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Abstract

Using Russia as a case study and a global VAR model as a methodological tool, we analyze how heightened geopolitical risk shocks propagate across advanced economies and quantify the economic effects of these events. The global VAR impulse response functions in response to the skyrocketing Russian geo-political risk shock after Russia's invasion of Ukraine revealed a contraction of GDP and an increase in inflation. Eastern European neighboring countries are particularly affected by the Russian geopolitical risk shock. We also document a strong component of the Russian geopolitical risk shock that is not driven by fossil fuel prices.

JEL-Codes: C320, E320, F510, F520.

Keywords: geopolitical risk, international business cycle transmission, global VAR model, Russia.

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1. Introduction

After years of increasing globalization, recent times have witnessed a shift in global economic relations. In this context, the Russian invasion of Ukraine constitutes a "Zeitenwende," which has highlighted how geopolitical risks (GPR) can upset hydrocarbon supply chains and result in weaponized international trade. Consequently, the war has put countries' risk–reward calculus under renewed scrutiny.

Even before the Russian invasion of Ukraine, geopolitical considerations have gained importance. The US-China trade war and the military threats in the Taiwan Strait and the South China Sea have exemplified the importance of political tensions and geopolitical risks as determinants of economic activity. In both instances, the lesson is to reduce economic dependencies that could be exploited for geopolitical gain. In addition to governmental de-risking initiatives, businesses move to blocs of like-minded countries—a strategy sometimes referred to as "nearshoring," or "friendshoring". One may say they are moving from "just in time" to "just in case" to make supply chains less vulnerable to geopolitical tides.[1]

In the face of disruptions of international supply chains and geostrategic threats highlighted by the COVID-19 pandemic and the war in Ukraine, economic policies are increasingly being directed towards geopolitical goals, even at the price of some duplication or inefficiency. Ultimately, this shift is paving the way for a more fragmented version of globalization in the future.

Reshaping the world's supply chains comes at a cost. The shift towards a more fragmented form of globalization may have profound economic implications, driven predominantly by differences in comparative cost advantage. The empirical literature provides varying estimates of the impact of increased geopolitical fragmentation. While some studies suggest that decoupling could result in a manageable 0.2% reduction in global GDP (Aiyar et al., 2023), others emphasize a more concerning decline ranging from 2% to 7%, depending on the extent of fragmentation (Aiyar et al., 2023; Javorcik et al., 2022; IMF, 2023, pp. 91-114). Against the backdrop of heightened political tensions and the associated geopolitical risks undermining economic prospects, our study makes three contributions.

We revisit the relationship between geopolitical risk indices and business cycles. Geopolitical fragmentation risk feeds through into real economic activity because uncertainty causes businesses and consumers to delay investment and consumption decisions. Alongside other risks, one can refer to an uncertainty triumvirate of economic uncertainty, policy uncertainty, and geopolitical risks. Economic uncertainty refers to the risk that occurs during the business cycle, while policy uncertainty is concerned with government interventions of different kinds. Here, we focus on geopolitical risk but recognize that periods of heightened geopolitical risk may contain elements of each going hand-in-hand. Given the transformative "Zeitenwende" described above, the particular focus of this study is on the geopolitical risks emanating from Russia and their macroeconomic impacts on advanced economies.

[1] See Jiang et al. (2022). A much-discussed question at present is whether this redivision of the world is already taking shape. The findings from the novel bottom-up exercise by Qiu et al. (2023) indicate that since the Russian invasion of Ukraine, global businesses are in the midst of a far-reaching de-risking realignment.

Furthermore, we provide evidence on cross-country geopolitical shock transmission. Despite the particular prominence of this issue, there are only a few studies on the cross-country economic knock-on impacts of the war in Ukraine. In contrast to our multi-country global vector autoregression (GVAR) modeling approach, Bruhin et al. (2023) have estimated separate structural vector autoregressions VARs with sign restrictions for five European countries considered in the study (France, Germany, Italy, Switzerland, and the United Kingdom). In terms of the conflict shock series, the authors draw on historical geopolitical conflicts that were associated with fears of and/or actual disruptions in energy supply and impose sign restrictions on their effects (the Yom Kippur War in 1973, the Middle East Conflicts in the 1980s, the Gulf War in the 1990s, the Iraq War in the early 2000s, and the Ukraine War). Those conflicts and the GPR shocks, which date back quite some time, are not the focus of our study. While other studies have analyzed the GPR impacts on specific markets (see Afonso et al., 2023; Aizenman et al., 2023; Federle et al., 2022; Li et al., 2022; Phan et al., 2022 and Wang et al., 2022), we are interested in the very topical macroeconomic repercussions of the Russian GPR shocks.

We employ the GVAR approach by Dees et al. (2008) and Georgiadis (2015) to close this research gap and to make an empirical contribution to this topical question. The GVAR modeling approach, originally proposed by Pesaran et al. (2004), comprises a compact model of the advanced economies designed to explicitly model cross-country interdependencies. The modeling approach comprises two steps. In the first step, country-specific vector error-correcting models (VECMs) are estimated based on the conditions of the remaining countries. These models feature domestic variables and (weighted) cross-section averages of foreign variables. In the second step, the individual country models are stacked and solved simultaneously as one large system: the global VAR model. Along with the empirical analysis, this paper offers a set of robustness checks for the empirical application.[2] A particular advantage of this approach is that the uneven reverberations of geopolitical shocks across countries can be pinpointed.[3] To our knowledge, this paper presents the first application of this appealing modeling approach to the geopolitical risk issue. Along with the empirical analysis, our paper offers a set of robustness checks for empirical application.[4]

The main results of the paper are as follows: First, a shock in Russian GPR of the magnitude of the Russian invasion of Ukraine results in a profound and encompassing reduction of economic activity. The shock propagates internationally through the trade channel, with decreasing terms of trade. Rising prices

[2] The empirical literature has used different modelling approaches to deal with spillover effects. Cipollini and Mikaliunaite (2020) applied a global VAR to macroeconomic and financial data in the euro Area. Greenwood-Nimmo et al. (2021) extended the approach by Diebold and Yilmaz (2012) and Diebold and Yilmaz (2014). Finally, Caggiano et al. (2020) used a nonlinear smooth transition VAR model to capture economic policy uncertainty spillovers from the US to Canada.

[3] Reversing the perspective, Bondarenko et al. (2023) have examined the repercussions of Russian GPR shocks on the Russian economy. The GPR index employed is based on Russian-language news sources.

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affect consumption adversely, and a deteriorating business climate reduces investments. It takes over three quarters before the knock-on effects begin to subside. Second, the magnitude of the geopolitical risk matters. Russian GPR shocks prior to the invasion of Ukraine in February 2022, including the Crimean annexation and the separatist movement in eastern Ukraine, had little to no economic impact on the rest of the world—a sharp contrast to the repercussions of the current full-blown war. Given these results and viewed in a broader context, this paper thus provides evidence on the impact of geopolitical and geostrategic challenges on the Euro-Atlantic region to uphold a free and open international order.

Finally, our results add to the conclusions of prior studies on the economic ramifications of wars. Glick and Taylor (2010) have studied the effects of wars on bilateral trade with available data extending back to 1870. They found large and persistent impacts of wars on trade and GDP. Caldara et al. (2022) quantified the global economic impact of the recent rise in global text-mining geopolitical risk measures, finding that the increase in global geopolitical risk constitutes a sizable drag on world GDP and boosts world inflation.

The layout of this paper is as follows: Section 2 describes how we assess geopolitical risk. Section 3 introduces the empirical GVAR methodology, encapsulating several potential shock propagation channels. The presentation of the data and the GVAR model specification is given in Section 4, followed by various model structural stability tests in Section 5. In Section 6, we report on our empirical results, with a special focus on how the war in Ukraine has increased geopolitical risk. We present our supplementary robustness tests in Section 7, while we present our conclusion in Section 8.

2. Geopolitical Risk Data

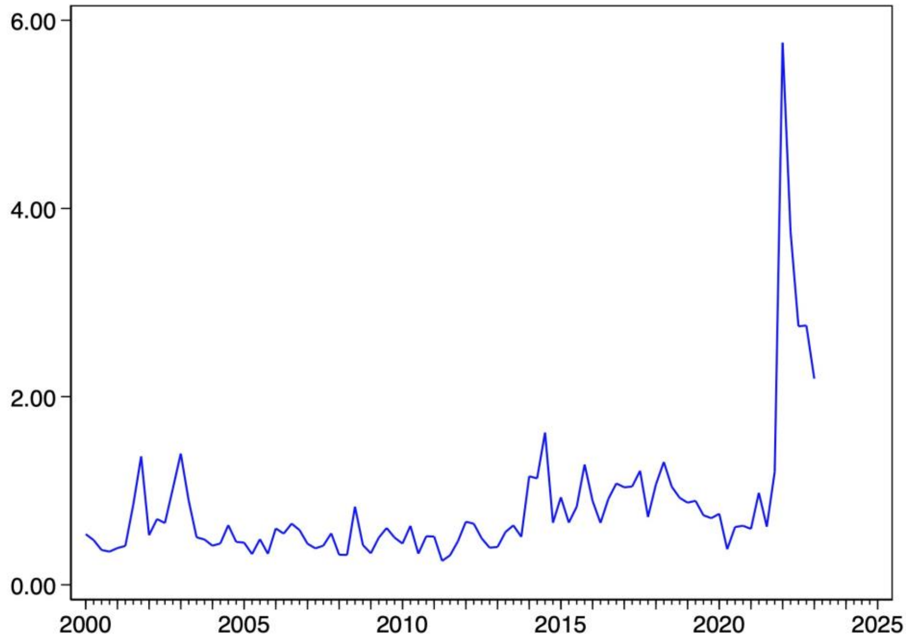
To estimate the effects of rising geopolitical risk tensions, we employ the geopolitical risk (GPR) indices of Caldara and Iacoviello (2022) as a proxy. The authors consider geopolitical risk as risk associated with wars, terrorist acts, and tensions between states that affect the normal and peaceful course of international relations. They aim to identify situations in which the power struggle between governments over territories is not resolved peacefully and democratically.

