Available online at www.sciencedirect.com

ScienceDirect

Journal of Policy Modeling 45 (2023) 305–319

www.elsevier.com/locate/jpm

The cost of war: Impact of sanctions on Russia following the invasion of Ukraine☆

Nobuhiro Hosoe

National Graduate Institute for Policy Studies, 7–22-1 Roppongi, Minato, Tokyo 106–8677, Japan

Received 23 October 2022; Received in revised form 12 March 2023; Accepted 2 April 2023
Available online 14 April 2023

Abstract

We use a computable general equilibrium model of world trade to quantify the possible impact of economic sanctions imposed by Western and other countries in response to Russia's invasion of Ukraine. If sender countries chose 100 % import tariffs and export taxes on trade with Russia, Russia's GDP would decline by 3–7 % due to the resulting significant reduction in exports. By contrast, the GDP loss for those countries would be 0.2 % for the European economies, but only about 0.05 % for Japan. Although unlikely, the effect of China's participation in the sanctions would be more significant than that of India. There are concerns about food and energy crises due to economic sanctions against Russia, but the effect on food supplies would not be a serious problem for either senders or third parties. The impact on energy supplies would affect all senders to some extent; for example, there would be a 3% reduction of energy consumption and a 3–4 % rise in electricity and town gas prices in Japan.

Keywords: Russian invasion; Ukraine; Economic sanctions; Energy security; Food security; Simulation

1. Introduction

In response to Russia's invasion of Ukraine, which began in February 2022, several countries—notably the United States and some European nations—demanded an immediate halt to the military invasion. Although military intervention is a common countermeasure to such

☆ The author thanks Toshitaka Gokan and the anonymous referees for their helpful comments and suggestions and gratefully acknowledges that this research was supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (No. 19K01622).

E-mail address: nhosoe@grips.ac.jp.

https://doi.org/10.1016/j.jpolmod.2023.04.001

military aggression, it is difficult to intervene against Russia, a nuclear power, considering the possibility that such intervention could trigger another world war. In addition, as a permanent member of the United Nations Security Council, Russia renders the United Nations dysfunctional regarding management of the Russia–Ukraine war. Rather than intervening, the United States, Europe, and Japan have taken the lead in imposing economic sanctions, particularly the blockage of Russia's fuel exports (natural gas, oil, and coal) to prevent Russia from earning foreign currency, and to restrict imports to impede Russian domestic economic activity. Those nations also decided to block access to financial markets and freeze the foreign currency and gold reserves of government agencies, and the personal assets of key government and business officials. The crisis triggered oil and wheat price hikes just after the war began, but prices returned to pre-crisis levels as of January 2023.

As the Russian veto has crippled the Security Council, the Security Council cannot impose the same kind of economic sanctions on Russia that it has imposed on Iran and North Korea. The UN General Assembly passed a withdrawal resolution by a majority vote. While it is not surprising that Russia and five other countries, including Belarus and North Korea, opposed the vote, the fact that 35 countries, including China and India, abstained shows that there are many countries in the world whose attitudes toward Russia differ significantly from those of Western countries. The economic sanctions have been imposed primarily by Western countries plus Japan. The "list of unfriendly countries" designated by Russia (dated March 5, 2022) indicates that only 48 countries and regions are imposing some form of sanctions.

In the work to assess the impacts of economic sanctions against Russia, we have not yet established common assumptions and analytical frameworks, because the full scope of the sanctions—sanction measures and countries involved—is still in flux, and the military invasion operation is ongoing. With a motivation like that of this study, Kumagai et al. (2022) use a computable general equilibrium (CGE) model that incorporates economies of agglomeration, à la Krugman (1991), to simulate prohibitively high transportation costs at the Russian border as an economic sanction. The results show that Russia's GDP would decline by 15.8 % if logistics at all Russian borders were impeded, and by 4.6 % if logistics were affected at all Russian borders except that with China. The authors report that these logistical impediments would impact Japan, with a 1.7 % decline in automobiles and a 2 % decline in production in the textile, clothing, and food processing sectors, while Japan's GDP would decline by just 0.1 %.[1] Chepeliev et al. (2022) use a world trade dynamic CGE model based on the Global Trade Analysis Project (GTAP) 10 Power Database (Chepeliev, 2020), to simulate the restriction of fossil fuel imports from Russia (natural gas, oil, coal, and petroleum products) by the European Union (EU) and other high-income countries; they find that that restriction would reduce imports by half in the short run and by 70–90 % in the long run. This would reduce Russia's annual real income by 4–8 %, while the EU's loss would be limited to about 0.04 % per year.

Economic sanctions were imposed on Russia after the outset of Russia's invasion of Ukraine and during the annexation of the Crimean Peninsula in 2014. Those sanctions targeted specific sectors (especially oil), corporations, and individuals, rather than trade in general. Ahn and Ludema (2020) measure the impacts of these sanctions using firm- and individual-level data. Financial sanctions isolated Russia from global financial markets (Nivorozhkin and Castagneto-

[1] Kumagai et al. (2023) simulate a mutual imposition of nontariff barriers in the range of 12–21% on trade between Russia-Belarus and Western coalitions, comparable to the nontariff barriers observed in the US-China trade war; they predict a 0.6% decrease in Russia's GDP and 0.1–0.2% losses for members of the Western coalition.

