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QUANTITATIVE ASSESSMENT OF THE ECONOMIC IMPACT OF THE TRADE DISRUPTIONS FOLLOWING THE RUSSIAN INVASION OF UKRAINE

by Alessandro Borin*, Francesco Paolo Conteduca*, Enrica Di Stefano*, Vanessa Gunnella**, Michele Mancini** and Ludovic Panon*

Abstract

We provide a quantification of the impact through international trade of the restrictive measures and related trade disruptions following the Russian invasion of Ukraine. We first exploit the multi-sector, multi-country, general equilibrium trade model by Antràs and Chor (2018). In this framework, Russia would suffer greatly from trade disruptions. Adding restrictive measures on energy exports would further amplify this loss. For sanctioning countries, the welfare impact is modest. This result arises mainly because the used model allows for a high degree of substitutability across inputs and countries, a feature arguably unrealistic especially in the short-run. When we relax this assumption by relying on the framework proposed by Bachmann et al. (2022) extended to a multi-country setting, we show that the impact on sanctioning countries might increase markedly in the short run and would be very sensitive to small changes in countries' possibility to diversify away from Russian energy.

JEL Classification: F51, F15, F17, Q43.

Keywords: war, trade disruptions, energy shock, international trade, global value chains.

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* Bank of Italy, Economic Research and International Relations; ** European Central Bank. The opinions expressed in this publication are those of the authors. They do not purport to reflect the opinions or views of the European Central Bank and the Bank of Italy.

1. Introduction[1]

On February 24, 2022, the Russian army invaded Ukraine. In response, a group of countries, which accounted for around 55% of the world GDP and absorbed almost 60% of the Russian exports in 2020, responded to the aggression by imposing restrictive measures on Russia's trade and financial linkages.[2] Those introduced so far include a variety of trade restrictions (tariff increases, including in some cases the suspension of Russia's MFN status under WTO, import and export bans to selected non-energy products), the halting or cancellation of infrastructure projects (e.g., halt to the Nord Stream 2 from the part of Germany), and the financial system (exclusion of most Russian banks from SWIFT and freezing of half of the official foreign currency reserves). Moreover, a list of individuals, among which members of the Russian government and parliament and several oligarchs, faced travel bans and asset freezes in countries adopting restrictive measures against Russia (for simplicity, hereafter referred to as *sanctioning countries*). Private companies, including large shipping multinationals, decided to suspend their activities in Russia or announced their exit from the Russian market in the coming months.[3] Others voluntarily curtailed their purchases of Russian products, including crude oil.

In response, Russia retaliated by imposing restrictions on trade while implementing measures to support the ruble. The government forced Russian exporting firms to convert their foreign currency revenues into rubles and introduced strict controls on capital outflows by foreigners and residents. Moreover, Russian authorities announced the possible nationalization of foreign companies to counteract business shutdowns and announced a switch of energy contracts to rubles.

Overall, bilateral barriers to trade increased enacting a substantial decoupling between Russia and the sanctioning countries. The actual rise in trade barriers is not easy to quantify, given that the list of restrictive measures is extremely complex and subject to frequent updates.[4] Moreover, restrictions on financial institutions may disrupt trade far beyond what the specific provisions on exports/imports may suggest. Besides official measures, voluntary decisions by private customers and companies (e.g., withdrawing from Russia) introduce additional frictions, whose consequences are hard to gauge. Nonetheless, we may expect the decoupling between Russia and the sanctioning economies to be substantial and likely to increase further.

Until the end of May 2022, most sanctioning countries, especially those more dependent on Russian imports, refrained from imposing an embargo on gas and oil imports.[5] This issue is currently at the heart of the public debate in EU countries, as many of them largely depend on imports from Russia for their energy needs.[6] On the one hand, because of technology and capacity constraints, embargo opponents highlight the difficulty of substituting large volumes of energy imports with supplies from other countries or with other

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[1] The opinions expressed in this publication are those of the authors. They do not purport to reflect the opinions or views of the European Central Bank and the Bank of Italy.

[2] For a more extensive description of the restrictive measures, see the box "The Invasion of Ukraine: sanctions on Russia and the impact on global financial markets and international trade" in Bank of Italy, Economic Bulletin, n. 2, 2022. The complete list of sanctioning and non-sanctioning countries is in the Appendix.

[3] See, for instance: "Western brands flee Russia in unravelling of 'capitalistic diplomacy' " (FT, March 3), "Big luxury brands suspend operations in Russia" (FT, March 5), "Gauloises maker Imperial Brands to make full exit from Russia" (FT, March 15).

[4] See the Peterson Institute for International Economics website for an updated timeline of the sanctions related to the Russia's war on Ukraine https://www.piie.com/blogs/realtime-economic-issues-watch/russias-war-ukraine-sanctions-timeline.

[5] One exception is the US that accounts for a small fraction of Russian energy exports.

[6] Can Europe survive painlessly without Russian gas?

domestic sources, at least in the short run. The inelastic supply, combined with an inelastic demand, would make a sudden stop of imports from Russia harmful to EU economies, reducing output and further increasing inflation, at a time when the prices of energy products are already at record highs. On the other hand, those in favor of the embargo argue that its impact would be moderate, as some substitution of Russian energy imports can be attained even in the short run. For instance, Bachmann et al. (2022) claim that, even assuming low substitutability, the economic impact of a ban on Russian oil and gas would be manageable for Germany, despite its high initial dependency on imports from Russia.

On top of that, excluding oil and gas from the package of restrictive measures is likely to partly offset the efficacy of enforced measures and enable Russia to fund its war efforts. Hausman (2022), Fadinger and Schymik (2022), and Gros (2022) argue that import tariffs on energy commodities from Russia may be a valuable compromise between the two opposing views. The gist of the argument supporting import tariffs is that the exporters would carry the burden given the low supply elasticity due to strict technological constraints (e.g., infrastructural difficulties in redirecting gas flows to other countries or reducing extractions below a certain threshold). However, the price elasticity of European demand for Russian gas is arguably low, given the technical limitations in increasing sourcing from other countries. Hence, Russian exporters would likely be able to shift part of the cost to importers.

In this note, we contribute to the ongoing policy debate by focusing on the restrictive trade measures of trade flows with Russia. Furthermore, we analyze how extending them to Russian oil and gas exports would affect importing countries' welfare.

First, we investigate the potential vulnerabilities by looking at pre-war interdependencies between Russia and the other economies. In particular, we rely on inter-country input-output (ICIO) data to assess the role of Russian final demand in absorbing other countries' productions and the dependency on Russian energy and industrial raw materials for input requirements. The analysis suggests that despite the modest GDP exposure to Russian final demand, the dependency on raw materials, especially the energy inputs, is sizable. Sanctioning countries in Central and Eastern Europe are the most exposed to a collapse in Russian demand and most dependent on Russian raw materials; among major economies, Germany and Italy also stand out. Our description of the demand- and supply-side exposures informs our understanding of the channels and the relative magnitudes of the effect of trade and value-chain disruptions with Russia.

Second, to simulate and quantify the possible impacts of trade disruptions with Russia on countries' welfare (i.e., real expenditure) in a general equilibrium framework, we rely on the quantitative trade model by Antràs and Chor (2018), which features inter-country input-output linkages. The model permits the estimation of welfare changes, assuming that all substitutions and adjustments take place and that increases in trade costs are permanent. Starting from a situation in which the energy imports from Russia are not affected by disruptions, we design three scenarios, assuming different intensities in trade disruptions. These are simulated as increases in bilateral trade barriers entailing different drops in trade flows to Russia: *i)* total exports from sanctioning countries to Russia drop by 20% (benign); *ii)* they drop by 50% (intermediate); *iii)* they drop by 75% (severe). The rise in trade barriers entails various decreases in Russian exports to sanctioning countries: they drop by 10% (benign), 20% (intermediate), and 33% (severe).

According to our simulations, trade disruptions would mainly affect Russia and its closest trade partners. Even without sanctions in the energy sector, the drop in real income for Russia ranges between 1% in the benign scenario and 4% in the severe scenario. The impact on the European Union is, instead, relatively mild, around 0.2% in the severe scenario, thanks to the relative size of the economies and to trade diversion. The latter is also the main driver of the small welfare increase found in some non-sanctioning countries (e.g., China).

Next, we build upon the scenarios and investigate the effects of extending sanctions to Russia's energy exports. The impact of including energy commodities would be large for Russia (with an overall welfare drop exceeding 6% in the severe scenario) but still mild for sanctioning countries, including the most exposed ones (about -0.4% for the EU27); in contrast, non-sanctioning countries (energy commodity exporters, in particular) would gain. However, the interpretation of these results requires some caution. While general equilibrium trade models, such as the one used for this exercise, provide valuable insights into the redirection of trade flows and the reorganization of production chains in the medium-long run, they ignore technological limitations, which bind in the short run (e.g., adjustment costs, capacity constraints). They are thus not appropriate to describe the shorter-run dynamics associated with production disruptions from a sudden stop of energy imports.

To mitigate some of these limitations, we resort to the two-sector framework (energy vs. non-energy sector) discussed in Bachmann et al. (2022). Despite its simplicity, the framework features lower elasticities of substitution, providing a more realistic description of the constraints and the frictions in place. Results from this exercise show that the short-run impact of an embargo on Russian energy products varies markedly, depending on the assumptions about the substitutability with imports from other countries and other domestic sources. For low but reasonable elasticities of substitution with other energy sources, the embargo on Russian energy can lead to an average GDP reduction for EU countries close to 4% in the short run. Unlike the results based on Antràs and Chor (2018), these estimates do not take into account the possible cross-country, cross-sector spillovers generated by a reduction of production in a given country and exhibit highly non-linear substitutability; therefore, they are subject to large uncertainty.