The GPR index is part of the rapidly growing literature on text search methods using newspaper archives. To create the GPR index, Caldara and Iacoviello (2022) gathered articles from electronic archives of the Chicago Tribune, the Daily Telegraph, Financial Times, The Globe and Mail, The Guardian, the Los Angeles Times, The New York Times, USA Today, The Wall Street Journal, and The Washington Post with broad worldwide coverage featuring events and threats associated with geopolitical conflicts such as wars, terrorist acts, ethnic and political violence, and geopolitical tensions. The automated text-mining search separately identifies war threats, peace threats, military buildups, nuclear threats, terror threats, beginning of war, escalation of war, and terror acts.[5] Complementing the global geopolitical situation, GPR indices

[5] Several sentiment indicators tracking the geopolitical sphere employing big data and advanced computational techniques have been developed recently. For example, the comprehensive and innovative open-source "Global

for 44 different countries are available. Country-specific indices are calculated analogously based on the overall GPR index, but with the supplementary requirement that articles must explicitly mention the name of the country or its major cities to be considered for inclusion. For each of the 10 newspapers, the authors collect monthly counts of GPR-related articles as a proportion of the total number of articles. Subsequently, the authors divide each monthly count by the mean from the year 2000 to the year 2009 of the series and multiply it by 100. In essence, the GPR index acts as a barometer that captures the ebbs and flows of geopolitical risk in real-time. In this paper, we use the Russian invasion of Ukraine as a case study on rising geopolitical tensions and their aftermath.[6]

Figure 1: Quarterly Russian GPR Index from 2000Q1 through 2023Q2



Notes: The quarterly text-mining GPR indices are calculated by the temporal aggregation of the monthly GPR indices. The GPR data were sourced from https://www.matteoiacoviello.com/gpr_country.htm.

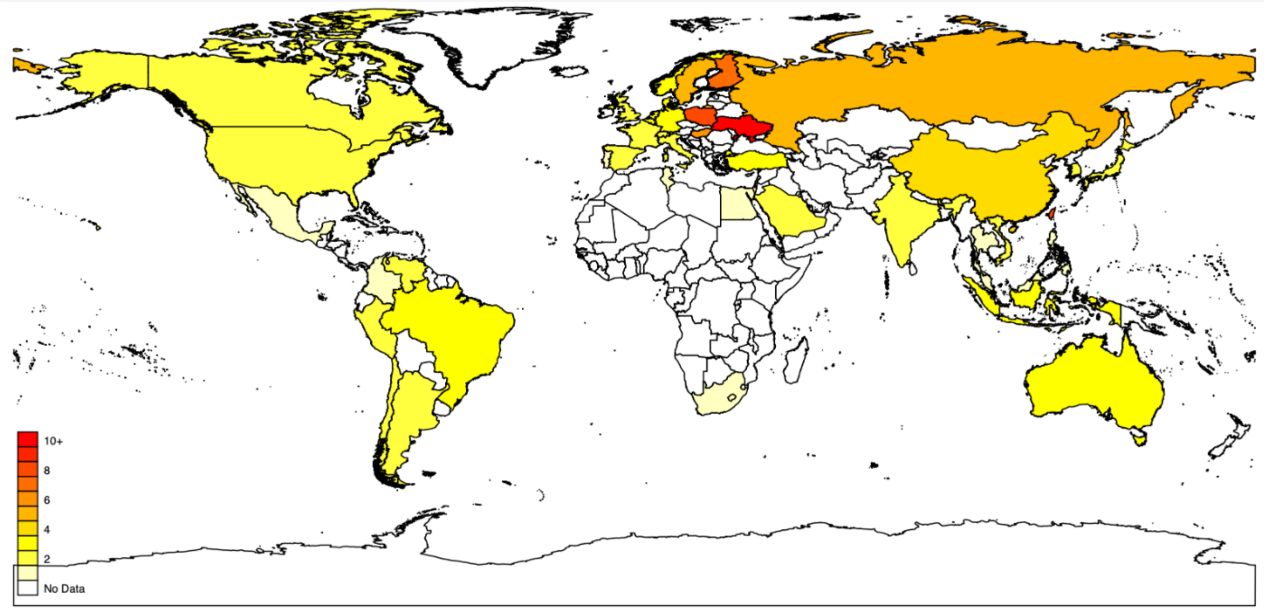
Figure 1 plots the movements in the Russian GPR index from 2000Q1 through 2023Q2. The calculated Russian GPR scores line up well with past geopolitical events that would typically be associated with high levels of uncertainty and, likewise, the recent GPR spike in the wake of the Russian invasion of Ukraine. The time series is characterized by various armed conflicts and terrorist acts since the turn of

Database of Events, Language and Tone" (https://www.gdeltproject.org/) extracts and parses digital news in broadcast, print and web media globally in over 100 languages on a daily basis, from global to local media sources. The algorithms can identify organizations, locations, news sources and events across the world as well as emotions and sentiments.

[6] Andres-Escayola et al. (2022) have explored how the selection of local-based versus foreign-based newspapers and the number of newspapers considered influences the course of the uncertainty indices and model results based on them. The main finding is that indices constructed by means of a sufficiently large number of newspapers from different countries deliver extremely similar macroeconomic IRFs. Another compelling argument for the Caldara and Iacoviello (2022) database is that the same text-mining data source enhances the cross-country comparability of the GPR scores.

the millennium. First, at the beginning of the 2000s, the guerrilla phase of the 2nd Chechen War led to several GPR spikes of different sizes. Among others, these include the killing of civilians by armed Chechen extremists in the Moscow theater hostage crisis in October 2002. Second, Russia's war in Georgia over the breakaway territories of Abkhazia and South Ossetia in August 2008 is discernible in another GPR rise. Third, the Euromaidan, the Russian annexation of Crimea in February - March 2014, and the war in the Donbas are evident in an especially pronounced GPR increase. Finally, the recurring GPR spikes from 2015 onwards were the result of repeatedly flaring tensions between Ukraine and Russia over Donbas. The long-run average of these spikes is about 0.8, and the standard deviation is 0.6. Finally, in the first quarter of 2022, the score reached 5.2, highlighting the significance of the Russian invasion of Ukraine in fuelling political and economic insecurity around the world.[7]

Figure 2: The Worldwide Geopolitical Risk Landscape (February 2022 - June 2023)



Notes: The map shows the average GPR indices from March 2022 to June 2023 (Index: January 1985 - February 2022 = 1). No GPR scores are available for countries marked in white. The country-specific GPR indices were sourced from https://www.matteoiacoviello.com/gpr_country.htm.

Figure 2 depicts a comparison between the average pre- and post-war geopolitical risk levels by country. In this visualization, changes in GPR indices are represented using varying colors, with darker shades indicating higher GPR scores. First, it is evident from the figure that there has been a notable global increase in average geopolitical risk across most countries since the outbreak of the war in February 2022. The amber shading of Russia confirms the assessment that the Russian war of aggression has turned the security and defense architecture of Europe upside down. Second, Ukraine, being the target of

[7] The Russian invasion of Ukraine prompted the US and 37 other governments to adopt several packages of economic sanctions and export controls aimed at diminishing Russia's economic base and weakening Russia's ability to finance the war. For a timeline of economic sanctions, see https://www.piie.com/blogs/realtime-economics/russias-war-ukraine-sanctions-timeline.

unprovoked Russian military aggression, is depicted with red GPR values, symbolizing the heightened risk it faces. Third, the map emphasizes the pivotal role of geographical proximity since countries located closer to the Russian-Ukrainian battleground have witnessed the most significant surge in domestic geo-political risk.

In the following chapter, we will analyze how the empirical evidence stacks up, including an in-depth analysis of the impact of Russia's invasion of Ukraine.

3. Model

In order to capture the transmission of heightened geopolitical risks, we employ a global VAR framework. The GVAR has been a popular choice for capturing spillover effects (Pesaran et al., 2004; Dees et al., 2007; Georgiadis, 2015; 2016; Eickmeier and Ng, 2015; Cuaresma et al., 2016) as it offers a balanced trade-off between parsimony and complexity. The premise of the GVAR is that each country $i = 1, \cdots, N$ is modelled as a reduced VAR model with exogenous variables (VARX)

$$y_t^i = b + B_1 y_{t-1} + \cdots + B_p y_{t-p} + G_0 x_t^i + \cdots G_q x_{t-q}^i + H_0 z_t + \cdots + H_r z_r + \varepsilon_t^i, \tag{1}$$

where y_t^i is a vector with *n* variables for country *i* in time *t* and is a function of its past *p* lags as well as a function of the exogenous variables x_t^i and z_t, which have *q* and *r* lags, respectively. The residuals ε_t^i have a variance-covariance matrix Σ^{i}, $\varepsilon_t^i \sim N(\mathbf{0}, \Sigma^{\mathrm{i}})$. The vector of exogenous variables x_t^i is a weighted average of the variables of all the other countries $N - 1$, namely

$$x_t^i = w_1^i y_t^1 + w_2^i y_t^2 + \ldots + w_i^i y_t^i + \cdots + w_N^i y_t^N. \tag{2}$$

The weights w_j^i in equation (2) denote the relative importance of the other countries with respect to country *i*, whereby $\sum_j w_j^i = 1$ and $w_i^i = \mathbf{0}$ is a vector of zeros. The GVAR literature primarily employs trade-weights (Dees et al., 2007) to model the multi-country relationships. In a few applications, however, financial weights were also employed (Eickmeier and Ng, 2015).

