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Synchronisation of business cycles in Russia and China

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Abstract

The past two decades have seen a rise in China's share of global trade. Its role has become particularly prominent in Russia's foreign economic relations after 2022, due to the reorientation of trade flows from Europe and the United States toward China and other Asian countries. This study aims to assess the impact of the changes in foreign trade on Russian business cycles. Specifically, we intend to verify a hypothesis about a greater degree of synchronisation in the business cycles of China and Russia since 2022, driven by the higher volumes of bilateral trade.

We use GVAR with time-varying weights as the method of our analysis. The weights are the shares of the countries that generate value-added foreign trade. We measure the degree of synchronisation between Russia and China based on an analysis of Russia's output impulse responses to simulated positive output shocks for China, taking into account the secondary effects of Asia, the US and Europe.

According to our research, the response of Russia's output to positive shock of China's local output in 2023 was almost double that in 2019. If we simulate a global economic crisis in which a shock in China triggers a proportional drop in the output of other countries, particularly the US and the EU, we find that the degree of synchronisation between 2019 and 2023 remains unchanged. Put differently, the response of Russia's output to shock of output in China is unchanged under this scenario.

Our results can be used to adjust macroeconomic models to the new environment for the Russian economy and thus improve predictive capabilities and analytics.

Key words: Russia, China, international business cycles, trade relations, OECD TiVA, Global VAR

JEL codes: C32, E32, F15, F44

1. Introduction

Between 2001 and 2023, China's share of global nominal GDP increased from 4.5 to 17.2%,[1] and its share of the gross turnover of global trade increased from 7 to 12%,[2] boosting China's influence on other economies. This trend is of much relevance to Russia, as the western sanctions imposed from February 2022 have been driving a transformation in its external relations. Between 2001 and 2023, Asia's share of Russian external relations increased from 13 to 66% as the country shifted its trade flows away from Europe and the US to Asian economies such as China. China's share of Russia's gross trade turnover grew from 5 to 36% over 2001–2023.[3] The EU and the countries aligned with it (the EU+ grouping) saw a decline in their share of Russia's turnover from 58 to 15%.[4] These changes in external relations may have transformed the dependency of the Russian economy on fluctuations in the economic activity of its partner countries.

According to research findings to date, trade volumes affect the degree of synchronization of countries' business cycles: on average the greater the relative level of trade of one economy with another, the more synchronized their business cycles are (Imbs, 2004). This study applies this relationship to the business cycles of Russia and China, specifically testing the hypothesis that the degree of synchronization between the business cycles of China and Russia increased in 2023 compared to 2019, which serves as a pre-shock period before the events of 2020 and 2022. The analysis is based on data on the dynamics of trade structure.

We measure the degree of business cycle synchronisation using the values of the impulse response functions of the domestic macroeconomic variables in country x as the response to exogenous shocks from country y (similar to the work of Huh et al. (2015), Arzoumanian (2023) and Zubarev and Kirillova (2023)). Business cycles are marked by changes in output, interest rates, and other macroeconomic indicators (Imbs, 2004). However, the authors of many empirical studies, like the current study, directly associate business cycle synchronization with real gross domestic product (GDP) synchronization (Imbs, 2004; Huh et al., 2015; Arzoumanian, 2023; Zubarev, Kirillova, 2023).

The characteristics of the synchronisation of Russia's business cycles with those of the EU and the US have been thoroughly studied in works focused on synchronisation (Darvas and Szapáry, 2008; Groth and Ghil, 2017; Tiunova, 2018). The literature includes works presenting evidence for the synchronisation of the business cycles of China and Russia from before 2021 (Dai et al., 2022; Zubarev and Kirillova, 2023). To the best of our knowledge, however, there are no studies that capture the structural changes in external relations between Russia and China in the post-2022 period, and our paper seeks to close this gap in the research.

To test the hypothesis, we rely on the analysis of the impulse response functions of a global VAR (GVAR) model featuring time-varying weights for inter-country relations. The weighs are country shares in value-added foreign trade. Given the exposure of China and Russia to other economies, our analysis must extend to the global economic system to make

[1] According to the IMF World Economic Outlook. 'China' includes Hong Kong and Macau.
[2] According to IMF DOTS. Authors' calculations. 'China' includes Hong Kong and Macau.
[3] According to IMF DOTS. Authors' calculations. From 2022 onwards, the calculations are based on mirror data on Russia's foreign trade. 'China' includes Hong Kong and Macau.
[4] The full list of the EU+ grouping is presented in Appendix C.

a proper assessment of the primary and secondary effects. Such models can be built with the help of GVAR. Of previous studies, Cesa Bianchi et al. (2011) present a similar approach to measure the degree of synchronisation of the business cycles of China and Latin America, taking into account China's growing share of turnover with Latin American countries.

Our findings suggest that the response of Russia's output to positive local output shock in China in 2023 is almost double that in 2019. However, in the case of a global economic crisis triggered by output shock in China which involves a proportional contraction in the output of other economies (such as the US and the EU), the response of Russia's output to this contraction is unchanged. This is likely due to significant network effects in the transmission of shocks, where the initial country of the shock becomes less important.

The findings of this study can be used to calibrate the large structural and semi-structural models which the Bank of Russia relies on for its analysis and forecasting. In the current Russian model framework, the external sector tends to be reduced to the impact of the major Western economies – the US and the EU – on the Russian economy, leaving the influence of China out of scope (Orlov, 2021; Korshunov and Nelyubina, 2021; Kryzhanovsky and Zykov, 2022). Considering the greater role of China in Russia's foreign economic relations, the quality of analysis and the accuracy of macroeconomic projections may be improved if this factor is included as part of the external sector.

2. Literature review

The existing literature presents several approaches to assessing the degree of business cycle synchronisation:

1) **Proximity of output growth**, measured as the modulus of the difference between two countries' GDP growth rates multiplied by -1 (Lee et al., 2022). This measure can also be used in regressions as the dependent variable;

2) **Pair correlation,** which is one of the best-known and simplest measures for the degree of business cycle synchronisation and is the correlation between the cyclical components of real GDP (Jenish, 2015). This approach enables the investigation of the effect of factors on synchronisation thanks to the use of the correlation as the dependent variable;

3) **Impulse response** functions can serve as another approach to measuring business cycle synchronisation. This approach helps obtain a direct estimate of the percentage of change in the output of one of the two countries in response to a 1pp change in the output of the other (Arzoumanian, 2023; Zubarev and Kirillova, 2023).

As the objective of this paper is the quantification of the degree of synchronisation of China's and Russia's output, the calculation of impulse responses is the best approach.

The degree of business cycle synchronisation tends to be higher between countries that have developed a close economic relationship with each other (Imbs, 2004; Lee et al., 2022; Arzoumanian, 2023). Among synchronising factors are trade integration, the flows of foreign direct investment and financial integration.

One of the best studied synchronising factors is the **trade channel**. The higher the relative volumes of trade between countries, the more synchronised their business cycles are (Frankel and Rose, 1998; Shin and Wang, 2004; Imbs, 2004; Duval et al. 2016; Lee et al., 2022; Arzoumanian, 2023). If demand shock causes an economic boom in country x, its consequences may theoretically spread to trading partners in the form of a rise in imports from them (Shin and Wang, 2004). Also, tighter trade integration may be responsible for a faster distribution of productivity shock, which will also bolster synchronisation (Frankel and Rose, 1998). For example, the more open a country is to foreign trade, the greater the beneficial effect of foreign research and development on its domestic output (Coe and Helpman, 1995). A significant drop in research and development costs in the trading partners of country x may reduce the output of country x through a drop in overall factor productivity in x (Coe and Helpman, 1995).

Foreign direct investment (FDI) is another important synchronising factor (Hsu et al., 2011; Araujo et al., 2017). However, its effect on synchronisation is asymmetric and must be accounted for in more complex non-linear models. For example, output shock affecting the investing country immediately feeds through to the recipient country, changing the status quo of the two parties. However, if the recipient country is hit by the output shock, the investing country may choose to reallocate resources to more lucrative areas and so avoid financial fluctuations (Lee et al., 2022).

Financial integration is another synchronising factor. Financial relations are understood as the totality of inter-country economic relations related to the distribution of financial resources via financial markets. The impact of this channel on the degree of business cycle synchronisation is also asymmetric. Several empirical works show that financial relations are strongly linked to business cycles (Adam et al., 2002; Bordo and Helbling, 2003; Imbs, 2006). Other authors argue that the integration of the equity and debt markets leads business cycles to play out differently (Davis, 2014). This means that the integration of credit markets has a positive effect on the synchronisation of business cycles, while the integration of stock markets has a negative effect. For example, if a bank extends credit to foreign entrepreneurs and has credit restrictions, negative shock of external output may bankrupt the foreign entrepreneurs, thereby reducing the supply of loans and ultimately sending domestic output lower (Davis, 2014). Equity market investors may redistribute their portfolios by removing the proportion of shares in the countries hit by the negative shock. This allows such investors to smooth out external shocks, which may have an adverse impact on the synchronisation of business cycles. During global shocks, the business cycles of most countries synchronise due to the withdrawal of funds from the banking system by economic agents (Kalemli-Ozcan et al., 2013; Lee et al., 2022; Arzoumaniam, 2023).

The synchronisation of international business cycles is viewed from different angles in the literature. For one, Karadimitropoulou (2018) explores the synchronisation of the business cycles of advanced economies, namely the US, France, Italy, Japan and the UK (G5), and 18 emerging economies at the sectoral level. The author builds a Bayesian dynamic model and conducts a variance analysis on macrodata for 1972–2009. She concludes that the synchronisation of the business cycles of the developing and advanced economies increases over time. The developing countries are increasing their share of the global economy as they are integrated into international trade. At the international level, the convergence of the economic structures of the developing and advanced countries is an important factor in business cycle synchronisation.

The index method is also used to study inter-country interdependencies (Galishcheva and Reschikova, 2022; Zuev et al., 2023). Huh and Park (2017) build an Asia-Pacific regional cooperation and integration index which is based on six dimensions. They conclude that Asia's integration extends only to trade. In terms of infrastructure, communications, the free movement of people, and institutional and social integration, the Asian countries are poorly connected.

Studies relying on the analysis of macroeconomic indicators make full use of vector autoregression (VAR) models and network analysis. Pontines et al. (2021) examine the synchronisation of Asian business cycles through the lens of a connectivity index they calculate. They understand this index as the predictive power of changes in the business cycles in a VAR model, that is, they explore how movements in the output of one country help predict movements in the output of others. The indicator is the proportion of explained forecast error variance. They discover that the connectivity index for Asian countries is increasing over time. Network analysis – which describes inter-country relations through the volume of trade – also shows that the bilateral network interconnection of the economies under study is intensifying over time.

Huh et al. (2015) use a factor-augmented vector autoregression (FAVAR) model to quantify the degree of business cycle synchronisation in Asia. They explore the ten major economies of Eastern Asia: the ASEAN-5 (Indonesia, Malaysia, the Philippines, Singapore and Thailand), China, Hong Kong, Japan and South Korea. The authors use seasonally adjusted quarterly data on real GDP, inflation, growth in the M1 money supply, and real imports and exports for the 1993 to 2010 period. They find that the functions of the GDP impulse response to regional and global shocks are highly synchronised between countries. According to the authors, China is an example of a country whose imports and exports (key trade channels) are quite strongly linked with most episodes of global turbulence.

Arzoumanian (2023) investigates how fluctuations in Russia’s output affect its neighbours. The findings are based on quarterly GDP data for 32 countries (the CIS+ and other countries) from 2004 to 2019. The author employed a VAR model as well as dynamic panel data models, where the quarterly growth of real GDP for each country was used as the dependent variable. They find that a 1pp increase in Russia's real GDP is correlated with an average 0.67pp increase in the real GDP of the CIS+ countries. The correlation is stronger for oil exporting countries, rising to 0.79pp. The fluctuations in Russia’s output are usually synchronous with those in the CIS+ countries in times of global shocks. The author argues that the significance of the trade channel on the synchronisation of the business cycles of Russia and the CIS+ countries grew throughout the period, especially after 2016.

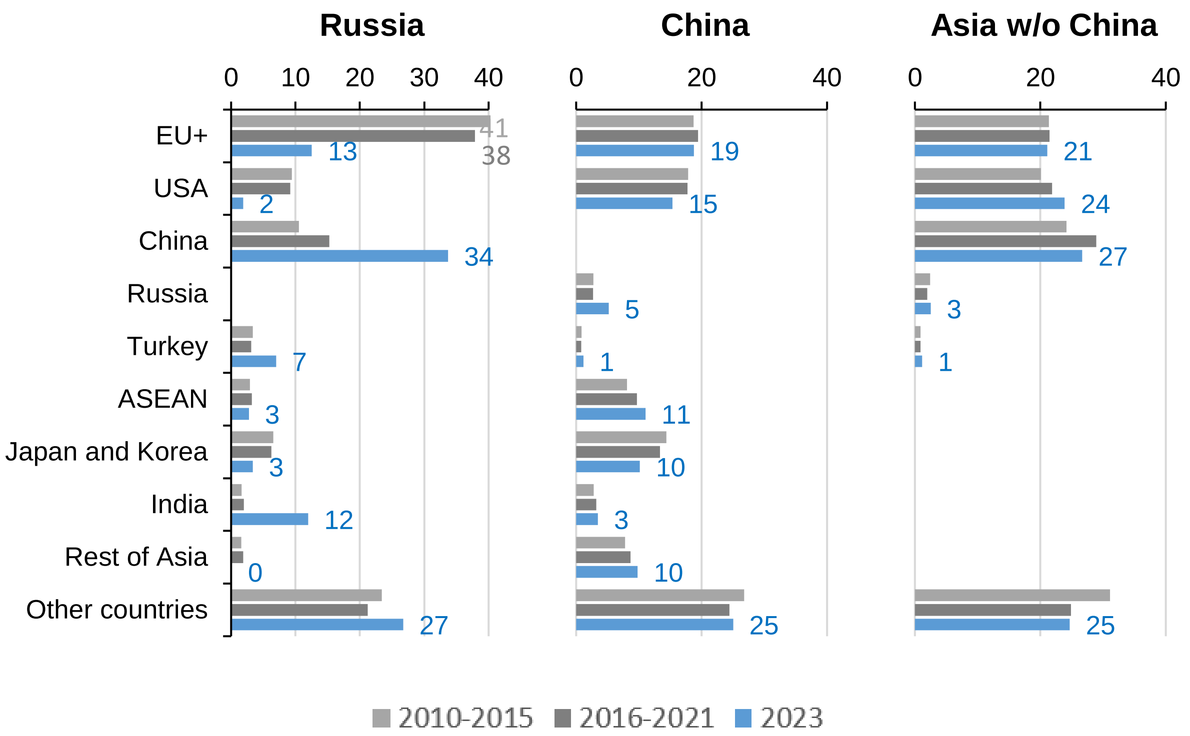
Zubarev and Kirillova (2023) analyse the effects of GDP shock in China and the US on Russia and other economies. For this purpose, they rely on a global vector autoregression (GVAR) model which includes Russia and the world’s 41 largest economies. According to their estimates, a 1pp decline in China's output triggers a 0.2pp decline in Russia's output in the first post-shock quarter, slowly recovering afterwards.

The literature we have studied distinguishes three factors of business cycle synchronisation: trade, finance and foreign direct investment. This study focuses on trade, assuming it can serve as a proxy variable for all external relations. However, our analysis intentionally excludes data on financial and investment relations. This is due to the statistical approaches to the accurate accounting of such data in the model, given that investors extensively use offshore companies (Casella et al., 2023).

3. Analysis of changes in external relations

To better understand the rationale behind the main hypothesis of this study, it is necessary to consider changes in the structure of trade by country over time. Before the sanctions against Russia were put into place in 2022, the EU+ had been Russia's key trading partner, with a 38% share of trade in 2016–2021 (Figure1), while China accounted for 15% in this period. The relations shifted dramatically after February 2022. In 2023, the share of the EU+ countries fell to 13%, and China emerged as Russia's key trading partner, with its share rising to 34%.

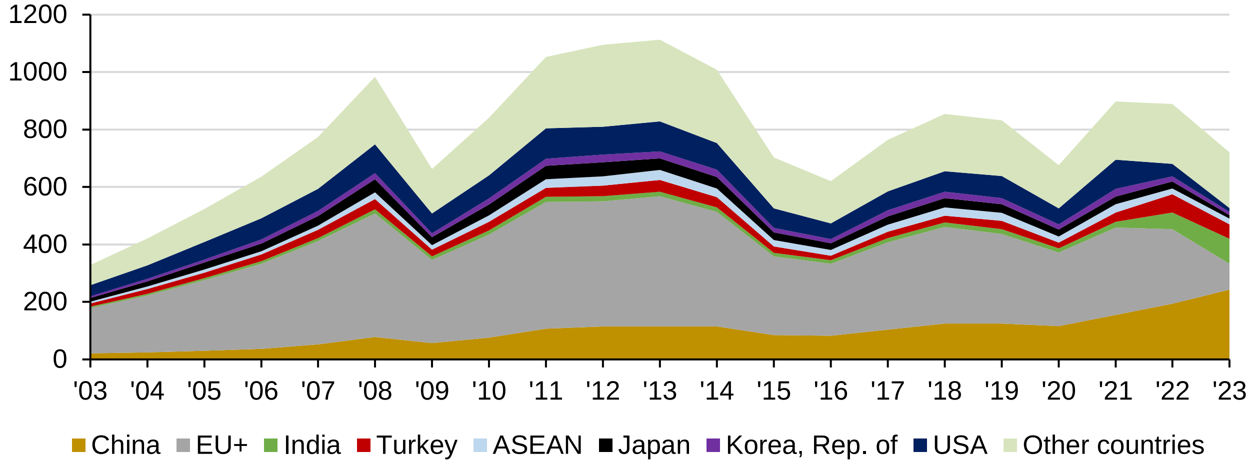
Figure 1. Structure of value-added trade of Russia, China and Asia excluding China, % of total value-added trade turnover



Source: IMF DOTS, OECD TiVA, authors' calculations.
Note: The countries in the economic groupings are listed in Appendix C.

In 2023, the Asian countries accounted for 52% of Russia's trade turnover. In 2016–2021, their share was 29%. China has been a major contributor, with its share increased by 18pp. The changes in the trading volumes are presented in Figure 2.

Figure 2. Trade turnover in Russia's value-added by country, billions of US dollars, 2023 prices



Source: IMF DOTS, OECD TiVA, authors' calculations.