More generally, all the analyses contained in this work focus exclusively on the real effect through the trade channel while neglecting other possible channels through which the war and the subsequent restrictive measures may affect the different economies, such as financial repercussions, potential changes in confidence, and adjustments stemming from commodity prices.[7]

2. Exposure to Russian demand and dependence on Russian raw materials: stylized facts

The economic impact of trade disruptions depends on the sanctioning countries' exposure to Russia on:

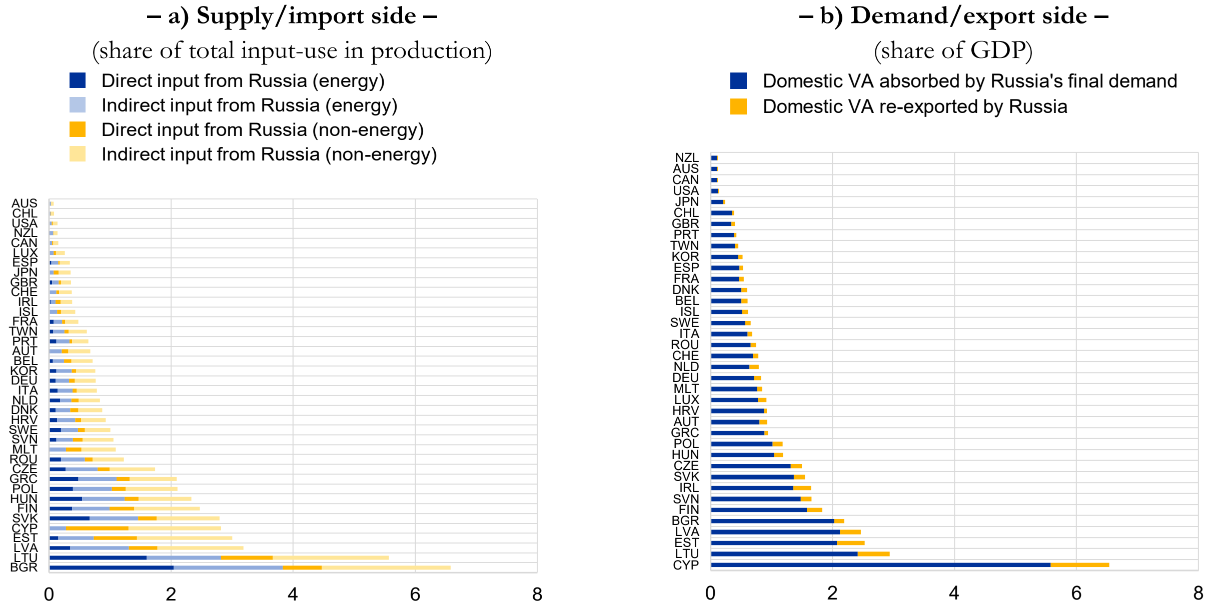
1) **the supply/import side**, due to increasing import costs or limiting imported goods from Russia, with amplification effects along the supply chains in the case of imported intermediates;
2) **the demand/export side**, due to decreasing export volumes of final or intermediate goods processed for further re-exporting to Russia.

It is important to notice that Russia is a major global commodity exporter and the largest foreign supplier of energy commodities for the European Union. In addition, Russia represents a relevant market for neighboring countries' exports. Hence, European countries are likely to be the most affected among sanctioning countries.

Figure 1, panel a) shows that Eastern European countries, Cyprus, and Finland are the most reliant on Russian intermediate inputs for their production. In most of these countries, the dependence is particularly sizable for energy production and energy- and raw-material-intensive sectors (e.g., metal, chemical, and transport sectors). This is also the case for other European countries, including Germany and Italy, among the large countries. As Russian raw materials are a primary input, their indirect contribution to downstream production processes is significant. The figure also shows that the exposure of faraway countries is negligible.

[7] For a more comprehensive modeling approach, see Box 3 "The impact of the conflict in Ukraine on the euro area economy in the baseline and two alternative scenarios" in ECB staff macroeconomic projections for the euro area – March 2022 and "Zu den möglichen gesamtwirtschaftlichen Folgen des Ukrainekriegs: Simulationsrechnungen zu einem verschärften Risikoszenario" in Bundesbank Monatsbericht – April 2022.

Figure 1. Sanctioning countries' exposure to Russia



Source: OECD TiVA 2021 and authors' calculations.
Note: The supply/import side exposure considers direct and indirect use of Russian energy and non-energy sectors' input in production for each country as a share of total direct and indirect input use. Calculations based on the Leontief inverse matrix derived from the intermediate use table from TiVA 2021 input-output tables. The demand/export side exposure considers *i*) countries' domestic value added in products finally consumed in Russia exported either directly or embodied in other countries' exports of final products to Russia (blue part), and *ii*) domestic value added contained in intermediate goods used in Russia's exports (yellow part). Data refer to 2018.

Figure 1, panel b) shows the demand/export-side exposure. Eastern European countries are the most vulnerable to impairments in Russia's demand, together with countries where linkages of services sectors are prevalent (such as Cyprus and Ireland).[8] For other European countries, the exposure to Russia is less sizable and mostly concentrated in mining supporting services, machinery, and air transport sectors. Again, non-European sanctioning countries are the least exposed.

3. The effect of restrictive measures through the lens of a quantitative trade model

We simulate the impact of changes in trade costs using the multi-country, multi-sector, general equilibrium trade model with input-output linkages developed by Antràs and Chor (2018; henceforth, A-C).

The model features N countries and S sectors and incorporates value chain trade through a so-called "roundabout" structure in which each industry produces a composite good with a Cobb-Douglas technology that mixes inelastically supplied labor with intermediate inputs;[9] composite goods may then either be consumed by the representative households of each country or be used as intermediates in the production of other goods. Finally, markets are perfectly competitive and trading across borders entails an iceberg cost. Moreover, it allows to simulate the trade flows from a sector k in a given country i toward a sector l in country j, distinguishing between intermediate and final goods. For example, an empirical counterpart of the model is the expenditure share of the Italian motor vehicle industry on energy-producing

[8] In the case of financial centers, multinationals' activity could lead to an overstatement of the exposure.
[9] The assumption on the production function implies that the elasticity of substitution across inputs is constant and equal to one.

inputs from Russia, another one is the share of the Italian electrical equipment industry or that of French final consumption.

Following Dekle et al. (2008), the equilibrium conditions can be characterized by using the data to characterize the starting point and expressing the variables of interest in terms of relative changes, after the shock on trade costs. Importantly, no information is required on the unobserved initial trade cost levels, which are not observable in the data, but only on their changes. This approach substantially decreases the number of parameters to calibrate and makes it easier to calculate the impact of trade cost changes on trade flows and welfare.

The A-C framework is well suited to study the effect of the restrictive measures on international trade bacause:

- It explicitly considers supply-chain linkages.
- It generates changes in trade at the country-sector level, thereby allowing us to study the impact of policy-induced trade shocks on specific industries that are particularly interesting for policymakers and to take into account countries' sectoral exposures.
- Its simulation only requires data directly available in input-output (I-O) tables.

The model, however, presents some limitations:

- Being a comparative statics exercise, it does not describe the adjustment and transition between two equilibria.
- It does not entail real and nominal rigidities, which may play a significant role in the current context.
- It assumes perfectly competitive markets and high substitutability among inputs in the production process, which may not be accurate for some critical inputs such as gas and oil.
- It requires formulating an assumption on the trade balances of each country after the trade shock. In this regard, we follow Antràs and Chor (2018) and Caliendo and Parro (2015) in assuming that the trade balances pre- and after- the restrictive measures are unchanged.

3.1. The simulation exercise

For the calibration, we rely on the OECD TiVA Inter-Country Input-Output Tables data for the year 2018, which is the most recent available year.[10] The data consist of inter-country input-output tables covering 67 countries (including the aggregate "Rest of the world") and 45 sectors.[11] Following official statements and news, we define the following as sanctioning countries: the European Union, the United Kingdom, the United States, Australia, Canada, Chile, Iceland, Japan, New Zealand, Republic of Korea, Singapore, Switzerland, and Taiwan.

We define the trade cost on a transaction from sector k in country i to sector l in country j as incorporating standard iceberg transport costs (IC), tariffs (T), and non-tariff barriers (NT) in a multiplicative way, namely:

$$\tau_{ij}^{kl} = IC_{ij}^{kl} \times T_{ij}^{kl} \times NT_{ij}^{kl}$$

[10] The simulations use data from the 2021 edition of the OECD Inter-Country Input-Output (ICIO) Tables. Detailed information and downloads available at http://oe.cd/icio. We obtain similar results using other sources of data, such as the World Input Output Database (2013 and 2016 editions) and the input-output tables provided by the Asian Development Bank. These alternatives differ from our main source in terms of geographical and time coverage.

[11] See Table A1 and Table A2 in the Appendix for the detailed list of countries and industries.

We assume that changes in trade costs arise from changes in the non-tariff barriers (NT_{ij}^{kl}) so that, for instance, a percentage change in that component entails the same variation in the overall trade cost, everything else being equal.[12] However, quantifying how much trade costs raise is very complicated due to the characteristics of the enforced restrictive measures.

To overcome this problem and simplify the interpretation of the results, we consider the impact of a wide range of trade cost increases instead of trying to quantify them. In selecting such ranges, we consider those that correspond to three scenarios with non-sanctioning countries' exports to Russia dropping by 20% (benign), 50% (intermediate), and 75% (severe).[13] In all scenarios, we assume that sanctioning countries coordinate and impose the same percentage trade cost increase on intermediate goods and final goods. Furthermore, we assume that changes in trade costs are bilateral so that Russia retaliates by imposing the same increases in trade barriers. Trade elasticities to trade costs are sector-specific (see table A2) and based on Cappariello et al. (2020).

Table 1. Change in Russian imports under alternative scenarios by country groups and sectors in response to an increase in trade costs

(*percentage change*)

	No restrictive measures on energy			**Restrictive measures extended to energy**		
	Benign	*Interm.*	*Severe*	*Benign*	*Interm.*	*Severe*
All countries	-9.52	-22.90	-33.44	-13.55	-33.67	-46.85
Energy sector	-1.60	-4.76	-2.87	-31.10	-60.49	-68.42
Non-energy sector	-9.66	-23.21	-33.97	-13.25	-33.21	-46.48
Sanctioning countries	**-21.10**	**-50.22**	**-75.07**	-25.23	-58.71	-81.68
Energy sector	-1.19	-3.76	-1.42	-50.17	-89.29	-97.38
Non-energy sector	-21.41	-50.95	-76.24	-24.84	-58.23	-81.43
Non-sanctioning countries	5.25	11.94	19.66	1.35	-1.72	-2.43
Energy sector	-2.04	-5.82	-4.40	-10.85	-29.91	-37.68
Non-energy sector	5.39	12.28	20.12	1.58	-1.19	-1.76

Source: OECD TiVA 2021 and authors' calculations.