The vector z_t collects the global variables that affect all countries (note the omission of superscript *i*), which also follows the familiar VAR form

$$z_t = B_0 + D_1 z_{t-1} + \cdots + D_s z_s + \varepsilon_t^z, \quad \varepsilon_t^z \sim N(\mathbf{0}, \Sigma^{\mathrm{z}}). \tag{3}$$

The GVAR modeling framework can be motivated in two ways. Dées et al. (2007) have derived the GVAR modeling approach as an approximation to a global factor model, while Chudik and Pesaran

(2011) have obtained the GVAR model as an approximation to a large system in which all variables are endogenous.

A special GVAR feature is the sparse parameterization, which allows practitioners to bypass the "curse of dimensionality" problem in large unrestricted VARs resulting from the fact that the number of parameters to be estimated grows at a quadratic rate with the number of variables in the system. By contrast, in the GVAR modeling framework, the number of parameters to be estimated for each country $i = 1, \cdots, N$ is independent of N and amounts to $[np + 1 + n(q+1) + n^z(r+1)]$. This independence from N also applies to the $0.5n(n-1)$ parameters of the variance-covariance matrix Σ^{i}. Nonetheless, the model offers extremely rich dynamics, as all countries mutually affect each other. Thus, even at low numbers of lags, complex relationships arise (Cuaresma et al., 2016). Moreover, the model may be estimated in vector error correction form (VECM) to capture both short and long-run relationships between the variables.[8]

An important consideration for the estimation stage is that the weighted variables of the other countries are at least weakly exogenous—a property that can be tested. Including a large variety of countries is a natural remedy, as within the limit, each VARX becomes a small open-economy specification (Chudik and Pesaran, 2011; Georgiadis, 2017). This is also important if the weights are constructed to sum to one, as a lower number of countries could overestimate the relative importance of a country.

After the estimation of *N* models, the GVAR can be solved in a mathematical sense (collecting all the variables in time *t* on the left-hand side) by simply substituting (2) for (1) and building the respective system of equations with all *N* countries and global variables (3), which may be written in a companion form:

$$\boldsymbol{A}\,\boldsymbol{y}_t = \boldsymbol{b} + \boldsymbol{F}\,\boldsymbol{y}_{t-1} + \boldsymbol{\epsilon}_t, \quad \boldsymbol{\epsilon}_t \sim N(\boldsymbol{0}, \boldsymbol{\Omega}), \tag{4}$$

with $\boldsymbol{y}_t = \left[y_t^{1'}, \ldots, y_t^{i'}, \ldots, y_t^{N'}, z_t', \ldots,\ z_s'\right]'$ and the matrices $\boldsymbol{b}, \boldsymbol{A}, \boldsymbol{F}, \boldsymbol{\Omega}$ containing the estimated coefficients from the first stage weighted by w_j^i. This step does not involve any estimation and may be used for structural analysis, such as calculating impulse response functions and variance or historical decompositions.

Finally, we use the generalized impulse response functions (GIRF) to quantify the effects of a GPR shock. Contrary to the IRFs driven by Cholesky factor orthogonalization, GIRFs are order invariant.[9] Given an information set Ω_{t-1}, the GIRF is defined as the difference between the forecast for a variable $\boldsymbol{y}_t^{\boldsymbol{k}}$, with a shock δ_j to variable *j* and the forecast in the absence of the shock, namely

[8] The common assumption of the multi-country GVAR modelling framework is the assumed linearity of the interrelationships. For a nonlinear threshold-augmented TGVAR extension of the GVAR model, see Chudik et al. (2021a, 2021b).

[9] Pesaran and Shin (1998) have derived the correspondence between GIRF and Cholesky-ordering IRFs in a linear VAR system.

$$\mathrm{GIRF}_{\mathrm{k,t+h}}\left(\Omega_{t-1}\right)=E\left(\boldsymbol{y}_{t+h}^{k}\mid u_{i,t}=\delta_{i,t},\Omega_{t-1}\right)-E\left(y_{t+h}^{k}\mid\Omega_{t-1}\right) \tag{5}$$

The GIRF is calculated from the moving average representation of the model given in equation (4). We follow Dees et al. (2007) and calculate a distribution of the GIRFs using the sieve bootstrap by resampling the residuals (Bühlmann, 1997).

4. Model Specification and Data

This section gives details on the countries and country clusters in the GVAR model. We also describe the data in detail.

4.1 Country Selection

We focus our analysis on the European Economic Area (EEA) and the Group of Seven (G7) countries. In the GVAR, the 26 countries are grouped, as shown in Table 1. The G7 countries comprise the United States, Canada, Japan, Germany, France, Italy, and the UK. These seven major industrialized countries are modelled individually in the GVAR. The remaining countries are grouped into different country clusters. The Baltic region (BAL) subgroup consists of Estonia, Latvia, and Lithuania. The Nordics subgroup (NRD) is made up of Finland, Denmark, Norway, and Sweden, while the Central and Eastern Europe (CEE) grouping comprises Bulgaria, the Czech Republic, Hungary, Poland, Romania, and Slovakia. Finally, the remaining EEA countries in our dataset, namely Austria, Belgium, Greece, Netherlands, Portugal, and Spain, form the EEA subgroup.[10] Overall, the formation of country groups allows for a parsimonious modeling while still estimating heterogeneous shock responses across countries. It is noteworthy that cross-country differences can be expected in this context. To a greater extent, domestically driven economies are likely more resilient vis-à-vis GPR spillovers than their more internationally-exposed counterparts. Moreover, GPR contagion effects are predictably amplified by geographic proximity and close economic ties with Russia.

[10] Due to the high volatility of the macroeconomic time series resulting from the GDP recalculations since 2015, Ireland has not been considered.

Table 1: Individual Countries and Groups of Countries in the GVAR Model

Individual G7 Countries	Baltic Countries (BAL)	Central and Eastern European Countries (CEE)	Nordic Countries (NRD)	Remaining European Economic Area Countries (EEA)
Canada (CAN)	Estonia	Bulgaria	Denmark	Austria
Germany (DEU)	Latvia	Czech Republic	Finland	Belgium
France (FRA)	Lithuania	Hungary	Norway	Greece
Italy (ITA)		Poland	Sweden	Portugal
Japan (JPN)		Romania		Netherlands
United Kingdom (GBR)		Slovakia		Spain
United States (USA)				

4.2 Data

We use the Russian GPR index as a proxy of the geopolitical tensions from Russia and model it as a weakly exogenous global variable z_t. We estimate the GPR impacts on the following variables: economic expectations (*PMI*), output (*Y*), consumption (C), investment (*I*), inflation (*P*), and interest rates (*R*). Economic expectations are predictably an important channel through which GPR shocks affect the real economy. For the expectations variable, we chose the Purchasing Manager Index (*PMI*) from S&P Global, which is available for the G-7 countries. The *PMI* data are closely watched to better understand where economies and markets are heading. For the remaining countries in the dataset, the Economic Sentiment Index (ESI) from the European Commission is employed. Furthermore, we take real GDP, real personal consumption, and real investment from the OECD database. Prices are measured by the consumer price index (CPI) or the harmonized consumer price index (HICP) for the euro area from Eurostat. Given the nature and diversity of recent central bank balance sheet policies, we employ the shadow short rate as a consistent representation of the monetary policy stance (Krippner, 2013, 2020).[11] For the European countries that joined the euro area later than the beginning of our sample, we take their domestic overnight bank rates until the accession date. The vector of variables for each country is, thus, $y_t = [PMI, Y, C, I, P, R]'$, and they are transformed as follows. The *PMI* and ESI time series are standardized to make them compatible with the GVAR framework, relying on identical units. *Y, C,* and *I* are in log levels and are seasonally adjusted, just like the CPI. The data have been obtained through Macrobond, while the GPR time series have been sourced from https://www.matteoiacoviello.com/gpr_country.htm. Our data is quarterly and runs from 2000Q1 to 2023Q2.[12]