Gissey, 2016). However, the impacts of the sanctions were not as large as that of oil price fluctuations observed in the same period (Dreger et al., 2016). If sanctions had been imposed on a broader range of trade, Russia would not have been able to sustain its business activities with only natural resource exports; exit by firms would be accelerated by the resulting decline in trade (Iwasaki et al., 2016). The sanctions against Russia spilled over negatively to trade and direct investment between Russia and former Soviet Union countries (Sedrakyan, 2022).

As well as fossil fuel supplies from Russia, food supplies are also at stake globally (Dalheimer et al., 2021).[2] This is a crucial problem, especially for low-income countries in Africa, which are reluctant to confront Russia with economic sanctions. Therefore, analyses of sanctions on Russia need to address the problem of food security, especially wheat. Since Ukraine, a breadbasket country, has been damaged by the war, food supplies from Russia have greater significance. As Kumagai et al. (2022) carefully consider, China's participation in the sanctions would be crucial for their success. No matter how strict the sanctions imposed are, loopholes in sanctions against Russia would undermine their effectiveness and increase the burden on those affected by them. Belarus is likely to engage in reexports for Russia so that Russian can evade the sanctions. How effective would the sanctions be, with and without China and India? How much collateral damage would be imposed on third parties, such as African developing countries? How much damage would those countries incur were they to participate in the sanctions?

Economic sanctions can be seen as a reversal of economic integration, if we focus on the trade aspect, on issues such as Brexit (Dhingra et al., 2017; Hosoe, 2018; Ortiz Valverde & Latorre, 2020) and the US–Mexico–Canada Agreement (Burfisher et al., 2019; Hosoe, 2022; United States International Trade Commission, 2019). Brexit is a case of self-sanctioning by the United Kingdom (UK), who allowed the EU 27 to impose higher tariffs and other trade barriers in order to achieve UK economic sovereignty. Export controls share the same political goals—to prevent and/or stop warfare with economic sanctions—and can be analyzed by taking a similar approach (Hosoe, 2020; Shin and Balistreri, 2022).

Setting aside the question of whether economic sanctions would effectively force Russia to abandon its military invasion, this study examines whether and to what extent economic sanctions could damage the Russian economy and the extent to which the impact would be enhanced by enlarging the coalition. That is, like other economic studies on sanctions, we evaluate effectiveness of sanctions in terms of damage inflicted, while the political science literature generally evaluates effectiveness in terms of changes in the target country's behavior (Felbermayr et al., 2021). Countries that impose sanctions are sure to incur losses; in that light, we also examine the impact on the world economy and the Japanese economy.

To these ends, we use a static world trade CGE model, as presented in Section 2, and assume that (1) the senders impose 100 % export taxes and import duties on Russia and on Belarus, and (2) the war halves the endowments of primary factors in Ukraine. We examine changes in various macro- and micro-economic variables that would result from these shocks. That is, we measure changes in bilateral trade, fossil fuel trade, sectoral production, and macroeconomic indicators of GDP and welfare (i.e., household consumption). Section 3 shows that Russia's GDP would decrease by 3–7 % due to the significant decline in exports. The larger the number of sender countries, the greater the losses that Russia would incur. Among many potential

[2] In addition to the issue of agricultural products, Russia's presence in developing countries is significant in terms of weapons supply. However, the arms trade will not be included in this discussion.

senders, but this doesn't seem likely, China's participation would be more important than that of India. For senders, GDP losses would be 0.2 % in Europe and 0.05 % in Japan. Similar results are obtained when household consumption, rather than GDP, is used as a welfare indicator. To achieve a 1-USD loss of GDP for Russia, the senders' GDP loss would have to be about 0.6 USD, if Western countries, Japan, India, and (unlikely) China participated in the sanctions. If every country but Russia and Belarus participated, Russia's losses would be the largest among the six cases we consider here. However, the cost-benefit balance of sanctions would deteriorate considerably; the senders' loss would increase to 0.9 USD for Russia's loss of 1-USD GDP. We find that the sanctions against Russia and the destruction of the Ukrainian economy would affect food supplies little, even in developing countries, but they would affect energy supplies to some extent. After a detailed presentation of the above in Sections 2 and 3, Section 4 provides a summary and discusses future issues.

2. World trade CGE model

2.1. Basic structure of the model

We develop a static world trade CGE model based on the standard model developed by Hosoe et al. (2010). Reading upward from the bottom in Fig. 1, value added is produced from various primary factors with a constant elasticity of substitution (CES) production function. Value added and various intermediate inputs (including energy composites, explained later) are combined to produce domestic output with a Leontief-type production function, as assumed in input–output models. Domestic production is allocated to domestic goods and export composites with a constant elasticity of transformation production function. Similarly, export composites are further disaggregated into exports to individual countries/regions. Symmetrically, imports from individual countries/regions are aggregated to produce import composites, which are then combined with domestic goods to produce Armington's (1969) composite goods, used for household consumption, government consumption, investment demand, and intermediate inputs.