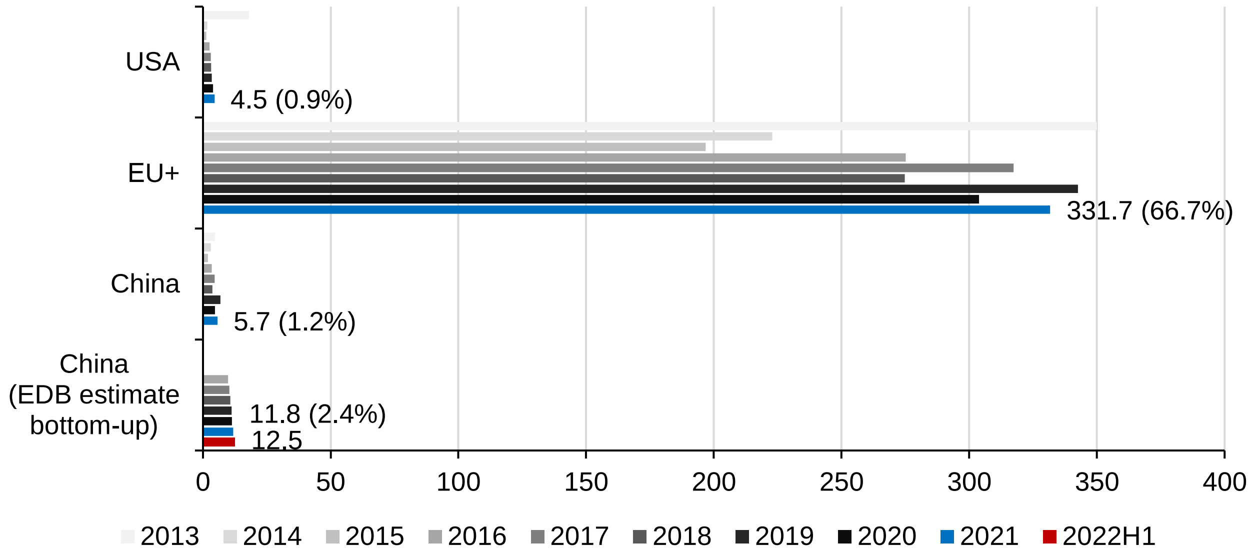
Note: Converted to constant prices using the US GDP deflator. The countries in the economic groupings are listed in Appendix C.

According to many works (Adam et al., 2002; Bordo, Helbling, 2003; Imbs, 2006; Hsu et al., 2011; Araujo et al., 2017), the degree of business cycle synchronisation is driven by the volumes of direct and financial investment. However, it is a real challenge to accurately measure the strength of the actual investment and financial links between individual countries (which are the ultimate beneficiaries) (Novopashina, 2014; Casella et al., 2023). This is explained by investors' extensive use of offshore companies, which precludes the accurate identification of the economic flows from one country to another and limits the ability to measure the degree of synchronisation based on investment and financial links.

Figure 3 presents the Bank of Russia's official statistics and the Eurasian Development Bank's (EDB's) estimates for accumulated foreign direct investment in Russia by country. The most recent Bank of Russia data are dated 1 January 2022. The publication of statistics has been suspended due to the sanctions risks. These official statistics are marked by all of the problems of measuring investment mentioned above. For example, according to the Bank of Russia's data, the volume of accumulated Russia investments originating from Cyprus (historically, a tax haven) amounted to 32.6% of total Russia investments as of 1 January 2022. According to the same data, direct investment in Russia from China (including Hong Kong and Macau) amounted to a mere 1.2% of total investment as of 1 January 2022. This is a very small amount compared to the volume of mutual trade and the size of the Chinese economy.

The problems of measuring the investment statistics led a group of researchers overseen by the Eurasian Development Bank (EDB) to estimate investments from China into Russia on a top-to-bottom basis, that is, based on media sources, company reports and other microdata. The EDB's survey of mutual investments in 2022 (Kuznetsov et al., 2022) supplies the following estimates: China's direct investment in Russia totalled $11.8 billion as of the end of 2021 (2.4% of the total volume according to Bank of Russia data) and $12.5 billion as of the end of 2022 H1. These are still insignificant numbers in comparison with the volumes of mutual trade and the size of China's economy.

Figure 3. Accumulated direct investment in Russian Federation by investing country, billions of US dollars



Source: Bank of Russia (statistics direct investment cumulative positions of the Russian Federation by instrument, directional principle), 2022 EDB monitoring of mutual investments (Kuznetsov et al., 2022)

Note: The data are as of the end of the period. The parentheses show the share of total investment according to the Bank of Russia. The countries in the economic groupings are listed in Appendix C.

The volume of direct investment from Russia to China being insignificant, the Ministry of Commerce of the People's Republic of China does not even distinguish it in their statistics on foreign investment.

The low volume of mutual direct investment between Russia and China – taking into account the problems of investment statistics – explains this study's focus on trade relations as the main proxy for external relations.

As a rule, data on financial relations are based on balance of payments statistics, the same primary sources used for foreign direct investment statistics. They are therefore characterised by similar measurement problems, and this work does not use them.

4. Methodology

This work relies on the global vector autoregression (GVAR) method following Pesaran et al. (2004), Dees et al. (2007), Chudik and Pesaran (2016), and Napalkov et al. (2021). GVAR enables the analysis of the economic dynamics of individual countries and captures cross-country relations and simulates their influence on one another alongside the impact of international factors. The economies under study are thus understood to be interdependent. This is the advantage of GVAR over traditional vector autoregression (VAR), which is usually limited to one country or region.

Among the alternative methods of analysis are general equilibrium models (CGEs). However, CGEs are not always adjusted to surprise changes in the economy, and they are unfit for the purpose of analysing short-term dynamic processes or business cycles in particular (Hosoe et al., 2010). Another approach, panel VAR (PVAR), is also not appropriate for this study due to its lack of all the characteristics of cross-country economic relations, which is a result of the averaging of the individual effects.

A GVAR system for each country i estimates a vector autoregression model whose exogenous variables (VARX) have the following structure:

$$\begin{aligned} x_{it} &= a_{i0} + \Phi_{i1}x_{i,t-1} + \cdots + \Phi_{ip_i}x_{i,t-p_i} \\ &+ \Lambda_{i0}x_{it}^* + \Lambda_{i1}x_{i,t-1}^* + \ldots + \Lambda_{iq_i}x_{i,t-q_i}^* \\ &+ \Psi_{i0}\omega_t + \Psi_{i1}\omega_{t-1} + \ldots + \Psi_{iq_i}\omega_{t-q_i} + \varepsilon_{it}, \end{aligned} \tag{1}$$

for $i = 0,1, \ldots, N$, where N is the number of countries in the model, x is a vector of the internal variables, x^* is a vector of the external variables (spillovers), which are weakly exogenous to it, ω is a vector of the global variables in the model, and ε is the residuals of the model.

The vector of the external variables (x^*) is calculated as the arithmetic mean of the weighted variables of all the external economies. This approach to accounting for external influence allows a considerable reduction in the dimensionality of the model compared to a conventional VAR model, which includes each variable for each country as an individual factor.[5]

The weights reflecting various degrees of cross-country relations are based on the structure of value-added trade turnover according to OECD-TiVA (OECD, 2023). Value-added trade is the better proxy for the power cross-economy relations in the analysis of the flows of business cycle shock and is preferred over the still commonly used gross trade statistics (Duval et al., 2016). The advantages of this source of data are outlined in Appendix A.

Weight w of country j in the trade of country i in period t is calculated by the formula:

$$w_{ijt} = \frac{Export\_VA_{ijt} + Import\_VA_{ijt}}{Export\_VA_{it} + Import\_VA_{it}} \tag{2}$$

where $Import_{VA} and\ Export\_VA$ are the volumes of exports and imports in value-added terms.

A separate estimate of the model is made for each country using the least squares (LS) method of formula (1). The model estimates for the countries are then consolidated by ‘stacking’ to solve the GVAR system as a unified whole. Chudik and Pesaran (2016) offer further details of the algorithm for the solution of the GVAR. The tool for model estimation is based on the GVAR Toolbox (Smith and Galesi, 2014).

The classical approach involves the estimation of the individual country models in the GVAR on the basis of vector error correction models with exogenous variables (VECMX) to take into account long-term relationships in the economy and solve the problem of the non-stationarity of the time series in levels (Pesaran et al., 2004; Dees et al., 2007; Chudik and Pesaran, 2016; Zubarev and Kirillova, 2023). This study deviates from this tradition slightly.

[5]Furthermore, the separate inclusion of each variable for each country in the model inevitably involves the problem of multicollinearity, which emerges as a result of the significant correlation between the macrovariables for different countries (Bordo and Helbling, 2003). Given multicollinearity, it is difficult to conduct a qualitative structural analysis of the impact of shocks of individual economies on the entire economic system, since the clear identification of the true sources of shock is difficult in this case.

The country models are grounded in the simpler VARX in GDP gaps and first-differences for all the other variables. This choice is explained by the fact that the selection of the VECM cointegration of each country in GVAR has considerable impact on the estimates. At the same time, the statistical tests for the selection of the cointegrating rank, such as the Johansen test, often have values for the test statistics that are practically indistinguishable across variations of cointegrating rank. All this creates a significant source of uncertainty in the specifications, making the unambiguous identification of a good model impossible.

In addition to the search for a model suitable for the study, a suitable indicator for the business cycle must be defined. In empirical works focused on synchronisation, this indicator is the output gap (Imbs, 2004; Arzoumanian, 2023). The problems of measuring the output gap have been covered in the literature extensively (Hamilton, 2018). This work defines it as the deviation of actual output from the trend. The trend is an unobservable value, and its estimation may be governed by multiple approaches.

The Hodrick–Prescott filter is one of the most popular tools to distinguish the trend (Hodrick and Prescott, 1997). This tool has met serious criticism (such as that of Hamilton (2018)). However, empirically, the Hodrick–Prescott filter is slightly different from more modern filtering methods when it is used as a predictor of economic crises (Drehmann and Yetman, 2018). In this work, the Hodrick–Prescott filter is used to estimate the output gap. Given its most prominent disadvantage – the problems of the initial and end points – the estimates of the Hodrick–Prescott filter are first based on the full sample, and then the first and last four quarterly observations are removed. The estimates of the output gap are presented in Appendix H.

The quarter-on-quarter growth of output is another alternative approach to accounting for it. However, the findings of empirical works show that the use of the output gap and output growth in GVAR models yield similar results (Imbs, 2011). In this work, the estimation of the GVAR model with output growth is part of the robustness check.

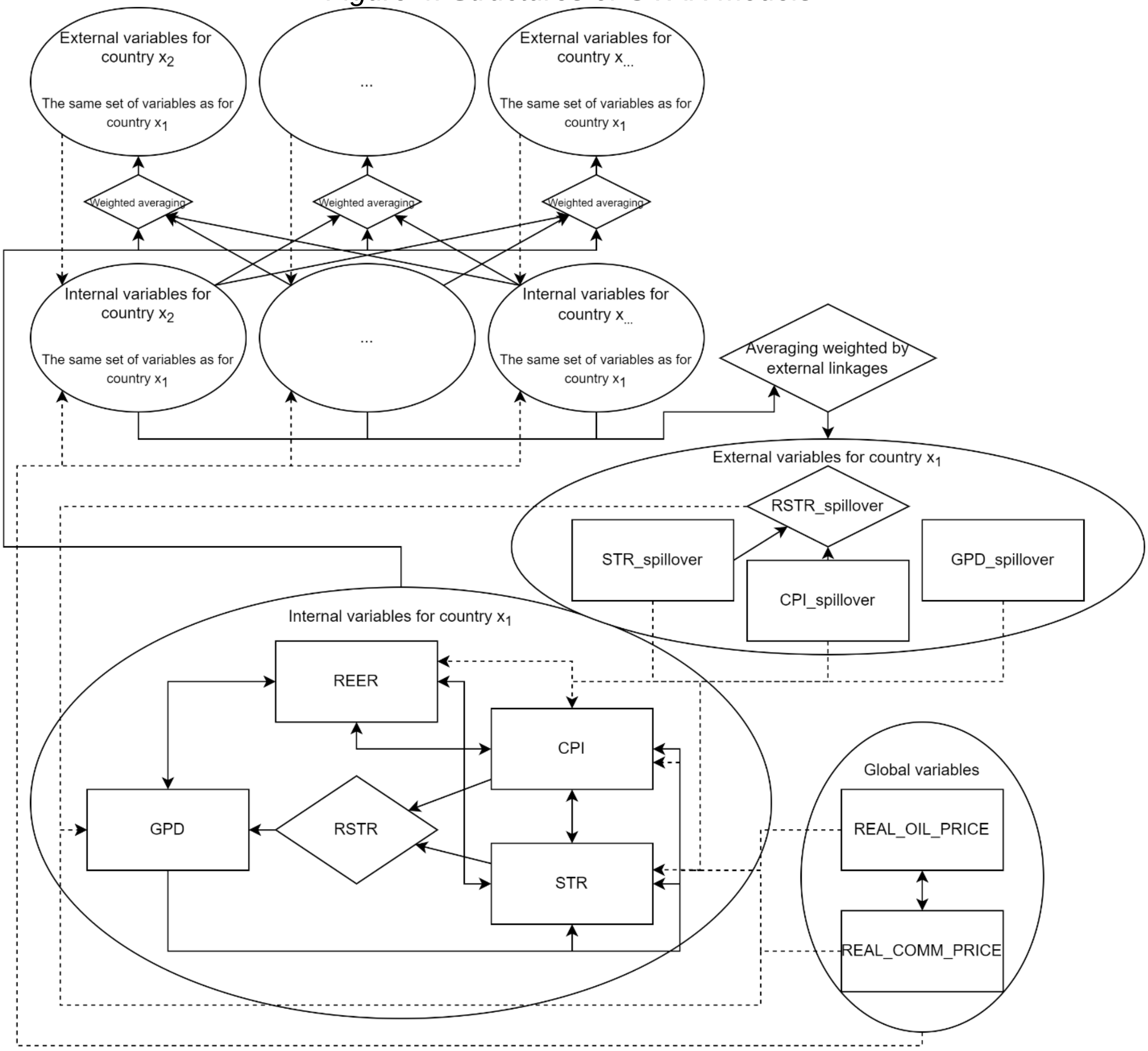
The real interest rate is included in the GDP equation but not in the other equations. The nominal interest rate and inflation are excluded from the GDP equation but included in all the other equations. This structure enables us to obtain correlations which are more correct from the point of view of economic theory: an increase in the real interest rate, all other things being equal, pushes output down. The cumulative effect of the interest rate and inflation on output, regardless of the structural constraints described above, runs counter to theory: an increase in the real rate in this case sends output higher rather than lower.

The external variables are all the weighted average values of the output, inflation and interest rates of the other countries. The weights are the shares of the countries in foreign trade, with the exception of the variable for the real effective exchange rate. The model includes only the internal values of this variable, since its nature already accounts for exchange rate movements in all other countries.

The global factors are included in the models for the individual countries as part of variable $\omega$of equation (1). These factors are modelled as simple first-order autoregression models.

The scheme of the model for the individual countries is presented in Figure 4.

Figure 4. Structures of GVAR models



Source: Compiled by the author.

Note: The arrows denote the direction of influence of the variables. GDP is gross domestic product, CPI is inflation, REER is the real exchange rate, STR is the short-term nominal interest rate, RSTR is the short-term real interest rate, the prefix 'spillover' denotes the external variables, REAL_OIL_PRICE is the real oil price, and REAL_COMM_PRICE is the real price of non-energy resources. Subscript index for x refers to a specific country.

This is a second-order model since it takes data up to the second time lag, except for the variable for the real effective exchange rate. Only the first lag of the model is added, assuming the relatively rapid adaptation of economic agents to changes in the foreign currency market. For example, Zhurakovsky et al. (2021) explore the pass-through of exchange rate shock to Russian inflation and find that most of the pass-through occurs within 3 to 4 months.

To study the dynamic properties of the GVAR through the analysis of the impact of shock on this system, we use orthogonal impulse response functions (OIRF) with Cholesky's recursive identification. The use of OIRF instead of generalised impulse response functions (GIRF), which are frequently used for GVAR, makes it possible to interpret the shocks as structural[6]. which is why they are preferable. In the construction of the OIRF in this work, the first-order variable in the GVAR is always a primary shock variable, such as of China's GDP or the GDP of the EU+.[7] In this case, OIRF shocks are independent of the order of the other variables (Pesaran and Shin, 1998) and are equivalent to estimates according to GIRF (Koop et al., 1996). In contrast to GIRF, OIRF strips out the correlation between shocks and flow variables. This explains the remaining difference between OIRF and GIRF in GVAR (Chudik and Pesaran, 2016). However, it is empirically found that the size of this difference is relatively small (Eickmeier and Ng, 2015). To apply the GVAR identification scheme through OIRF in practice, the condition of a strong exogenous shock variable (ie output in this work) must be met.

Total output in the context of international business cycle analysis is often considered a variable with less exposure to policies and short-term fluctuations. This makes it more exogenous compared to other macroeconomic variables such as inflation, the interest rate or the exchange rate. This logic is based on real-business cycle theory, in which production shocks are major drivers of economic dynamics (Kydland and Prescott, 1982). Interest rates, inflation and exchange rates are more sensitive than output to central bank action, fiscal measures and financial shocks, which makes them more endogenous in the short- and medium-terms. Therefore, in the GVAR model, output shocks are more exogenous than shocks of inflation, the exchange rate and the interest rate.

This paper aims to estimate changes in the degree of synchronisation of the Russian and Chinese business cycles in 2022–2023 compared to the pre-2021 period. In the contemporary literature, such studies are conducted by dividing time series into subsamples, but the limited length of the time series in our case disqualifies this approach.

Alternatively, the estimates may be based on a model whose parameters depend on the exogenous structure of external relations. Assuming that change in the structure of trade is the key structural change in the transformation of Russia's external relations after February 2022, we can exogenously change the structure of trade. This will affect all of the other relationships in the model.

GVAR sets the weight of inter-country relations exogenously. In our case, we use time-varying weights based on trade statistics in value-added terms (see Appendix D for examples of the weights). Their exogenous use creates the risk of incorrect model specification driven by significant changes in economic activity or in trade conditions, which may have a major impact on the weight matrix. However, the structure of international trade by country – the basis for the exogenous weights – is quite stable in the medium term in the absence of major economic crises (Papadopoulos et al., 2023). This stability is also

[6]At the same time, it is technically impossible in GVAR to unambiguously distinguish between supply, demand and monetary policy shocks. This is due to the model's focus on structural relations and inter-country dependencies rather than domestic economic processes. As a result, the shocks identified by GVAR are more complex and include a mix of certain types of economic shocks (Smith, 2013). Although the missing explicit breakdown of shocks is a major downside to theoretical analysis, the GVAR estimates can be useful in empirical analysis. In any case, in real data, there are no *net* shocks of supply, demand or monetary policy (Madeira, 2023; Ivashchenko, 2024). In this context, the GVAR estimates are based on average historical mixes of the shocks adjusted for cross-country interactions. More structural models can divide these shocks into types, but their estimates are usually less data-driven and more difficult to account for cross-country interactions (Smith, 2013).

[7]The 27 countries of the European Union and the UK. See Appendix C for the full names of the abbreviated economic regions.

observed in the Russia data in Figure 1. The average structure of trade over 2016–2021 is slightly different (the average absolute change in the share of each country is 1.1pp) from the structure of 2010–2015, despite the beginning of sanctions pressure in 2015. However, the change in the structure of trade after 2022 is unprecedented (the average absolute change in the share of each country totals 7.6pp). Since the forecasts of such shocks have considerable variance, while the structure of trade in other cases is relatively steady, the exogenous weights attain a practical balance between the complexity of the model and the accuracy of its estimates. At the same time, it is important to understand that such estimates must be periodically updated as fresh data on the structure of trade come in.