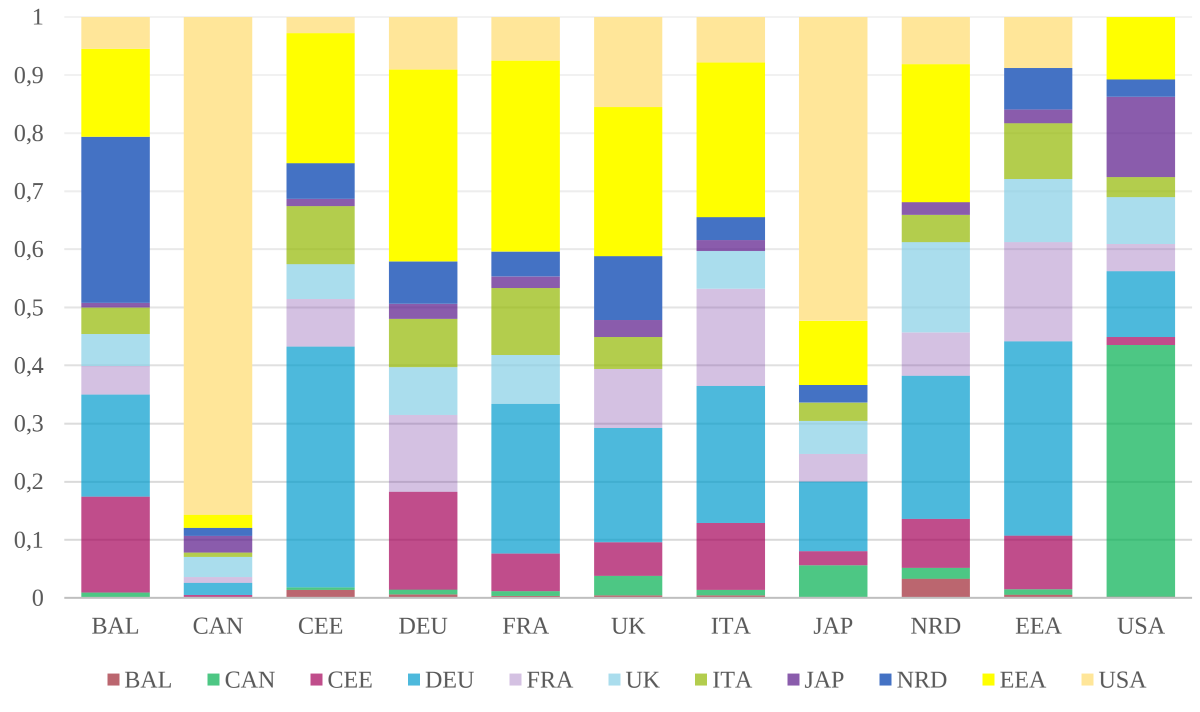
[11] The shadow short rate can be negative, reflecting the additional easing through a variety of unconventional policy measures referred as quantitative easing (QE). See https://www.ljkmfa.com/visitors/. In line with this, the ECB maintains a "two-pillar strategy" explicitly featuring monetary analysis beyond the interest rate pillar (ECB, 2021).
[12] The sample period is constrained by the inflation series of some of the newer EU member states such as Bulgaria and Estonia, who experienced episodes of economic turmoil in their transition periods from planned economies in the late 1990s. For example, Bulgaria experienced hyperinflation in 1997, which did not stabilize until 1999.

We obtain trade weights from “The Atlas of Economic Complexity” (Hausmann et al., 2019), which compiles trade data originally sourced from the United Nations Statistical Division (COMTRADE). To aggregate the regions, we use GDP in purchasing power parity (PPP) based weights obtained from the World Bank. Next, we present a variety of econometric tests to validate the empirical approach.

5. Model Validation and Estimation

Before turning to the estimation, we present the calculated trade shares in Figure 3. We see a high level of international integration among the countries and country clusters considered, which is important for the GVAR framework, which relies on the interconnected country assumption at the estimation stage. Although Canada, Japan, and the USA have high two-way trade flows, they are also major trading partners for the remaining countries. Unsurprisingly, Germany is a highly important trading partner for all countries, and Canada trades predominantly with the USA.

Figure 3: Calculated Trade Shares



To set the number of lags for the endogenous and exogenous variables (*p, q, r, s),* we use the Bayesian information criteria, which support one lag for each variable. One of the advantages of the GVAR modeling framework is that it offers rich dynamics even without the presence of many lags due to the interconnectedness of all countries (Cuaresma et al., 2016).

Next, we test for the presence of cointegration using the Johansen test, which indicates at least two long-run relationships within each region, with up to three for the UK and Italy and four for Germany, validating the choice of the VEC model.

Furthermore, the GVAR relies on the assumption that the linear combination of the foreign variables is weakly exogenous. We follow the testing approach used by Dees et al. (2007), which is an F-test of the joint significance of the error correction terms in a regression for each foreign variable. Table 2 presents the results of the test, indicating strong evidence for no rejection of the weak exogeneity assumption.

Table 2: F-Tests for Weak Exogeneity of the Exogenous Variables in the GVAR

Region	F-test	PMI	Y	C	I	P	R	GPR
BAL	F(4,70)	1,57	1,44	0,89	0,07	1,09	0,77	0,83
CAN	F(4,70)	0,88	0,58	2,52*	0,59	1,77	1,01	1,50
CEE	F(2,72)	1,53	1,44	0,16	0,20	2,70	0,10	0,13
GER	F(2,72)	3,51	2,23	1,37	0,08	0,76	0,11	0,23
FRA	F(4,70)	0,74	0,83	0,85	1,46	2,34	3,53*	2,10
GBR	F(2,72)	0,24	0,67	0,26	1,24	0,06	1,74	1,50
ITA	F(2,72)	0,21	0,56	0,64	0,24	0,55	1,84	0,44
JPN	F(2,72)	0,17	0,56	2,74	0,22	0,58	2,26	0,65
NRD	F(3,71)	3,89*	2,00	0,90	0,85	2,97*	2,48	4,16*
EEA	F(4,70)	2,97*	0,73	0,94	4,02*	0,50	0,88	0,78
USA	F(1,73)	0,32	0,01	1,60	0,13	3,19	0,53	1,29

Note: A star (*) denotes a rejection of the weak exogeneity assumption at the 5% significance level.

Another important issue that may arise in the GVAR modeling framework is the potential instability of the parameters over time. This is particularly relevant as the sample period comprises the COVID-19 pandemic period and the resultant disruptions to global supply chains.[13] The extensive structural stability tests in the tradition of Dees (2007), as shown in Appendix A, reveal several takeaways. Given the number of equations and variables, we do find some evidence for structural instability, similar to the original contribution of Dees et al. (2007). However, significant instabilities only emerge for an exceedingly small subset of all region/variable combinations. For example, using the CUMSUM test and the Quandt (1960) likelihood ratio (QLR) test for all potential breakpoints yields 6 and 8 instances of structural breaks among 66 model estimates, respectively. In light of these results, we employ a sequential two-stage testing procedure and apply a GVAR model specification approach based on this process.

First, we follow the approach of Schorfheide and Song (2022) by excluding observations from the early stage of the pandemic (i.e., 2020Q2—the quarter when the pandemic's economic effects significantly unfolded worldwide) from our sample. We note that the ongoing quarters from 2020 Q3 until 2023 Q2 are neither modified nor excluded from the sample. By doing so, we guarantee that model coefficients are not drastically altered by extreme shifts in economic activity associated with quarantine measures adopted to tackle the spread of the COVID-19 virus.

[13] As the COVID-19 pandemic unfolded, macroeconomists struggled to make sense of their VAR models. See, for example, Lenza and Primiceri (2022) and Schorfheide and Song (2022).

Second, we consider the potential effects of the war in Ukraine on the estimates of the long-run cointegration relationships. The energy price upheavals since the Russian invasion of Ukraine have squeezed supply and added heavily to the inflationary pressures. High inflation had an immediate negative impact on consumption and investment. Furthermore, higher wage claims in order to recoup the real wage losses associated with higher inflation lead to risks of mutually reinforcing feedback effects (Battistini et al., 2022). This, together with the skyrocketing GPR scores, results in significant changes in the estimated cointegration relationships when the estimation period is extended until 2023Q2. We tackle the instability of the long-run VAR parameters by imposing the long-run cointegration relationships estimated until 2019Q4 as remaining valid until 2023Q2.[14] On the contrary, the short-term VAR coefficients are estimated without restriction. This allows the short-term coefficients to soak up the abnormal short-run variation while the invariant long-term cointegration relationships stabilize the parameter estimates. We believe it is still too soon to ascertain a break in the long-term economic propagation mechanisms. Thus, long-term parameters should not display dramatic changes with respect to pre-war times. Next, we present the GVAR estimation results.

6. Results

We present the estimated knock-on effects of an increase in geopolitical risk in Russia on advanced economies by computing the generalized impulse responses of all variables to a Russian GPR shock over a period of four years. In our baseline scenario, we considered the full span of data until 2023 Q2 for the estimation. The observed jump in the Russian GPR index after the invasion of Ukraine amounts to seven standard deviations. Accordingly, we simulated a Russian GPR shock of this magnitude. In Figures 4 and 5, we depict the generalized impulse response functions for the six variables in the GVAR. We plotted the median response as well as the 68% and 90% confidence intervals calculated by means of the sieve bootstrap procedure.

The GVAR modeling results unearth several key findings. The economic knock-on effects of the Russian GPR shock are felt throughout the Western economies, whereby the GVAR model classifies the much-elevated Russian GPR scores as a contractionary supply shock.[15] The impulse response functions indicate a significant GDP decline in all countries as a result of the Russian GPR shock propagating within and across countries.[16] After the initial hit, output declines up to two quarters before slowly recovering over the subsequent four to six quarters. The CPI reaction is consistently positive, although not significant in

[14] Detecting unknown (multiple) structural breaks in cointegrating VARs has emerged as an important problem in the econometrics literature. In system equations models, tests for the cointegrating rank with structural change typically assume the existence of structural change, whereas tests for structural change require the knowledge of the cointegrating rank. To the best of our knowledge, there is no test for the cointegrating rank with unknown structural break points in cointegrating GVAR models.

[15] The interdependencies across countries may foster international policy coordination to mitigate the GPR's collateral damage.

[16] The contractionary supply shock estimates are consistent with Caldara et al. (2023) and Bruhin et al. (2023) who use structural VARs to gauge the impact of the invasion of Ukraine, and with Liadze et al. (2023), who assess the effects of the war in Ukraine using the National Institute Global Econometric Model (NiGEM).

many cases due to wide confidence intervals.[17] We find that the transmission process takes place via the expectation and sentiment indicators as well as via consumption and investment. Businesses adopt wait-and-see investment behavior, and consumers increase precautionary savings, exercising a drag on economic growth.[18] Finally, the GPR shock and the subsequent CPI increase also triggered a more contractionary monetary policy. Japan is one exception to this.