Note: The figures refer to the percentage change in Russian imports from the indicated country groups ('All countries', 'Sanctioning countries', 'Non-sanctioning countries'). Within each country group, the first row represents the overall change in all sectors, the other rows distinguish the impact on imports in the 'Energy' (Mining and quarrying - energy producing products and Coke and refined petroleum products) and 'Non-energy' sectors.

In each scenario, we run a two-step simulation. First, we impose that trade costs increase in all industries except the energy sectors.[14] Second, we apply the same increases to *all* industries (i.e., including energy). In this manner, we can single out the impact of trade disruptions in the energy sectors. As a reference, Table 1 and Table 2 summarize some descriptive statistics of Russian imports and exports associated with the three scenarios. For each of them, we consider trade flows to and from three country groups ('All countries', 'Sanctioning countries', 'Non-sanctioning countries'), and we report the export change in the energy and

[12] This assumption entails *de facto* a decoupling between Russia and the sanctioning countries. The extent depends on the magnitude of the increase in trade barriers. This exercise is close to Felbermayr et al. (2022) who analyze different trade war scenarios in a standard Caliendo and Parro (2015) framework.

[13] The combinations of trade costs increases respectively on intermediate and final goods corresponding to the three scenarios are: +10% and +10% for the benign scenario; +50% and +20% for the intermediate one; +90% and +100% for the severe one.

[14] We define as energy-related the following sectors from the OECD TiVA : (i) 'mining and quarrying, energy producing products', (ii) 'coke and refined petroleum products', and 'electricity, gas, steam and air conditioning supply'.

non-energy sectors – in addition to the overall change. Moreover, we also show how the extension of sanctions to the energy sector would affect Russian exports ('No restrictive measures on energy' and 'Restrictive measures extended to energy').

Overall, the imports from non-sanctioning countries do increase but the total change in Russian imports is negative across scenarios. Similarly, the rise in sales to non-sanctioning countries do not fully offset the foregone exports to sanctioning ones. The extension of restrictive measures on the energy sector would cause a further drop in exports (from -19% to -30% in the severe scenario), driven by the reduction of flows toward sanctioning countries (from -32% to -80%), only partly offset by the increase in exports to the other countries (from -2% to +30%).[15]

Table 2. Change in Russian exports under alternative scenarios by country groups and sectors in response to an increase in trade costs

(*percentage change*)

	No restrictive measures on energy			**Restrictive measures extended to energy**		
	Benign	*Interm.*	*Severe*	*Benign*	*Interm.*	*Severe*
All countries	-5.06	-12.46	-18.52	-8.80	-22.12	-30.11
Energy sector	0.93	3.09	1.13	-10.69	-26.13	-34.78
Non-energy sector	-10.20	-25.81	-35.38	-7.17	-18.68	-26.10
Sanctioning countries	**-9.17**	**-22.73**	**-32.05**	-21.33	-58.49	-80.14
Energy sector	0.80	2.71	0.67	-24.02	-64.89	-87.44
Non-energy sector	-19.57	-49.27	-66.21	-18.51	-51.81	-72.51
Non-sanctioning countries	-0.14	-0.14	-2.28	6.24	21.53	29.93
Energy sector	1.12	3.67	1.82	9.59	32.83	45.32
Non-energy sector	-0.98	-2.72	-5.05	3.99	13.91	19.55

Source: OECD TiVA 2021 and authors' calculations.

Note: The figures refer to the percentage change in Russian exports towards the indicated country groups ('All countries', 'Sanctioning countries', 'Non-sanctioning countries'). Within each country group, the first row represents the overall change in all sectors, the other rows distinguish the impact on exports in the 'Energy' (Mining and quarrying - energy producing products and Coke and refined petroleum products) and 'Non-energy' sectors.

3.2. Impact on welfare

The simulations obtained excluding restrictive measures on the energy sector suggest that Russia is the most affected country in terms of welfare (Figure 2, left panel). The loss ranges from 1% (benign scenario) to 4% (severe scenario). The disruptions in energy trade imply much higher losses, going from 1.8% to 6.5%, depending on the scenario.

Among the other countries, the sanctioning ones are affected to a much lower extent (Figure 2, right panel) because sanctioning countries are able to substitute their trade with Russia with either domestic production or trade with other countries. For example, in the intermediate scenario the EU27 experiences a welfare loss equal to 0.13% or 0.28%, depending on whether measures on energy industries are imposed. Not surprisingly, the welfare loss experienced by the USA is one order of magnitude smaller than that of the EU, because the country is much less exposed to Russia. Overall, the relative magnitude of the results broadly confirms the descriptive analysis of Section 2 based on the OECD TiVA data.

[15] Russian exports in the energy sector slightly increase when no measures on energy commodities are enforced because the Russian energy commodities become more attractive due to the decrease in domestic wages.

Among non-sanctioning countries, China slightly benefits from the adoption of restrictive measures because of trade diversion. Overall, losses at the global level are only partially compensated. We estimate a (net) negative impact on the world welfare ranging from -0.02% (benign) to -0.10% (severe).[16]

Figure 3 reports the welfare losses for sanctioning countries associated with the severe scenario . When energy trade is not restricted, welfare losses are heterogeneous across countries:

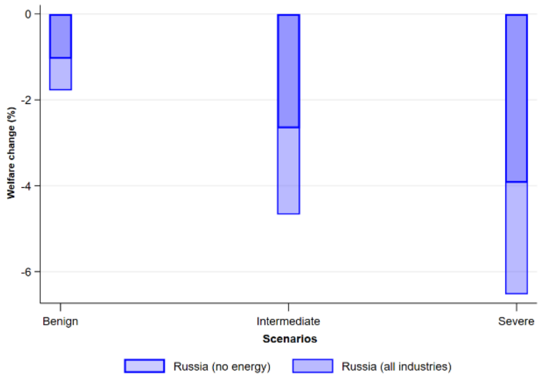
- The drop in welfare is larger for countries more integrated with the Russian economy such as Bulgaria, Lithuania, Slovakia, Hungary, and Latvia.
- Within the Euro area, Germany, Italy, France, and Spain face limited losses, amounting to 0.2%, 0.13%, 0.11%, and 0.07%, respectively.
- The reduction in welafare is smaller for countries located far away or with limited linkages with Russia, like New Zealand and the US.

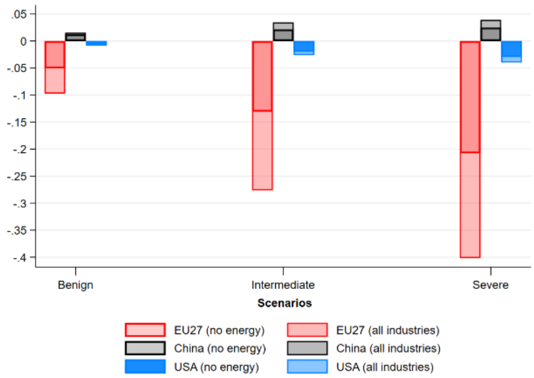
When restrictive measures are extended to the energy sector:

- The additional loss is larger for countries more exposed to energy imports from Russia, i.e., Eastern European countries.
- Among the largest EU countries, the drop for Germany, Italy, France, and Spain becomes 0.37%, 0.31%, 0.22%, and 0.13%, respectively.[17]

Figure 4 finally shows the impact on the welfare of non-sanctining countries which is generally low or slightly positive. When energy trade is restricted, Norway, Kazakhstan, Saudi Arabia benefit the most by replacing Russia as energy providers.

Figure 2. The impact of restrictive measures on welfare
- Russia and selected countries-





Sources: OECD TiVA 2021 and authors' calculations.
Note: The three scenarios differ in terms of trade cost increases. In each of them, the increase is chosen in order to generate a drop in Russian exports equal to -20% (benign), -50% (intermediate), and -75% (severe), respectively. EU27 and the United States are sanctioning countries in the exercise; China is not. Trade elasticities are from Cappariello et al. (2020). Welfare corresponds to real expenditure.

The role of supply chain linkages

The A-C model accounts for cross-sector, cross-country spillovers due to impairments to trade in intermediate products. Trade disruptions affect production processes throughout the value chain, with

[16] As trade balances at the world level, changes in world GDP and welfare are equal.

[17] The magnitude of the effects is in line with the results obtained for Germany and France by employing the model by Baqaee and Fahri (2021) in Bachmann et al. (2022) and Baqaee et al. (2022).

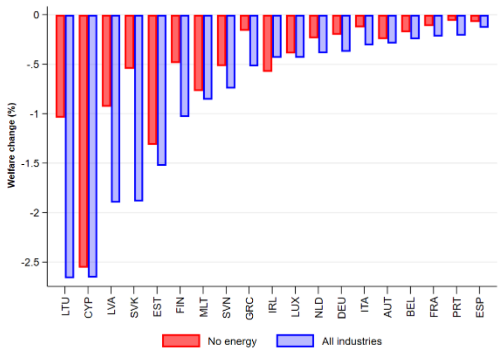
production costs affected at all stages. To quantify the amplification effects of supply chain linkages, we compare the welfare effects with global GVC with the same model in which trade would only involve final goods.[18] Figure 5 shows that this indirect effect through supply chains plays an important role in transmitting and amplifying trade disruptions between Russia and sanctioning countries. GVCs amplify the welfare effects of trade disruption largely: by at least 50% for some Eastern European countries and more than 100% for other European countries.[19] As discussed in Section 2, the fact that Russia is a key supplier of primary products (energy and raw materials), which are goods located upstream in the production process, explains the large cross-sector and cross-country amplification effects.