Our model distinguishes 14 sectors and goods, consisting of three agri-food products (wheat, other agriculture, and food) and five types of energy goods (coal, oil, natural gas, electricity, and

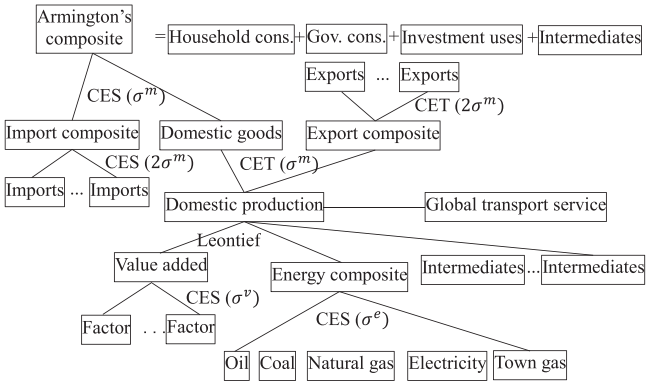

Figure 1. Production Structure. Note: CES/CET stands for constant elasticity of substitution/transformation.

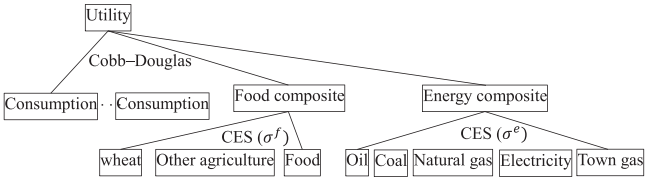

Figure 2. Household Utility Function.

town gas).[3] We extend the standard model to describe substitution among these goods separately to achieve a detailed analysis of food and energy issues (Fig. 1). Agri-food or energy goods are first aggregated into food composite goods or energy composite goods using a CES production function (Fig. 2) and then placed in the household utility function. The other consumption goods are immediately placed in the household utility function. For this utility function, we assume a Cobb–Douglas function. For intermediate inputs of energy goods, we consider a similar energy composite (Fig. 1).

Five types of primary factors are considered: land, capital, natural resources, skilled labor, and unskilled labor. The first three are not mobile across sectors, and none are internationally mobile. The government earns revenues from direct taxes, production taxes, factor input taxes, import duties, and export taxes. Indirect taxes are all ad valorem taxes. Revenue is proportionately allocated between consumption and savings. Household and government savings plus foreign savings (i.e., current account deficits) are used to finance domestic investment. It is assumed that demand for each investment good is determined proportionally. Foreign savings is fixed in US dollar terms.[4] We distinguish 14 countries and regions in the world economy (Table 1). All markets are assumed to be perfectly competitive, and general equilibrium is achieved by flexible adjustments of prices in each market.

We calibrate the model to GTAP Database version 11 (prerelease 2), whose base year is 2017. Armington's (1969) elasticity of substitution σ^m and the elasticity of substitution between factors of production σ^v are obtained from the GTAP Database. The elasticities of substitution in the food composite production function σ^f and the energy composite production function σ^e are assumed to be 1.1 and 0.5, respectively, due to the lack of reliable elasticity estimates globally. Sensitivity analysis is conducted to verify the robustness of our simulation results by alternatively assuming 30% larger or smaller values for these elasticities.[5]

We choose land service used in the other agriculture sector as our numeraire; this is an effective reference for measuring relative prices. When we use unskilled or skilled labor alternatively as a numeraire, the changes in agri-food and energy prices are only 0.3–0.4 % points higher in Scenarios 1–5, and 0.2–0.3 % points lower in Scenario 6.

[3] For the details of sectoral and regional aggregation, see the Appendix, available upon request.

[4] In a static model where the "next period" never arrives, foreign savings (current account deficits) become debt that need not be repaid, i.e., transfers from abroad (Hosoe et al., 2010), Thus, changes in foreign savings directly impact welfare, making fair evaluation difficult.

[5] Results of the sensitivity analysis are reported in the Appendix, available upon request.

Table 1
Regional Aggregation and Sender and Target Countries in Simulation Scenarios.

Country/Region	Scenario					
	1	2	3	4	5	6
	(West+Japan)	(+India)	(+China)	(+India, China)	(+Belarus)	(Worldwide)
Japan	X	X	X	X	X	X
North America (incl. Mexico)	X	X	X	X	X	X
Europe (EU, UK, EFTA)	X	X	X	X	X	X
Oceania	X	X	X	X	X	X
Russia	Y	Y	Y	Y	Y	Y
Belarus					Y	Y
Ukraine						X
China (incl. Hong Kong)			X	X	X	X
India		X		X	X	X
Other Asia						X
Middle East and North Africa						X
Sub-Saharan Africa						X
South America						X
Rest of the world (Central Asia, former Soviet Union)						X

X: sender, Y: target. EFTA: European Free Trade Association.