When the repercussions for the four country clusters are considered, some noticeable differences become apparent. Particularly large impacts are evident in the three Baltic countries (BAL). As Russia has been an above-average export market for the Baltic countries, these countries have experienced weakening economic growth after sanctions were imposed against Russia following its invasion of Ukraine. In addition, Baltic countries are particularly exposed to international energy price increases. These external dependencies also explain the high inflation rates in the Baltic states. In 2022, annual CPI inflation in the Baltics (19.4% in Estonia, 18.9% in Lithuania, and 17.2% in Latvia) was the highest in the EU and significantly exceeded the euro area average (8.4%). Food and energy take up the largest share of the consumer basket in the Baltics compared to the euro area average (40% vs. 26%), whereas services take up the smaller share (27% vs. 44%). Hence, a sharp increase in energy and food prices in 2022 caused by, to a large extent, the Russian invasion of Ukraine raised overall inflation in the Baltics substantially more than the euro area average.

At the opposite end of the spillover spectrum are the Nordic countries (NRD), where no significant GDP or inflation effects are discernible. This is likely due to the fact that Norway is a major fossil fuel exporter. In summary, one can say that the magnitude of cross-border GPR spillovers is larger for countries with above-average foreign trade with Russia, relatively high bilateral trade concentration, low export diversification, high energy import dependencies, and weaker external buffers.

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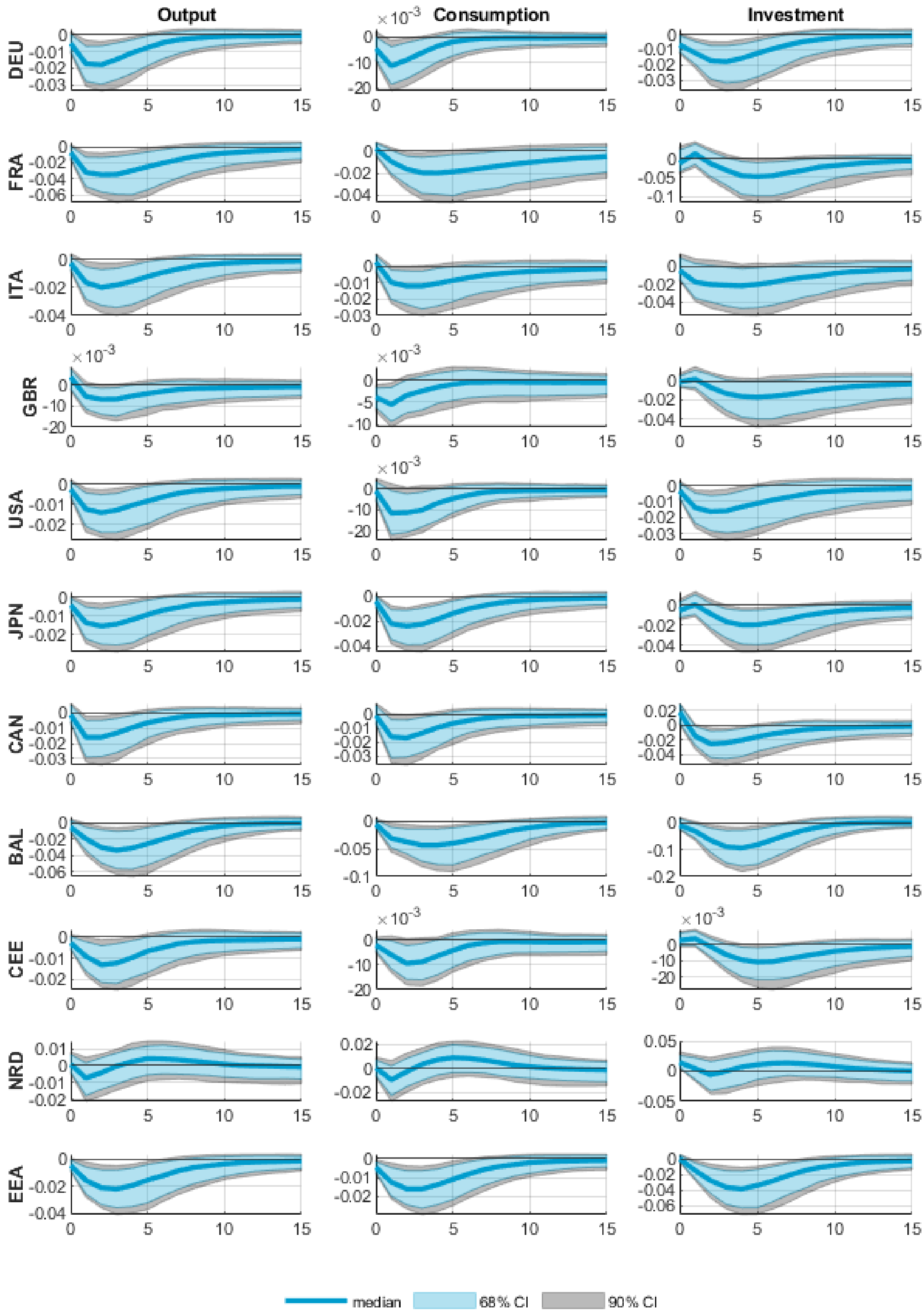
[17] In countries where demand is depressed, more expensive oil and gas could eventually weaken price pressures by weighing on consumption and output. The model-based assessment in Attinasi et al. (2023a, 2023b) shows that geostrategic conflict could boost inflation by as much as 5% in the short run and around 1% over the longer term.

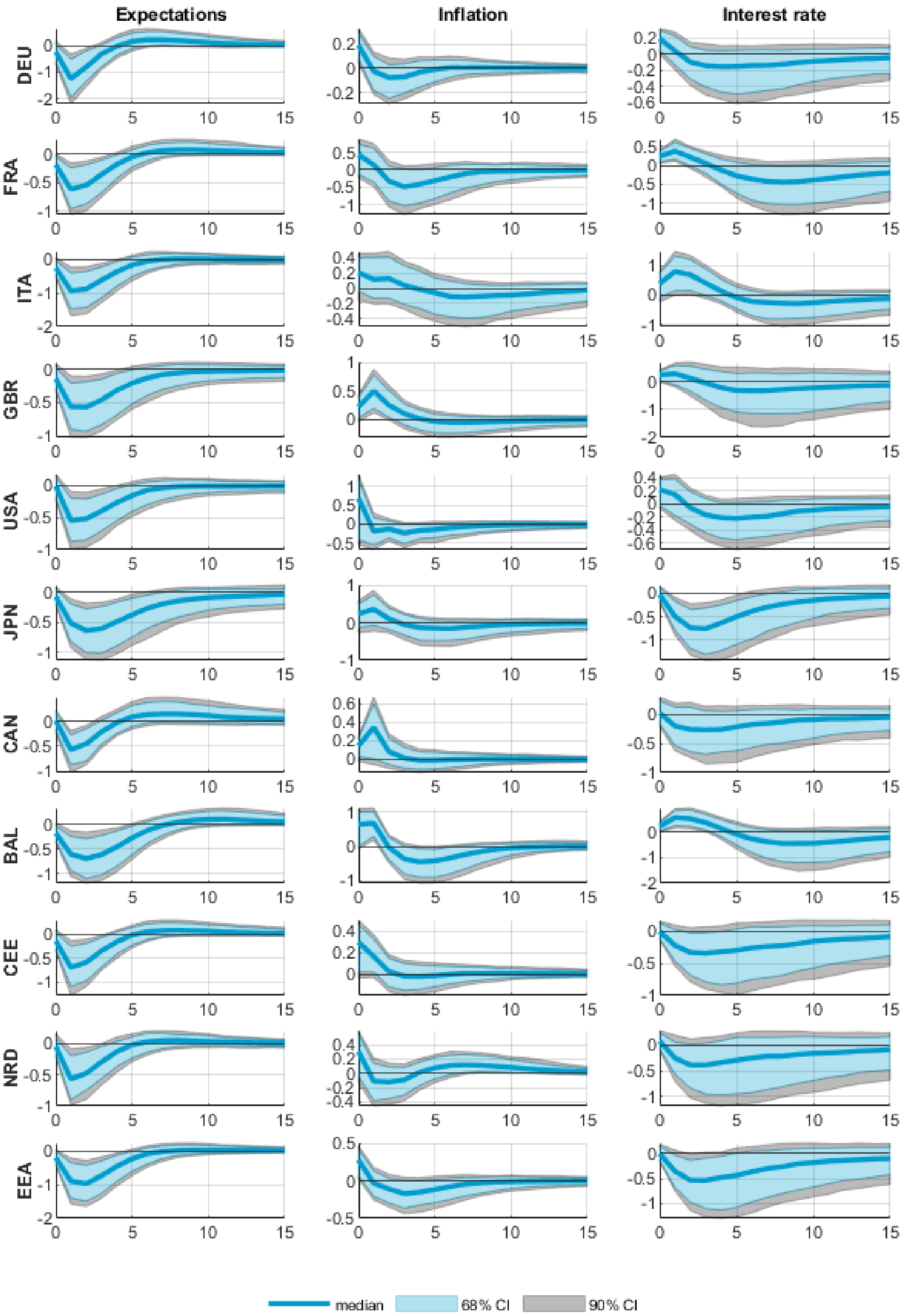
[18] See Bobasu and De Santis (2022). The war-induced soaring inflation and tightening monetary and financial conditions have also caused pent-up demand to peter out in the aftermath of COVID-19 (Dossche et al., 2022).

