE countries

In the current environment, global risks have intensified and a resurgence of the pandemic is not ruled out, despite vaccination campaigns becoming manifest. While economic conflicts have the potential to amplify, elevated uncertainties regarding the unfolding of the pandemic persist. The materialization of one or more risk factors could have a significant impact on

small and open economies such as Czechia, Hungary, Poland and Romania. On the one hand, they can be affected directly, through the commercial channel, the financial one or the labour migration one. On the other hand, indirect influences could also intervene on the back of worsening economic growth prospects of main commercial partners, in tandem with the increase in risk premiums given the worsening economic sentiment of investors.

Given the increased interdependence between economies, as previously shown in related literature, global spillover effects could be substantial. For exemplification and as a prequel to estimating a GVAR model, we have chosen three transmission channels: the trade channel, the financial and labor migration one. We have investigated how selected CEE countries could be affected amid their main economic partners. Results are used when choosing the variables and countries for the GVAR estimations.

Firstly, as regards trade spillovers, those are highly relevant amid the fast growth of global value chains. Once with the expansion of large chain stores domestically, such as hypermarkets, supermarkets, discounters, cash&carry and proximity stores, and the increase in the preference for modern trade, the degree of CEE countries' integration in global value chains has increased as well. Any bottlenecks could affect the cost and availability of specific intermediate goods essential to the production of a wide range of final products. For instance, the recent semiconductors crisis has brought several industries of European countries to a standstill, as Europe is heavily dependent on third-country suppliers. Furthermore, consequences of global value chains disruptions could also imply a considerable lengthening of suppliers' delivery times and a rise in import prices, with adverse effects on domestic consumer prices. Such evolutions have recently occurred amid the swift reactivation of global trade following the worldwide lockdowns during the COVID-19 pandemic. At the same time, trade tensions could generate uncertainty that can lower investment amid confidence shocks.

In case of selected CEE countries, Germany is the main trading partner in terms of both exports and imports (Figures A.1 and A.2 in the Appendix). Besides Germany, with few exceptions, Czechia, Hungary, Poland and Romania share almost the same trading partners, which are mostly intra-EU countries, such as the Netherlands, Italy and France.

Secondly, in terms of the financial channel, we focus on foreign direct investment (FDI) inflows, also linked to the investment channel. FDI is expected to generate valuable productivity spillover gains. This might occur through demonstration effects – in order not to lose competitiveness, domestic firms might try to imitate technology, management or marketing used by their affiliates. Vertical linkages are another channel of pass-through, by making the new technology available to suppliers of FDI firms. Nonetheless, people are also expected to benefit from the know how within FDI firms. Other spillover effects refer to labour mobility.

As regards selected CEE countries, close to 20% of the FDI stock relates to Netherlands, followed by Germany and Luxembourg, which are also important FDI partners (Figure A.3 in the Appendix).

Lastly, the channel of labor force migration is also relevant in case of Czechia, Hungary, Poland and Romania, especially in the context of lingering structural vulnerabilities (Figure A.4 in the Appendix). A potential increase in labor migration with an impact on labor supply would exert wage pressures. Production prices would be higher, which could affect production or final consumers' prices. By the contrary, positive externalities could stem from

immigrants in the context of highly skilled labor supply, having more possibilities to find or even create new job positions. Moreover, it might address critical labor shortages, especially in the context of ageing population.

In selected CEE countries, especially in case of Romania, labour market is characterized by a relatively high degree of tightness. This is partly explained by structural problems that have become chronic over time, such as: (i) low mobility of labour force, (ii) difficulties encountered by companies in the recruitment process and (iii) the ageing process. Under these circumstances, emigration intensified in the last years. The favourite destinations of CEE people remain the countries in the European Union. According to Eurostat data, the top destination of emigration in case of Czechs, Hungarians and Polish citizens is Germany. Even though this country is also preferred by Romanians, Italy seems to stand on the first position in terms of emigration. Taking into consideration the incipient degree of implementation of labour market reforms in the home countries, the flow of emigrants choosing to return to Czechia, Hungary, Poland or Romania is expected to be low. Besides, in case of Romania, the significant gap between the average wage in this country and that of developed economies in the European Union is yet another factor in favour of a low flow of emigrants returning home.

3. Methodology – the GVAR model

GVAR models were initially developed by Pesaran et al. (2004) as a response to the 1997 Asian crisis, aiming to quantify the effects of different macroeconomic shocks on the results of credit institution.

The GVAR model can be described in two steps. Initially, small sized models specific to each country (VARX*) are estimated. Those contain specific variables of each country and average values from other studied countries. Consequently, individually estimated coefficients are aggregated and used within a single model (the GVAR one), in order to obtain results at a global stage.

The construction of VARX* models starts from the hypothesis of the existence of $N + 1$ countries or regions in global economy, denoted by $i = 0, 1, \ldots, N$, where economy 0 is considered to be the reference one. The aim is to model, for the $N + 1$ countries, a series of national specific macroeconomic variables of interest, synthetized through a vector x_{it} over the time span $t = 1, 2, \ldots, T$. All national specific factors, as well as observable global factors are treated as endogenous variables, which leads to an oversizing of the dataset. In order to solve this issue, when the VARX* model for country i is built, the GVAR model imposes a weak exogeneity condition to all global factors and to national factors specific to countries $1, 2, \ldots, i-1, i+1, \ldots, N$. As a consequence, except for the reference country, all other N economies are assumed to be small and open economies. The number of domestic and external variables defined for each country can differ from a country to another. Basically, $VARX^{*}(2,2)$ models for country i start from the following structure:

$$x_{it} = a_{i0} + a_{i1t} + \Phi_{i1} x_{i,t-1} + \Phi_{12} x_{i,t-2} + \Lambda_{i0} x^{*}_{i,t} + \Lambda_{i1} x^{*}_{i,t-1} + \Lambda_{i2} x^{*}_{i,t-2} + u_{it}, \qquad (1)$$

where x_{it} is the vector of the $k_i \times 1$ domestic variables, x^{*}_{it} is the vector of the $k^{*}_i \times 1$ external

variables and $u_{it} \sim IID\left(0, I_N\right)$. Foreign variables are obtained as weighted averages of all the other N economies. In other words, $x_{it}^{*} = \sum_{j=0}^{N} w_{ij} x_{jt}$, where w_{ij} for $j = 0, 1, \ldots, N$ represents a set of weights for which $w_{ii} = 0$ and $\sum_{j=0}^{N} w_{ij} = 1$. These weights are predetermined and play the role of illustrating the importance of each country j for economy i, conditional on the analysed subject.

The GVAR methodology can be applied to both stationary and integrated series. According to these, the distinction between short term and long-term effects is made – the latter ones are treated as cointegration relations, as the VECMX* models start from the below formula:

$$\Delta x_{it} = c_{i0} - \alpha_i \beta_i' \left[z_{i,t-1} - \gamma_i \left(t-1 \right) \right] + \Lambda_{i0} \Delta x_{it}^{*} + \Gamma_i \Delta z_{i,t-1} + u_{it}, \tag{2}$$

where $z_{it} = \left(x_{it}', x_{it}^{*\prime} \right)$, α_i is a matrix $k_i \times r_i$ of rank r_i and β_i is a matrix $\left(k_i + k_i^{*} \right) \times r_i$ of rank r_i. VECMX* models are estimated for each country introduced in the analysis and are conditional on x_{it}^{*}, where x_{it}^{*} is first order integrated and weak exogenous in relation with the VECMX* model parameters. Additionally, possible cointegration relations between x_{it}, as well as between x_{it} and x_{it}^{*} are considered. Subsequently, the built model for each country provides results regarding the number of cointegration relations – r_i, the speed of adjustment coefficients – α_i and cointegration vectors – β_i. As shown in Pesaran et al. (2000), in most macro-economic applications of interest, where the variables of interest contain deterministic trend components, the appropriate vector error correction model is the one where the trend coefficients are restricted so that they lie in the cointegrating space.

As previously mentioned, global variables (d_t) can as well be introduced in the model, for which a weak exogeneity condition is also assumed. In this case, the VARX* model becomes:

$$\begin{aligned} x_{it} = {} & a_{i0} + a_{i1t} + \Phi_{i1} x_{i,t-1} + \Phi_{12} x_{i,t-2} + \Lambda_{i0} x_{i,t}^{*} + \Lambda_{i1} x_{i,t-1}^{*} + \\ & \Lambda_{i2} x_{i,t-2}^{*} + \Upsilon_{i1} d_t + \Upsilon_{i2} d_{t-1} + \Upsilon_{i3} d_{t-2} + u_{it}. \end{aligned} \tag{3}$$

Going back to the general example, after solving the VARX* model for each of the N countries analysed, the GVAR methodology is applied at a global level, for the whole formed system with all the variables being endogenous. Starting from the $VARX^{*}\left(2,2\right)$:

$$x_{it} = a_{i0} + a_{i1} t + \Phi_{i1} x_{i,t-1} + \Phi_{i2} x_{1,t-2} + \Lambda_{i0} x_{it}^{*} + \Lambda_{i1} x_{i,t-1}^{*} + \Lambda_{i2} x_{i,t-2}^{*} + u_{it}, \tag{4}$$

$z_{it} = \left(x_{it}', x_{it}^{*\prime} \right)$ is defined, for each economy resulting:

$$A_{i0} z_{it} = a_{i0} + a_{i1} t + A_{i1} z_{i,t-1} + A_{12} z_{i,t-2} + u_{it}, \tag{5}$$

where $A_{i0} = \left(I_{k_i}, -\Lambda_{i0} \right), A_{i1} = \left(\Phi_{i1}, \Lambda_{i1} \right), A_{i1} = \left(\Phi_{i2}, \Lambda_{i2} \right)$. Considering that matrices W_i of dimension $\left(k_i + k_i^{*} \right) \times k$, are defined by weights w_{ij}, the following relation is obtained:

$$z_{it} = W_i x_t, \tag{6}$$

where $x_t = \left(x_{0t}', x_{1t}', \ldots, x_{Nt}' \right)'$ is a $k \times 1$ vector which collects all endogenous variables of the system. Thus, for $i = 0, 1, 2, \ldots, N$, results:

$$A_{i0}W_i x_t = a_{i0} + a_{i1}t + A_{i1}W_i x_{t-1} + A_{12}W_i x_{t-2} + u_{it}. \quad (7)$$

Subsequently, these individual relations are aggregated in order to generate the model for x_t:

$$G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + G_2 x_{t-2} + u_t, \quad (8)$$

where:

$$G_0 = \begin{pmatrix} A_{00}W_0 \\ A_{10}W_1 \\ \cdots \\ A_{N0}W_N \end{pmatrix}, G_1 = \begin{pmatrix} A_{01}W_0 \\ A_{11}W_1 \\ \cdots \\ A_{N1}W_N \end{pmatrix}, G_2 = \begin{pmatrix} A_{02}W_0 \\ A_{12}W_1 \\ \cdots \\ A_{N2}W_N \end{pmatrix}, \quad (9)$$

$$a_0 = \begin{pmatrix} a_{00} \\ a_{10} \\ \cdots \\ a_{N0} \end{pmatrix}, a_1 = \begin{pmatrix} a_{01} \\ a_{11} \\ \cdots \\ a_{N1} \end{pmatrix}, a_0 = \begin{pmatrix} a_{0t} \\ a_{1t} \\ \cdots \\ a_{Nt} \end{pmatrix}.$$