2.2. Simulation scenarios

We create six scenarios, using two types of shock: (1) 100 % import and export tariffs on trade from senders to targets with variations in the composition of those two groups; and (2) destruction of the Ukrainian economy (Table 1). As for the makeup of the sender group, Scenario 1 includes only Western countries (North America, Europe, and Oceania) and Japan; even if unlikely, Scenario 2 adds India to this list, while Scenario 3 adds China instead. Scenarios 4 and 5 are the most unlikely, though useful to examine: they add both India and China. In Scenario 6, all countries except the targets (Russia and Belarus) participate. Regarding the targets, Russia is the target in all six scenarios; in Scenarios 5 and 6, Belarus is added. Ukraine's primary factors are assumed to be uniformly reduced by half in all six scenarios.

As the situation is ongoing and fluid, we consider simplistic scenario factors to grasp the overall changes expected in the global economy and perhaps the largest economic losses that would be achieved through trade restrictions, while actual sanctions may occur in various forms and magnitudes and differ by sector and country. Restrictions have been imposed on Russia's fossil fuel exports, and the G7 trade ministers confirmed sanction policies to restrict G7 exports of luxury goods to Russian on top of high-tech products and machine tools with potential military applications (Takahara, 2022). The G7 countries imposed a price cap on Russian oil exports from December 2022. However, there are several hurdles concerning Japan's fossil fuel trade. Japan will not abandon the Sakhalin natural gas development project (Nikkei Asia, 2022). Japan is dependent on Russia for only 15% of its coal supply, but nearly half of the coal used for cement production in Japan is imported from Russia. While trade bans and quotas rather than tariffs and taxes are presupposed in planning such sanctions, the two groups have the same effect. In our simulation experiments, we focus on the effects of sanctions through trade

Table 2
Impacts on Russia's Trade [Unit: changes from the baseline equilibrium, mill. USD].

	Scenario					
	1 (West+ Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Imports	– 114,930	– 119,588	– 151,913	– 157,386	– 155,830	– 245,252
Exports	– 52,376	– 54,581	– 67,082	– 69,211	– 68,059	– 83,462
Coal	*– 1801*	*– 1904*	*– 3190*	*– 3341*	*– 3346*	*– 5064*
Oil	*– 1395*	*– 1591*	*– 8827*	*– 9298*	*– 9802*	*– 6241*
Natural gas	*– 554*	*– 521*	*– 735*	*– 699*	*– 694*	*– 3186*
Subtotal of fossil fuel exports	– 3750	– 4016	– 12,752	– 13,338	– 13,842	– 14,491
Fossil fuel contribution [%]	7.2	7.4	19.0	19.3	20.3	17.4

Note: Aggregated with Laspeyres prices. Excluding import tariffs, export taxes, and global transport services.

restrictions with import tariffs and export taxes, and ignore the effects of other measures, such as asset freezes, sanctions through financial markets, and restrictions on entry by key government officials and business executives.

3. Simulation results

3.1. Impacts on Russia's Trade

In Scenario 1, sanctions by the smallest sender group would reduce Russia's imports and exports by 115 billion USD (37 % of the baseline value) and 52 billion USD (16 %), respectively (Table 2).[6] The reason for the larger decline in imports than in exports can be attributed to the deterioration in the terms of trade (i.e., the depreciation of the Russian ruble). Export taxes and import tariffs imposed by senders would raise import prices and lower export prices for Russia, respectively. Fossil fuel exports would account for 7 % of the total decrease in exports of the three types of fuel. Coal and oil exports would decrease significantly. Natural gas exports would decrease by a much smaller magnitude because Russian natural gas is exported mostly to continental Europe and Asia by pipeline, and some to Japan in the form of liquefied natural gas.

By adding more senders, particularly India and China, the coalition would increase the impact of the sanctions. If India participated (Scenario 2), Russia's trade would be further reduced by about 4 %. Alternatively, if China joined (Scenario 3), Russia's trade would be 30 % less than in Scenario 1. Fossil fuel trade with China, which comprises 50 % of Russian exports to China in the status quo, would fall sharply; this would increase the contribution of fossil fuels to export reduction to 19 %. Among the three fossil fuels, China's participation would particularly reduce oil exports. In total, China's participation would have more impact than that of India, since China's GDP is five times that of India, and since Russia's exports to and imports from China are five times and nine times larger than India's, respectively—and also because

[6] Under the sanctions, bilateral trade between Russia and senders would be reduced by 74–93 % for Russian imports and 17–84 % for Russian exports. See the Appendix for details.