Sensitivity to trade elasticities and trade barriers

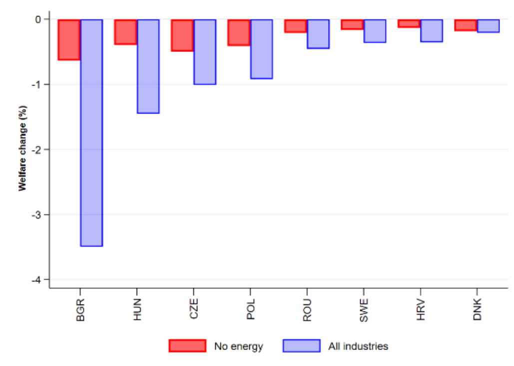
As a robustness check, we investigate the sensitivity of our results to trade elasticities changing them by +/- 20% for each sector from the baseline. With lower elasticities, we get an amplification of the welfare losses because it is more difficult for producers to find alternative suppliers when trade barriers increase. In other words, the benefits of trade diversion are partly offset. To account also for the uncertainty regarding the increase in trade barriers, we compare the effects of extending restrictions to the energy sector considering a grid of trade costs increases for final and intermediate goods, ranging from 10% to 100%, with an incremental step size of 10pp (Figure A1 in the Appendix). Our results remain in the same ballpark as those shown in Figure 2 and Figure 3.

Figure 3. The impact of restrictive measures on welfare by countries and country groups (Sanctioning countries, severe scenario)

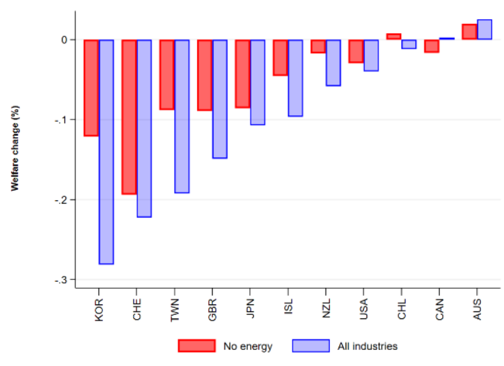
- Euro area -



- Other EU -



- Other sanctioning -

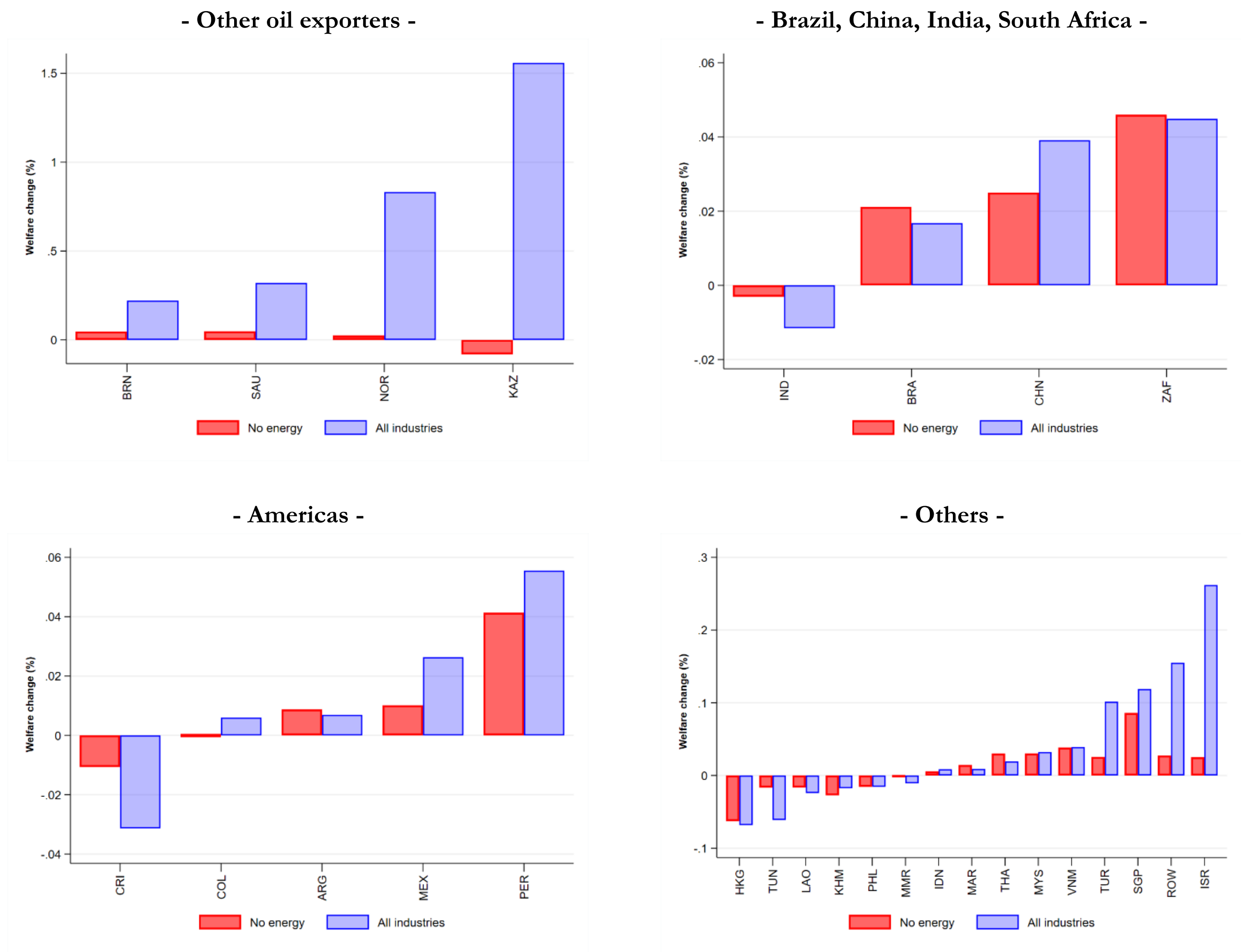


Sources: OECD TiVA 2021 and authors' calculations.
Note: Welfare change (%) represents the change in welfare (i) when trade costs increase in all sectors but oil and gas (red bars), (ii) when trade costs increase in all sectors (blue bars). Energy sector corresponds to 'Mining and quarrying, energy producing products', 'Coke and refined petroleum products', and 'Electricity, gas, steam and air conditioning supply'. Trade elasticities are from Cappariello et al. (2020). Welfare corresponds to real expenditure.

[18] Trade between sectors within a country is also totally attributed to final goods in the model without GVCs.

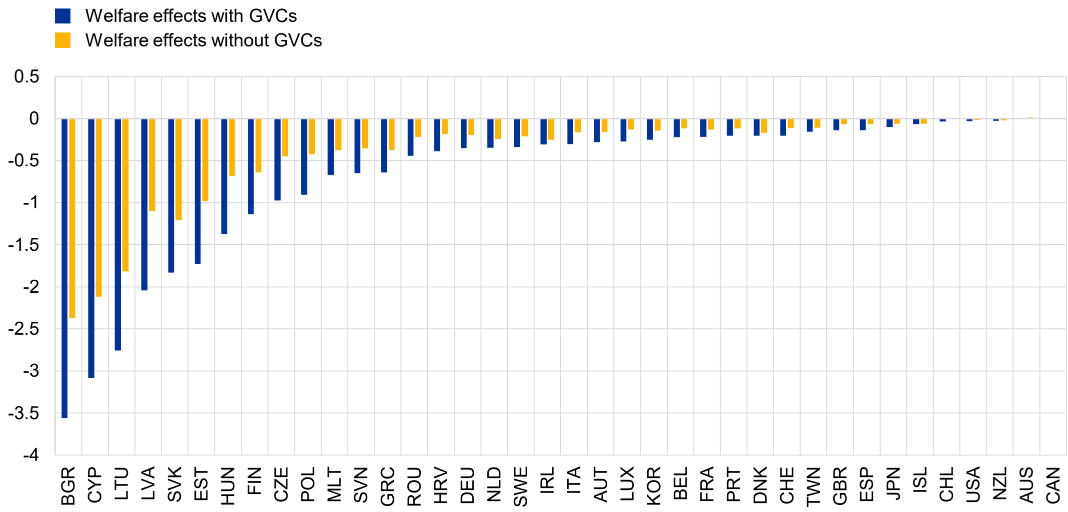
[19] Effects for Russia (not shown) are amplified by 83%.

Figure 4. The impact of restrictive measures on welfare by countries and country groups (Non-sanctioning countries, severe scenario)



Sources: OECD TiVA 2021 and authors' calculations.
Note: Welfare change (%) represents the change in welfare (i) when trade costs increase in all sectors but oil and gas (red bars), (ii) when trade costs increase in all sectors (blue bars). Energy sector corresponds to 'Mining and quarrying, energy producing products', 'Coke and refined petroleum products', and 'Electricity, gas, steam and air conditioning supply'. Trade elasticities are from Cappariello et al. (2020). Welfare corresponds to real expenditure.

Figure 5. Amplifying effects of global value chains
(Sanctioning countries, severe scenario)
(percentage drop in welfare)



Sources: OECD TiVA 2021 and authors' calculations.
Notes: The model with GVCs relies on a full input-output structure. The model without GVCs utilizes an altered input-output structure where trade in intermediate products is attributed to trade in final products.

4. A simplified framework for energy shortage

The A-C model yields relatively modest effects from restricting energy imports from Russia. Even assuming low levels for trade elasticities, firms and customers can adjust to the shock by sourcing products from other countries and smoothly change their input and consumption mix.[20] However, it is plausible that a sudden stop to a large share of imported energy may induce relevant shortages due to the difficulties of accessing alternative energy sources, at least in the short run. Contractual obligations and capacity constraints, for example, may dramatically reduce the cross-country reallocation of trade flows, especially in product markets like natural gas, whose transportation depends on specific infrastructures (pipelines, LNG regasification terminals).

It is complicated to embed these frictions into the A-C model and – more in general – into a complex general equilibrium framework. Alternatively, we complement our analysis by relying on Baqaee and Farhi (2021). They rely on a non-parametric production function that allows the cross-sectoral input substitutability to change, contrary to the A-C framework in which it is constantly equal to one. In particular, we consider a lower cross-sectoral input substitutability and a non-linear propagation of the shocks along the supply chain. In this case, the effects of an embargo of energy imports from Russia on EU countries remain modest and similar in magnitude to the results reported in Section 3.[21]

In another exercise, we also resort to a much simpler but tractable two-sector framework drawing from Bachmann et al. (2022) and Baqaee et al. (2022). Despite its simplicity, this basic modeling strategy allows us to consider severe energy shortages induced by a possible application of the restrictions to the energy sector and to estimate the effects on countries' welfare depending on basic assumptions on input

[20] The latter is partly driven by the Cobb-Douglas technology that lead to a unitary cross-sectoral elasticity of substitution of inputs.