Figure 4: Output, Consumption, and Investment Responses to the Russian GPR Shock, 2000Q1 – 2023Q2



Notes: Displayed are the generalized impulse response functions to the Russian GPR shock on impact and for the subsequent 15 quarters. Decimals represent percentage points (i.e., -0.02 equals a contraction of 2%). The shock is scaled to seven standard deviations, mimicking the increase in the GPR index in 2023Q2. The central median impulse response is indicated by the blue line. The 68% and 90% confidence intervals (CI) are presented in the light blue and gray shaded areas, respectively. The countries are labeled with three-digit ISO codes. For the compilation of the country clusters, see Table 1.

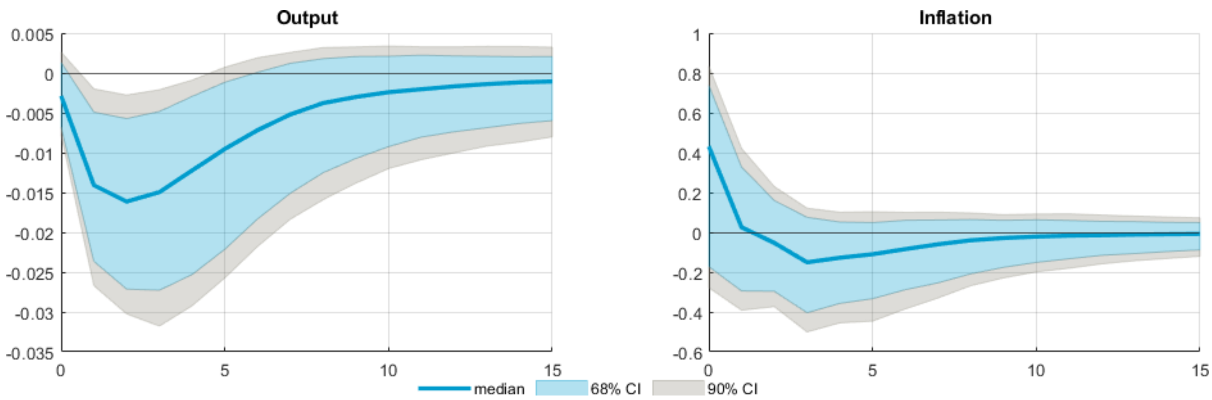
Figure 5: Expectations, Inflation, and Interest Rate Responses to the Russian GPR Shock, 2000Q1 – 2023Q2



Notes: Displayed are the generalized impulse response functions to the Russian GPR shock on impact and for the subsequent 15 quarters. Decimals represent percentage points (i.e., -0.02 equals a contraction of 2%). The shock is scaled to seven standard deviations, mimicking the increase in the GPR index in 2023Q2. The central median impulse response is indicated by the blue line. The 68% and 90% confidence intervals (CI) are presented in the light blue and gray shaded areas, respectively. The countries are labeled with three-digit ISO codes. For the compilation of the country clusters, see Table 1.

As a supplementary evaluation, Figure 6 displays the international business cycle transmission to the Russian GPR shock for the PPP-weighted aggregate of all countries and country clusters in the GVAR. The impacts may be interpreted as a proxy for the geopolitical repercussions of the Russian invasion of Ukraine on the group of like-minded sanctioning countries. The generalized impulse response functions in Figure 6 reveal a significant slowdown in economic growth. The contractionary GDP impact of the GPR shock is about 1.5% for three quarters in a row, followed by a gradual recovery. The inflation impact of the contractionary supply shock is positive, albeit poorly significant. The reason for the statistical insignificance is the heterogeneous exposure to the Russian pipeline gas supply freeze and the subsequent varying energy price increases. In this regard, Figure 6 hides divergent degrees of impact across countries and/or country groups, as evident in Figures 4 and 5.

Figure 6: Weighted Aggregate Output and Inflation Impacts on the Russian GPR Shock, 2000Q1 – 2023Q2



Notes: The weighted aggregation was executed using purchasing power parity (PPP) USD. Displayed are the generalized impulse response functions to the Russian GPR shock on impact and for the subsequent 15 quarters. Decimals represent percentage points (i.e., -0.02 equals a contraction of 2%). The shock is scaled to seven standard deviations, mimicking the increase in the GPR index in 2023Q2. The central median impulse response is indicated by the blue line. The 68% and 90% confidence intervals (CI) are presented in the light blue and gray shaded areas, respectively.

7. Robustness

Finally, three robustness tests are presented to complement the analysis. The supplementary tests aim to identify the specific contribution of the geopolitical shock triggered by the Russian invasion of Ukraine. To achieve a meaningful cross-comparison, the Russian GPR increase following the invasion of Ukraine is assumed to be a shock in all scenarios. In other words, possible differences in the generalized impulse response functions for different sample periods and/or GVAR model specifications are not due to different shock sizes but rather to differing economic relationships.

As part of the multi-stage approach, the GVAR model is first estimated up to 2019Q4, thus excluding both the COVID-19 pandemic shock and the knock-on impact of the Russian invasion of Ukraine in 2022Q1. By contrast, the illegal annexation of the Crimean peninsula in 2014 is included in the subsample. Appendix B1 contrasts the generalized impulse responses and associated 90% confidence intervals up to 2019Q4 with those for the entire sample period up to 2023Q2. The head-to-head comparison reveals two findings for the pre-pandemic sample period of 2000Q1 – 2019Q4. First, no discernible GDP setback as a result of the hypothetical Russian GPR shock is recognizable. Second, with a few exceptions, no rise in inflation has been observed. These findings are reflective of the rather vaguely formulated sanctions imposed by the US, the EU, and other like-minded countries against Russia in the aftermath of the annexation of the Crimean peninsula in 2014, including the exclusion of Russia from the G8, as well as restrictions on specific firms and individuals with close ties to the Russian government. The sanctions also included restrictions on the export and re-export of technology for the Russian defense sectors, while many other technology exports—especially those aimed at the Russian energy sector—were exempt from the trade restrictions. Russian crude oil and natural gas exports were also unaffected, partly because of the fear of Russia retaliating by cutting off natural gas supplies. Overall, the sanctions at the time were rather half-hearted and had hardly any impact.[19]

In the second step of the robustness analysis, the generalized impulse responses for the baseline GVAR model estimated over the pre-pandemic sample period 2000Q1–2019Q4 and the pre-war sample period 2000Q1–2021Q4 were compared. The pre-war sample period 2000Q1–2021Q4 includes the COVID-19 pandemic but does not account for the impacts of the full-scale invasion of Ukraine in 2022Q1. The comparison of the generalized impulse response functions to the hypothetical Russian GPR shock for both sample periods is graphically illustrated in Appendix B2. One main observation emerges. While the generalized impulse responses for the sample period from 2000Q1 – 2021Q4 show comparatively larger pandemic-induced downturns in GDP and CPI inflation, these downturns are not statistically significant. All in all, the GPR spillovers underline that the estimation results for the entire sample period from 2000Q1–2023Q2 are not due to the effects of the COVID-19 pandemic.

Finally, we tested for the robustness of our results by explicitly including fossil fuel prices as an additional exogenous variable in the GVAR framework. To this end, we employed the "HWWI Energy Raw Materials Price Index" (https://www.hwwi.org/en/data-offers/commodity-price-index/). The HWWI fossil fuel price index consists of the three most relevant forms of energy commodities: crude oil, coal, and natural gas. The index weightings calculated from the corresponding import shares of the OECD countries for 2017 - 2019 are 70% for crude oil, 8% for coal, and 22% for natural gas, respectively. The generalized impulse response functions for the estimation period from 2000Q1 - 2023Q for a GVAR model with and without the HWWI fossil fuel price index are illustrated in Appendix B3. In economic terms, the comparison of the impulse responses provides a conceptual decomposition of the entire Russian GPR shock impact into the "pure" weaponized fossil fuel price impact on the one hand and all remaining GPR-induced impediments to the growth process on the other hand. The latter include, among others, slowing

[19] For the economic footprint of layered sanctions and countersanctions following Russia's annexation of Crimea in 2014, see Ashford (2016) and Belin and Hanousek (2021). Korovkin and Makarin (2023) have shown that during the Russian-Ukrainian war in the Donbass in 2014, established Russian trade networks with geographically close Ukrainian businesses were particularly disrupted.

global trade and foreign direct investments, declining exports to Russia, heightened uncertainty taking a toll by delaying consumption and investment decisions, tightened financing conditions for households and businesses due to central banks' need to bring inflation back to target rates, the economic fallout of supply chain disruptions, and governments facing substantially higher sovereign bond yields to finance their sizable fiscal deficits. The decomposition thus opens the door to a richer understanding of the transmission process of the Russian GPR shock on economic growth while at the same time pointing to potential levers for economic policy. Zooming in on the detailed impulse response functions in Appendix B3 reveals a short to medium-term peak-rebound trajectory of GDP. Moreover, the declining expectations proxy is reflective of an increase in perceived uncertainty and subsequent drop in consumption and investment. Taken together, this confirms that the contractionary Russian GPR supply shock unfolds by means of a multitude of the same directional and mutually interacting transmission processes. As expected, the magnitude of the GDP and inflationary effects of the energy price increases are particularly pronounced in the European countries affected by the loss of cheap pipeline gas. This result elucidates why economic policy debates in many European countries have shifted to developing fiscal stabilization packages designed to cushion households and businesses from the energy crisis.[20] It also confirms the findings on the weighted aggregated effects in Figure 6.