Taking into consideration that G_0 is a known non-singular matrix which depends on the weights in trade and estimated parameters, the GVAR model can be described as follows:

$$x_t = b_0 + b_1 t + F_1 x_{t-1} + F_2 x_{t-2} + \varepsilon_t, \quad (10)$$

where: $F_1 = G_0^{-1}G_1, F_2 = G_0^{-1}G_2, b_0 = G_0^{-1}a_0, b_1 = G_0^{-1}a_1, \varepsilon_t = G_0^{-1}u_t$.

The GVAR model can be solved recursively and allows interactions between analysed economies through three distinct channels, respectively:

1. Contemporary dependencies of domestic variables x_{it} on specific external variables x_{it}^* and on their lags;
2. Contemporary dependencies of domestic variables x_{it} on global variables d_t;
3. Contemporary dependencies of shocks from country *i* on shocks from country *j*.

4. Setting up the GVAR model

The GVAR methodology was practically implemented using the GVAR Toolbox software (Smith & Galesi, 2014), which is a collection of Matlab procedures with an Excel based interface. In this paper, we use and study generalized impulse response functions (GIRF) in order to notice the propagation of shocks. These are an alternative to orthogonal impulse response functions and the order of variables and the countries included in the model are invariant. Therefore, putting aside the potential deficiencies of the GIRF, for which the economic literature points out that they might be based on identifying assumptions that contradict each other (Kim, 2013), GIRF have the advantage of providing information about the pass-through of individual shocks in the system, in the absence of certain a priori information regarding the order of shocks or economies. Practically, GIRF functions help us eliminating the problem of ordering errors for the orthogonalization of the variance matrix. These were initially described by Koop et al. (1996) and subsequently adapted for VAR models by Pesaran and Shin (1998).

In order to define GIRF functions, we start from the model obtained through the GVAR solution, expressed in terms of errors specific to individual country models in Eq. (8). GIRF functions are defined through the following relation:

$$GIRF\left(x_t;u_{ilt},n\right)=E\left(x_{t+n}\mid u_{ilt}=\sqrt{\sigma_{ii,ll}},I_{t-1}\right)-E\left(x_{t+n}\mid I_{t-1}\right), \tag{11}$$

where T_{t-1} is information available at moment $t-1$, $\sigma_{ii,ll}$ is the element from the main diagonal of the Σ_u variance-covariance matrix corresponding to the l equation of country i, and n is the time horizon.

In the hypothesis that u_t follows a normal multivariate distribution, it results that the GIRF function corresponding to a one standard deviation shock of variable j in equation l at moment t is given by element j of the relation:

$$GIRF\left(x_t;u_{lt},n\right)=\frac{e_j^{'}A_nG_0^{-1}\Sigma_u e_l}{\sqrt{e_l^{'}\Sigma_u e_l}},\ n=0,1,2,\ldots,\ l,\ j=1,2,\ldots,k, \tag{12}$$

where $e_l=\left(0,0,\ldots,0,1,0,\ldots,0\right)'$ is a selection vector, where element l equals to 1 in case of a country specific shock.

4.1. Data

The Global Vector Autoregressive, GVAR, methodology is in essence a compact representation of the global economy. It provides an analysis framework for modelling economic and financial interdependencies between countries. From this point of view, the GVAR model involves various countries and regions. For the purpose of this study, namely quantification of spillover effects on the selected CEE economies, we included both emergent and developed economies. The reference economy is that of the United States of America, while the countries that are Euro Area members are treated both individually and as a region.

As regards economies included in the analysis, we chose, on the one hand, emerging economies within the Central and Eastern Europe, namely Poland, Romania, Czechia and Hungary and on the other hand, developed economies, especially from the Western and Southern Europe, such as Italy, the Netherlands, Germany, France, Spain, the United Kingdom. At the same time, the materialization of adverse shocks in economies such as that of Germany, France or Spain is expected to have large spillovers in emerging economies. Additionally, the linkages of the CEE countries with the external front were also taken into consideration, as already mentioned in previous sections: (i) most foreign direct investment (FDI) are made in relation with the Netherlands or Germany, (ii) on the exports side, most commercial transactions over the last years were made with Germany, Italy, France, while (iii) on the imports side, main trading partners are Germany, Italy and, not lastly, (iv) Germany, Spain and Italy are the countries where a significant number of people emigrate.

In order to capture various spillover channels, the previously mentioned countries were modelled according to various indicators. Datasets for each of the 11 countries/regions consist of:

1. Country specific factors – domestic variables: (i) gross domestic product (GDP) – expressed in real terms, 2010 = 100; (ii) prices – the harmonized consumer price – 2015 = 100;

(iii) short term interest rate – the three months interbank average interest rate; (iv) long term interest rate – in case of European and Euro Area countries, we used the bond yields used for the European Monetary Union convergence criteria; in case of the USA we used the yields of 10 years maturity bonds; (v) main stock market indices – for each country, we chose a reference index, such as Czechia – PX, Euro Area – Euro Stoxx 50, Romania – BET, France – CAC40, Germany – DAX, Italy – FTSE MIB, Spain – IBEX35, Poland – WIG30, USA – S&P500, Hungary – BUX, United Kingdom – FTSE100, the Netherlands – AEX and (vi) the real exchange rate;

2. External factors – foreign variables – for each country, these were computed as weighted averages of the indicators corresponding to the other countries (the weights are defined given the commercial linkages): (i) gross domestic product (GDP); (ii) prices; (iii) short term interest rate; (iv) long term interest rate; (v) main stock market indices and (vi) exchange rates;
3. Global factors: (i) Brent oil price; (ii) agri-food commodity prices and (iii) price of metals (the used index includes the price of basic and precious metals).