The structure of trade in the GVAR influences all the interrelations through the external variable channel. To calculate the IRF, given a GVAR estimated using the entire sample with time-varying weights, we can use the weights for a specific year. This methodology allows the calculation of the IRF with the weights for 2019 and 2023 and the comparison of their paths. Our assumption is that the trade structure of 2023 reflects most of the structural changes in Russia's external relations after February 2022. We further assume that the data for the trade structure of 2019 capture the structure of Russia's external relations before the crisis episodes of 2020–2022. This methodology for calculating IRFs with changing trade weights has been applied in research into the temporal evolution of China's influence on Latin America (Cesa-Bianchi et al., 2011).

In GVAR modelling, the identification of local and global shocks is essential to IRF analysis (Chudik and Pesaran, 2016). Barring the limitations in the scenario for output shock of a major economy, GVAR simulates a kind of a global crisis. A shock that originates in China, for example, spreads widely throughout the world in its early stages. Thereafter, its impact on each country is amplified by significant cascade effects.

The concept of cascade effects is borrowed from papers on the distribution of shocks in financial networks (Elliott et al., 2014). This line of research gained currency in the aftermath of the cascade crises of 2008–2009. In this work, a ‘cascade effect’ for which the final value of, for example the output gap of the EU+, is determined not only on the basis of the shock in its source country but also from inter-country interplay. For example, China's output shock drives EU+ and US output higher, EU+ output growth pushes up US output, US output growth pushes up EU+ output, and so on until a certain state of equilibrium is reached.

In addition to the global crisis, we simulate local output shock in China. This simulation is conducted by excluding the secondary effects of inter-country influence in the model during period t_0, that is, during the period of the shock. This is technically realised by zeroing the coefficients in the inter-country relations matrix in period t_0. The logic of this limitation is simple: we simulate a shock that spreads throughout the world more slowly, and the secondary effects have a lag of one quarter.

Also, it is possible to control which year's weights are used in the different scenarios. By changing the weight year, we can assess the impact of the transformation of the structure of trade on the relationship between Russia and China after 2023.

We obtain a total of three variations of shock simulation. The first is an output shock in a major economy such as China or the EU+, without any limitations on its spread (a global shock). The second is a shock with limitations on the spread of shocks in period t_0 (local shock in China). Finally, the third is China's shock, which in t_0 extends without limitations to

Asia but is limited in its spread to other economies (Asian shock). In this case, we are simulating the shock which is closest to reality. Table 1 presents a description of all the variations of the model we estimate.

Table 1

Variations of shock depending on degree of locality and trade structure in GVAR

Spread of shock	Restrictions (conditional IRF)	Restrictions realised in model	Trade structure (weights)	Designation of simulation
Global shock of China (cascade effects)	Influence of secondary effects of China's shock in period t_0 on all countries	No restrictions	2019	global/2019
			2023	global/2023
Local China shock (lagged impact on all countries)	Influence of secondary effects of China's shock in period t_1 on all countries	The weights of the spillovers of countries other than China are 0 in t_0; from that time onwards, they are without limitations	2019	local/2019
			2023	local/2023
Asian shock of China (lagged impact on all non-Asian economies)	Impact of secondary effects of shock of China in period t_0 on Asian countries, from t_1, on other countries	The weights of the spillovers of non-Asian countries are 0 in t_0, from that time onwards, they are without limitations	2019	asia/2019
			2023	asia/2023

Source: Compiled by the author.

Note: Set of Asian countries in the model: China including Hong Kong and Macao, ASEAN5, India, Japan and South Korea

We use two-way confidence intervals[8] to assess 80% of the statistical significance of the IRF model paths. They are calculated with the block bootstrap algorithm on a moving intersecting window (Kunsch, 1989). The fixed window width of the block is set to be eight quarters assuming the average duration of economic crises and the period of broad recovery (the estimates are based on the dating of business cycles by NBER (2023)). The bootstrap is calculated in 200 iterations for each IRF.

[8]The confidence level of 80% is chosen due to the high volume of noise in global macroeconomic processes. At an increased confidence level of 90%, the multitude of the output responses is no longer statistically significant in the early periods of the impulse response functions.

5. Data

The estimates are based on quarterly data for 2007–2023 on the list of countries and country groupings: the US, Russia, the EU+ (the EU27 and the UK), Japan, South Korea, India, the ASEAN5 (Indonesia, Malaysia, the Philippines, Singapore and Thailand), and China (including Macau and Hong Kong). These countries accounted for 72% of global GDP in purchasing power parity (PPP) in 2022 according to the World Bank. The groupings of the EU and the UK and the ASEAN5 are treated as single entities within the model. Time-varying weights based on GDP in PPP with a one-year lag are used for aggregating the indicators of the European Union with the United Kingdom and the ASEAN5 countries.

The indicators, their sources, and other attributes of the data are presented in Table 2.

Table 2

Statistical indicators in the model

Name	Description	Source	Transformation	Purpose	Notes
Internal variables					
Gross domestic product	gdp..gap_log	International Monetary Fund (IMF), International Financial Statistics (IFS), National Bureau of Statistics of China	SA, deviation of the log of real output growth from trend	Proxy for business cycle fluctuations	Identification of trend using Hodrick–Prescott filter, lambda = 1600
Consumer Price Index	cpi..diff1_log	IMF IFS	SA, log, Δ	Measure of inflation	
Real effective exchange rate	reer..diff1_log	Bank for International Settlements.	SA, log, Δ	Indicator of terms of trade	
Short-term nominal interest rate	str..diff1	Statistics agencies and national central banks (see Appendix B for details)	Δ	Monetary tightness indicator	
Short-term real interest rate	rstr..diff1	rstr..diff1 = str..diff1 – cpi..diff1_log	Δ	Monetary tightness indicator	By ex post formula based on actual historical inflation rates
Global variables					
Real oil price	real_oil_price..diff1_log	IMF Primary Commodity Prices (PCP), U.S. Bureau of Economic Analysis (BEA)	Average Brent, WTI and Dubai Fateh spot prices, log, Δ	Proxy for the state of the global business cycle	USD prices are adjusted using the US GDP deflator (SA)

table 2 continuation

Global variables					
Real price of non-energy commodities (agricultural products and metals)	real_comm_ price..diff1_log	IMF PCP, BEA	log, Δ	Proxy for the state of the global business cycle	USD prices are adjusted using the US GDP deflator (SA)
Data for calculation of weights					
GDP by PPP	gdp_ppp_ weights	World Bank International Comparison Program	-	Weights for aggregation into country groupings	
Physical trade volumes by country	trade_weights	IMF Direction of Trade Statistics (DOTS)	-	Data for nowcasting and temporal disaggregation of the OECD TiVA weights	Includes only product flows
Volumes of value-added trade by country	trade_VA_ weights	OECD TiVA	nowcast of 2021–2023, in terms of quarterly frequency based on trade_ weights for the correspondi ng period	Weights for calculating external spillovers	Export is 'Domestic value-added embodied in foreign final demand', Import is 'Foreign value-added embodied in domestic final demand'. Includes data on trade in services

Source: Compiled by the author.

Note: SA is seasonally adjusted (X13-ARIMA-SEATS), log is in logarithms, Δ is one quarter's growth.

Data on trade volumes in terms of value-added are available up to 2020. To extend the horizon of analysis, we estimate data for the period from 2021 Q1 to 2023 Q4 with the help of nowcasting models and disaggregate them into a quarterly frequency using the intra-annual distributions of volumes by gross trade in commodities of IMF DOTS by quarter.

To obtain estimates of the volumes of value-added trade from 2021 Q1 to 2023 Q4, we build paired linear regressions for the correlation between *value added* and *gross* trade turnover free of constants for every inter-country flow. The estimates of the models are based on annual data from 2003 to 2020. For all the regressions, the coefficient of determination is 0.9 or more. The data on gross trade flows show a strong correlation with movements in value-added trade flows, which is why the resulting models can be used to nowcast them. The trade weights are presented in Appendix D.

Following the Federal Customs Service (FCS) of Russia's decision in April 2022 to suspend the publication of foreign trade statistics by country, from 2022 onwards, gross trade flows to Russia are analysed by means of mirror data from IMF DOTS.

The data on mirror exports are converted from CIF to FOB prices; the import data are converted from FOB to CIF prices based on the average historical difference between the mirror and the official FCS statistics Russia's trade by country in 2012–2021. The IMF DOTS statistics on Russia's mirror trade do not significantly differ from the official FCS data. The average relative deviation in trade turnover module [9] in value terms (mirror statistics) from the official number is 6.8%. Annex E presents a detailed comparison.

To aggregate the external variables, quarter-moving volumes of trade are used as weights, with a 4-quarter window to ensure that all the structural changes are 'smoothly' accounted for.

Before estimation, dummy variables are introduced to the model for the first periods of global and Russian crises. This helps obtain a more correct estimate of the model coefficients when historical crisis shocks cannot be modelled based only on the past values of the main macroeconomic variables. Outlier dates:

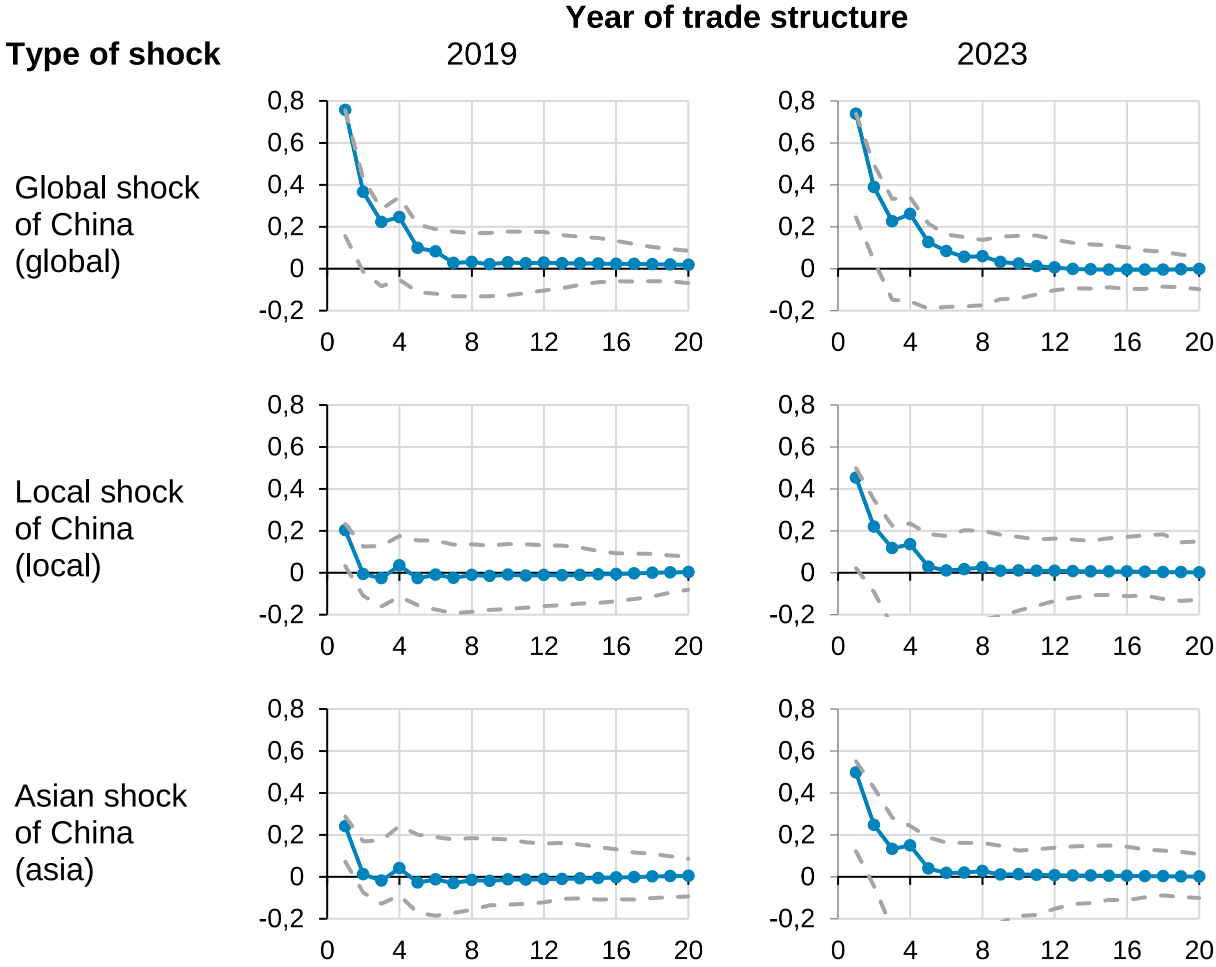
1. 2008 Q4 – 2009 Q1 – the shocks of the 2008 financial crisis;
2. 2015 Q1 – the foreign currency crisis in Russia;
3. 2020 Q1–Q2 – COVID-19 shock;
4. 2022 Q1–Q2 – introduction of sanctions against Russia.

6. Results

The impulse responses of Russia's output gap to a positive output shock of 1pp in China under different scenarios are presented in Figure 5. The values of impulse response functions of output in the different scenarios are presented in Appendix F.

[9]Based on comparisons between the 2012 and 2021 data on average for all periods and for all trade flows with the countries in the GVAR.

Figure 5. Impulse response functions of Russian GDP gap to 1pp GDP gap shock in China

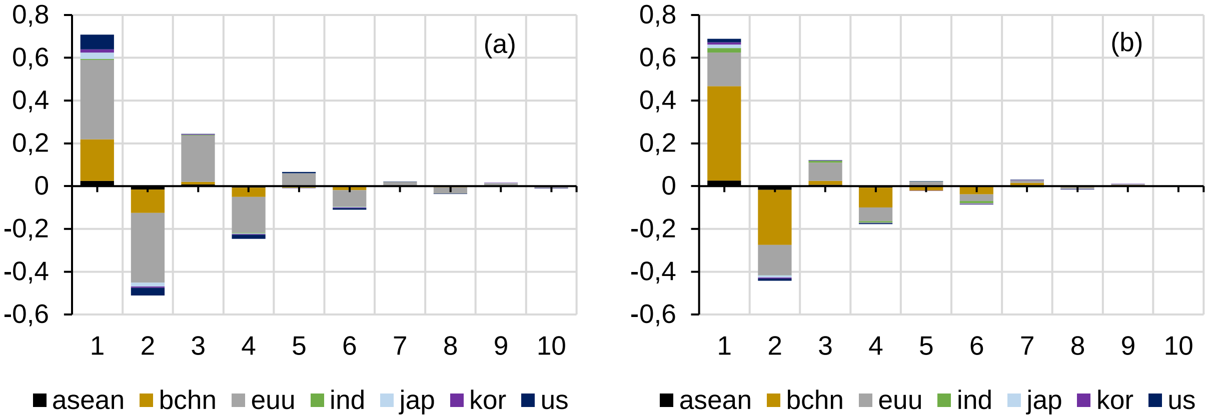


Source: Authors' calculations.

Note: The vertical axis denotes the output gap in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals.

When China's output shock spills over to all countries in the same period, the global shock models show the magnitude of Russia's output response almost regardless of the year of the weights (the global/2019 and global/2023 simulations). An output shock of 1pp in China triggers a change in Russia's output gap by 0.75pp in the first period. A deeper analysis of the model calculations reveals that with the structure of 2019, most of the global shock feeds through to Russia via Europe. With the structure of 2023, it mostly spreads directly from China (Figure 6).

Figure 6. Total contribution of dynamics of external output to Russian output gap by country with simulated global shock of 1pp gap in China's GDP with trade structures of 2019 (a) and 2023 (b)



Source: Authors' calculations.

Note: The vertical axis denotes the contribution to the output gap, in percentage points; the horizontal axis denotes the number of quarters after the shock. The size of the contribution of country x is calculated as the sum of GDP gaps x for all the lags, multiplied by the share x in Russia's trade, multiplied by the corresponding coefficient Λ from equation (1) for Russia's output gap.

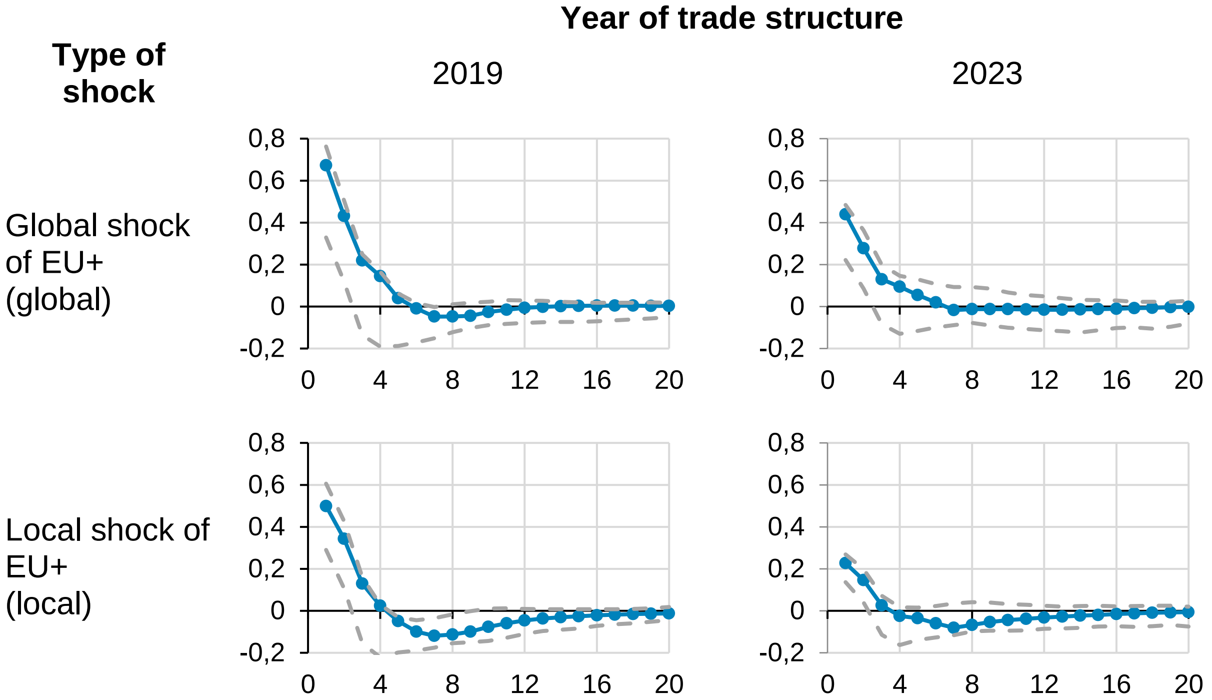
In the case of local output gap shock in China, which has a one-quarter lag before it affects the globe, the response of Russia's output gap depends on the year of the weights in use. In the 2019 trade structure, the response of Russia's output gap to local output gap shock in China in the first period is 0.20pp. (local/2019). In 2023, it increases to 0.45pp on the back of China's stronger influence on Russia through direct trade flows (local/2023 simulation).

The response of Russia's output gap in the first period is 0.24pp in asia/2019, 0.2pp in local/2019, 0.50pp in asia/2023, and 0.45pp in local/2023. The *local* and *asia* scenarios show a negligible difference in terms of their influence on Russia's output, even adjusted for the secondary effects of the flows of shock within Asia. This is indirect evidence of China's central role in Russia's economic relationship with Asia. When all Asian countries are taken into account in *asia/2019* and *asia/2023,* the degree of influence of shock on Russia's output changes only marginally relative to the local-type models.