Table 3
Impacts on domestic production in Russia [Unit: changes from the baseline equilibrium, %].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Wheat	3.4	3.4	3.8	3.9	3.8	− 1.6
Other agriculture	0.7	0.8	0.3	0.4	0.3	3.8
Coal	− 3.1	− 3.3	− 5.8	− 6.2	− 6.2	− 10.9
Oil	− 0.2	− 0.2	− 0.5	− 0.6	− 0.6	− 0.5
Natural gas	0.2	0.2	0.4	0.4	0.4	− 0.2
Other mining	1.5	0.9	2.4	2.0	2.0	6.0
Food	− 0.7	− 0.7	− 2.2	− 2.2	− 2.3	− 4.5
Petroleum and coal products	− 5.3	− 5.2	0.1	0.5	0.9	4.0
Light manufacturing	7.2	7.2	15.0	15.3	15.1	28.8
Heavy manufacturing	9.6	9.8	15.7	16.1	16.2	22.1
Electricity	0.5	0.5	1.4	1.5	1.4	3.2
Town gas	− 9.5	− 9.5	− 8.7	− 8.7	− 8.3	− 2.4
Transportation	0.3	0.3	0.2	0.2	0.2	4.7
Other services	− 1.3	− 1.3	− 2.3	− 2.4	− 2.4	− 4.4

China's import tariffs are lower initially and thus would increase more sharply, to 100 %.[7] The impacts of sanctions by India and China are combined in Scenario 4.

As Russia could trade through Belarus to avoid sanctions, Belarus is also assumed to be subject to sanctions (Scenario 5). Contrary to our expectations, Russia's trade volume would remain virtually unchanged. If all countries and regions joined the sanctions (Scenario 6), the impact would increase significantly. Compared to the trade impact in Scenario 1, in Scenario 6, the reduction would double in total imports and increase by 60 % in total exports. Notably, the reduction in fossil fuel exports would nearly triple. Compared to the baseline equilibrium, exports and imports would then be reduced by 25 % and 79 %, respectively.

3.2. Impact on sectoral production

Sanctions would adversely affect the coal, oil, and petroleum and coal product sectors in Russia as well as food and other service sectors, which mainly serve domestic consumption (Table 3). The light and heavy manufacturing sectors would increase production by mobilizing labor from these declining sectors. This is the reverse of Dutch disease. Comparing the results of the six scenarios, we find that the participation of China would crucially affect changes in sectoral output. If China joined the sanctions, Russian coal and oil exports to China would decrease and their sales destination would be shifted to domestic users so as to increase the production of petroleum and coal products. The disruption of Chinese manufacturing exports in exchange for fossil fuel imports would allow Russian domestic producers to increase their manufacture of light and heavy goods markedly.

[7] According to the GTAP 11 database, China set import tariffs of about 6% on imports from Russia, while India set higher rates ranging from 8 % to 55 %. By contrast, as China set higher export tax rates, imposed mostly on fossil fuel exports, export tax hikes would not have much impact on Russia.

Table 4
Impacts on domestic production in Japan [Unit: changes from the baseline equilibrium, %].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Wheat	1.1	1.1	1.2	1.2	1.2	1.3
Other agriculture	0.0	0.0	0.0	0.0	0.0	0.0
Coal	0.3	0.3	0.4	0.4	0.4	0.3
Oil	0.3	0.3	0.4	0.4	0.4	0.2
Natural gas	0.3	0.3	0.4	0.3	0.4	0.6
Other mining	0.5	0.6	0.6	0.7	0.7	0.5
Food	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
Petroleum and coal products	−1.7	−1.7	−2.2	−2.3	−2.3	−0.9
Light manufacturing	0.2	0.2	0.2	0.2	0.2	−0.1
Heavy manufacturing	0.2	0.2	0.2	0.2	0.2	0.1
Electricity	−0.2	−0.1	−0.2	−0.2	−0.2	−0.5
Town gas	−1.5	−1.6	−2.1	−2.1	−2.2	−1.9
Transportation	−0.1	−0.1	−0.2	−0.2	−0.2	−0.4
Other services	0.0	0.0	0.0	0.0	0.0	0.0

It is noteworthy that in Scenario 6 wheat production by Russia would be negative only if Russia faced global sanctions. In other words, even if Western countries, Japan, India, and China reduced wheat imports from Russia, as assumed in Scenarios 1–5, wheat production would be enhanced by 3–4 % to earn hard currency through the export of wheat to third parties.

The sanctions against Russia would mainly affect Japan in terms of industrial exports and material imports. Japan's domestic production would increase slightly in the wheat, coal, and petroleum sectors, given the reduced competition with imports (Table 4). However, those increases would have little significance since domestic production of those goods is negligible in Japan. Japan's food, oil and coal products, electricity, and town gas sectors depend on imports of fossil fuels and raw materials and thus would be negatively affected. The light and heavy manufacturing sectors, less affected by the sanctions, would increase production slightly. Overall, the impact on domestic production would be very moderate and little affected by the scale of sanctions.