All data are on a quarterly frequency and refer to the 2005Q1 – 2020Q4 period. The raw series with monthly frequencies were aggregated at a quarterly frequency using the average of monthly observations. The series were sourced from the national central banks databases of the analysed countries, Eurostat, International Monetary Fund – International Financial Statistics (IMF – IFS) and Bloomberg. All calculations and data transformations have been computed according to the methods applied by Mohaddes and Raissi (2020).

For defining the necessary weights for the transformation of variables related to each country into variables related to defined regions, as well as for obtaining impulse response functions for each analysed economy and for the forecast error variance decomposition in regional factors we use the GDP PPP weight matrix. In addition, in order to define the existing relations and linkages between defined countries and regions, we use the trade relations matrix. Thus, we compute the vector of commercial relations for each economy *i* using balance of payments data (exports and imports of goods and services). The relations between the selected countries are defined as follows:

$$x_{in,t} = \frac{\frac{1}{2}\left(export_{\text{country } i \text{ to country } n} + import_{\text{country } i \text{ from country } n}\right)}{\sum_{j=i}^{N} \frac{1}{2}\left(export_{\text{country } i \text{ to country } j} + import_{\text{country } i \text{ from country } j}\right)}. \quad (13)$$

For the defined countries and regions, an (7×7) matrix reflecting trade relations was built based on IMF data, on a yearly basis, from 2005 to 2020, containing the commercial linkages between the following countries: Poland, Hungary, Romania, Czechia, the United Kingdom, Euro Area and the United States of America. The option of a time varying matrix was chosen in order to capture potential changes regarding trade relations between countries, so that possible shocks simulated at the level of an economy/region to be transmitted with a high accuracy.

For a clearer picture of the trading relations in Europe, Figure 1 illustrates the commercial links between 12 European countries (the 10 countries included in the analysis, Croatia

and Portugal). In order to do this, an extended (12×12) matrix for 2007 and 2020 was build containing the commercial linkages between these 12 countries. The colour green represents a trade link of more than 30% between country *i* and country *j* from the total trade relations of country *i* with the other European economies included in the study. The thickness of the line joining two nodes is given by the magnitude of trade transactions between the two points. Furthermore, the intensity of blue colour illustrating the background of each country represents the strength of the trade linkages of the country with the USA, while the ranking of the linkages between Euro Area and the analysed countries is represented through the size of the node corresponding to each country.

As regards trade relations at European level, we notice that Germany is the main trade partner for most analysed countries, a position that is maintained both for 2007 and 2020 (Figure 1), as well as for the entire sample between 2005 and 2020. Moreover, out of the 9 EU countries, Germany is also the main trade partner of both USA and Euro Area. Therefore, France, Poland, Netherlands, Czechia, Italy and Hungary registered a weight of trade relations with Germany larger than 30% in total exports and imports in all analysed years. Nevertheless, Germany has also the strongest trade link with the Euro Area region. Therefore, a potential shock in the euro area could be felt in the analysed countries through the commercial channel. In case of Italy, Figure 1 shows strong trade relations with Croatia and Romania in 2007, which diminished thereafter and are no longer above the 30% threshold in 2020.

4.2. Variables included in individual country models

As previously mentioned in the methodology section, the first step in estimating the GVAR model is the estimation of small scaled models for each country (VARX*) including country specific variables of each economy as well as average values for the rest of the countries. In this paper, the VARX* models are built in line with Table 1.

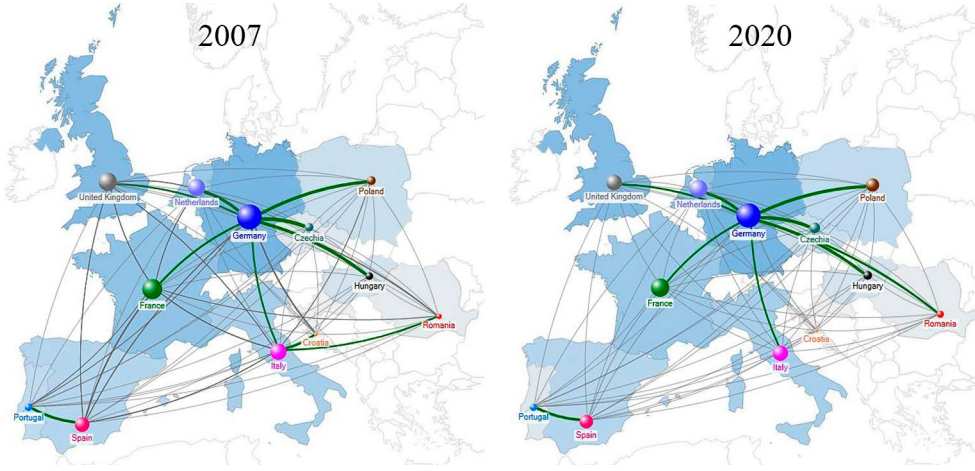

Figure 1. The evolution of trade relations between analysed countries
(source: IMF, authors' calculations)

Table 1. Individual models specifications (source: authors' calculations)

	Domestic variables						Foreign variables						Global variables		
	y	Dp	eq	ep	r	lr	y	Dp	eq	ep	r	lr	poil	pmat	pmet
CZ	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
EA	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
HU	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
PL	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
RO	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
UK	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
USA	1	1	1	0	1	1	1	1	0	1	0	0	1	1	1

Note: digit 1 is attributed to variables included in individual model while digit 0 is attributed to excluded variables; abbreviations: y – real GDP, Dp – inflation rate, eq – real equity prices, ep – real exchange rate, r – nominal short term interest rate, lr – nominal long term interest rate, poil – Brent oil price, pmat – raw materials price, pmet – metal price.