Of note, shocks of the output gap in the external sector have the greatest impact on Russia's output gap in the first period, followed by a fall in their impact. In the first period, the responses of Russia's output gap in all the scenarios are statistically significantly different from zero. In almost all of the models under study, Russia's output gap returns to its equilibrium within eight quarters after the shock. In the global crisis scenario (*global/2023*), it takes 12 quarters for Russia's output gap to return to zero.

In addition to the sharp increase in China's share, the post-2022 change in the trade structure has come with a comparable drop in the share of the EU+ in Russia's value-added foreign trade turnover. To enable a more in-depth analysis of this change, we consider the response of Russia's output gap to an EU+ output gap shock of 1pp. (Figure 7).

Figure 7. Impulse response functions of Russian output gap to EU+ output gap shock of 1pp



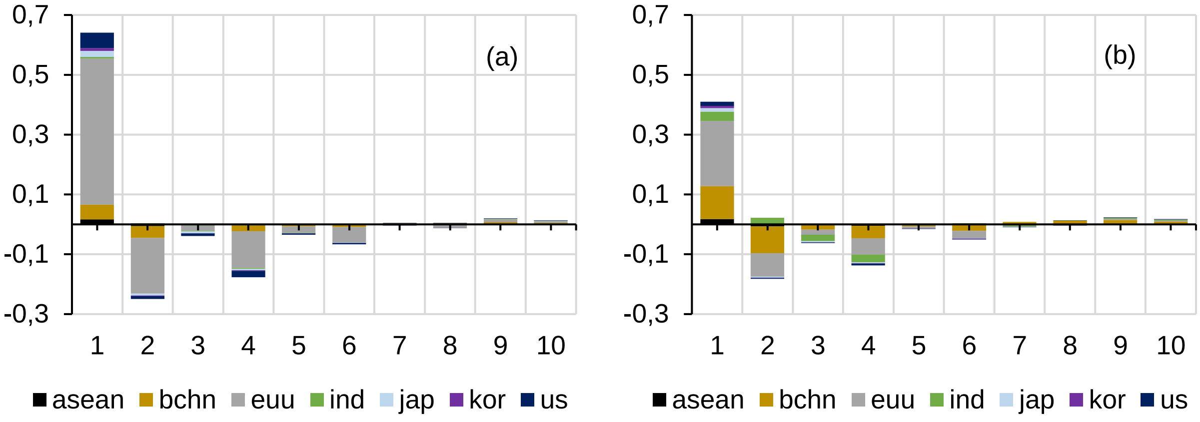
Source: Authors' calculations.

Note: The vertical axis denotes the output gap in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals.

In the 2019 trade structure, the response of Russia's output gap to the local EU+ output gap shock in the first period is 0.5pp. In the 2023 trade structure, this value drops to 0.27pp due to the reduction in the relative volume of direct trade flows between the economies.

In the case of global shock, the response of Russia's output is 0.67pp with the 2019 trade structure and declines to 0.44pp with the 2023 trade structure. Unlike global shock of China, the degree of global shock of the EU+ on Russia's output depends on the structure of trade. This effect is explained by the relatively low historical susceptibility of China's output to shocks of external business cycles. A deeper analysis of the model calculations (Figure 8) makes it clear that the impact of output shock of the EU+ on China is less than that of output shock of China on the EU+. In the 2023/global scenario, shock of the EU+ influences Russia to a greater degree through the direct trade channel rather than through a country like China, with which Russia has significantly expanded its relative trade volumes since 2022.

Figure 8. Total contribution of dynamics of external output to Russia's output gap by country in simulation of global shock of EU+ GDP gap of 1pp with trade structures of 2019 (a) and 2023 (b)

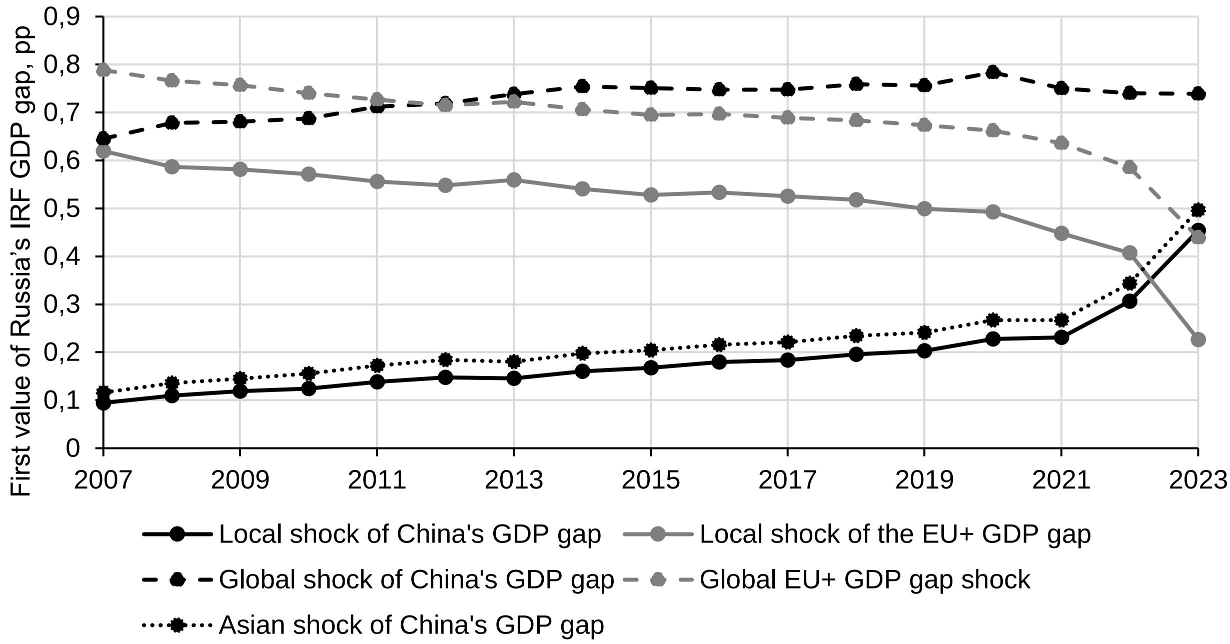


Source: Authors' calculations.

Note: The vertical axis denotes the contribution to the output gap, in percentage points; the horizontal denotes the number of quarters after the shock. The size of the contribution of country x is calculated as the sum of the GDP gaps$x$ for all the lags, multiplied by the share x of Russia's trade, and multiplied by the corresponding coefficient Λ from equation (1) for Russia's output gap

Since the IRF of Russia's output to external partner shocks likely depends on the trade structure year used, this correlation is worth exploring in greater detail (Figure 9).

Figure 9. First-period change in impulse response of Russian GDP gap to local GDP gap shocks of 1pp in China and EU+ depending on year of trade structure

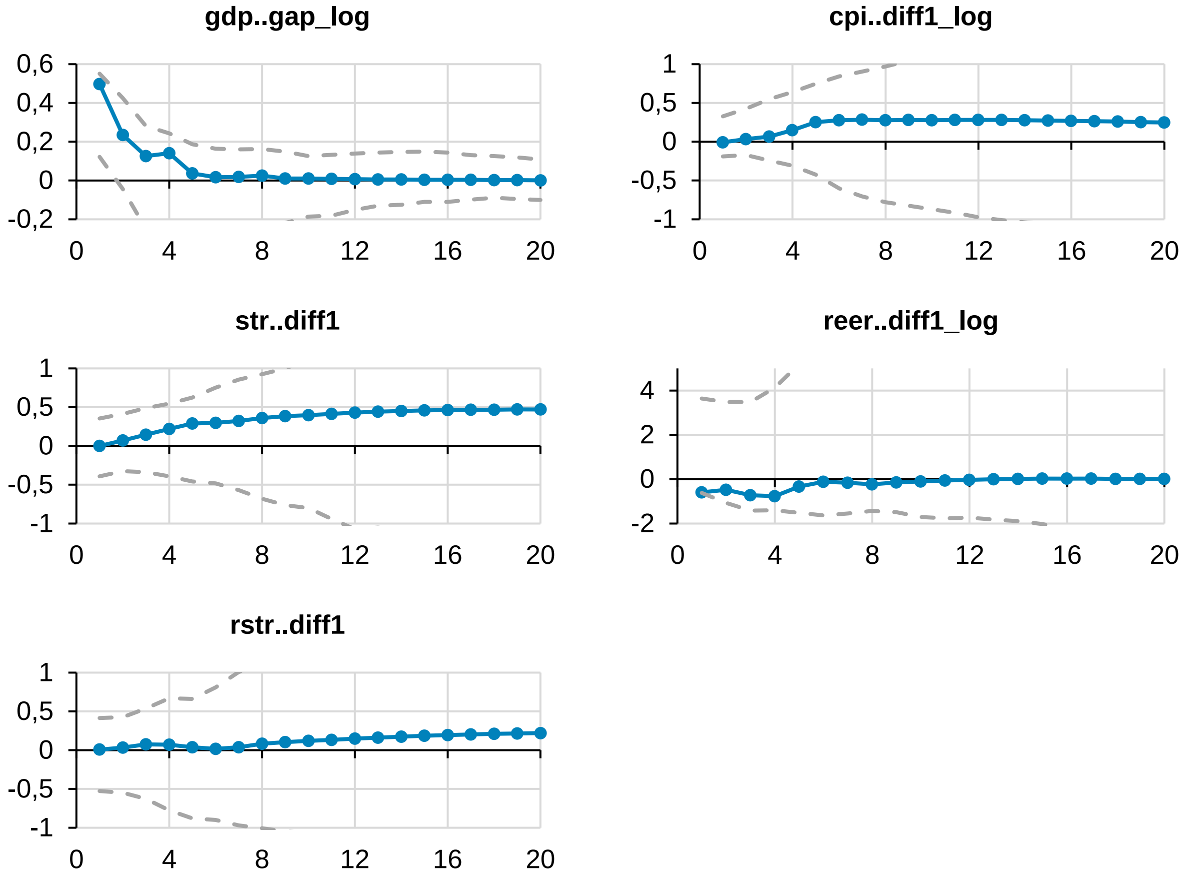


Source: Authors' calculations.

The trend towards a gradual decrease in the impact of shocks from the EU+ and an increase in the impact of China on Russia's output had been observed even before 2022. At the same time, the period of 2022–2023 saw a strengthening of the synchronisation of Russia's business cycle with external partners: synchronisation with China strongly increased, but synchronisation with the EU+ decreased.

To verify that the model is governed by macroeconomic logic, we consider the responses of other Russian macroeconomic variables (real and nominal inflation and exchange rates) to output gap shock of China. Figure 10 shows the changes in the impulse response functions of Russia's macroeconomic variables to a 1pp output gap shock of China, based on the asia/2023 model (the other simulations are presented in Appendix H).

Figure 10. Impulse response functions of Russia's main macroeconomic variables to 1pp output gap shock of China in asia/2023 model



Source: Authors' calculations.

Note: The vertical axis denotes the output gap in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals. The IRF indicators in diff1 and diff1_log are presented as the increases accumulated since the onset of the shock, while gdp..gap_log is presented as gaps

The results show that the models in this paper provide a proper description of the relationships between the main macroeconomic variables. External output gap shock sends Russia's output gap upwards, which may potentially be caused by changing demand for Russian exports. This leads to a rise in total demand in Russia. With supply failing to rapidly adjust to the new, higher level of demand, the output gap in the domestic market rises. Aiming to tame inflation and stabilise the economy, the central bank's inflation targeting regime responds by raising the nominal interest rate. The increase in interest rates helps strengthen the ruble but increases the cost of borrowing, reducing investment and consumer demand. This pushes total demand down to its potential level and thereby drags inflation down.

According to the calculations presented above, shocks originating in China can significantly impact Russia's output dynamics. However, it is not entirely clear how often output shocks attributed to China actually originate there, rather than being global in nature. It is conceivable to imagine an economic system in which unique shocks specific to China do not exist, and all fluctuations in its output gap are fully dependent on the global business cycle. In such a scenario, studying the impact of China's business cycle on Russia would hold little significance, as it would essentially reflect the influence of the global business cycle on Russia.

We can address this question by analyzing the model residuals, interpreting them as shocks. In the context of the model, the deviations (residuals, errors) of the modeled series from the actual values for each country consist of two components:

1. Country-specific (idiosyncratic) shocks.

2. Other unaccounted effects, such as the omission of important factors in the model, improper handling of outliers, an insufficient number of lags, and other issues that arise in constructing any economic model.

In our GVAR model, when estimating the output equation for China and other countries at time t_0, information about the weighted average output of all partner countries at the same time t_0 is used. This structure minimizes the effect of the second component on the size of the residuals due to the actual synchronization of business cycles across countries[10]. This allows us to interpret the model residuals as country-specific shocks independent of the global business cycle dynamics.

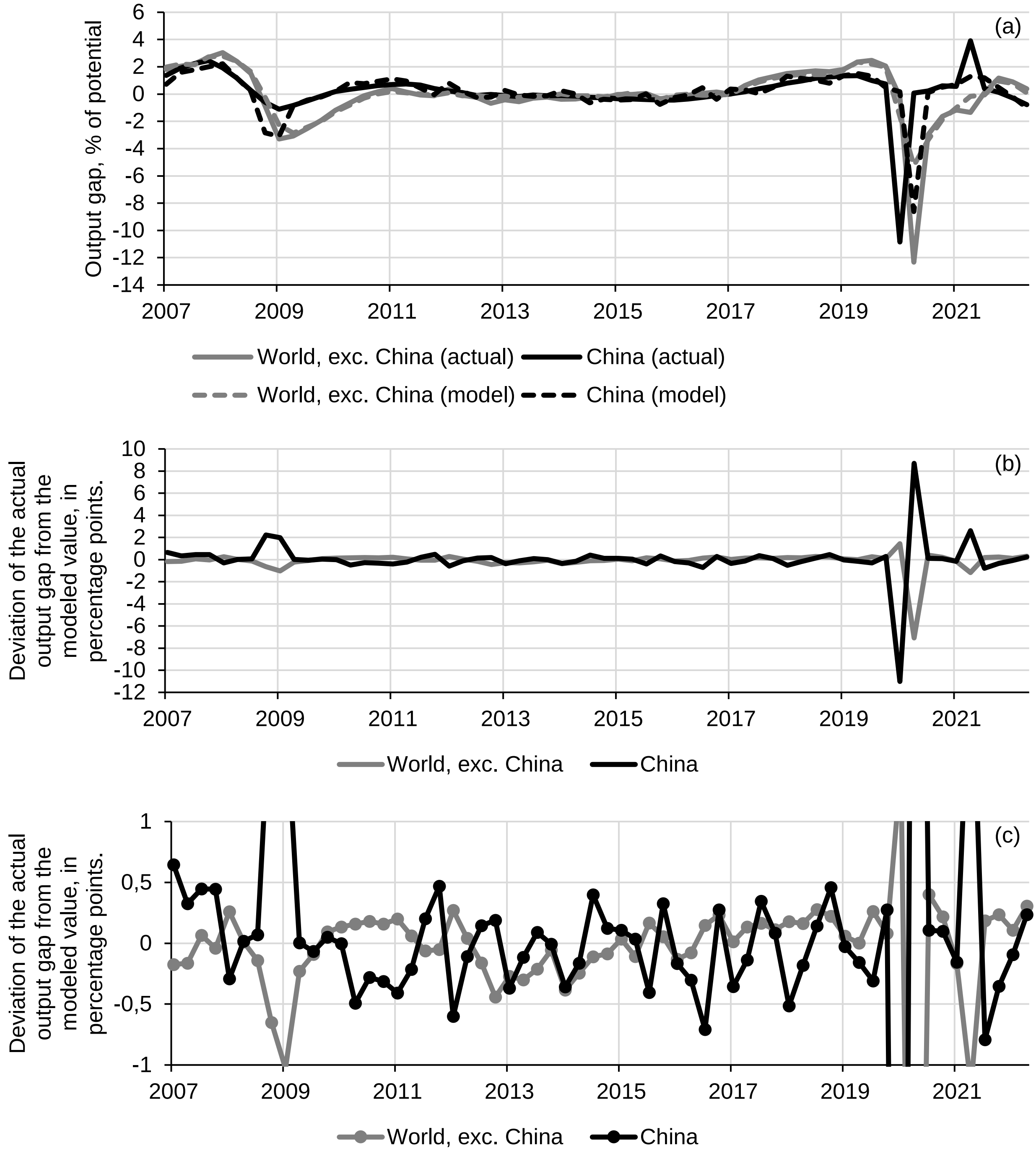
If the modeled values of a country's macroeconomic variables differ significantly from the actual values, it is highly likely that these deviations are caused by idiosyncratic country-specific shocks. To enhance the accuracy of identifying such shocks, we can also examine the residuals of the model for global economic indicators excluding those of the country of interest—in this case, China. If we observe shocks in China that are not mirrored in the rest of the world[11], it is likely that these are idiosyncratic shocks specific to China.

Below, we present the actual and modeled series for China's output gap and the rest of the world, as well as the model residuals (Figure 11).

[10] Presence of synchronization helps accurately model the variables at t_0 based on the variables of partner countries also at t_0.

[11] Proxy variables based on the remaining countries included in the model.

Figure 11. Actual and modeled series for the output gap of China and the rest of the world (a), model residuals (b), and a zoomed-in view of the residuals graph (c).



Source: Authors' calculations.

Note: The rest of the world is represented as a proxy based on all other countries included in the model, weighted by time-varying GDP PPP weights. If dummy variables are applied to a data point in the series, the residuals are represented by the coefficient values of the corresponding dummy variables.

Let us mark some of China's potential idiosyncratic shocks based on Figure 11:

1 COVID-19 shock in Q1 2020 (-11.0 percentage points) and the subsequent rapid economic recovery in Q2 2020 (+8.7 percentage points).

2 Shock in Q2 2021 (+2.6 percentage points), linked to the economic recovery

after COVID-19 and the implementation of government economic stimulus policies.

3 Shock in Q3 2021 (-0.8 percentage points), associated with the onset of liquidity problems for the developer Evergrande and the broader crisis in China's construction sector.

4 The "shocks" in Q4 2007 and Q1 2008 are difficult to classify as shocks in the usual sense. The global financial crisis of 2007–2008 had only a limited impact on China's output gap during this period, likely due to China's relatively low integration into international financial markets at the time.

It is potentially possible to identify other idiosyncratic shocks in China; however, shocks with small absolute values are significantly harder to distinguish from statistical noise. It can be concluded that idiosyncratic shocks in China do exist, but they relatively rarely reach large magnitudes outside the fluctuations of the global business cycle.

To conclude on the results of the structural analysis of the GVAR, we find that the degree of synchronisation of the business cycles of Russia and China increased after 2022. This translates into a significantly increased average degree of transmission of output gap shock of China to Russia following the change in the structure of trade between 2019 and 2023. At the same time, there has been a decline in the degree of synchronisation between Russian and EU+ output.