3.3. Macroeconomic impacts

Sanctions only by Western countries and Japan (Scenario 1) would reduce Russia's GDP by 3.2%. While India's participation would inflict only a little additional loss, China sanctions alone would inflict more than one-percentage point losses on Russia, more than one-third the losses resulting from sanctions by Western countries and Japan. Although unlikely to happen, China's impacts are sufficiently large to cause collateral damage to regions with trade ties with Russia, as seen in Scenario 6. The ROW (i.e., Central Asia and the former Soviet Union) would lose at most an additional 0.08 % points, followed by other Asia, the Middle East, and North Africa. If China and India joined (Scenario 4), Russia's GDP loss would reach 4.5 % (Table 5). Sanctions against Belarus (Scenario 5) would have little impact on the trade and GDP of Russia—they would, of course, result in significant losses for Belarus, even greater than those

Table 5
GDP Impacts [Unit: changes from the baseline equilibrium, %].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.03**
Russia	−3.24	−3.35	−4.41	−4.53	−4.54	−7.40
Belarus	−0.48	−0.51	−0.94	−1.01	−5.01	−9.82
Ukraine	−50.97	−50.98	−51.14	−51.16	−51.18	**−51.12**
China	−0.02	−0.02	**−0.06**	**−0.06**	**−0.06**	**−0.05**
India	−0.01	**−0.05**	−0.04	**−0.05**	**−0.05**	**−0.03**
Other Asia	−0.03	−0.04	−0.08	−0.09	−0.09	**−0.06**
North America	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.01**
Europe	**−0.17**	**−0.17**	**−0.16**	**−0.15**	**−0.16**	**−0.11**
Middle East and North Africa	−0.07	−0.08	−0.12	−0.13	−0.13	**−0.08**
Sub-Saharan Africa	−0.03	−0.03	−0.03	−0.03	−0.03	**−0.02**
Latin America	−0.01	−0.01	−0.03	−0.03	−0.03	**−0.04**
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
Rest of the world	−0.12	−0.13	−0.20	−0.21	−0.21	**−0.51**
World total	−0.19	−0.19	−0.22	−0.23	−0.23	−0.27
Sanction efficiency	0.76	0.75	0.63	0.62	0.64	0.86

Note: Percentage changes in expenditure-side GDP (private and government consumption, investment, and net exports) aggregated with Laspeyres prices. Bolded figures are for senders; underlined figures are for targets. Sanction efficiency is the total GDP decreases for senders divided by the GDP decrease for Russia.

for Russia. If the sanctions were imposed worldwide, Russia's GDP loss would exceed 7 %. Note that in the scenario where the war is assumed to halve factor endowments, Ukraine would almost immediately experience the halving of its GDP, a devastating loss. The new senders in Scenario 6, aside from the ROW and Latin America, would reduce losses slightly, compared with their collateral damage under Scenario 5.

Sanctions inflict losses not only on targets but also on senders; this discourages nations from participating. A free rider problem also discourages them—sanctions by other senders impact targets even if one country does not join. Among the senders, Europe has strong economic ties with Russia and thus would suffer the largest losses, 0.2 % of GDP, followed by Japan (0.05 %), North America (0.02 %), and Oceania (0.02 %). The losses in Western countries and Japan would change only marginally if India and China participated or if the sanctions were also imposed on Belarus. China and India would suffer small collateral losses as a result of the contraction of global trade, even if they did not join. If they did join the sanctions, they would lose just as much as Japan and North America would.

If the entire world participated in the sanctions (Scenario 6), the losses for incumbent senders in Scenario 5, particularly Europe, would decrease. While third parties would suffer collateral damage from shrinking world trade in Scenario 5, some would gain, and others would lose in Scenario 6 by participating. Among them, the ROW, which consists mostly of Central Asia and the former Soviet Union countries, would lose significantly owing to negative impacts from Russia through their strong economic ties.

Senders would quite likely want to minimize their own losses and maximize losses for targets. The bottom row of Table 5 shows the ratio of the senders' GDP losses to those of Russia. The smaller this ratio is, the more efficient is the implementation of the sanctions. Note

Table 6
Welfare Impacts [Unit: Hicksian equivalent variations, % of baseline GDP].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Japan	**−0.18**	**−0.18**	**−0.21**	**−0.22**	**−0.22**	**−0.16**
Russia	−3.69	−3.84	−5.06	−5.25	−5.21	−8.28
Belarus	2.42	2.55	4.32	4.53	−1.34	0.25
Ukraine	−26.47	−26.45	−26.20	−26.16	−26.12	**−27.74**
China	0.00	0.00	**−0.17**	**−0.17**	**−0.17**	**−0.08**
India	−0.13	**−0.24**	−0.17	**−0.31**	**−0.31**	**−0.20**
Other Asia	−0.03	−0.02	0.00	0.01	0.01	**−0.14**
North America	**−0.03**	**−0.03**	**−0.03**	**−0.02**	**−0.03**	**−0.02**
Europe	**−0.31**	**−0.31**	**−0.31**	**−0.31**	**−0.32**	**−0.18**
Middle East and North Africa	0.44	0.46	0.66	0.69	0.70	**0.23**
Sub-Saharan Africa	0.19	0.20	0.33	0.34	0.35	**0.13**
Latin America	0.05	0.06	0.09	0.09	0.10	**−0.01**
Oceania	**0.10**	**0.11**	**0.15**	**0.16**	**0.16**	**0.26**
Rest of the world	0.93	0.95	1.26	1.29	1.30	**−0.43**
World total	−0.16	−0.17	−0.19	−0.20	−0.21	−0.26
Sanction efficiency	1.21	1.26	1.16	1.21	1.26	0.64