The estimation of country specific models allows the computation of contemporary effects of foreign variables on domestic ones. According to Dées et al. (2007), these could be interpreted as elasticities between domestic and external variables. For instance, a positive and statistically significant coefficient of GDP shows that domestic production reacts immediately and in the same direction as the external GDP changes.

5. Results of the GVAR model

The GVAR model was built in order to study the exposure of the CEE economies to external shocks through the impulse response functions. Subsequently, in this section we analyse cumulative generalized impulse response functions (GIRFs). The simulated shock was a one standard deviation inflationary supply shock in the Euro Area.

By using the GVAR toolbox and the methodology previously described in section 4, results show that a one standard deviation supply shock in Euro Area leads to a decrease of approximately 0.1 percentage points in the economic growth of Romania, Hungary and Czechia, with Hungary recording the strongest decrease (Romania and Czechia 0.08 percentage points and Hungary 0.1 percentage points), while Poland has a lower response, of only 0.03 percentage points (Figure 2).

The confidence intervals for Poland are also thinner than in the other cases. For all the selected CEE countries, an amplification of the shock is observed in the first 5–7 quarters, the shock being then completely absorbed in the first 30 quarters, with a higher persistence in case of Romania and Hungary, than for Poland and Czechia. The long duration of the shock absorption period shows that a supply shock in the euro area not only has effects on the actual GDP growth, but also on potential GDP. A shock in the Euro Area block has effects on the perception and expectations of foreign investors and, implicitly, on capital inflows in emerging countries. Therefore, the results indicate that systematic shocks have structural effects on emerging economies. The response of the two feedback variables in the model, namely the real GDP and inflation, cannot offset the effects of the shock, and, therefore, the response remains in the negative side for the entire 40 quarters interval.

Comparing the results obtained for the CEE economies with the ones of the developed countries, we observe that the latter generally display lower responses, except for Spain (Figure 3). More precisely, the United Kingdom and the Netherland have a maximum response of 0.03 percentage points, followed by France with 0.04 percentage points, Italy and Germany with 0.05 percentage points, while Spain records a decrease of 0.16 percentage points of the

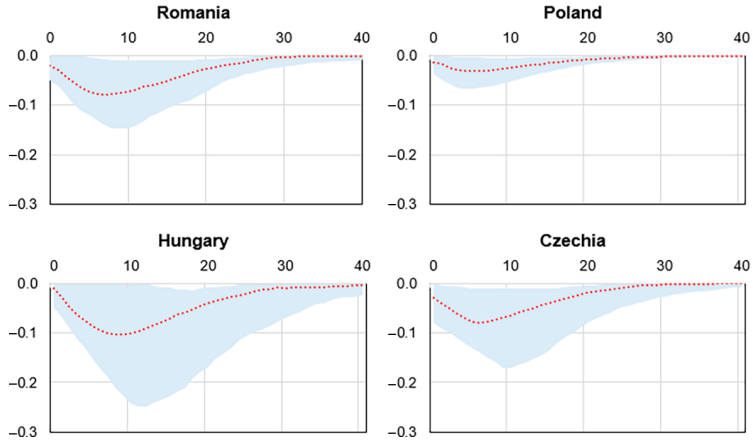

Figure 2. Impulse response functions of a one standard deviation supply shock in Euro Area on the selected CEE countries real economic growth (source: authors' calculations)

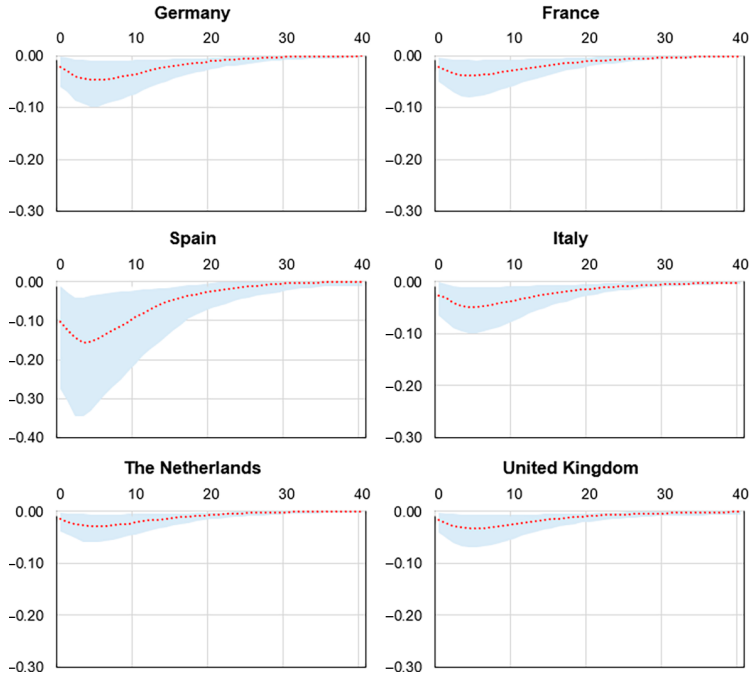

Figure 3. Impulse response functions of a one standard deviation supply shock in Euro Area on the selected developed European countries economic growth (source: authors' calculations)

economic growth. Moreover, the shock is absorbed faster, up to 20 quarters. The response observed for Spain highlights once again the persistent structural differences between southern and western developed European countries.