[21] Our results are in line with Bachmann et al. (2022) who apply the model by Baqaee and Farhi (2021) on Germany finding a loss in GDP of about 0.3%.

substitutability. In the next subsection, we extend the simple calculations proposed by Bachmann et al. (2022) to a large set of countries.

4.1 The framework proposed by Bachmann et al. (2022)

Bachmann et al. (2022) resort to a parsimonious model to provide a general assessment of the possible effects of an embargo on Russia energy in the short run. In each country, the output is produced with imported energy (*E*) and other inputs (*X*), which also include other domestic sources of energy production (e.g., renewable sources). The production function features a constant elasticity of substitution (CES),

$$Y = \left[\alpha^{\frac{1}{\sigma}} E^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} X^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

where α is the so-called "share parameter," associated with the initial expenditure share on imported energy, and σ is the elasticity parameter that measures the substitutability between imported energy E and other inputs X. The cut in energy supply is modeled as an exogenous reduction of E.

When σ approaches 1, the production function is Cobb-Douglas, i.e., $Y = E^{\alpha} X^{1-\alpha}$. Therefore, changes in Y are proportional to changes in E with factor α, i.e., $\Delta logY = \alpha\, \Delta logE$. Instead, when $\sigma \to 0$, inputs cannot be substituted at all and the production function becomes a Leontief, i.e., $Y = min\left\{\frac{E}{\alpha}, \frac{X}{1-\alpha}\right\}$. In this case, each negative shock on E fully transmits to Y, i.e., $\Delta logY = \Delta logE$.

Many trade models, including A-C, rely on the Cobb-Douglas technology. However, the implied unitary elasticity of substitution may not adequately fit the limited cross-sectoral substitutability expected in the case of some inputs such as energy. When $0 < \sigma < 1$, it can be shown that the second-order approximation of the impact of a supply shock (affecting *E*) on output takes the following form: [22]

$$\Delta logY \approx \alpha \Delta logE + 0.5\left(1 - \frac{1}{\sigma}\right)\alpha(1-\alpha)\Delta logE^2.$$

When $\sigma = 1$, the second term goes disappears. It differs from zero when $0 < \sigma < 1$ adding a (negative) impact due to the low substitutability of the energy input. The magnitude of this effect becomes increasingly relevant as σ approaches zero.[23]

4.2 Shock design and calibration of the parameters

The size of the energy cut (i.e., $\Delta logE$) and the parameters α and σ determine the potential impact of the restrictive measures. Assuming a complete embargo on the Russian energy sector, $\Delta logE$, i.e., the magnitude of the shock on total imported energy, depends on the ability of countries to substitute Russian energy commodities with purchases from other providers. For instance, if imports from other energy producers compensate the entire volume of energy imported from Russia, $\Delta logE$ would be equal to zero. On the contrary, if the substitution is impossible, $\Delta logE$ would be equal to the entire dependency on

[22] While useful to highlight the mechanisms at play, the second order approximation is inaccurate for low levels of the elasticity of substitution. Therefore, we do not use it to compute the effects of a negative supply shock.

[23] In principle, it could be possible to retrieve the competitive equilibrium price that clears the imported energy market given the new supply level after the shock. However, one might argue that the *shadow price* obtained in this way might be lower than the actual equilibrium price of imported energy, especially in the gas market. The lack of pipelines and regasification terminals often do not allow agents to increase their demand and exert upward pressure on prices in the "wholesale" market (i.e., natural gas producers – distributors). Moreover, regulation and policy interventions might also prevent extreme increases in prices in the retail market (i.e., distributors – firms/households), so that the relative price of imported energy could remain below the marginal productivity (marginal utility) ratio.

Russian energy. The parameter α is the initial share of imported energy on total expenditure. We calibrate it for each country by using data from the latest release of the OECD TiVA. The value of α is equal to the ratio between a country's total imports in the two sectors associated with fossil fuels' production ('Mining and quarrying - energy producing products' and 'Coke and refined petroleum products') and the country's total expenditure.[24] Finally, the elasticity of substitution σ shapes the possibility of replacing E with inputs in X, for instance other domestic sources (e.g., renewable energy) or other products.[25]

Choosing the assumptions on the imported energy shortfall ($\Delta logE$) for a large set of countries is critical. The framework of Bachmann et al. (2022) presents relevant limitations in this regard. On the one hand, general equilibrium models with inter-country linkages such as A-C may overlook the frictions that reduce international reallocation of the goods, especially in the short run. On the other hand, the country-by-country approach of Bachmann et al. (2022) ignores that a certain degree of international integration across markets always exists. Clearly, the two-sector model discussed here is not suited to endogenously account for country interdependences, the substitution of energy supply through trade, impact on international commodity prices. Extending the analysis by simply reproducing the same computation country by country would entail assuming that each economy is isolated from the others and that the energy market is segmented along national borders. Under this hypothesis, the effect of a ban on Russian energy products would be only a function of countries' energy dependency on Russian exports.[26] When extending Bachmann et al. (2022) to a large set of countries, we account for some integration among them by carefully designing and calibrating the energy shock.

In a nutshell, we focus on two scenarios, **adverse** and **severe**, which differ in the degree of substitutability of the energy inputs across countries and between the two sectors (energy and other inputs). For each economy, the magnitude of the energy shock depends on *i*) the enforcement of restrictive measures, and *ii*) the reliance on imports from Russia. Moreover, we assume that sanctioning countries can partly substitute Russian imports with energy products imported from other countries, while non-sanctioning countries are somehow affected by the tightness in international commodity markets caused by the restrictions. Indeed, although non-sanctioning countries can buy Russian commodities at a discounted price, this benefit may not fully compensate for the general increase in international commodities prices caused by the measures. This assumption is especially suitable for products like natural gas, which are hard to redirect towards other destinations through existing pipelines.

When a complete or partial ban on Russian energy exports comes into force, we may expect some reallocation of energy supply across the globe. For example, sanctioning countries may start to import more from other energy exporters, while non-sanctioning ones may source more from Russia and less from other suppliers. However, due to contractual frictions and infrastructure constraints, reallocation is incomplete, and total energy supply decreases globally. To this end, we assume that the overall reduction of energy supply is equal to 35% (adverse scenario) and 60% (severe) of total Russian exports of energy commodities. We also assume that about 25% of the supply shortfall affects non-sanctioning countries. Since each group

[24] Using OECD TiVA data, we can obtain a homogenous calibration for all the 67 countries covered by the dataset. However, this choice has some drawbacks. First, it is not possible to distinguish different energy sources, since Input-Output tables sectors are too aggregated. Second, the latest year available is 2018.

[25] In a dynamic framework, another factor could affect the ability to substitute away from Russian exports in the energy sector. When a reduction in global supply occurs, countries may find it hard to find alternative sources for energy products not only for technological reasons but also because they may have a lower bargaining power for supplies than other competing countries.

[26] This is an extreme assumption, as it completely disregards the potential substitution with imports from other foreign sources or the potential international spillovers through commodity prices and potential coordination and competition among countries in securing alternative supply sources. This is particularly true when considering the market for energy commodities such as oil and coal, which are traded on public exchanges.

of countries accounts for about half of Russian overall energy exports, we are implicitly assuming that the cut in energy imports is, on average, three times larger for sanctioning countries than for non-sanctioning ones. All non-sanctioning countries have the same reduction in total energy imports. Consistently with the assumptions described above, this is equal to -2% and -4% in the adverse and severe scenarios, respectively. For sanctioning countries, the shock consists of two components with similar weights on the cut of energy supply. The first component is equal for all the countries of the group (-3.5% and -6% of total energy imports in the adverse and severe scenarios, respectively), while the second one is proportional to the dependency on Russian energy imports. This scheme implicitly assumes some modest level of solidarity within the group of sanctioning countries, which mitigates the disruptive effect of the embargo on the most exposed countries.

The overall cut in energy imports for each country is reported in Figure 6. Altogether, for EU countries, the assumptions imply an average cut of about 8% (14%) of the total energy imports in the adverse (severe) scenario, which corresponds to about 25% (42%) of the total energy that the EU imports from Russia. These assumptions are arbitrary, but they are broadly consistent with the evaluations of international agencies on the possibility of substituting Russian energy imports in the short run with purchases from other countries.[27] For instance, consistently with the International Energy Agency's short-run evaluations,[28] the adverse scenario considers the case in which the EU imposes a full embargo on Russia's energy products, In this case, oil and coal imports are fully compensated by purchases from other countries while about 20% of Russian natural gas is sourced from other countries. The severe scenario broadly corresponds to the case in which frictions extend to the oil and coal markets so that a perfect substitution of imports cannot immediately occur.

Importing energy products from other countries is not the only way to compensate for the cut in Russian supply.[29] Indeed, it might be possible to substitute imported energy with other factors of production (i.e., σ). In considering a plausible range for σ, we ruled out the Leontief case, which is implausible even in the short run at the aggregate level (see Jones, 2005). It is important to remember that the elasticity of substitution is not only a measure of substitutability between imported energy inputs and other factors of production but also includes energy savings due to higher efficiency and changes in customers' behavior. From an empirical standpoint, estimated short-run (within one year) elasticities range from 0.02 to 0.29 (see Labandeira et al., 2017). Bachmann et al. (2022) consider that an elasticity equal to 0.04 can be regarded as a "very conservative" assumption when assessing the average effect at the one-year horizon. In presenting the results, we take elasticities in the range [0.03, 0.10], which is large in the literature. Considering the entire range allows us to show how the economic impacts vary depending on the assumptions about the elasticity of substitution. Within this range and in line with Bachmann et al. (2022), an elasticity equal to 0.04 can be considered a conservative reference point for the adverse scenario. Moreover, we select an even lower elasticity equal to 0.035 as a reference value for the severe scenario. Despite the small difference, this change in elasticity has a non-negligible impact, given the highly non-linear relationship.

[27] See, for evaluations by International Energy Agency (https://www.iea.org/news/how-europe-can-cut-natural-gas-imports-from-russia-significantly-within-a-year) and by the European Commission (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN).