Note: Senders are in bold, and targets are underlined. Sanction efficiency is computed by dividing the total welfare loss of senders by Russia's welfare loss. The world total is the simple sum of welfare gains/losses in individual countries and regions, expressed in percentage of the world total baseline GDP.

that the senders differ across the scenarios and that the losses suffered by Belarus are not considered as target's losses consistently in this sanction efficiency index, reflecting our assumption that the goal of the sanctions is only to damage the Russian economy. If Western countries and Japan alone imposed sanctions on Russia (Scenario 1), they would have to sacrifice 0.8 USD of their GDP to inflict 1 USD of GDP losses on the Russian economy. India's participation (Scenario 2) would not have much impact, as discussed above. By contrast, China's unlikely participation (Scenario 3) would not only exacerbate Russia's losses: it would also improve sanction efficiency considerably. Sanctions against Belarus (Scenario 5) would not have a significant effect on Russia's trade and thus would reduce sanction efficiency only slightly. As Russia's losses would be maximized by worldwide sanctions (Scenario 6) but outpaced by the increase in senders' losses, sanction efficiency would deteriorate significantly.

Table 6 provides welfare impacts with Hicksian equivalent variations (EVs), which measure changes in household consumption, and shows a pattern similar to that for impacts measured in GDP. When senders suffer in GDP, they also suffer in welfare. Under Scenario 3, China's participation would be impactful but would bring Chinese losses just as large as Japan's. This would improve sanction efficiency in EV by 4 %. A large trade diversion triggered by China's participation would benefit many regions in welfare.[8] As long as Belarus is a third party (Scenarios 1–4), it would benefit from receiving Russia's trade diverted from senders. Being a

[8] This appears to be the reverse of the abovementioned GDP loss, but they are two sides of the same coin. That is, net exports positively affect GDP, as they contribute to final demand, but negatively affect welfare, as they reduce resources available for domestic consumption.

Table 7
Impacts on Food Consumption and Prices in Scenario 6 [Unit: changes from the baseline equilibrium, %].

	Household consumption	Consumer price		
	Food composites	Wheat	Other agriculture	Food
Japan	− 0.2	3.9	0.5	0.5
Russia	− 19.0	− 27.0	− 7.2	− 15.0
Belarus	− 2.5	− 26.9	− 10.6	− 13.7
Ukraine	− 42.5	− 6.9	− 7.2	− 11.5
China	− 0.1	0.8	0.2	0.3
India	− 0.2	1.2	0.1	0.3
Other Asia	− 0.1	6.0	0.2	0.4
North America	0.0	4.7	0.0	0.0
Europe	− 0.3	3.0	0.6	0.6
Middle East and North Africa	0.6	2.1	1.2	1.2
Sub-Saharan Africa	0.2	4.3	0.0	0.0
South America	0.2	4.9	1.0	1.3
Oceania	0.8	6.3	2.7	3.2
Rest of the world	− 0.6	10.2	3.0	5.7

target (Scenario 5), Belarus would lose a large part of this benefit but would still be better off than Russia in welfare, unlike the case for GDP.[9] A larger sanction coalition would inflict larger losses on Russia. If the entire world joined the sanctions (Scenario 6), Russia would trade with no countries but Belarus. Again, this trade diversion effect would favor Belarus slightly.

Notably, EVs—compared with GDP—show some contrasting results with positive gains from the sanctions for some countries. Third parties can free-ride senders' sanction efforts and exploit trade diversion effects (since the sanctions make them alternative trade partners for both senders and targets) to improve welfare. Free riders, such as the Middle East and North Africa, Sub-Saharan Africa, Latin America, and the ROW, would gain. The first two would enjoy positive gains, although their participation would reduce their gains from free-riding in Scenario 5.

Worldwide sanctions (Scenario 6) would be welfare-deteriorating overall but, thanks to trade diversion effects among senders, would improve sanction efficiency, unlike GDP-based sanction efficiency. Incumbents, particularly China, India, and Europe, would see reduced losses. Joining the sanctions, most of the new senders would relinquish gains from trade diversion effects with Russia but would still benefit from diversion effects with the incumbent senders. The notable exception is the ROW, the largest gainer as a third party in Scenario 5 but the largest loser as a sender in Scenario 6. The incumbents would also benefit from trade diversion effects with the new senders. Therefore, senders' sanction costs in EV (as much as 1.3 USD to inflict a 1 USD loss on Russia's EV in Scenario 1–5) would be halved in Scenario 6.

3.4. Impacts on food and energy supply

There is widespread concern that global trade restrictions could undermine food and energy security. We examine that possibility with Scenario 6, which assumes worldwide sanctions

[9] The welfare impacts on Belarus are complex and dependent on elasticity assumptions, especially the Armington elasticity. For more details, see the results of the sensitivity analysis in the Appendix.

Table 8
Impacts on Energy Consumption and Price in Scenario 6 [Unit: changes from the baseline equilibrium, %].