From the analysed CEE countries, Poland displays the most similar pattern with the developed economies, both in terms of dynamics, shape and confidence intervals amplitude. This fact indicates that among the countries in its region, Poland has a more mature economy, similar to the countries in the euro area. The differences identified between the other three analysed CEE countries, namely Romania, Hungary and Czechia and the developed economies of France, Italy, Germany, the Netherlands and the United Kingdom, point out the structural differences of the two groups, with the former still being under the process of consolidating their fiscal stance and of anchoring their inflation expectations.

To analyse the response to a shock originated outside of the Euro Area, we also simulated a one standard deviation inflationary supply shock in the United States of America. Once again, Romania and Hungary record the most material responses, although smaller than in the case of the previously discussed Euro Area shock – Romania 0.013 percentage points and Hungary 0.017 percentage points (Figure 4). Poland has the smaller response, 0.005 percentage points, closely followed by Czechia, with 0.007 percentage points. The supply shock originated in US is absorbed faster by the selected CEE countries than the EA shock, its duration being 20–25 quarters. An important aspect is related to the confidence intervals, which, although not necessarily much wider, indicate less statistically significant responses. The responses remain only in the negative side.

Moving to the developed European countries, we notice that, except for Spain, all the other countries have rather small responses, which persist for 20 quarters in almost all cases (Figure 5). Once again, among the selected CEE countries, Poland is the one that responds mostly as the developed economies.

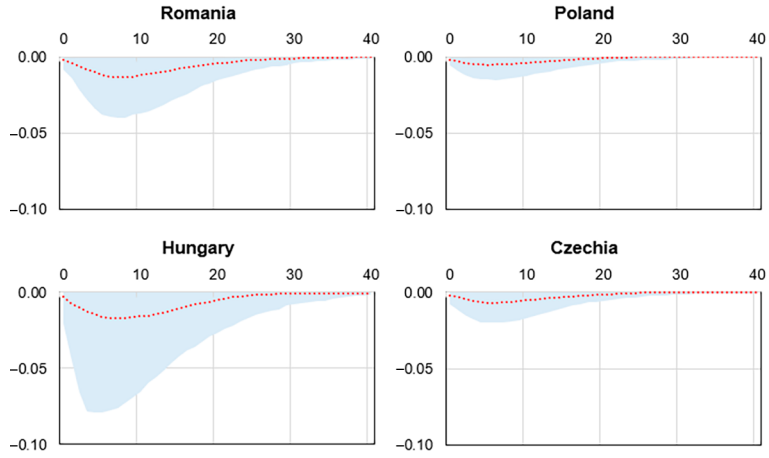

Figure 4. Impulse response functions of a one standard deviation supply shock in US on the selected CEE countries real economic growth (source: authors' calculations)

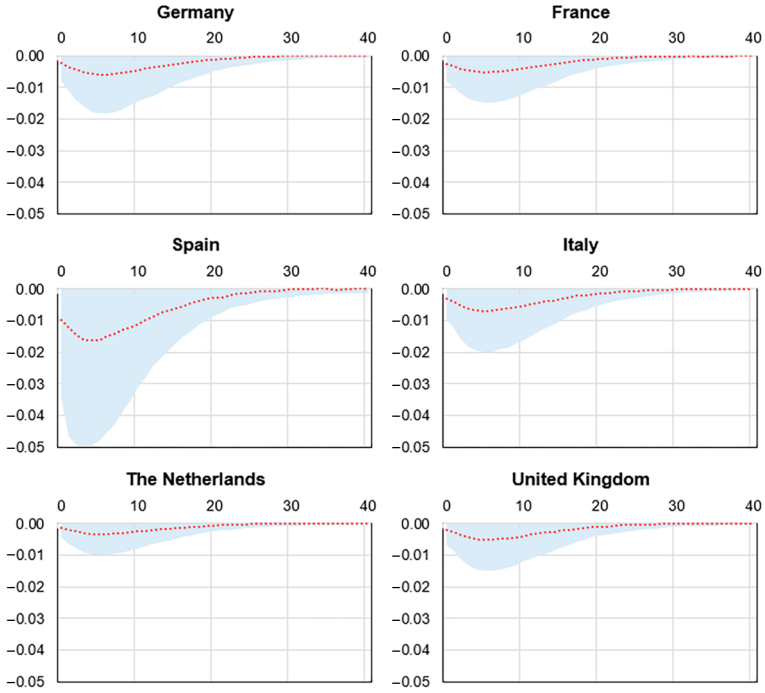

Figure 5. Impulse response functions of a one standard deviation supply shock in US on the selected developed European countries economic growth (source: authors' calculations)

Conclusions

Global events occurred in the past few years have created a fragile and tense international background, characterized by recurrent geopolitical tensions and technological and trade conflicts. The potential of the negative effects generated by these global issues were amplified within the Euro Area and the European Union by the withdrawal from the EU of the United Kingdom, namely Brexit, as well as its associated uncertainty and, more recently, by the COVID-19 pandemic. These events worsened the economic prospects of the European economies and added further pressure on an environment already characterized by increased vulnerabilities.

In this context, this paper analyses the potential adverse effects induced by the materialization of global or European risks on a group of four countries in CEE region, namely Poland, Hungary, Romania and Czechia. The main channel analysed is the one of trade relations. The main trade partner of the analysed CEE countries is the Euro Area and, on an individual level, Germany. At the same time, Germany has strong commercial links with the developed European countries in the study, such as France, Italy, Spain, the Netherlands and the United Kingdom.