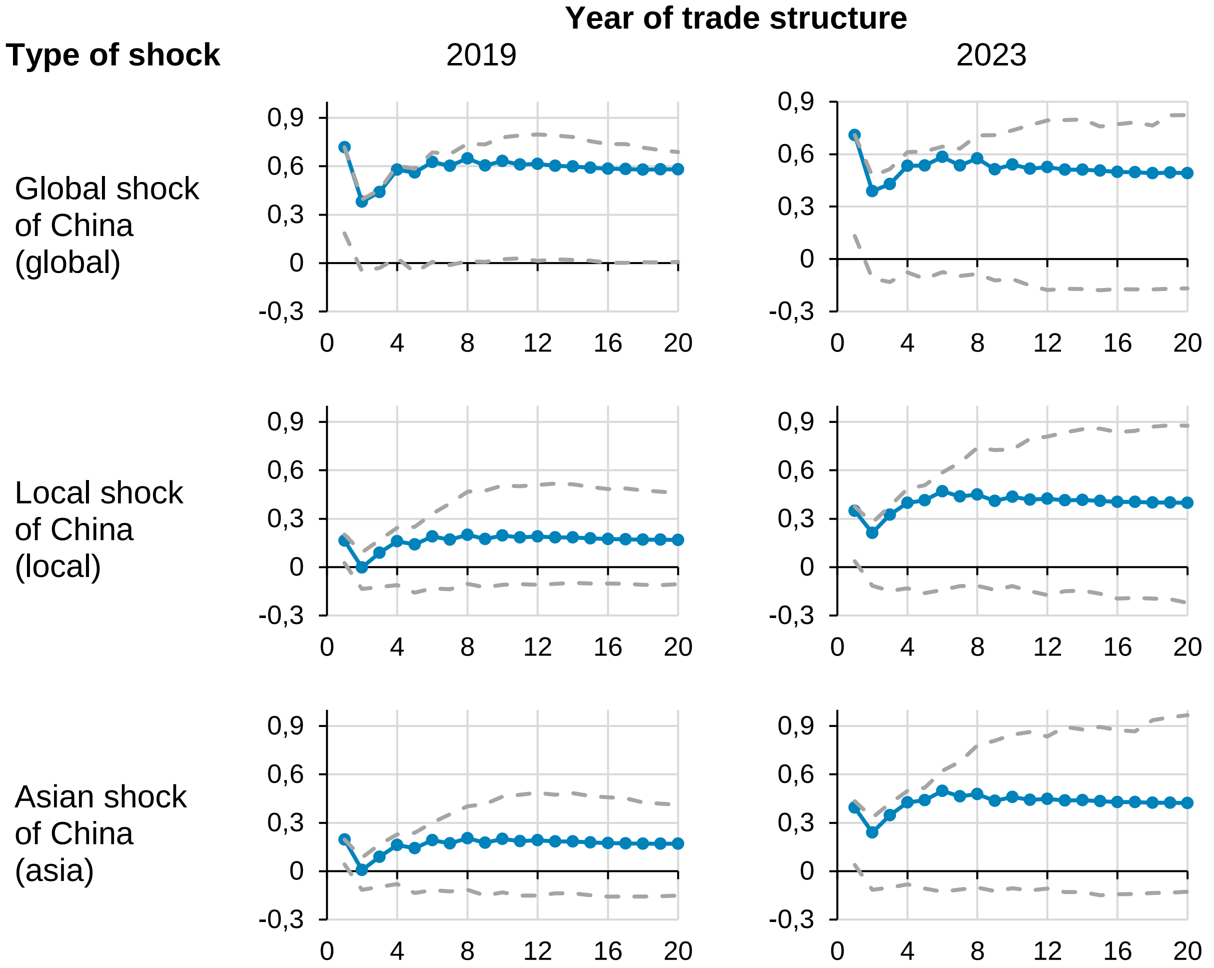
7. Robustness check

7.1 GVAR estimates in terms of output growth

To check robustness, we build a GVAR model for growth in output.

Figure 12 shows the dynamics of the impulse responses of Russia's output growth to a 1pp positive output shock of China by scenario.

Figure 12. Impulse response functions of Russia's output to 1pp output growth shock of China



Source: Authors' calculations.

Note: The vertical axis denotes the accumulated growth of output after the shock in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals.

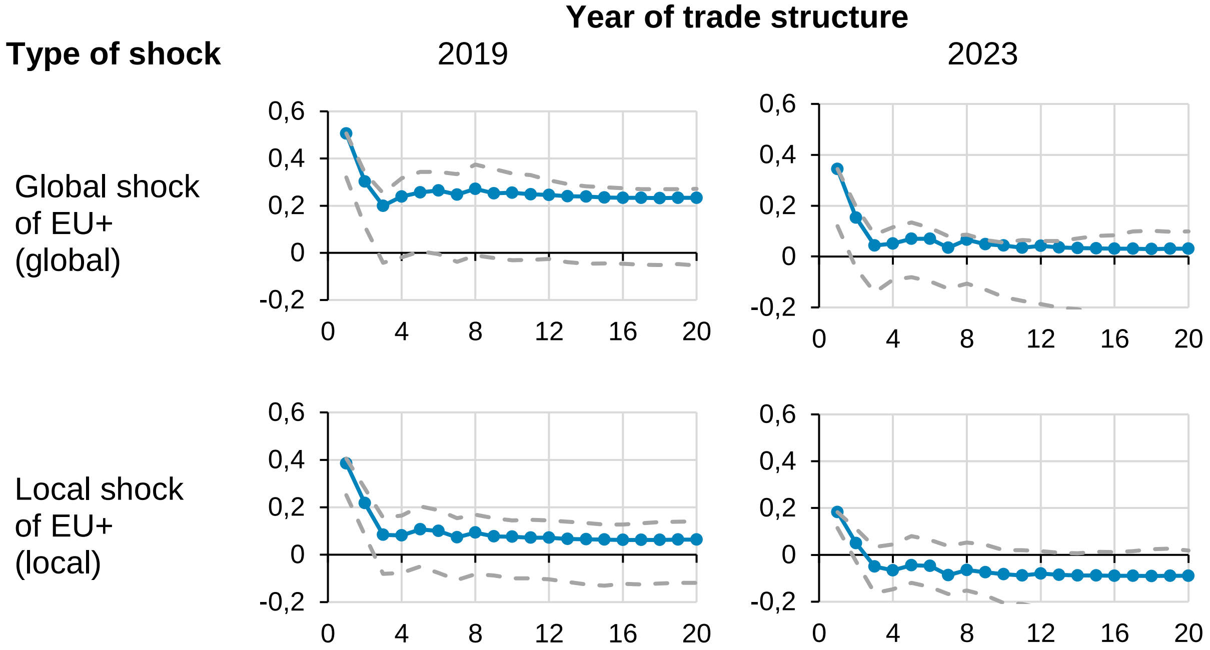
In the 2019 trade structure, the response of Russia's output growth to output growth shock of China in the first period is 0.16pp. In 2023, it rises to 0.35pp.

The analysis of global shock shows that the magnitude of impact of shock of China on Russia in this cases essentially does not depend on the year of the weights: It is 0.71pp in 2019 compared with 0.7pp in 2023. The shock of 0.7pp feeds through to Russia in the first period, which is consistent with the model of the real output gap described above. The shock stabilises over time. The system reaches equilibrium in three years, which is consistent with the model of the real output gap above.

Similar to the model for the gap, and consistent with the 80% bilateral confidence intervals in the first period, the responses of Russia's real output in all scenarios are statistically significantly different from zero.

We also consider an EU+ output shock of 1pp. Figure 13 presents the impulse responses of Russia's output growth to this output shock.

Figure 13. Impulse response functions of Russia's output growth to output growth shock of EU+ of 1pp



Source: Authors' calculations.

Note: The vertical axis denotes the post-shock increase in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals.

In the 2019 trade structure, the response of Russia's output growth to local shock of EU+ output growth is 0.4pp in the first period. With the 2023 trade structure, this value decreases to 0.18pp. As follows from the analysis of global shock, the pass-through of a change in EU+ output into Russia's output is 0.5pp with the 2019 trade structure and 0.34pp with the 2023 structure. The comparison of the shocks reveals differing trends for China and the EU+ over four years, but the results are consistent with the results of the output gap model. China's influence is intensifying, in contrast to the EU+.

To conclude on the comparison of the models in real output gap and in pace of growth, it is possible to say that the results are similar. Both the recovery period and the long-term changes in the values in the two models are similar.

7.2 Validation of GVAR model

A procedure for validating the model is necessary to ensure that the GVAR impulse response functions meet quality requirements. Validation is often understood as a comparison of model forecasts based on real data to establish whether the model is fit for purpose (McKinion and Baker, 1982; Mayer and Butler, 1992). It is critical to validate the model to identify the domain-specific models that have greater generalisation capabilities and even suggest better interpretability (Ho et al, 2020).

Measuring the forecast errors of the model is one method to assess the validity of the model (Mayer, Butler, 1992). The lower the error, the more valid the model. In practice, comparisons are made between out-of-sample forecast errors and the errors of benchmark models (Fildes and Kourentzes, 2011). A similar approach is used to validate structural macroeconomic models (Smets and Wouters, 2007).

We compare the forecast error of the GVAR model with the analogous error of the benchmark models specified in the table below. The RMSE metric is used to compare the models in terms of level of error. The calculations are then normalised as the ratio of model error to the error of random walk models. This ratio enables the simple comparison of the relative predictive power of the models.

Table 3

Benchmark models

Name of model	Estimation methodology
GVAR	Described in the methodology and data sections
Random walk	Modelling all the macroeconomic variables as random-walk processes marked by drift
AR(1)	Modelling all the macroeconomic variables as first-order autoregressive processes with an exogenous variable in the form of a dummy for the period (accounting for outliers)
ARIMA	Modelling all the macroeconomic variables with ARIMA with an exogenous variable in the form of a dummy for the period (accounting for outliers). The parameters of the model are selected with the auto.arima command.
Dynamic factor model (DFM)	Modelling all the macroeconomic variables simultaneously with a dynamic factor model. The outliers are accounted for by averaging two neighbouring periods. We select parameters that minimise the information criterion. The AIC criterion is used to select the number of lags, and IC1 is used to select the number of factors (Bai and Ng, 2002).

Source: Compiled by the authors.

The error is calculated using the *out of sample rolling-origin* method. It is governed by the following algorithm:

1) The forecast horizon and the minimum size of the training sample are selected.

2) The model is estimated on the training sample.

3) The model makes a forecast for a certain future horizon.

4) The size of the training sample increases by one observation. For the time series, the next period is included in the training sample.

5) Steps 2–4 are repeated for as long as the observations outside of the training sample are sufficient;

6) The average forecast error is calculated for each horizon.

This procedure allows the reduction of the number of forecasts in the error calculation as well as the reduction of the sensitivity of the error to the extreme obtained in the training sample (Tashman, 2000).

The crisis episodes are viewed as outliers and accounted for with the help of a dummy variable. The outliers are used to train the GVAR, AR(1) and ARIMA models. The outliers include: 2008 Q4 2009 Q1 2015 Q1

The 2020–2023 period is removed from the test sample because the change in the outliers in this period significantly changes the error. Most likely, this is the result of the several waves of the coronavirus epidemic, which considerably complicates the temporary structure of the main economic interdependencies. Thus, the early training of the models uses the 2005 to 2016 sample. Thereafter, consistent with the procedure above, the training sample is gradually expanded to 2019.

The results of the comparison of the predictive power of the output models are presented in Table 4.

We should mention that the GVAR forecasts are not much inferior to the other models. Up to the fourth forecast horizon, GVAR proves to be at the level of AR(1), ARIMA and DFM. This result can be considered acceptable, and the model can be considered appropriate. The most significant impulse responses also emerge in the first two quarters, suggesting that the greater error on the fourth forecast horizon is not critical.

Table 4

Out-of-sample RMSEs of output gap forecast by model, economy and forecast horizon

as ratio to corresponding error of random-walk model

Model	RW	GVAR	DFM	AR(1)	ARIMA
Forecast horizon: 1					
ASEAN	1.00	1.18	2.45	1.64	1.72
China	1.00	1.35	0.62	1.12	0.61
EU+	1.00	0.88	1.33	1.27	0.94
India	1.00	1.04	1.62	1.25	1.47
Japan	1.00	0.96	0.95	0.95	0.99
Korea	1.00	1.14	0.88	1.00	0.94
Russia	1.00	1.63	2.78	1.01	1.48
US	1.00	1.18	1.27	1.00	1.05
Average of all countries	1.00	1.17	1.49	1.15	1.15

table 3 continuation

Forecast horizon: 2					
ASEAN	1.00	1.89	1.55	1.72	1.78
China	1.00	1.45	0.85	1.14	0.70
EU+	1.00	1.12	1.05	1.33	1.40
India	1.00	1.20	1.54	1.48	1.81
Japan	1.00	1.15	0.97	0.98	1.10
Korea	1.00	1.14	0.82	1.09	1.06
Russia	1.00	1.19	1.91	1.08	1.38
US	1.00	0.74	0.66	0.96	1.05
Average of all countries	1.00	1.24	1.17	1.22	1.28
Forecast horizon: 3					
ASEAN	1.00	2.79	1.32	1.68	1.74
China	1.00	1.73	1.18	1.21	0.96
EU+	1.00	1.60	1.09	1.46	1.93
India	1.00	2.21	1.72	1.64	2.06
Japan	1.00	1.54	0.91	1.01	1.26
Korea	1.00	0.85	0.60	1.09	1.06
Russia	1.00	1.23	1.47	1.06	1.07
US	1.00	0.64	0.55	0.93	1.03
Average of all countries	1.00	1.57	1.11	1.26	1.39
Forecast horizon: 4					
ASEAN	1.00	3.83	1.39	1.61	1.67
China	1.00	2.76	1.40	1.25	1.21
EU+	1.00	2.88	1.63	1.62	2.48
India	1.00	3.77	1.77	1.61	2.07
Japan	1.00	2.50	0.91	1.05	1.40
Korea	1.00	3.70	0.94	1.85	1.87
Russia	1.00	2.78	0.66	1.00	1.03
US	1.00	1.58	0.52	0.94	1.10
Average of all countries	1.00	2.97	1.15	1.37	1.60

Source: Compiled by the authors.

8. Discussion

The degree of synchronisation of the business cycles of Russia and China was up significantly in 2023 compared to 2019. This rapid change in Russia's external relations was mainly caused by the full-scale western sanctions, which forced Russian businesses to shift their foreign trade activities to China, India, Turkey and other countries.

However, viewed from a longer-term perspective, these changes have occurred within a broader trend of the decoupling of developing countries from advanced economies (Kose and Prasad, 2011). Although the reasons may vary significantly from country to country, this trend is overall spurred by more rapid growth in emerging markets and especially China relative to developed markets (Kose and Prasad, 2011).

The findings of this study are broadly consistent with the assessments of a similar study based on GVAR for Russia (Zubarev and Kirillova, 2023). The authors analyse the implications a 1pp negative shock of China's GDP growth. In this scenario, the decrease in the output of China triggers a decline in Russia's output of 0.16pp in the early post-shock period. In our GVAR model in terms of output growth with the 2019 trade weights, the absolute effect of local shock of China is exactly the same (0.16pp). Long term, China's shock in the Zubarev and Kirillova model pushes Russia's output down by about 0.28pp. In our model of the same configuration, this effect is 0.17pp. At the same time, these two papers cannot really be compared to one another in practice, as Zubarev and Kirillova (2023) do not mention how they take into account outliers and the trade structures of different years.

Since this study distinguishes between local and global shocks, the question arises: what should be used in practical models? The final choice depends on the expert assumptions of the researcher about the nature of the shock—whether it will rapidly propagate across the world (global) or remain primarily localized within a single country (local).

History provides examples of both types of shocks. The concept of a global shock is closely tied to cascading effects in economic networks (Elliott et al., 2014). For instance, the global financial crisis of 2008 was a global shock. In contrast, the liquidity crisis in China's construction sector, which began in 2021 with the liquidity crisis of the Evergrande Company, has so far remained largely localized within China. While it has the potential to spread across the global system, accurately predicting such developments is currently impossible due to the complexity of economic networks.

It is important to note that this work treats value-added trade as a proxy variable for the structure of all the external relations that must be accounted for. This assumption is a simplification of reality. Follow-up studies should also consider changes in international financial and capital flows to obtain a full economic picture. It is also necessary to take into account the multiple known problems of the quantitative analysis of these data, such as the problem of offshore accounting in foreign investment statistics, among others (Casella et al., 2023).

The dynamics of how China's output affects Russia's output over time (Figure 9) strongly depend on the dynamics of trade structure (Figure 2), as determined by the very structure of the GVAR model used. The assumption that the dynamics of synchronization can be accurately measured through the dynamics of trade structure is central here. It is also assumed that trade in 2019 and 2023 reflects the real structure of external linkages before and after 2022. In the future, with the availability of updated and more relevant datasets, it will be necessary to test the robustness of these results, for example, through regression models on subsamples before and after 2022.

9. Conclusion

The hypothesis of increased synchronisation of the business cycles of China and Russia in the aftermath of 2022 is not rejected. Simulating positive local output gap shock of China of 1pp with instant spillovers to and between Asian countries, the shock increases

Russia's output gap in the first period by 0.25pp with the 2019 trade structure and by 0.5pp with the 2023 trade structure. In the logic of the GVAR model, this change is a direct consequence of the transformation occurring in Russia's foreign trade structure in terms of partner countries.

If synchronisation is measured via the simulation of global shocks, the impacts of shock of China on Russia with the trade structures of 2019 and 2023 are almost the same (0.76pp in 2019 and 0.74pp in 2023). This is explained by the sizeable influence of secondary effects, which lead to a drastic change in output in all countries. This is the case for the simulation of a global crisis in which the origin of the initial shock is not really relevant.

The totality of these findings emphasise the growing importance of China for Russia as well as the need for a review of macroeconomic analysis models in line with the structural changes in the aftermath of February 2022.

Further potential avenues of research might include:

– Consideration of the impact of changes in the structure of external financial and investment relations on business cycle synchronisation;

– Consideration of the changes after February 2022 based on the analysis of subsamples to account for all the structural changes.