8. Conclusion

After years of increasing globalization, geopolitics has fundamentally changed the global economy and will continue to do so. The COVID-19 pandemic and the resultant disruptions to global supply chains have heightened concerns about supply security and have brought about a preference for reshoring and friendshoring. More than anything else, the Russian invasion of Ukraine in February 2022 has altered the geopolitical landscape and triggered a seismic shift in the global order. As Russia cut natural gas supplies and energy prices skyrocketed, a new preference for de-risking policies designed to avoid excessive dependencies emerged. It is, as yet, unclear how far the geoeconomic fragmentation will go. However, there is no doubt that this current period represents a significant turning point in the global order, and global economic integration is at risk of fragmentation driven by strategic considerations.[21]

The unprecedented increases in Russian GPR scores after the invasion of Ukraine raise the question of the extent to which geopolitical tensions and risks threaten the outlook for industrialized economies. The multi-country GVAR approach enables us to measure how Russian GPR disturbances propagate across interconnected countries and how this propagation mechanism evolves over time, which is a particularly appealing feature given the diversity of international countries. This paper thus contributes to the

[20] For a fiscal policy tracker of measures shielding European consumers from the direct impact of rising energy prices, see https://www.bruegel.org/dataset/national-policies-shield-consumers-rising-energy-prices.

[21] This assessment is supported by the fact that already since the global financial crisis 2008-2009, growing anti-trade sentiment has rippled across countries, polarizing politics within them. At the core is the political globalization trilemma view according to which global economic integration, national sovereignty, and democracy are mutually incompatible. See Funke and Zhong (2024).

literature on international business cycle transmission by systematically analyzing the channels through which GPR spillovers are transmitted to other countries. To our knowledge, this paper presents the first analysis of the unprecedented increases in Russian GPR scores since the invasion of Ukraine.

As the contractionary GPR supply shocks unfold, the attendant uncertainty exercises a drag on economic growth, for example, as firms delay investment decisions and households increase precautionary savings. How these impacts will evolve in the longer run is difficult to predict. The impacts are sharp at the business cycle horizon because the elasticities of substitution are lower. However, economies are adaptive. The experience of European countries in dealing with the Russian natural gas cut-off is a case in point.[22]

The results from this study have notable implications for geopolitical policy designs that aim to rearrange international supply chains to make them less vulnerable to geopolitical tides. An important economic policy question in this context will be whether a "de-risk" strategy can be achieved without concomitant growth-reducing "decoupling."

[22] The idea that elasticities increase with time has become known as the so-called Le Chatelier principle (Milgrom and Roberts, 1996). See Atkeson and Kehoe (1999) for models of energy use that rationalize the Le Chatelier principle.

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Appendices to “Economic Knock-On Effects of Russia’s Geopolitical Risk on Advanced Economies: A Global VAR Approach”

Appendix A: Structural Stability Tests

Number of Rejections of the Null of Parameter Constancy per Variable in the Country-Specific Models at the 5% Level

Alternative Test Statistics	Domestic Variables (%)						Numbers (%)
	PMI	Y	C	I	PI	R	
PK_{sup}	2 (0.18)	1 (0.09)	1 (0.09)	1 (0.09)	0 (0)	0 (0)	5 (0.08)
PK_{msq}	1 (0.09)	3 (0.27)	1 (0.09)	1 (0.09)	0 (0)	0 (0)	6 (0.09)
Nyblom	2 (0.18)	3 (0.27)	4 (0.36)	3 (0.27)	3 (0.27)	7 (0.64)	22 (0.33)
robust-Nyblom	1 (0.09)	2 (0.18)	2 (0.18)	5 (0.45)	3 (0.27)	3 (0.27)	16 (0.24)
QLR	3 (0.27)	4 (0.36)	6 (0.55)	2 (0.18)	3 (0.27)	2 (0.18)	20 (0.3)
robust-QLR	0 (0)	3 (0.27)	2 (0.18)	1 (0.09)	1 (0.09)	1 (0.09)	8 (0.12)
MW	2 (0.18)	3 (0.27)	6 (0.55)	4 (0.36)	3 (0.27)	5 (0.45)	23 (0.35)
robust-MW	2 (0.18)	3 (0.27)	3 (0.27)	6 (0.55)	2 (0.18)	1 (0.09)	17 (0.26)
APW	2 (0.18)	3 (0.27)	6 (0.55)	2 (0.18)	3 (0.27)	2 (0.18)	18 (0.27)
robust-APW	0 (0)	3 (0.27)	1 (0.09)	3 (0.27)	1 (0.09)	1 (0.09)	9 (0.14)

Notes: PK_{sup} and PK_{msq} denote Ploberger and Krämer’s (1992) maximal OLS cumulative sum (CUSUM) statistic for the identification of a structural break in the underlying time series. To test for the stability of the parameters, we use the Nyblom (1989) test. A battery of sequential Wald-type tests is employed designed to identify a single break at an unknown change point: the Wald form of Quandt’s (1960) likelihood ratio statistic (QLR), the mean Wald statistic (MW) of Hansen (1992) and Andrews and Ploberger (1994) and the Andrews and Ploberger (1994) Wald statistic based on the exponential average (APW). The prefix ‘robust’ denotes that a heteroskedasticity-robust version of the test is applied. All test results correspond to a significance level of 5%.

Additional References:

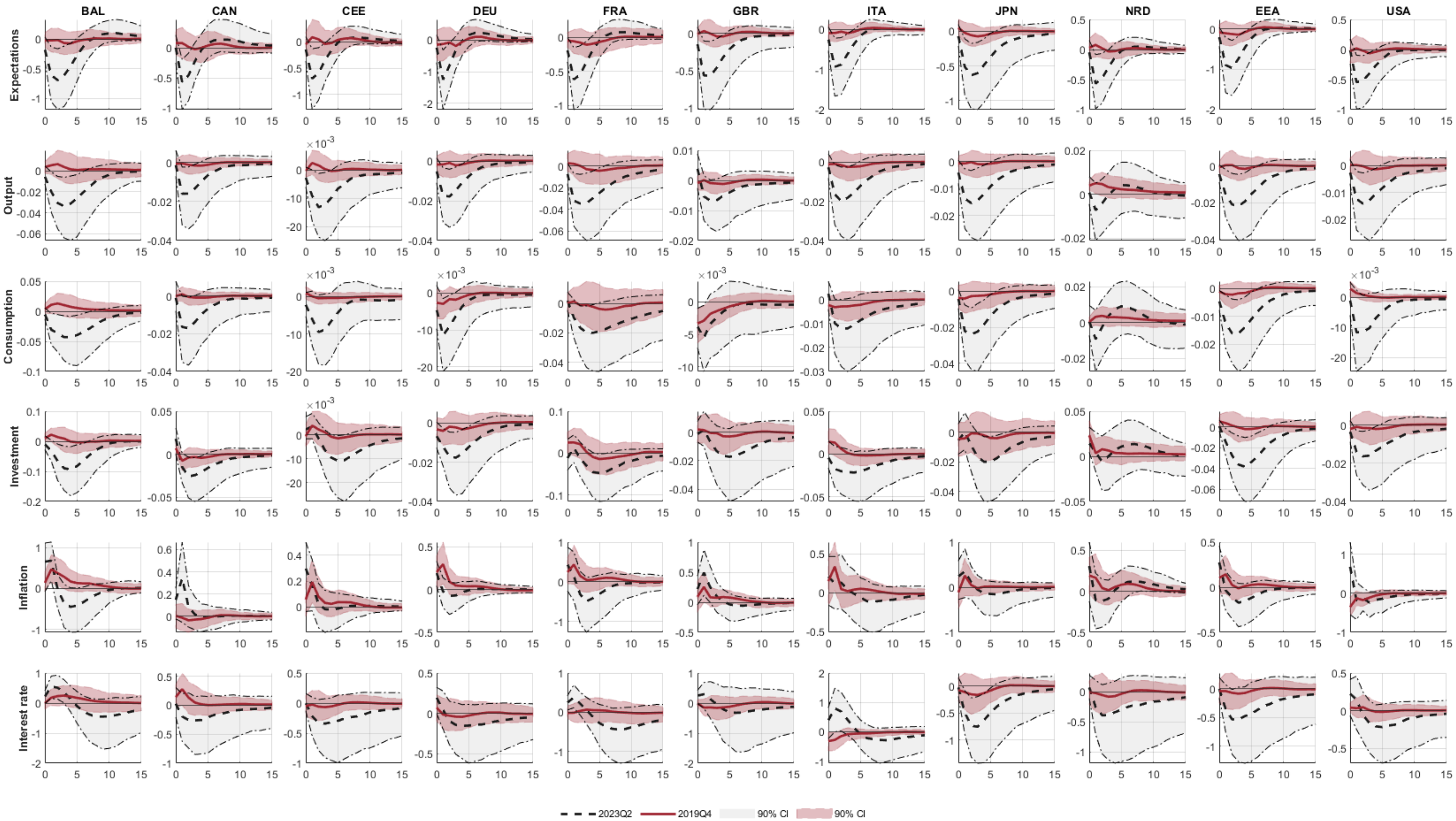
Andrews D. W. K. and W. Ploberger (1994) “Optimal Tests when a Nuisance Parameter is Present only Under the Alternative”, *Econometrica* 62: 1383-1414.

Hansen B.E. (1992) “Tests for Parameter Instability in Regressions with I(1) Processes”, *Journal of Business and Economic Statistics* 10: 321-336.

Nyblom J. (1989) “Testing for the Constancy of Parameters over Time”, *Journal of the American Statistical Association,* 84: 223-230.