[28] At the current prices, natural gas accounts for about 33% of the energy products that the EU imports from Russia. According to the IEA, only 20% of it can be substituted with imports from other countries within a year. This means that the EU27 has to cut energy imports by about 80% of Russian gas or about 26% (i.e., 33% x 80%) of total energy imports, which is very similar to the "adverse" scenario hypothesis.

[29] For instance, IEA e EU Commission plans include the possibility of increasing domestic productions of energy (e.g., renewable sources, nuclear energy), as well as implementing various strategies to reduce overall energy consumption (e.g., increase energy efficiency, change customers' behavior)

As a final remark, our exercise assumes σ to be constant over time, and it proposes a comparative statics following an energy shock. However, countries develop alternative strategies to absorb the shocks so that the parameter σ can actually increase over time.

4.3 Results

Compared to a situation with no energy disruption, in the short run the enforcement of restrictive measures on the energy sector would lead to an additional loss in euro area welfare of around 0.8% and 3.0% in the adverse and severe scenarios, respectively, once we assume low and very conservative levels of substitutability.[30] Given the lower direct exposure to Russian energy, losses for other countries would be more limited. In fact, at the global level, excluding the euro area and Russia itself, the welfare contraction is around 0.2% and 0.7% in the two scenarios (Figure 7). For countries with a relatively high dependency on Russian oil and gas, the effects can be sizable, especially when assuming low substitutability with other sources. Indeed, the assumption about the elasticity of substitution σ plays a key role in determining the results. Figure 8 and Figure 9 highlight the non-linear relation between the welfare effects and the elasticity of substitution. The non-linearity is more pronounced when the elasticity is closer to zero. Indeed, the lower substitutability assumed in the severe scenario (0.035) per se implies an additional loss of 0.5% in the Euro Area, compared to a severe scenario with the same substitutability (0.04) assumed for both scenarios. As reported in Figure 10 and Figure 11, countries' heterogeneity is substantial, reflecting the level of dependency on Russian energy. However, if we assume that available energy can be redistributed within the EU27 through "solidarity" mechanisms, the losses for more vulnerable countries are considerably lower with a modest impact on the other economies (see Figure 12).

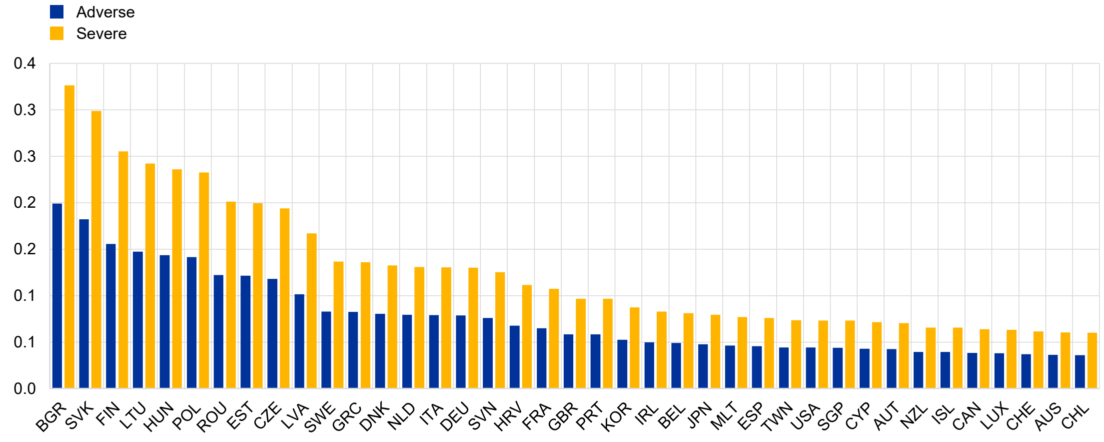
In addition, it is also possible to report the effects of a reduction in Russian energy supply for the adverse and severe scenarios only due to an elasticity of substitution lower than one. In other terms, we might subtract from the total effect based on a CES production function the effect that would be found in the standard Cobb-Douglas case. The latter result might be useful if the effect has to be added to static or dynamic models, which already feature the trade and the commodity price channels.

Compared to a situation with no energy disruptions, in the severe (adverse) scenario, the effects on euro area GDP not taken into account through standard trade or commodity channels might be between 0.5% and 3.2% of GDP (0.1% and 0.9%). If we consider conservative levels for the elasticity (0.04 and 0.035, respectively), the GDP loss in the euro area would be equal to 0.5% in the adverse scenario (2.5% in the severe one). These results and country-level evidence are reported in Figures A2-A5 in the Appendix.

[30] Here we report the effects on real Gross National Expenditure or domestic absorption, which equals welfare in this simplified framework. This does not exactly correspond to GDP. However, as reported in Bachmann et al. (2022) the difference is rather small, as in the case of Germany GNE is about 94% of German GDP. According to OECD TiVA data, on average GNE is around 99% of GDP in our country sample. Given the high uncertainty of the effects, driven by the non-linearity in the elasticity parameter, we believe that the effects reported on GNE are a good proxy for GDP.

Figure 6: Imported energy reduction for sanctioning countries

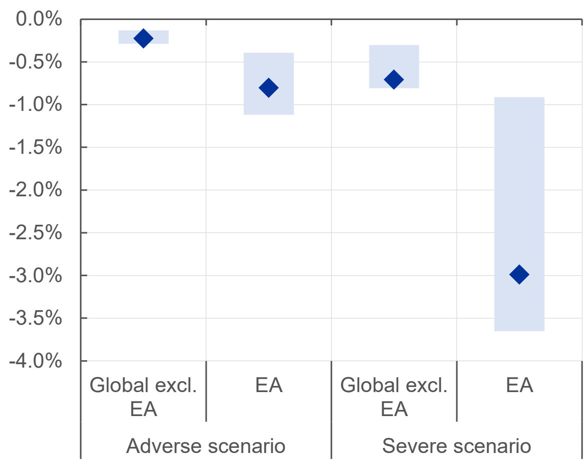
(share of total imported energy)



Source: own calculations based on OECD TiVA.

Figure 7: Production-side effects of energy disruptions

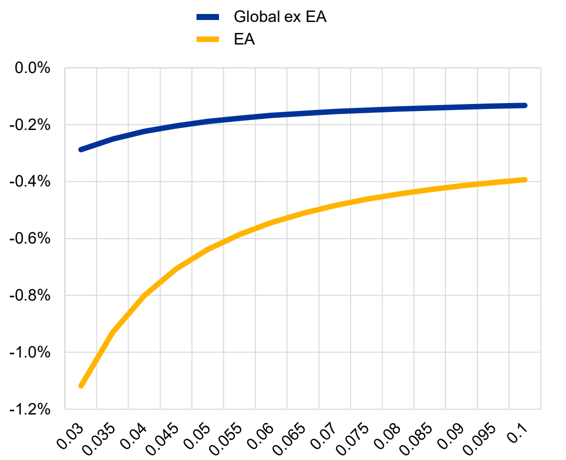
(percentage drop in welfare)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022).

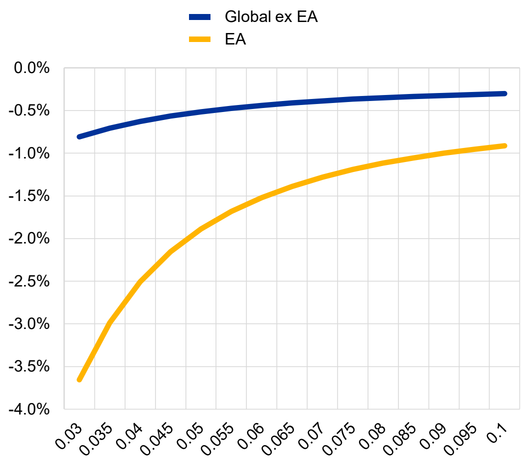
Notes: shaded areas report the effects obtained within the range [0.03; 0.1] for the elasticity of substitution.

Figure 8: Effect of energy disruptions in the short run for different substitutability, adverse scenario



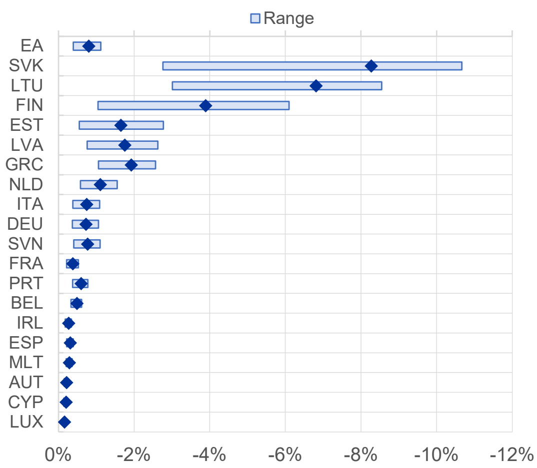
Source: own calculations based on OECD TiVA and Bachmann et al. (2022).

Figure 9: Effect of energy disruptions in the short run for different substitutability, severe scenario



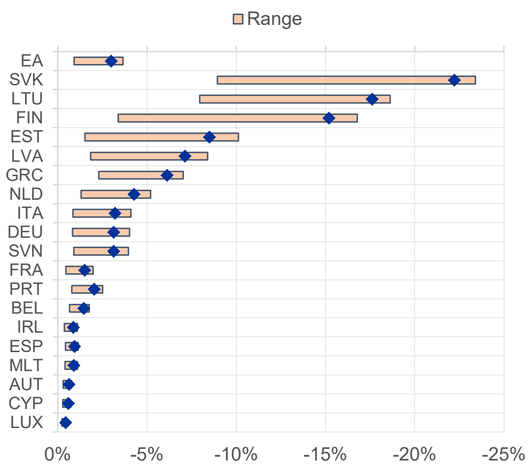
Source: own calculations based on OECD TiVA and Bachmann et al. (2022).

Figure 10: Short-run effect of energy disruptions on EA countries Adverse scenario (%)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022).
Notes: shaded areas report the effects obtained within the range [0.03,0.10] of the elasticity of substitution. Diamonds indicate the results corresponding to an elasticity equal to 0.04.