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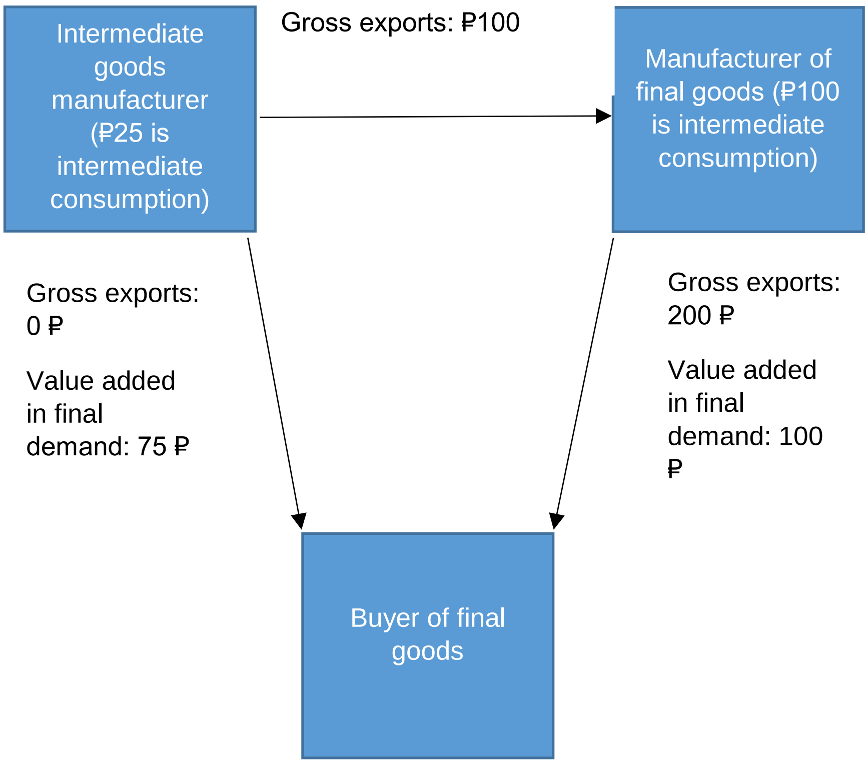
Appendix A. Accounting of trade in value-added terms

The trade channel is one of the best-studied channels of business cycle synchronisation. The closer the trade relationship between two countries, the more synchronised their business cycles are (Frankel and Rose, 1998; Shin and Wang, 2004; Duval et al. 2016; Lee et al., 2022). Data on gross trade flows are commonly used in practice to model inter-country trade relations (Frankel and Rose, 1998; Calderon et al., 2003; Shin and Wang, 2004; Lee et al., 2022). However, Duval et al. (2016) make a case for value-added trade as the preferred method to account for the trade channel in analysing business cycle synchronisation.

Gross trade measures are considered insufficient to fully understand current trends in trade, especially given the cross-country distribution of supply chains. These measures overestimate the importance of final goods exporting countries and hence lead to multiple trade records that distort the true level of inter-country trade. These problems are solved by measuring trade in terms of value-added, in which the value of exports and final demand are decomposed into the contributions of suppliers located higher in the value-added chain (Johnson, 2014). The trade between the US and Mexico is an example of a significant difference between gross trade and value-added trade. Castro and Cardozo-Medeiros (2020) show that the balance of US trade with Mexico in manufacturing changes its sign depending on whether the indicator is gross trade or value-added trade. Such differences may lead to incorrect conclusions and undermine subsequent policies. Figure A1 presents an example of how exports are accounted for in terms of gross and value-added trade.

Figure A1. Commodity value in gross and value-added trade statistics



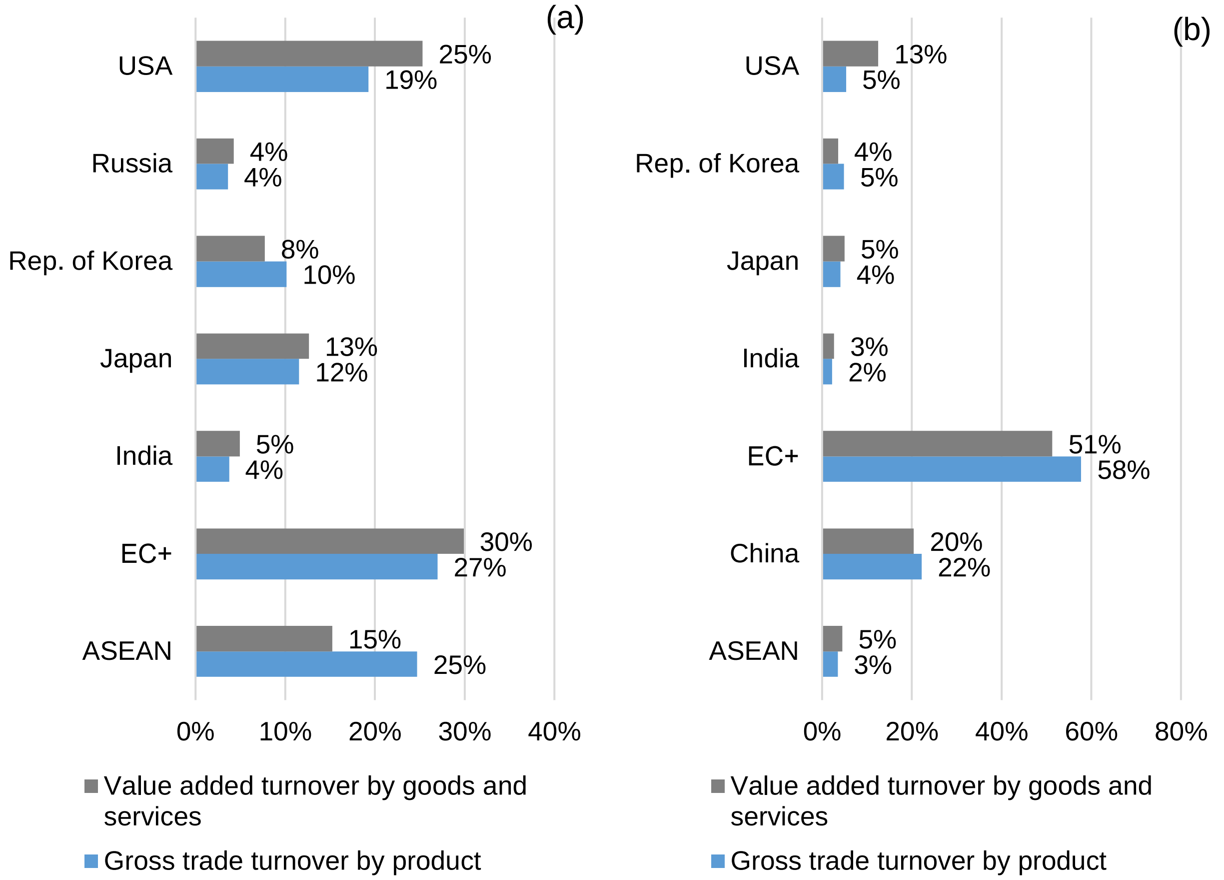
Source: Compiled by the author.

Data on value-added trade are sourced from the well-known OECD TiVA database (OECD, 2023). In addition to Duval et al. (2016), who show the importance of accounting specifically for value-added flows in trade to measure business cycle synchronisation, these data have been used by many other authors (Iossifov, 2014; Kowalski et al., 2015; Miroudot and Cadestin, 2017). 'Foreign value-added embodied in domestic final demand' and 'Domestic value-added embodied in foreign final demand' are used as indicators for trade in terms of value-added. These indicators may be called 'value-added imports' and 'value-added exports respectively.

The OECD TiVA database includes annual data up to 2020. To improve model quality and extend the horizon of analysis, the TiVA data are expanded through 2023 using nowcasting models and disaggregated into quarterly frequency with the help of intra-annual distributions of volumes by gross trade across the quarters.

Figure A2 shows a comparison of the country-by-country trade structures for data on gross trade flows based on IMF DOTS and value-added trade based on OECD TiVA. Importantly, IMF DOTS contains data only on gross trade in goods, while OECD TiVA also includes data on trade in services.

Figure A2. Foreign trade structures of China including Hong Kong and Macao (a) and of Russia (b) in 2019, foreign trade statistics



Source: IMF DOTS, OECD TiVA, authors' calculations.

Appendix B. Sources of data on short-term nominal interest rates in money market

Table B1

Sources of data on short-term nominal money market rates

Country	Name	Source
UK	Interest rates: Immediate rates	OECD short-term interest rates
Euro area as proxy for entire EU27 grouping	Interest rates: Immediate rates	OECD short-term interest rates
India	Interbank rate	Reserve Bank of India
Indonesia	Interest rates: Immediate rates	OECD short-term interest rates
People's Republic of China	CHIBOR before 2006 SHIBOR since 2006	Federal Reserve Bank of Atlanta China Foreign Exchange Trade System
Malaysia	The calculation of the ASEAN5 rate excludes Malaysia due to the lack of sufficiently long time series	
Russia	MIACR 1 day	Bank of Russia
Singapore	Interbank rate	Development Bank of Singapore
United States	Interest rates: Immediate rates	OECD short-term interest rates
Thailand	TENOR	Bank of Thailand
Philippines	IBCLR	Bangko Sentral ng Pilipinas
South Korea	Interest rates: Immediate rates	OECD short-term interest rates
Japan	Interest rates: Immediate rates	OECD short-term interest rates

Source: Compiled by the author.

Note: The overnight rate is implied unless otherwise indicated

Appendix C. Country abbreviations and economic groupings

Table C1

Country abbreviations and economic groupings

Abbreviation of economy	Name of economy	Composition of block
ASEAN	Association of Southeast Asian Nations	BRN, IDN, KHM, LAO, MYS, MMR, PHL, SGP, THA, VNM
ASEAN5	Association of Southeast Asian Nations (five founding countries)	IDN, MYS, THA, PHL, SGP
ASIA OECD TiVA	Asian countries in OECD TiVA statistics	AUS, BGD, BRN, KHM, CHN, HKG, MAC, IND, IDN, JPN, LAO, MYS, MMR, NZL, PAK, PHL, SPG, THA, VNM, KOR
BCHN, China	China includes Hong Kong and Macao	CHN, HKG, MAC
EU+, euu	27 European Union countries and the UK. (Norway and Switzerland are also included in the foreign trade calculations but not in the GVAR)	AUT, BEL, CZE, DNK, EST, FIN, FRA, DEU, GRC, HUN, IRL, ITA, LVA, LTU, LUX, NLD, POL, PRT, SVK, SVN, ESP, SWE, BGR, CYP, HRV, MLT, ROU, UK. (CHE and NOR are included in the foreign trade calculations but not in the GVAR)
EU27	27 European Union countries	AUT, BEL, CZE, DNK, EST, FIN, FRA, DEU, GRC, HUN, IRL, ITA, LVA, LTU, LUX, NLD, POL, PRT, SVK, SVN, ESP, SWE, BGR, CYP, HRV, MLT, ROU
AUS	Australia	
AUT	Austria	
BGD	Bangladesh	
BEL	Belgium	
BGR	Bulgaria	
BRN	Brunei	
UK	United Kingdom	
HUN	Hungary	
VNM	Vietnam	
DEU	Germany	
HKG	Hong Kong	
GRC	Greece	
DNK	Denmark	
IND	India	
IDN	Indonesia	
IRL	Ireland	
ESP	Spain	
ITA	Italy	
KHM	Cambodia	
CYP	Cyprus	
CHN	People's Republic of China	
LAO	Laos	
LVA	Latvia	
LTU	Lithuania	
LUX	Luxembourg	
MAC	Macau	
MYS	Malaysia	

table C1 continuation

MLT	Malta	
MMR	Myanmar	
NLD	Netherlands	
NOR	Norway	
NZL	New Zealand	
POL	Poland	
PRT	Portugal	
KOR	Republic of Korea	
RUS	Russia	
ROU	Romania	
SGP	Singapore	
SVK	Slovakia	
SVN	Slovenia	
US, USA	United States of America	
THA	Thailand	
TUR	Turkey	
PHL	Philippines	
FIN	Finland	
FRA	France	
HRV	Croatia	
CZE	Czech Republic	
SWE	Sweden	
CHE	Switzerland	
EST	Estonia	
JPN	Japan	

Sources: Compiled by the author.

Appendix D: Time-varying weights used in GVAR for aggregation of external variables as of particular dates based on value-added trade

Table D1 presents the moving weights used in the GVAR for the aggregation of external variables as of particular dates, based on value-added trade.

Table D1.

Moving weights used in GVAR for aggregation of external variables for individual periods based on value-added trade,

percentage of total

Country	Period	asean5	bchn	eu+	ind	jap	kor	rus	us
asean5	1–4Q2007	0.0	9.4	8.0	11.5	12.7	9.5	2.7	7.7
bchn	1–4Q2007	16.3	0.0	15.0	12.5	18.9	20.1	9.4	16.7
eu+	1–4Q2007	27.9	30.3	0.0	38.6	26.8	25.9	63.7	49.6
ind	1–4Q2007	5.3	3.3	5.1	0.0	2.2	2.8	1.7	3.6
jap	1–4Q2007	18.7	16.0	11.3	7.0	0.0	15.8	5.9	14.3
kor	1–4Q2007	6.3	7.7	4.9	4.0	7.1	0.0	3.1	5.0
rus	1–4Q2007	1.8	3.7	12.4	2.5	2.7	3.1	0.0	3.0
us	1–4Q2007	23.6	29.5	43.3	24.0	29.6	22.9	13.5	0.0
asean5	1-4Q2012	0.0	12.5	8.7	13.4	16.8	11.7	4.2	8.5
bchn	1–4Q2012	23.9	0.0	21.1	16.9	25.6	27.0	14.8	22.9
eu+	1–4Q2012	22.2	28.3	0.0	31.1	20.2	19.8	56.4	42.3
ind	1–4Q2012	6.6	4.3	6.0	0.0	2.9	4.2	2.4	5.3
jap	1–4Q2012	19.1	15.3	9.0	6.8	0.0	13.2	6.4	12.5
kor	1–4Q2012	6.5	7.9	4.3	4.7	6.5	0.0	3.4	5.0
rus	1–4Q2012	2.6	4.9	13.9	3.1	3.5	3.9	0.0	3.5
us	1–4Q2012	19.0	26.8	37.0	24.0	24.5	20.3	12.5	0.0
asean5	1–4Q2014	0.0	12.7	8.6	13.8	16.1	11.4	4.2	8.3
bchn	1–4Q2014	27.0	0.0	24.4	19.7	27.5	29.3	16.1	26.1
eu+	1–4Q2014	22.3	29.5	0.0	29.3	20.8	20.0	55.6	41.4
ind	1–4Q2014	6.5	4.4	5.4	0.0	2.7	3.8	2.1	5.1
jap	1–4Q2014	16.5	13.3	8.3	5.8	0.0	10.6	5.6	10.8
kor	1–4Q2014	6.4	7.7	4.4	4.5	5.8	0.0	3.6	5.2
rus	1–4Q2014	2.4	4.3	12.2	2.5	3.1	3.6	0.0	3.2
us	1–4Q2014	19.0	28.1	36.8	24.4	24.1	21.3	12.8	0.0
asean5	1–4Q2016	0.0	13.3	8.8	13.6	14.9	11.0	4.3	8.7
bchn	1–4Q2016	27.7	0.0	23.6	19.5	26.9	30.6	18.1	25.2
eu+	1–4Q2016	22.0	28.5	0.0	28.7	21.4	18.9	54.9	42.8
ind	1–4Q2016	6.7	4.6	5.6	0.0	2.8	4.0	2.5	5.4
jap	1–4Q2016	15.0	13.0	8.6	5.8	0.0	10.4	5.2	10.9
kor	1–4Q2016	6.0	8.0	4.1	4.4	5.7	0.0	3.3	5.2
rus	1–4Q2016	1.6	3.3	8.2	1.9	1.9	2.3	0.0	1.8
us	1–4Q2016	20.9	29.2	41.1	26.2	26.3	22.9	11.8	0.0
asean5	1–4Q2019	0.0	15.2	8.8	14.5	14.6	11.4	4.5	9.6
bchn	1–4Q2019	30.5	0.0	25.0	19.8	28.0	31.6	20.4	23.4

eu+	1–4Q2019	21.0	29.9	0.0	28.3	22.0	18.7	51.3	43.4
ind	1–4Q2019	7.2	4.9	5.9	0.0	3.1	4.2	2.7	5.8
jap	1–4Q2019	13.1	12.6	8.3	5.7	0.0	9.3	5.0	10.4
kor	1–4Q2019	5.6	7.7	3.8	4.1	5.0	0.0	3.5	5.0
rus	1–4Q2019	1.9	4.3	9.0	2.3	2.3	3.0	0.0	2.4
us	1–4Q2019	20.7	25.3	39.2	25.3	24.9	21.9	12.5	0.0
asean5	1–4Q2023	0.0	17.3	8.5	12.3	15.4	12.6	4.2	11.3
bchn	1–4Q2023	31.2	0.0	24.6	16	24.5	25.4	50.9	17.3
eu+	1–4Q2023	19.4	29.3	0.0	25	23.1	20.8	19	49.1
ind	1–4Q2023	6.9	5.4	6.3	0.0	3.9	4	18.1	7
jap	1–4Q2023	11.3	9.3	7.1	4.8	0.0	7.8	2.6	8.9
kor	1–4Q2023	6.3	6.6	4.8	3.9	5.4	0.0	2.5	6
rus	1–4Q2023	1.3	8.1	2.5	12.5	1.1	1.8	0.0	0.3
us	1–4Q2023	23.6	24	46.1	25.4	26.6	27.5	2.8	0.0

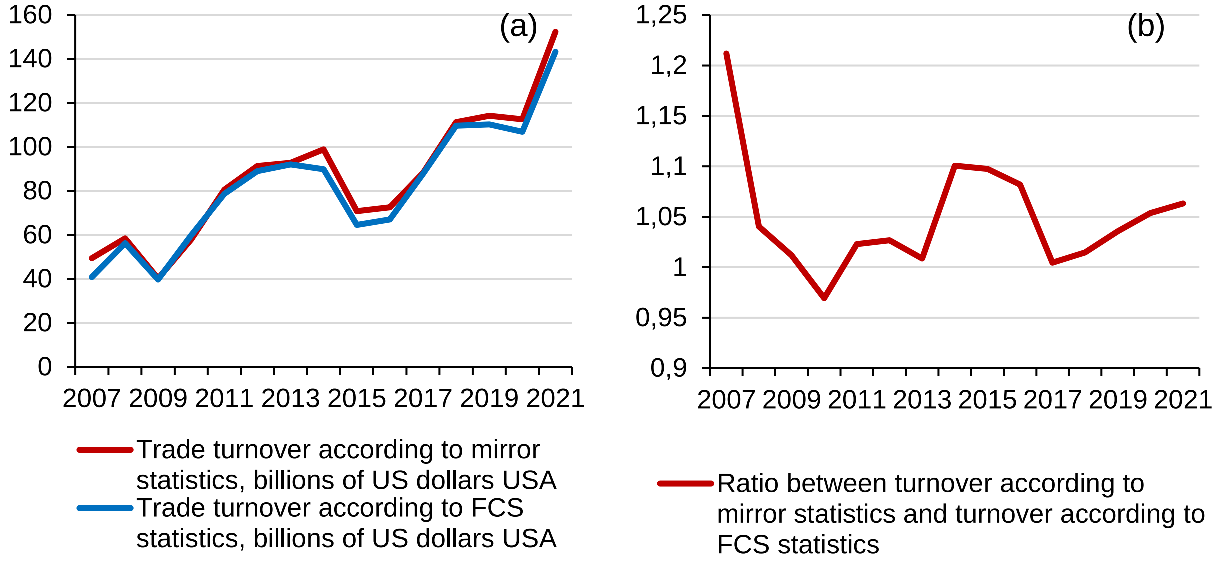
Source: IMF DOTS, OECD TiVA, authors' calculations.

Note: The trade share of country i in relation to country j is calculated as the sum of the imports of country i from country j and the exports to country j divided by the total imports and exports of country i. All trade indicators are in value-added terms. The indicators are presented in columns by country such that the sums of the columns within the same period are equal to 100%.

Appendix E. Comparison of Federal Customs Service trade data and IMF DOTS mirror statistics

Figure E1 presents a comparison of the trade turnover series for Russia and China in 2007–2021.