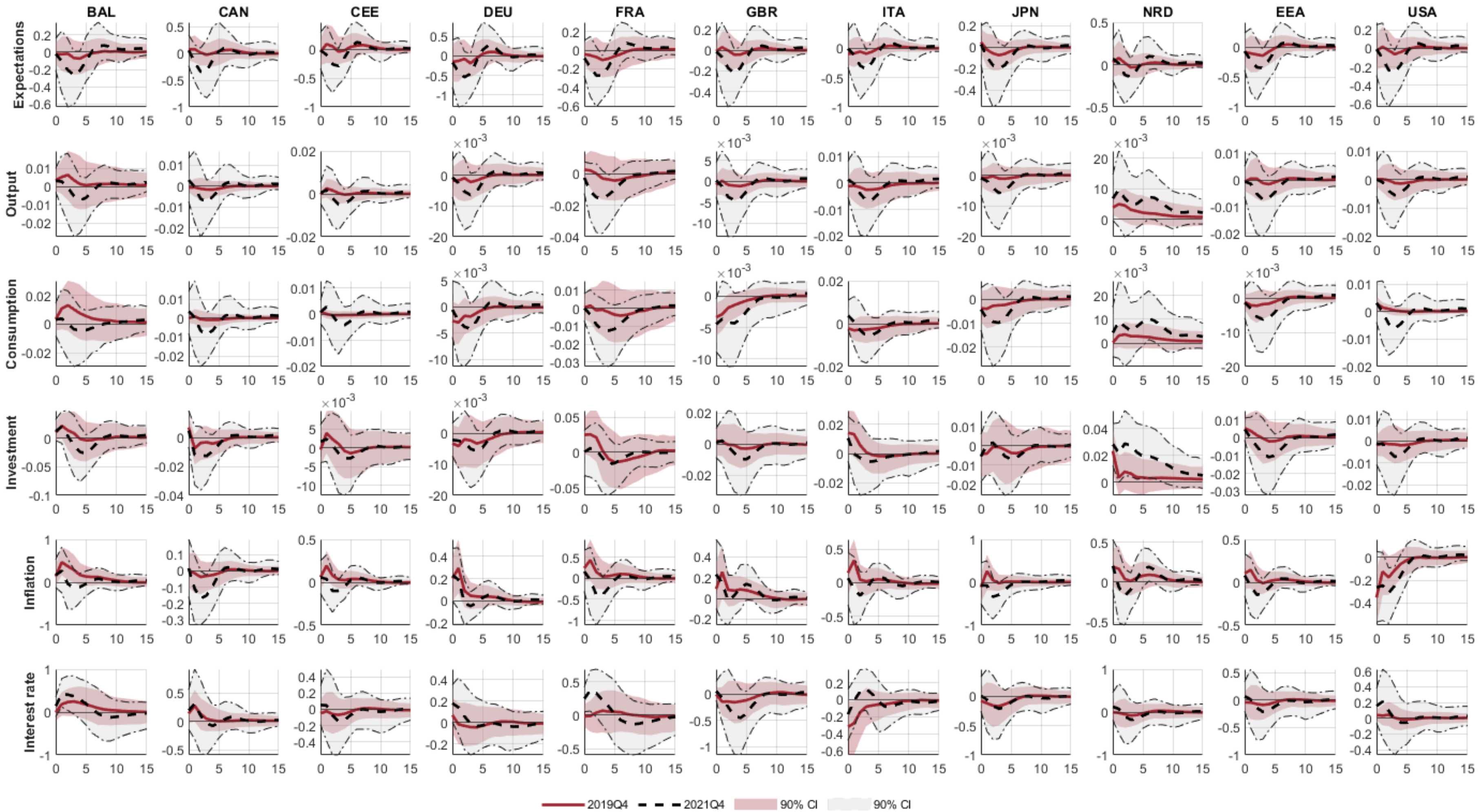
Ploberger, W., and W. Krämer (1992) “The CUSUM Test with OLS Residuals”, *Econometrica* 60: 271-286.

Appendix B1: Generalized Impulse Responses to the Russian GPR Shock, 2000Q1 – 2019Q4 versus 2000Q1 – 2023Q2



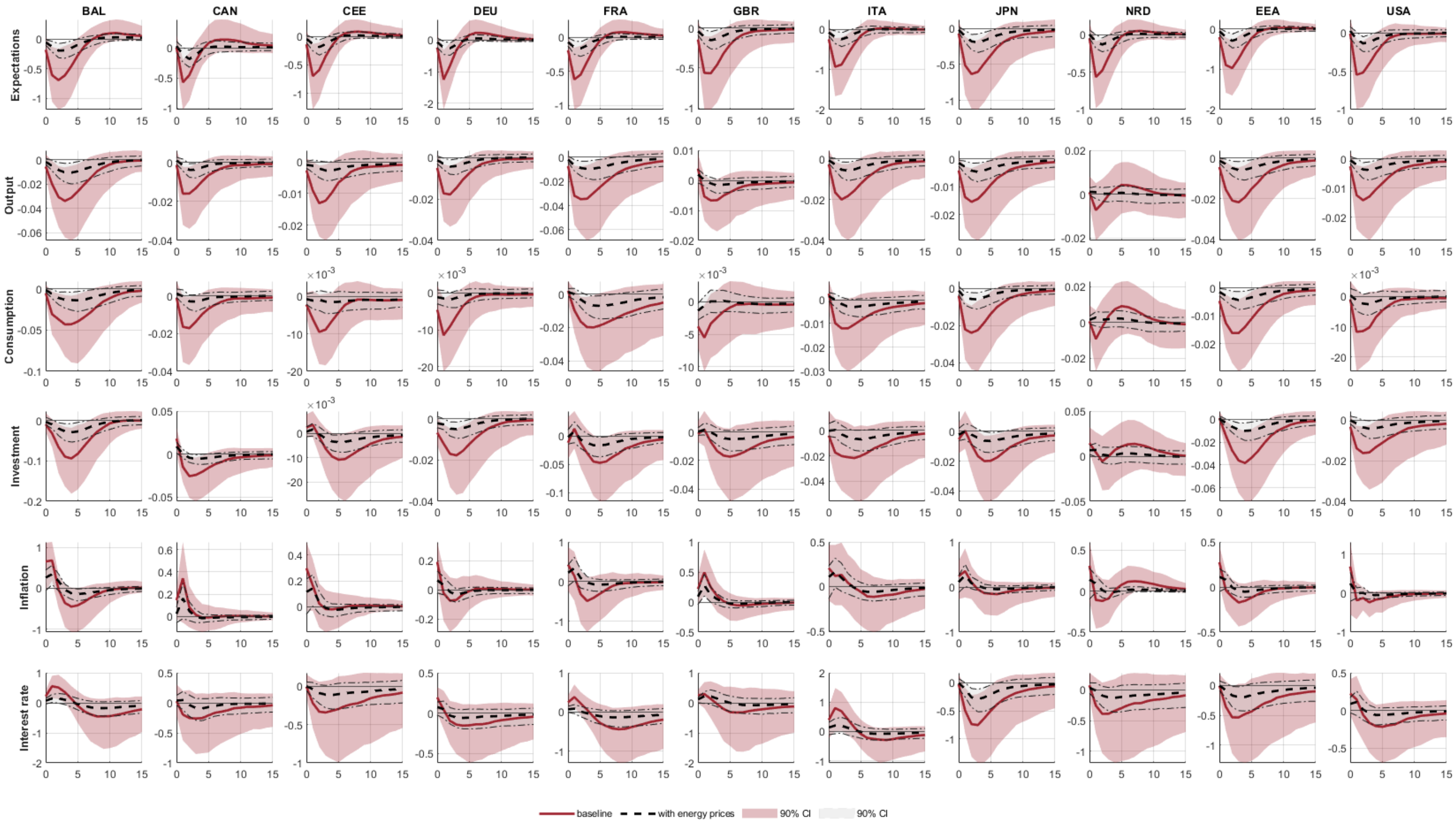
Notes: Displayed are the GIRFS to the Russian GPR shock on impact and for the subsequent 15 quarters. Decimals represent percentage points, i.e., -0.02 equals a contraction of 2%. The shock is scaled to seven standard deviations, mimicking the increase in the GPR index in 2023Q2. The central median impulse responses are given by the solid red and dashed black lines. The 90% confidence intervals are presented by the red and gray shaded areas, respectively. The countries are labeled with three-digit ISO codes. For the compilation of the country clusters, see Table 1.

Appendix B2: Generalized Impulse Responses to the Russian GPR Shock, 2000Q1 – 2019Q4 versus 2000Q1 – 2021Q4



Notes: Displayed are the GIRFS to the Russian GPR shock on impact and for the subsequent 15 quarters. Decimals represent percentage points, i.e., -0.02 equals a contraction of 2%. The shock is scaled to seven standard deviations, mimicking the increase in the GPR index in 2023Q2. The central median impulse responses are given by the solid red and dashed black lines. The 90% confidence intervals are presented by the red and gray shaded areas, respectively. The countries are labeled with three-digit ISO codes. For the compilation of the country clusters, see Table 1.

Appendix B3: Generalized Impulse Responses to the Russian GPR Shock With versus Without Fossil Fuel Prices, 2000Q1 – 2023Q2



Notes: Displayed are the GIRFS to the Russian GPR shock on impact and for the subsequent 15 quarters. Decimals represent percentage points, i.e., -0.02 equals a contraction of 2%. The shock is scaled to seven standard deviations, mimicking the increase in the GPR index in 2023Q2. The central median GIRFs for the baseline GVAR model are given by the solid red lines; the dashed black lines give the GIRFs for the GVAR, including the HWWI fossil fuel price index. The 90% confidence intervals are presented by the red and gray shaded areas, respectively. The countries are labeled with three-digit ISO codes. For the compilation of the country clusters, see Table 1.