The study starts from the construction of a GVAR model including 11 economies, the above mentioned 10 European countries and the United States of America, which is included in the model as the reference country. These economies are subsequently grouped into

7 entities, namely: USA, Euro Area, Romania, Czechia, Poland, Hungary and the United Kingdom. The linkages between these entities are defined based on a time-varying the trade matrix, while the analysed time period spans from 2005 to 2020, with a quarterly frequency.

The impulse response functions of the real economic growth to a one standard deviation inflationary supply shock in the Euro Area shows the selected CEE countries would be similarly impacted, Hungary, Czechia and Romania recording a decrease of 0.1 percentage points in the first 5 quarters. These results indicate that systematic shocks have structural effects on emerging economies. The response of the two feedback variables in the model, namely the real GDP and inflation, cannot offset the effects of the shock, and, therefore, the response remains in the negative side for the entire 40 quarters interval. On the other hand, Poland's response is much smaller, being more similar to the developed European countries' responses, which record a decrease of approximately 0.05 percentage points in the first 5 quarters. Moreover, while the persistence of the shock lasts up to 30 quarters for Romania, Czechia and Hungary, Poland and the developed economies absorb the shock in only 20 quarters. However, the response observed for Spain is significantly more material than the ones of the other developed economies included in this study, highlighting the persistent structural differences between southern and western developed European countries.

Nevertheless, the differences identified between the responses to an one standard deviation supply shock in Euro Area of the selected CEE countries and responses recorded in case of the developed economies point out the further needed consolidation of the fiscal stance in case of the former group, as well the need for further anchoring of their inflation expectations.

As the economic intuition dictates, the strongest impact on the European economies stems from the simulation of a Euro Area shock. However, the above-mentioned conclusions remain valid when simulating an inflationary supply shock in the United States, although the impulse response functions indicate lower responses, with smaller durations. Once again, Poland responds more similarly to the developed economies than to the CEE ones, indicating a higher level of maturity for this market than for Hungary, Romania and Czechia. The structural effects are still visible, but the duration of the shock absorption period decreases for the CEE economies with more than two years, from 30 to 20 quarters. To sum up, given the magnitude of the COVID related shocks, contagion effects could be significant. As a result, relevant downside risks to economic activity are also stemming from the external environment, especially amid a flare-up in the pandemic. The study has its limitations, as there are also views regarding potential misleading economic inferences yielded by generalized impulse response functions.

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APPENDIX

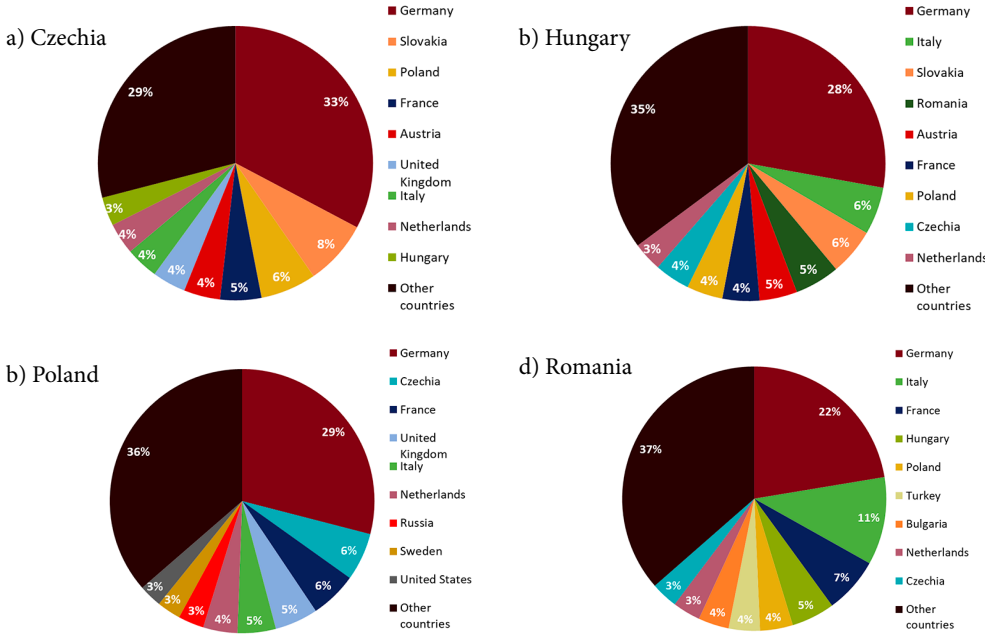

Figure A.1. Exports structure on main trade partners after the first 7 months of 2021 (12 months cumulated data) (source: Eurostat, authors' calculations)