Figure E1. Russia's trade turnover with China: comparison of FCS statistics and IMF DOTS mirror data Comparison by way of contrast: series (a) and through the ratio of series (b)



Source: IMF DOTS, FCS, authors' calculations.

The graphs show that the mirror statistics in the period under study approximate FCS statistics on Russia's trade with China relatively well.

However, it is no less important to ensure that trade between Russia and other countries is fairly accurately captured by mirror trade. Table E1 shows the ratio of mirror turnover to the turnover of the FCS statistics for several countries.

Table E1

Ratio of Russia's trade turnover based on mirror statistics by IMF DOTS to turnover by FCS trade partner statistics

Trading partner	2007	2010	2014	2018	2020	2021
ASEAN	0.88	1.08	1.06	1.04	0.87	0.95
China	1.21	0.97	1.10	1.01	1.05	1.06
EU+	1.10	1.15	1.01	1.01	1.03	1.03
India	0.64	0.66	0.68	0.84	0.90	0.89
Japan	1.05	1.07	1.10	1.07	1.01	1.10
Korea	1.00	1.00	0.95	1.00	0.89	0.91
US	1.55	1.49	1.17	1.08	0.91	1.02
Turkey	1.25	1.39	1.00	1.02	1.07	1.05
World	1.10	1.07	1.02	0.99	0.98	0.99

Source: IMF DOTS, FCS, authors' calculations.

It is clear from this table that the mirror statistics also fairly accurately describe the changes in of Russia's trade turnover. The cases of strong deviations of the mirror statistics from the official data are sporadic and short-lived. As a result, the data of the mirror statistics are in good alignment with the official data.

Appendix F. Impulse response functions

Table F1

Impulse response functions of real output gap of countries to real output gap shock with different modifications

of output gap shock in percentage points for period

Shock scenario	Post-shock quarters	asean5	bchn	eu+	ind	jap	kor	rus	us
China shock global/2019	1	0.58 (0.23; 0.58)	1 (1; 1)	0.76 (0.06; 0.76)	0.17 (-0.19; 0.34)	0.63 (0.09; 0.63)	0.42 (0.13; 0.42)	0.76 (0.16; 0.76)	0.58 (0.04; 0.58)
	2	0.3 (0.07; 0.42)	0.57 (0.57; 0.74)	0.31 (-0.13; 0.34)	0.19 (-0.05; 0.49)	0.36 (0.02; 0.45)	0.27 (0.05; 0.3)	0.37 (-0.01; 0.43)	0.34 (0.01; 0.38)
	4	0.18 (-0.03; 0.35)	0.19 (0.14; 0.42)	0.23 (0.04; 0.38)	0.2 (-0.13; 0.37)	0.13 (0; 0.29)	0.17 (-0.01; 0.22)	0.25 (-0.05; 0.34)	0.09 (-0.01; 0.23)
	8	0.04 (-0.12; 0.29)	-0.02 (-0.02; 0.18)	0.01 (-0.06; 0.16)	-0.04 (-0.19; 0.26)	0 (-0.05; 0.14)	0.01 (-0.03; 0.15)	0.03 (-0.13; 0.17)	0.01 (-0.03; 0.16)
China shock local/2019	1	0.23 (0.14; 0.37)	1 (1; 1)	0.29 (0.04; 0.29)	0.08 (-0.11; 0.27)	0.26 (0.01; 0.26)	0.17 (0.08; 0.27)	0.2 (0.03; 0.23)	0.17 (-0.08; 0.17)
	2	0.07 (0.01; 0.28)	0.62 (0.61; 0.76)	0.05 (-0.13; 0.13)	0.11 (-0.07; 0.47)	0.11 (-0.04; 0.23)	0.1 (0; 0.22)	-0.01 (-0.11; 0.13)	0.05 (-0.08; 0.17)
	4	0.07 (-0.04; 0.27)	0.3 (0.18; 0.44)	0.16 (0.04; 0.3)	0.25 (-0.08; 0.39)	0.13 (0; 0.26)	0.1 (-0.03; 0.21)	0.04 (-0.11; 0.18)	0.03 (-0.02; 0.21)
	8	0.04 (-0.11; 0.24)	0.09 (-0.01; 0.21)	0.09 (-0.06; 0.14)	0.05 (-0.24; 0.23)	0.05 (-0.05; 0.13)	0.05 (-0.02; 0.13)	-0.01 (-0.19; 0.14)	0.06 (-0.03; 0.12)
China shock asia/2019	1	0.27 (0.16; 0.4)	1 (1; 1)	0.37 (0.06; 0.37)	0.1 (-0.12; 0.38)	0.3 (0.05; 0.3)	0.21 (0.09; 0.34)	0.24 (0.07; 0.29)	0.22 (-0.05; 0.22)
	2	0.1 (0.01; 0.29)	0.62 (0.59; 0.75)	0.09 (-0.11; 0.18)	0.13 (-0.04; 0.52)	0.14 (-0.01; 0.27)	0.12 (0; 0.25)	0.01 (-0.07; 0.17)	0.08 (-0.06; 0.2)
	4	0.08 (-0.07; 0.3)	0.29 (0.17; 0.44)	0.17 (0.03; 0.36)	0.24 (-0.1; 0.44)	0.13 (-0.03; 0.27)	0.11 (-0.05; 0.21)	0.04 (-0.09; 0.24)	0.04 (-0.02; 0.23)
	8	0.04 (-0.18; 0.23)	0.08 (-0.04; 0.19)	0.08 (-0.06; 0.15)	0.04 (-0.28; 0.26)	0.04 (-0.09; 0.13)	0.04 (-0.04; 0.12)	-0.02 (-0.16; 0.18)	0.05 (-0.05; 0.13)
China shock global/2023	1	0.56 (0.23; 0.56)	1 (1; 1)	0.71 (0.07; 0.71)	0.14 (-0.18; 0.34)	0.59 (0.1; 0.59)	0.39 (0.15; 0.39)	0.74 (0.24; 0.74)	0.54 (0.07; 0.54)
	2	0.28 (0.08; 0.37)	0.56 (0.56; 0.73)	0.28 (-0.13; 0.32)	0.11 (-0.13; 0.47)	0.32 (0.01; 0.41)	0.24 (0.06; 0.29)	0.39 (0.04; 0.5)	0.3 (0.01; 0.34)
	4	0.15 (-0.03; 0.33)	0.16 (0.1; 0.44)	0.19 (0.07; 0.35)	0.11 (-0.19; 0.37)	0.11 (0.01; 0.27)	0.15 (0; 0.21)	0.26 (-0.16; 0.34)	0.08 (-0.02; 0.21)
	8	0.03 (-0.14; 0.2)	-0.01 (-0.06; 0.19)	0.02 (-0.08; 0.16)	0 (-0.22; 0.22)	0.01 (-0.09; 0.12)	0.01 (-0.06; 0.13)	0.06 (-0.17; 0.14)	0.01 (-0.05; 0.12)
China shock local/2023	1	0.23 (0.17; 0.35)	1 (1; 1)	0.3 (0.05; 0.3)	0.08 (-0.1; 0.23)	0.22 (0.03; 0.25)	0.14 (0.07; 0.22)	0.45 (0.02; 0.5)	0.12 (-0.07; 0.12)
	2	0.07 (0.03; 0.27)	0.62 (0.61; 0.76)	0.06 (-0.1; 0.14)	0.08 (-0.04; 0.39)	0.08 (-0.02; 0.22)	0.08 (0.01; 0.18)	0.22 (-0.09; 0.35)	0.01 (-0.08; 0.12)
	4	0.07 (-0.04; 0.31)	0.28 (0.18; 0.48)	0.16 (0.05; 0.31)	0.21 (-0.14; 0.33)	0.11 (0.01; 0.25)	0.08 (-0.03; 0.19)	0.14 (-0.28; 0.23)	0.02 (-0.03; 0.2)
	8	0.05 (-0.1; 0.25)	0.09 (-0.01; 0.27)	0.1 (-0.05; 0.18)	0.07 (-0.24; 0.22)	0.05 (-0.05; 0.18)	0.04 (-0.03; 0.14)	0.03 (-0.22; 0.2)	0.06 (-0.02; 0.16)
China shock asia/2023	1	0.27 (0.16; 0.39)	1 (1; 1)	0.36 (0.06; 0.36)	0.1 (-0.1; 0.27)	0.27 (0.04; 0.27)	0.18 (0.09; 0.27)	0.5 (0.12; 0.55)	0.17 (-0.07; 0.17)
	2	0.09 (0.03; 0.31)	0.61 (0.58; 0.76)	0.1 (-0.11; 0.18)	0.09 (-0.05; 0.43)	0.11 (-0.03; 0.24)	0.1 (0.02; 0.2)	0.25 (-0.04; 0.42)	0.05 (-0.07; 0.15)
	4	0.07 (-0.05; 0.28)	0.27 (0.14; 0.46)	0.17 (0.05; 0.32)	0.2 (-0.17; 0.39)	0.11 (0; 0.24)	0.09 (-0.03; 0.19)	0.15 (-0.26; 0.24)	0.03 (-0.04; 0.19)
	8	0.04 (-0.14; 0.21)	0.08 (-0.05; 0.23)	0.09 (-0.08; 0.19)	0.06 (-0.22; 0.27)	0.05 (-0.07; 0.11)	0.04 (-0.04; 0.13)	0.03 (-0.26; 0.16)	0.05 (-0.05; 0.12)
EU shock global/2019	1	0.38 (0.2; 0.41)	0.26 (0.12; 0.27)	1 (1; 1)	0.2 (-0.29; 0.3)	0.43 (0.11; 0.43)	0.27 (0.13; 0.34)	0.67 (0.33; 0.76)	0.43 (0.1; 0.43)
	2	0.25 (0.04; 0.3)	0.12 (0; 0.17)	0.66 (0.53; 0.73)	0.25 (-0.11; 0.4)	0.3 (0.05; 0.35)	0.2 (0.09; 0.27)	0.43 (0.12; 0.5)	0.33 (0.07; 0.35)
	4	0.08 (-0.14; 0.11)	-0.04 (-0.17; -0.01)	0.21 (-0.02; 0.27)	0.1 (-0.25; 0.15)	0.03 (-0.1; 0.17)	0.09 (-0.03; 0.09)	0.14 (-0.19; 0.17)	0.07 (-0.09; 0.11)
	8	-0.03 (-0.12; 0.06)	-0.06 (-0.09; 0.02)	-0.04 (-0.08; 0.03)	-0.02 (-0.09; 0.12)	-0.03 (-0.09; 0.03)	-0.03 (-0.08; 0)	-0.05 (-0.12; 0.01)	-0.04 (-0.08; 0.01)
EU shock local/2019	1	0.16 (0.11; 0.21)	0.15 (0.07; 0.16)	1 (1; 1)	0.15 (-0.18; 0.23)	0.2 (0.08; 0.22)	0.11 (0.06; 0.15)	0.5 (0.29; 0.61)	0.27 (0.05; 0.27)
	2	0.11 (0; 0.16)	0.07 (-0.01; 0.12)	0.73 (0.59; 0.75)	0.24 (-0.08; 0.31)	0.17 (0.03; 0.22)	0.11 (0.05; 0.16)	0.34 (0.11; 0.43)	0.24 (0.04; 0.26)
	4	-0.02 (-0.2; 0.01)	-0.03 (-0.15; -0.02)	0.21 (-0.05; 0.22)	0.15 (-0.22; 0.17)	0 (-0.1; 0.14)	0.04 (-0.06; 0.06)	0.02 (-0.22; 0.03)	0.04 (-0.11; 0.07)
	8	-0.08 (-0.15; 0.05)	-0.01 (-0.08; 0.04)	-0.02 (-0.08; 0.03)	0.02 (-0.07; 0.15)	-0.02 (-0.08; 0.04)	-0.03 (-0.07; 0)	-0.11 (-0.15; -0.02)	-0.03 (-0.07; 0.01)
EU shock global/2023	1	0.38 (0.2; 0.38)	0.25 (0.13; 0.27)	1 (1; 1)	0.19 (-0.25; 0.32)	0.44 (0.17; 0.44)	0.28 (0.13; 0.36)	0.44 (0.22; 0.48)	0.45 (0.1; 0.45)

	2	0.25 (0.04; 0.27)	0.11 (0.01; 0.17)	0.67 (0.55; 0.74)	0.23 (-0.17; 0.38)	0.32 (0.07; 0.36)	0.21 (0.09; 0.29)	0.28 (0.09; 0.36)	0.34 (0.09; 0.38)
	4	0.07 (-0.15; 0.1)	-0.06 (-0.18; -0.02)	0.2 (0; 0.25)	0.02 (-0.29; 0.12)	0.02 (-0.07; 0.17)	0.08 (-0.03; 0.1)	0.09 (-0.13; 0.15)	0.08 (-0.09; 0.13)
	8	-0.04 (-0.16; 0.06)	-0.07 (-0.12; 0.02)	-0.04 (-0.09; 0.04)	-0.02 (-0.09; 0.12)	-0.03 (-0.11; 0.02)	-0.03 (-0.08; 0)	-0.01 (-0.08; 0.09)	-0.04 (-0.09; 0.01)
EU shock local/2023	1	0.15 (0.1; 0.19)	0.15 (0.06; 0.15)	1 (1; 1)	0.13 (-0.12; 0.19)	0.21 (0.06; 0.22)	0.12 (0.09; 0.18)	0.23 (0.14; 0.27)	0.31 (0.09; 0.31)
	2	0.1 (-0.01; 0.14)	0.07 (-0.02; 0.11)	0.74 (0.61; 0.75)	0.21 (-0.06; 0.29)	0.17 (0.03; 0.22)	0.12 (0.07; 0.18)	0.15 (0.04; 0.2)	0.26 (0.08; 0.29)
	4	-0.04 (-0.22; 0)	-0.05 (-0.17; -0.04)	0.19 (-0.07; 0.21)	0.05 (-0.25; 0.13)	-0.01 (-0.08; 0.12)	0.04 (-0.06; 0.05)	-0.02 (-0.16; 0.02)	0.05 (-0.1; 0.09)
	8	-0.09 (-0.19; 0.03)	-0.04 (-0.08; 0.04)	-0.03 (-0.08; 0.04)	0 (-0.06; 0.15)	-0.03 (-0.08; 0.03)	-0.04 (-0.08; -0.01)	-0.07 (-0.1; 0.04)	-0.04 (-0.08; 0.02)

Source: Authors' calculations.

Note: The parentheses show the lower and upper bounds of the 80% confidence interval.

Table F2

Impulse response functions of real output growth of countries to output growth shock with several variations

of GDP shock, growth from beginning of shock, percentage points

Shock scenario	Post-shock quarters	asean5	bchn	eu+	ind	jap	kor	rus	us
China shock global/2019	1	0.54 (0.27; 0.54)	1 (1; 1)	1 (0.26; 1)	0.8 (0.38; 0.89)	0.65 (0.12; 0.65)	0.4 (0.04; 0.44)	0.72 (0.18; 0.72)	0.71 (0.14; 0.71)
	2	0.24 (0.07; 0.36)	0.67 (0.63; 0.81)	0.4 (-0.15; 0.43)	0.46 (0.13; 0.64)	0.39 (0.06; 0.48)	0.27 (-0.03; 0.34)	0.38 (-0.05; 0.39)	0.39 (0.01; 0.48)
	4	0.27 (-0.03; 0.33)	0.63 (0.6; 0.98)	0.46 (0.05; 0.56)	0.4 (0.08; 0.61)	0.3 (0.02; 0.43)	0.36 (0.09; 0.47)	0.58 (0.03; 0.6)	0.33 (0.12; 0.47)
	8	0.29 (0.02; 0.36)	0.32 (0.32; 1.09)	0.14 (-0.07; 0.41)	0.2 (-0.01; 0.49)	0.09 (0.01; 0.46)	0.3 (0.08; 0.61)	0.65 (0.01; 0.74)	0.05 (0; 0.44)
China shock local/2019	1	0.19 (0.16; 0.31)	1 (1; 1)	0.31 (0.11; 0.31)	0.2 (0.14; 0.4)	0.23 (0.05; 0.25)	0.15 (-0.01; 0.23)	0.16 (0.03; 0.2)	0.2 (-0.01; 0.2)
	2	0.04 (0; 0.24)	0.77 (0.69; 0.85)	0.03 (-0.14; 0.11)	0.1 (0.02; 0.36)	0.08 (-0.01; 0.23)	0.11 (-0.06; 0.19)	0 (-0.14; 0.09)	0.05 (-0.06; 0.17)
	4	0.15 (-0.09; 0.18)	0.77 (0.7; 1.05)	0.19 (0.02; 0.38)	0.23 (-0.03; 0.47)	0.17 (-0.02; 0.28)	0.24 (0.03; 0.35)	0.16 (-0.11; 0.24)	0.08 (0.01; 0.33)
	8	0.17 (-0.04; 0.26)	0.58 (0.58; 1.16)	-0.01 (-0.1; 0.34)	0.07 (-0.1; 0.37)	0.02 (-0.06; 0.34)	0.22 (0.04; 0.44)	0.2 (-0.1; 0.47)	-0.08 (-0.09; 0.31)
China shock asia/2019	1	0.23 (0.15; 0.36)	1 (1; 1)	0.4 (0.14; 0.4)	0.26 (0.2; 0.43)	0.26 (0.09; 0.29)	0.18 (0.07; 0.24)	0.2 (0.04; 0.2)	0.26 (0.01; 0.26)
	2	0.06 (-0.01; 0.25)	0.76 (0.68; 0.86)	0.08 (-0.14; 0.16)	0.13 (0.02; 0.37)	0.11 (0.02; 0.27)	0.12 (-0.02; 0.21)	0.01 (-0.12; 0.08)	0.09 (-0.06; 0.21)
	4	0.16 (-0.05; 0.22)	0.75 (0.7; 1.05)	0.22 (0.02; 0.39)	0.24 (-0.05; 0.45)	0.17 (0.02; 0.32)	0.25 (0.06; 0.37)	0.16 (-0.08; 0.23)	0.1 (0.03; 0.33)
	8	0.18 (-0.02; 0.29)	0.55 (0.55; 1.15)	0.01 (-0.06; 0.33)	0.08 (-0.1; 0.41)	0.02 (-0.05; 0.37)	0.23 (0.08; 0.52)	0.2 (-0.12; 0.4)	-0.07 (-0.07; 0.33)
China shock global/2023	1	0.53 (0.27; 0.53)	1 (1; 1)	1 (0.25; 1)	0.79 (0.35; 0.84)	0.64 (0.16; 0.64)	0.41 (0.11; 0.41)	0.71 (0.13; 0.71)	0.72 (0.13; 0.72)
	2	0.23 (0.04; 0.34)	0.67 (0.62; 0.82)	0.38 (-0.16; 0.45)	0.43 (0.07; 0.56)	0.36 (0.06; 0.46)	0.26 (0.02; 0.28)	0.39 (-0.11; 0.47)	0.35 (-0.01; 0.43)
	4	0.26 (-0.05; 0.32)	0.61 (0.59; 1.05)	0.41 (0.04; 0.59)	0.35 (0.01; 0.61)	0.26 (-0.01; 0.4)	0.34 (0.09; 0.43)	0.53 (-0.08; 0.61)	0.29 (0.07; 0.42)
	8	0.29 (-0.07; 0.33)	0.36 (0.36; 1.19)	0.12 (-0.15; 0.48)	0.21 (-0.14; 0.49)	0.09 (-0.05; 0.39)	0.3 (0.1; 0.49)	0.58 (-0.09; 0.71)	0.04 (-0.05; 0.37)
China shock local/2023	1	0.19 (0.15; 0.3)	1 (1; 1)	0.32 (0.12; 0.32)	0.17 (0.09; 0.28)	0.2 (0.04; 0.2)	0.13 (0.05; 0.19)	0.35 (0.04; 0.38)	0.15 (-0.03; 0.15)
	2	0.04 (-0.03; 0.18)	0.77 (0.7; 0.86)	0.03 (-0.15; 0.08)	0.07 (-0.08; 0.23)	0.05 (-0.03; 0.17)	0.08 (-0.04; 0.15)	0.21 (-0.12; 0.28)	-0.01 (-0.12; 0.09)
	4	0.14 (-0.09; 0.26)	0.74 (0.71; 1.09)	0.17 (0.01; 0.39)	0.19 (-0.05; 0.39)	0.12 (-0.04; 0.29)	0.2 (0.02; 0.32)	0.4 (-0.13; 0.49)	0.03 (-0.05; 0.27)
	8	0.17 (-0.06; 0.3)	0.59 (0.59; 1.27)	0 (-0.18; 0.35)	0.05 (-0.21; 0.36)	-0.01 (-0.07; 0.34)	0.2 (0.04; 0.45)	0.45 (-0.12; 0.74)	-0.11 (-0.15; 0.24)
China shock asia/2023	1	0.22 (0.16; 0.32)	1 (1; 1)	0.39 (0.15; 0.39)	0.22 (0.11; 0.36)	0.24 (0.07; 0.26)	0.15 (0.06; 0.21)	0.39 (0.04; 0.43)	0.21 (0.02; 0.21)
	2	0.06 (-0.01; 0.19)	0.75 (0.66; 0.86)	0.07 (-0.14; 0.14)	0.09 (-0.06; 0.3)	0.08 (-0.01; 0.21)	0.1 (-0.02; 0.17)	0.24 (-0.12; 0.33)	0.03 (-0.07; 0.15)
	4	0.15 (-0.1; 0.26)	0.72 (0.69; 1.1)	0.19 (0.01; 0.43)	0.2 (-0.04; 0.49)	0.13 (-0.05; 0.32)	0.22 (0.05; 0.35)	0.43 (-0.08; 0.5)	0.05 (-0.02; 0.29)
	8	0.18 (-0.02; 0.35)	0.56 (0.56; 1.26)	0.01 (-0.12; 0.36)	0.06 (-0.14; 0.41)	-0.01 (-0.11; 0.39)	0.2 (0.08; 0.49)	0.48 (-0.1; 0.78)	-0.1 (-0.12; 0.3)
EU shock global/2019	1	0.29 (0.17; 0.31)	0.16 (0.04; 0.18)	1 (1; 1)	0.52 (0.38; 0.74)	0.37 (0.1; 0.37)	0.2 (0.12; 0.27)	0.51 (0.32; 0.51)	0.43 (0.24; 0.43)
	2	0.14 (0.03; 0.16)	0.03 (-0.08; 0.05)	0.65 (0.57; 0.73)	0.34 (0.18; 0.53)	0.26 (0.03; 0.28)	0.12 (0.05; 0.18)	0.3 (0.11; 0.34)	0.27 (0.1; 0.3)