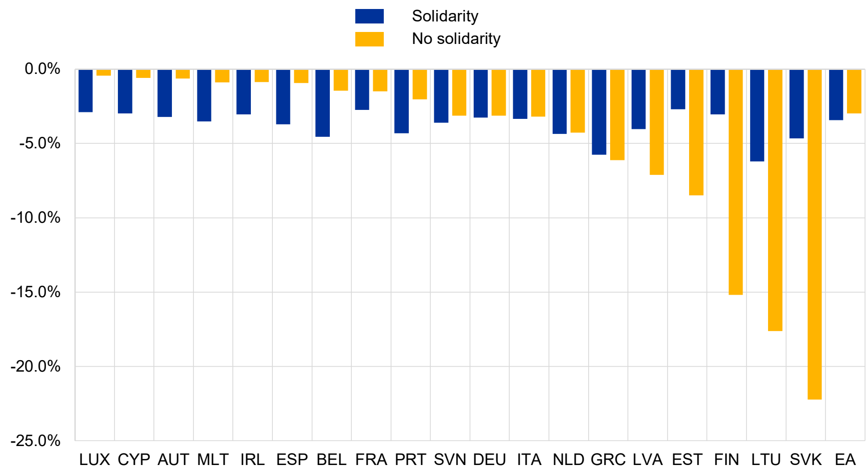
Figure 11: Short-run effect of energy disruptions on EA countries Severe scenario (%)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022).
Notes: shaded areas report the effects obtained within the range [0.03,0.10] of the elasticity of substitution. Diamonds indicate the results corresponding to an elasticity equal to 0.035.

Figure 12: Production-side effects of energy disruptions, severe scenario with solidarity

(percentage drop in welfare)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022).
Notes: elasticity of substitution equal to 0.035.

5. Concluding remarks

This work provides a quantification of the impact of restrictive measures that followed the Russian invasion of Ukraine on the welfare of 67 countries. We first exploit a multi-sector, multi-country general equilibrium model of international trade to evaluate the effect of trade disruptions following the Russian invasion of Ukraine. We also provide an assessment of the additional effect of extending the ongoing restrictive measures to the energy sector. Given the model limitation in considering the frictions associated with a sudden stop of imports of energy from Russia, we try to obtain a broader range of the possible effects of this measure in the short run by resorting to the very simple two-sector model used by Bachmann et al. (2022) to analyze the case of Germany.

The main results of the simulation exercises are the following:

- Restrictive measures have the strongest impact on Russia. Its welfare (in real terms) losses range from 1% to 6%, depending on the severity of the measures and on the hypotheses regarding the associated drop in trade with Russia.
- Sanctioning countries are also negatively affected. Specifically, those highly integrated with Russia experience the largest decrease in welfare.
- Non-sanctioning countries are relatively shielded from restrictive measures in all scenarios. Some of these countries experience minor welfare losses, while some others slightly gain from trade diversion effects, most notably China and oil exporters.
- The extension of ongoing measures to the energy sector magnifies the losses for Russia and for sanctioning countries. According to simulations based on the general equilibrium quantitative trade model by Antràs and Chor (2018), welfare reductions would be quite modest, up to 0.4% for EU27.
- In a framework that allows for relatively low substitutability of Russian energy, the magnitude of the effects on welfare can increase markedly, reaching about 4% for EU27 in the short run.
- Overall, the results for an extension of sanctions to the energy sector critically depend on the underlying assumptions regarding energy substitution and the associated large uncertainty around substitutability.

These are some policy implications one can draw from our simulation results:

- Trade restrictive measures impose larger welfare losses on Russia than on sanctioning countries.
- Extending the measures to the energy sector appears to be effective in imposing additional adverse effects on Russia but may have non-negligible effects on some sanctioning countries in the short-run as well, especially in case of very limited diversification of energy sources.
- Coordinated initiatives among EU countries aiming at diversifying away from Russian energy may significantly mitigate the non-negligible effects that an embargo would have on the member states highly dependent on Russian energy commodities.

APPENDIX

Table A1. List of countries in the OECD TiVA data

Argentina	Indonesia	Russian Federation
Australia	Israel	Saudi Arabia
Brazil	Japan	Singapore
Brunei Darussalam	Kazakhstan	South Africa
Cambodia	Republic of Korea	Switzerland
Canada	Lao People's Democratic Republic	Taiwan
Chile	Malaysia	Thailand
China	Mexico	Tunisia
Colombia	Morocco	Turkey
Costa Rica	Myanmar	United Kingdom
European Union (27 countries)	New Zealand	United States
Hong Kong	Norway	Viet Nam
Iceland	Peru	*Rest of the world*
India	Philippines	

Source: OECD TiVA 2021 and authors' elaboration.

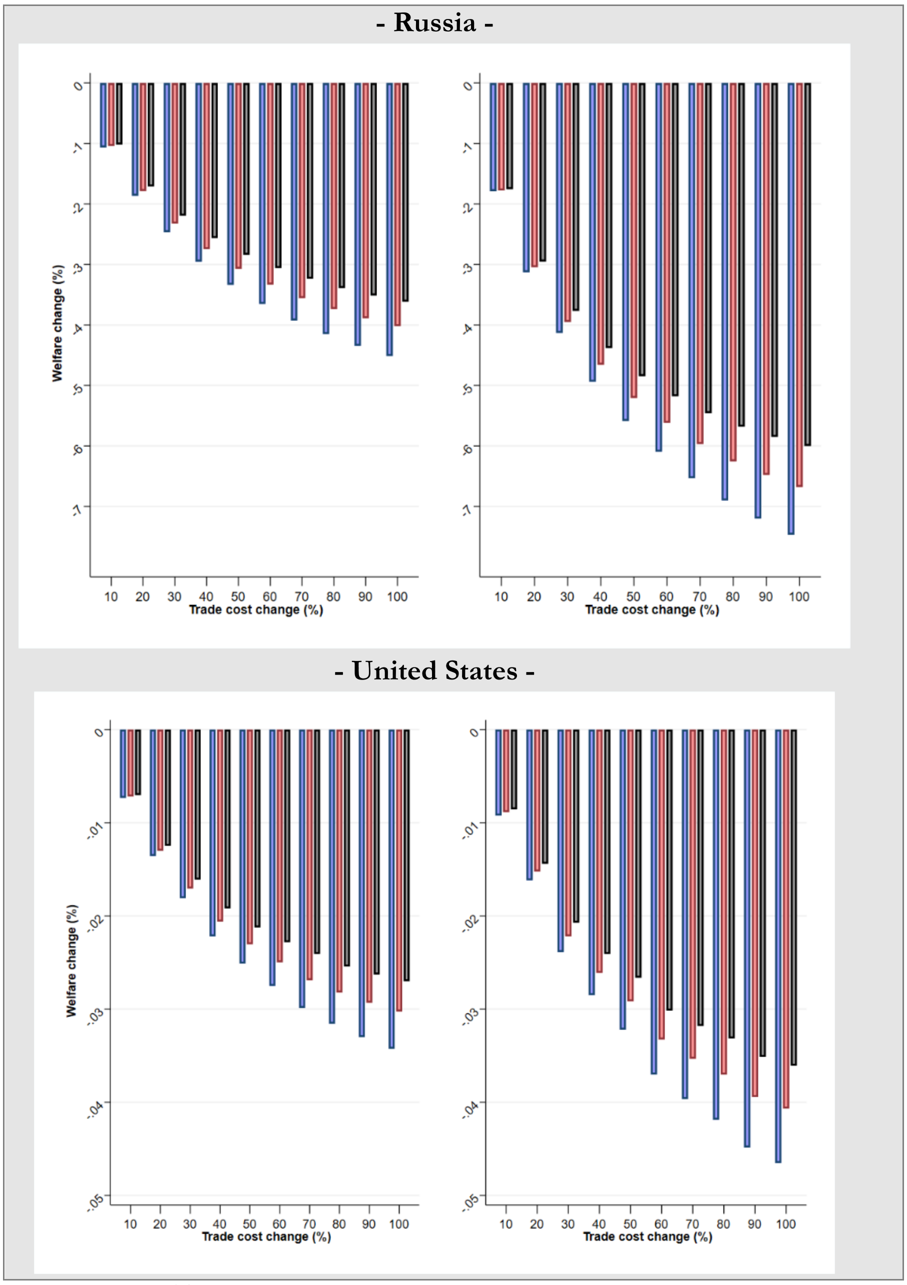
Note: sanctioning countries are highlighted in yellow, and groups of countries are in italic; the European Union includes Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

Table A2. List of industries in the OECD TiVA data

Code	*Description*	*Elasticity*
D01T02	Agriculture, hunting, forestry	1.956
D03	Fishing and aquaculture	3.584
D05T06	Mining and quarrying, energy producing products	3.584
D07T08	Mining and quarrying, non-energy producing products	3.584
D09	Mining support service activities	1.559
D10T12	Food products, beverages and tobacco	1.634
D13T15	Textiles, textile products, leather and footwear	3.584
D16	Wood and products of wood and cork	3.584
D17T18	Paper products and printing	1.037
D19	Coke and refined petroleum products	6.039
D20	Chemical and chemical products	3.776
D21	Pharmaceuticals, medicinal chemical and botanical products	5.703
D22	Rubber and plastics products	2.815
D23	Other non-metallic mineral products	1.417
D24	Basic metals	4.715
D25	Fabricated metal products	1.841
D26	Computer, electronic and optical equipment	5.731
D27	Electrical equipment	6.424
D28	Machinery and equipment, nec	7.509
D29	Motor vehicles, trailers and semi-trailers	4.39
D30	Other transport equipment	5.173
D31T33	Manufacturing nec; repair and installation of machinery and equipment	2.485
D35	Electricity, gas, steam and air conditioning supply	1.559
D36T39	Water supply; sewerage, waste management and remediation activities	1.559
D41T43	Construction	1.559
D45T47	Wholesale and retail trade; repair of motor vehicles	1.559
D49	Land transport and transport via pipelines	1.559
D50	Water transport	1.559
D51	Air transport	1.559
D52	Warehousing and support activities for transportation	1.559
D53	Postal and courier activities	1.559
D55T56	Accommodation and food service activities	1.559
D58T60	Publishing, audiovisual and broadcasting activities	1.559
D61	Telecommunications	1.559
D62T63	IT and other information services	1.559
D64T66	Financial and insurance activities	1.559
D68	Real estate activities	1.559
D69T75	Professional, scientific and technical activities	1.559
D77T82	Administrative and support services	1.559
D84	Public administration and defence; compulsory social security	1.559
D85	Education	1.559
D86T88	Human health and social work activities	1.559
D90T93	Arts, entertainment and recreation	1.559
D94T96	Other service activities	1.559
D97T98	HHs' activities as employers; HHs' undifferentiated goods-and services-producing activities for own use	1.559

Source: OECD TiVA 2021 and authors' elaboration, trade elasticities are from Cappariello et al. (2020).