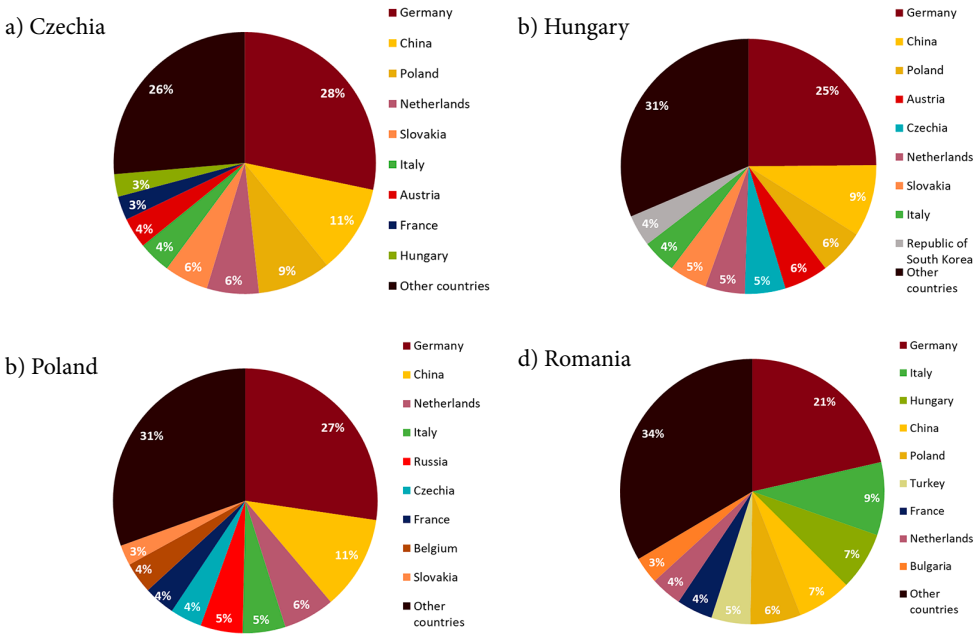

Figure A.2. Imports structure on main trade partners after the first 7 months of 2021 (12 months cumulated data) (source: Eurostat, authors' calculations)

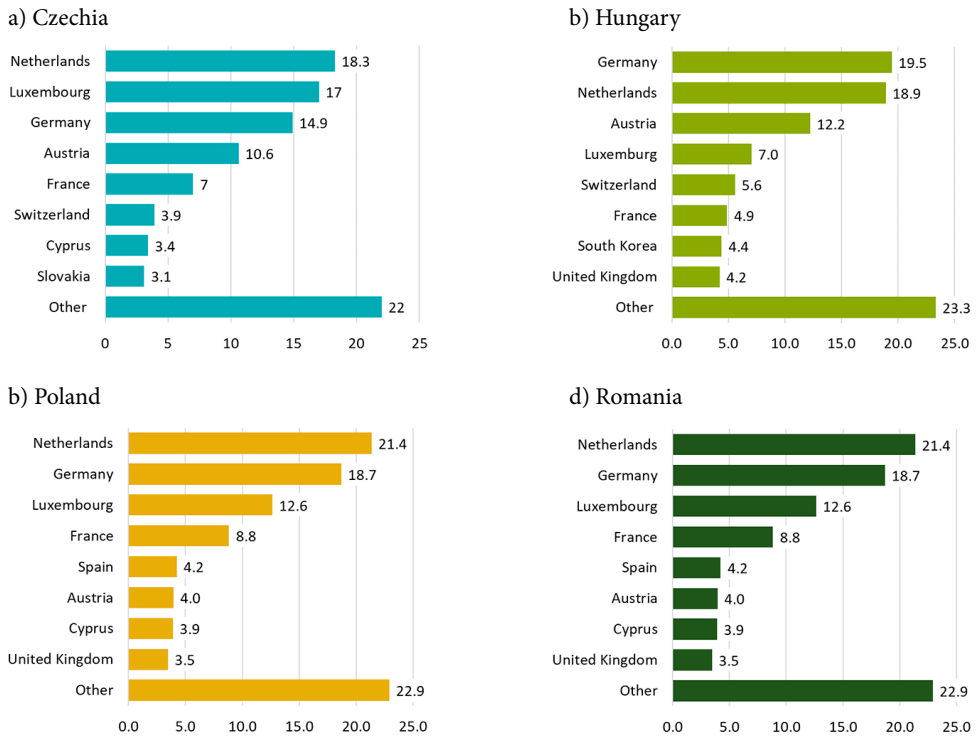

Figure A.3. FDI stock distribution by country at 31 December 2019 (source: Czech National Bank, Magyar Nemzeti Bank, Narodowy Bank Polski, National Bank of Romania, authors' calculations)

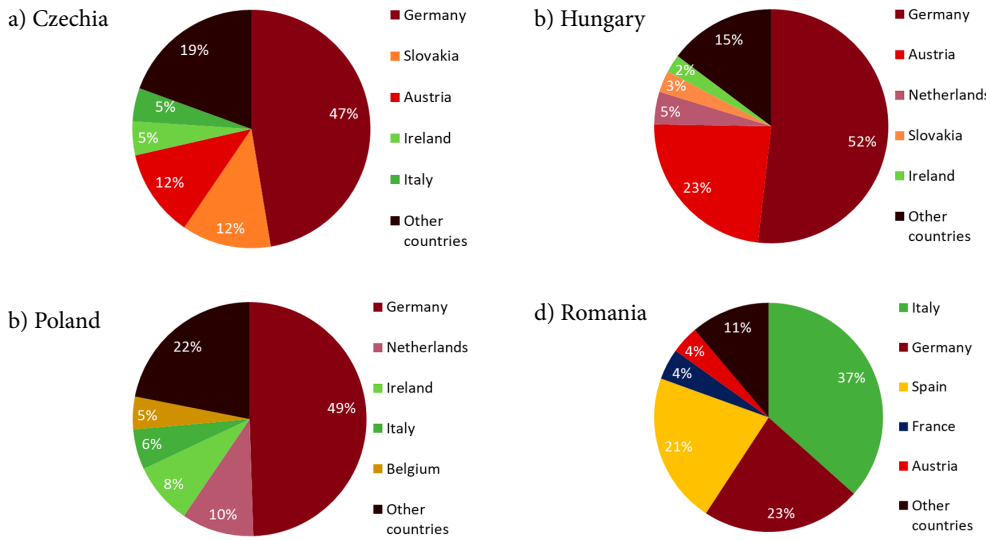

Figure A.4. Citizens in EU countries (source: Eurostat, authors' calculations)