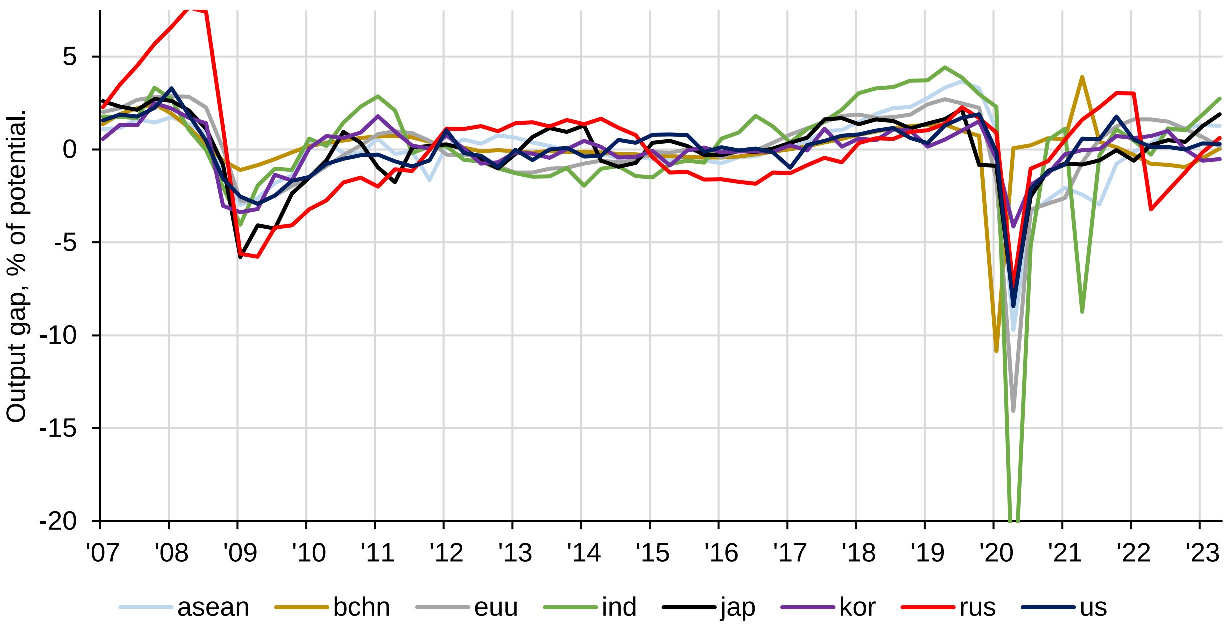
	4	0.05 (-0.07; 0.08)	-0.04 (-0.14; 0)	0.44 (0.23; 0.49)	0.11 (-0.11; 0.17)	0.05 (-0.06; 0.11)	0.09 (-0.01; 0.12)	0.24 (-0.02; 0.32)	0.19 (0; 0.21)
	8	0.07 (-0.02; 0.08)	-0.17 (-0.26; -0.06)	0.34 (0.22; 0.43)	0.1 (-0.06; 0.17)	0.03 (-0.08; 0.07)	0.05 (-0.03; 0.09)	0.27 (-0.01; 0.37)	0.06 (-0.07; 0.13)
EU shock local/2019	1	0.14 (0.09; 0.17)	0.09 (0.03; 0.11)	1 (1; 1)	0.28 (0.22; 0.46)	0.18 (0.06; 0.18)	0.09 (0.07; 0.14)	0.38 (0.25; 0.41)	0.34 (0.19; 0.34)
	2	0.03 (-0.04; 0.07)	-0.03 (-0.07; 0.02)	0.72 (0.65; 0.8)	0.22 (0.1; 0.41)	0.11 (-0.01; 0.14)	0.04 (0; 0.1)	0.22 (0.08; 0.28)	0.22 (0.09; 0.26)
	4	-0.04 (-0.15; 0)	-0.12 (-0.16; -0.03)	0.45 (0.25; 0.53)	0.04 (-0.23; 0.1)	-0.07 (-0.12; 0.06)	0.01 (-0.05; 0.06)	0.08 (-0.08; 0.16)	0.12 (-0.02; 0.17)
	8	-0.01 (-0.13; 0.01)	-0.21 (-0.28; -0.07)	0.41 (0.28; 0.51)	0.08 (-0.15; 0.14)	-0.06 (-0.12; 0.03)	-0.03 (-0.11; 0.02)	0.09 (-0.08; 0.17)	0.04 (-0.09; 0.12)
EU shock global/2023	1	0.29 (0.18; 0.32)	0.16 (0.03; 0.18)	1 (1; 1)	0.51 (0.38; 0.7)	0.39 (0.11; 0.39)	0.22 (0.15; 0.3)	0.34 (0.12; 0.34)	0.48 (0.28; 0.48)
	2	0.13 (0.03; 0.17)	0.03 (-0.1; 0.05)	0.64 (0.55; 0.7)	0.33 (0.17; 0.49)	0.27 (0.04; 0.28)	0.13 (0.07; 0.21)	0.15 (-0.05; 0.2)	0.3 (0.14; 0.32)
	4	0.05 (-0.07; 0.08)	-0.04 (-0.15; 0.01)	0.41 (0.21; 0.5)	0.09 (-0.13; 0.19)	0.06 (-0.06; 0.13)	0.1 (0.01; 0.14)	0.05 (-0.09; 0.11)	0.2 (0.02; 0.25)
	8	0.07 (-0.05; 0.09)	-0.18 (-0.28; -0.07)	0.31 (0.18; 0.44)	0.1 (-0.06; 0.15)	0.03 (-0.08; 0.08)	0.07 (-0.03; 0.12)	0.07 (-0.11; 0.09)	0.07 (-0.08; 0.13)
EU shock local/2023	1	0.13 (0.07; 0.15)	0.08 (0.04; 0.1)	1 (1; 1)	0.25 (0.19; 0.41)	0.19 (0.07; 0.19)	0.1 (0.08; 0.15)	0.18 (0.11; 0.18)	0.39 (0.22; 0.4)
	2	0.02 (-0.06; 0.06)	-0.03 (-0.08; 0.02)	0.72 (0.62; 0.8)	0.19 (0.02; 0.33)	0.12 (0; 0.17)	0.06 (0.02; 0.11)	0.05 (-0.03; 0.11)	0.26 (0.11; 0.31)
	4	-0.05 (-0.16; 0.01)	-0.13 (-0.16; -0.01)	0.44 (0.24; 0.55)	0.03 (-0.22; 0.11)	-0.07 (-0.11; 0.06)	0.02 (-0.05; 0.07)	-0.07 (-0.15; 0.04)	0.15 (0; 0.2)
	8	-0.02 (-0.12; 0.03)	-0.24 (-0.28; -0.05)	0.39 (0.26; 0.53)	0.08 (-0.13; 0.13)	-0.07 (-0.12; 0.05)	-0.01 (-0.09; 0.05)	-0.06 (-0.15; 0.05)	0.06 (-0.07; 0.16)

Source: Authors' calculations.

Note: The parentheses show the lower and upper bounds of the 80% confidence interval.

Appendix G. Estimated dynamics of output gap

Figure G1. Estimated dynamics in output gap via Hodrick-Prescott filter



Source: Authors' calculations.
Note: The abbreviations for the economic regions are presented in Appendix C.

As Figure G1 shows, the output gaps of various countries are unidirectional during the 2008 and 2020 global crises.

One of the focal areas is the relatively synchronous dynamics of the output gaps of Russia and China between 2022 Q2 and 2023 Q1. In this, the reasons behind these movements in each country are for the most part independent of one another: in China, it is the fallout from the restrictions related to the pandemic in 2022 Q2; in Russia, it is idiosyncratic shocks as a result of the sanctions enacted against Russia after February 2022.

Theoretically, such *coincidences* may significantly distort the model estimates unless they are accounted for in a specific way. In our GVAR, the effects of these 'coincidences' are neutralised by the following mechanisms:

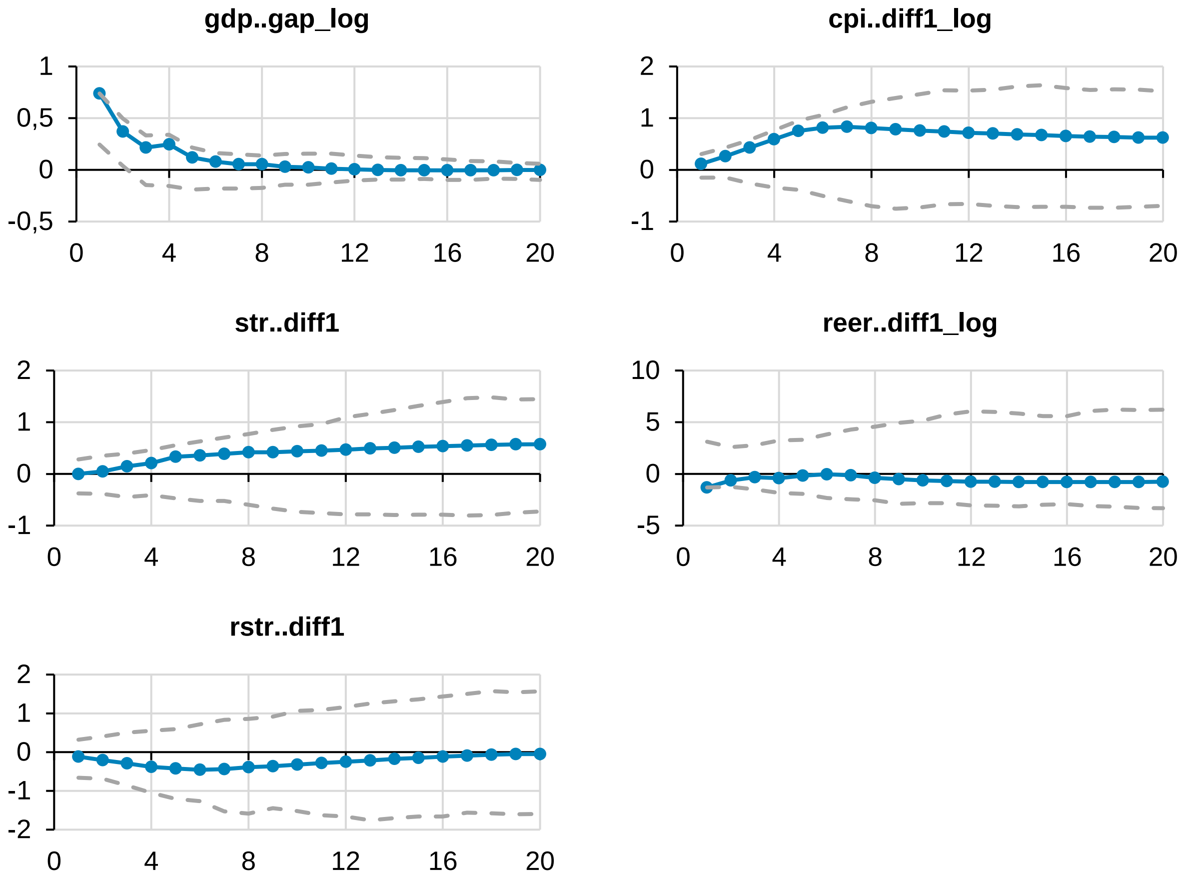
1. The model is estimated on the basis of long time series: from 2007 to 2023. A few observations, if they are not outliers, will unlikely have much impact on the model coefficients;

2. The GVAR does not include direct dependencies of Russia's output gap on the output gap of a particular country, nor does it include a dependency of Russia's output gap on the output gap of Russia's entire external sector. Such a structure would average the effects of 'coincidences';

3. The direct moments of shocks are designated as outliers, and they do not affect the estimates of the coefficients.

Appendix H. Impulse response functions of Russia's main macroeconomic variables to 1pp output gap shock of China in global/2023 and local/2023 models

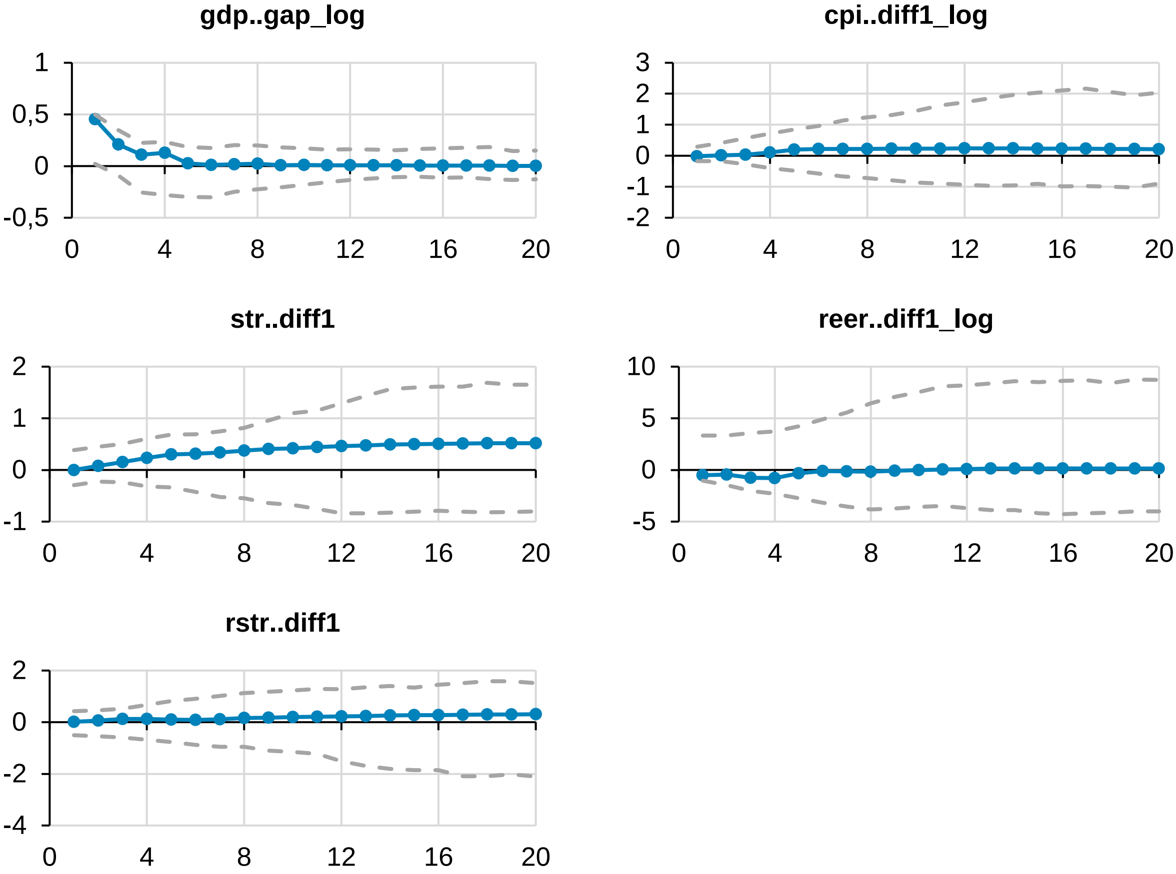
Figure H1. Impulse response functions of Russia's main macroeconomic variables to 1pp output gap shock of China in global/2023 model



Source: Authors' calculations.

Note: The vertical axis denotes the output gap in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals. The IRF indicators in diff1 and diff1_log are presented as the increases accumulated following the onset of the shock, and gdp..gap_log is presented as gaps

Figure H2. Impulse response functions of Russia's main macroeconomic variables to 1pp output gap shock in local/2023 model



Source: Authors' calculations.

Note: The vertical axis denotes the output gap in percentage points; the horizontal axis denotes the number of quarters after the shock. The grey dashed lines denote the 80% confidence intervals. The IRF indicators in diff1 and diff1_log are presented as the increases accumulated following the onset of the shock, and gdp..gap_log is presented as gaps