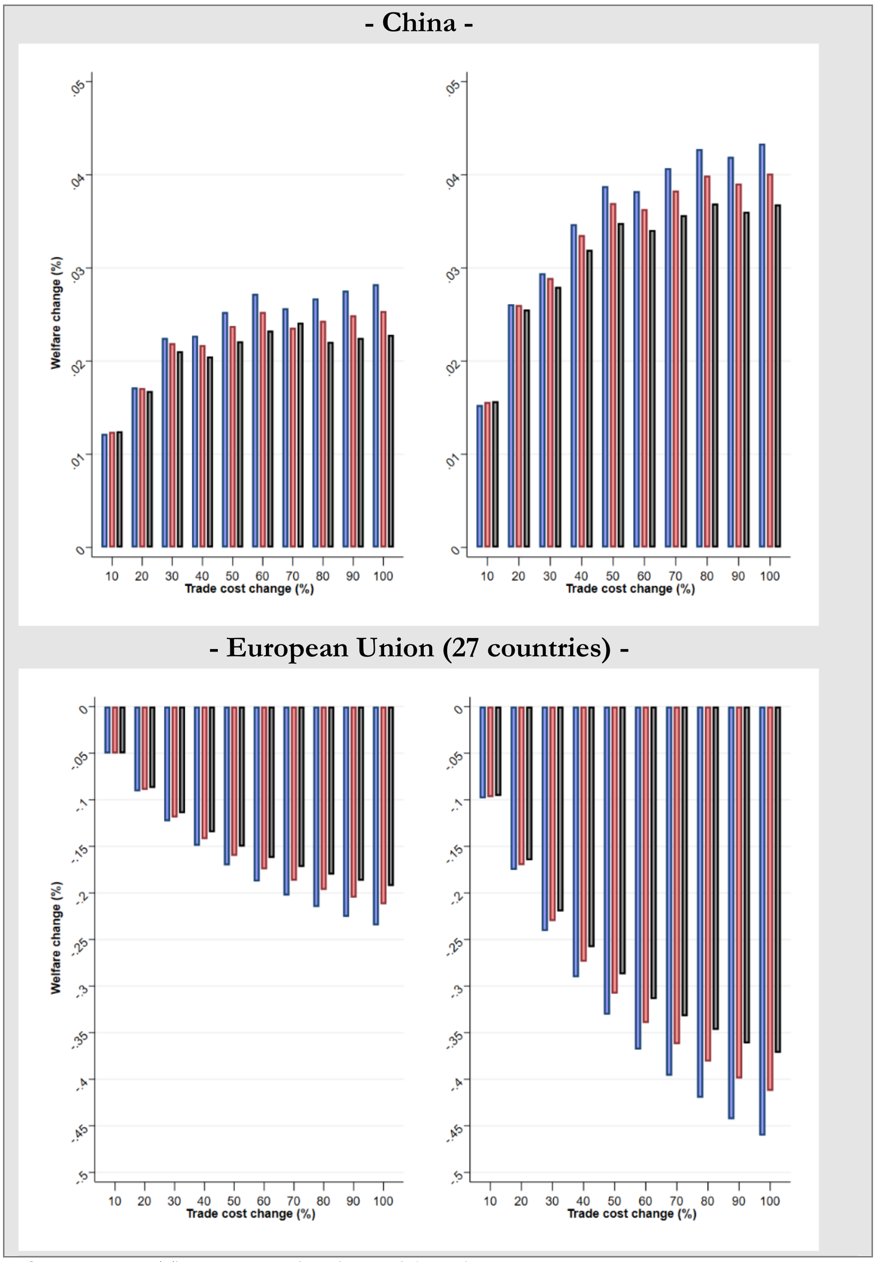
Figure A1. Impact of restrictive measures on welfare for selected combinations of parameters



Source: OECD TiVA 2021 and authors' elaboration.

Note: Left panels simulate the scenario with restrictive measures in all industries, excluding oil; right panels simulate the scenario with measures extended to the energy sector, as well. Baseline trade elasticities are from Cappariello et al. (2020); low elasticities reduce the baseline elasticities by 20%; high elasticities increase the baseline elasticities by 20%.

Figure A1. (cont'd)

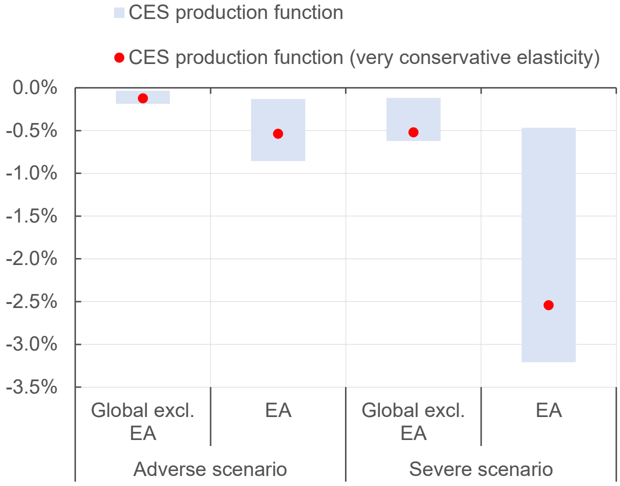


Source: OECD TiVA 2021 and authors' elaboration.

Note: Left panels simulate the scenario with restrictive measures in all industries, excluding oil; right panels simulate the scenario with measures extended to the energy sector, as well. Baseline trade elasticities are from Cappariello et al. (2020); low elasticities reduce the baseline elasticities by 20%; high elasticities increase the baseline elasticities by 20%.

Figure A2. Production-side effects of energy disruptions

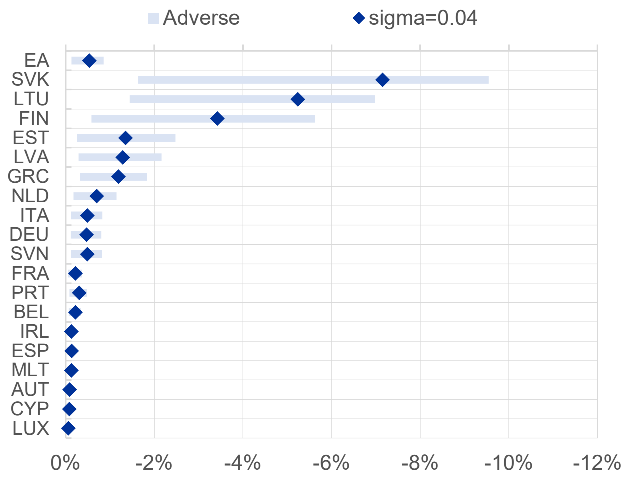
(percentage drop in welfare)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022). Notes: shaded areas report the effects obtained within the range [0.03,0.10] of the elasticity of substitution. Conservative elasticity is equal to 0.04 in the adverse scenario and 0.035 in the severe scenario.

Figure A3. Effect of energy disruptions in the short run, adverse scenario EA country results

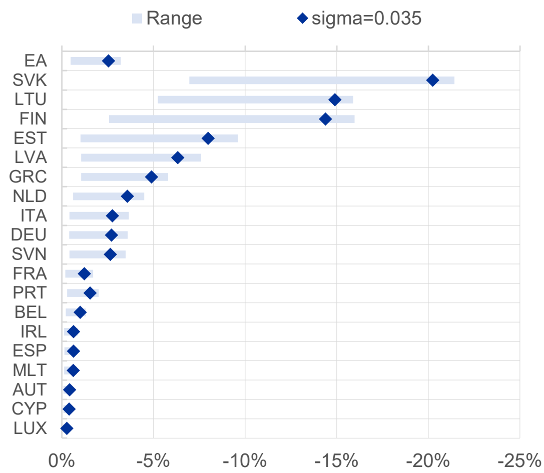
(percentage drop in welfare)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022). Notes: shaded areas report the effects obtained within the range [0.03,0.10] of the elasticity of substitution.

Figure A4. Effect of energy disruptions in the short run, severe scenario EA country results

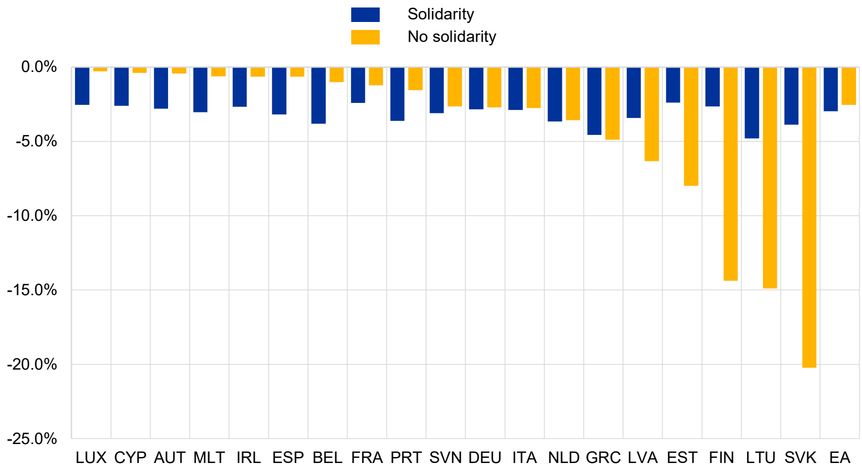
(percentage drop in welfare)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022). Notes: shaded areas report the effects obtained within the range [0.03,0.10] of the elasticity of substitution.

Figure A5. Production-side effects of energy disruptions, severe scenario with solidarity

(percentage drop in welfare)



Source: own calculations based on OECD TiVA and Bachmann et al. (2022).
Notes: elasticity of substitution equal to 0.035.

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