	Household consumption	Consumer price					
	Energy composites	Coal	Oil	Natural gas	Petroleum and coal products	Electricity	Town gas
Japan	−3.3	6.5	4.1	13.7	4.1	2.9	3.9
Russia	−8.8	−22.4	−33.9	−24.9	−27.0	−22.3	−22.2
Belarus	9.3	−36.3	−48.9	−38.3	−39.2	−18.3	−11.3
Ukraine	−42.9	−18.0	−20.2	−11.2	−18.6	−5.4	−19.3
China	−1.7	3.3	3.1	11.9	2.7	1.2	4.4
India	−1.9	4.8	3.9	12.1	2.7	1.2	2.8
Other Asia	−2.7	6.3	3.6	12.5	3.2	2.2	2.3
North America	−1.7	4.3	3.1	9.7	2.9	0.8	1.1
Europe	−3.2	7.5	4.9	13.2	4.7	2.0	4.5
Middle East and North Africa	−2.4	7.8	3.5	11.6	3.7	4.3	3.0
Sub-Saharan Africa	−1.6	4.1	2.7	11.3	2.5	0.9	2.2
South America	−1.6	6.9	4.4	11.8	4.0	2.3	3.5
Oceania	−1.2	7.7	5.2	14.6	5.3	4.7	4.0
Rest of the world	−0.6	−4.8	6.3	14.8	6.5	3.6	5.1

(Table 7). Consumption of food composites, consisting of agri-food products, would be affected little in all economies but Russia and Ukraine. Consumer prices, especially for wheat, would rise by up to 10 %. This is not so severe, in light of the assumed 100 % import tariffs. Moreover, tariff and tax revenues would be reimbursed to affected households to mitigate impact on their income. Other agriculture and food would show moderate price changes.

Unlike food consumption, household consumption of energy composites, comprised of six energy goods, would decrease for all senders. The decrease would be larger than that of consumption of food composites, but still only about 3% (Table 8). Primary energy prices would rise noticeably in Europe, which is heavily dependent on Russia for energy. Other countries and regions would face comparable price rises. In Japan, primary energy prices would rise by 4–14 %. As there are few alternative natural gas suppliers, a gas price rise is particularly significant; the rises in oil and coal prices are about one-third and half of the gas price rise, respectively. The price of electricity would inevitably rise, but in smaller magnitude than the rises in primary energy prices. The rise in electricity prices would be 2 % in Europe and 3 % in Japan.

4. Conclusion

We quantified the impacts of economic sanctions as a countermeasure using import tariffs and export taxes as weapons against Russia's invasion of Ukraine. While trade measures would reduce Russia's GDP by 3–7 %, senders' GDP losses would be at most 0.2% in Europe and 0.05 % or less in other Western countries and Japan. A larger coalition would bring larger sanction impacts. Among non-Western senders, although highly unlikely to ever happen, China would play a significant role, inflicting an additional one percentage point of GDP loss on Russia, improving sanction efficiency, and bringing collateral damage to third parties. Sanctions imposed against Belarus so as to block Russia's commodity shunting through that country would

not increase the damage to Russia much. A worldwide coalition would reduce the incumbent senders' losses. This implies that equitable burden-sharing would lower the hurdle for entry by key players, especially China.

As the crisis broke out in Europe, natural gas attracted much attention. However, the simulation results demonstrate the importance of sanctions imposed on trade in general, rather than solely on the natural gas trade, which geographically is largely confined to the countries neighboring Russia and is smaller in volume than the coal and oil trade. There would be some price hikes in primary energies, particularly in natural gas, while food security would not be a serious concern for any countries, including developing countries. This is consistent with the observations of fuel and crop prices, which as of January 2023 are almost back to pre-crisis levels.

Socioeconomic indicators that we observe daily amid the storm arising from the Ukraine crisis show overwhelmingly extreme changes in direction and magnitude. Even before the crisis created by the Russia invasion, the Japanese economy had suffered many recent shocks—the outbreak of the new coronavirus, supply disruptions of liquefied natural gas (not a result of the current crisis), electricity shortages due to natural disasters, and commodity price bubbles caused by prolonged monetary easing. Nevertheless, when making policy decisions, such as economic sanctions (which would cause serious damage to the macroeconomy and the world economy), it is necessary to quantify policy impacts by controlling for other factors.

Our analysis has several limitations. Due to data limitations, our simulation experiments are based on GTAP database version 11 for 2017. Russia's trade-GDP ratio rose from 47 % in 2017 to 52 % in 2021, according to the World Economic Indicators: this might cause underestimation of the impacts of sanctions on Russia. While we considered trade restrictions as sanction devices, there are other sanction measures, such as asset freezing, travel bans, the blocking of Russian banks. As we omitted these measures, our analysis provides lower-bound estimates of losses for targets and senders. For Japan, the supply of natural gas will depend crucially on the fate of the Sakhalin natural gas development project. We also need to consider dynamic effects of sanctions through foreign direct investment, as seen in Sedrakyan's (2022) analysis of the Crimean crisis. Our macroeconomic model, even with elaborations on food and energy security issues, can capture aggregate impacts of the sanctions. However, there are a wide variety of heterogeneous agents in an economy. Ahn and Ludema (2020) analyzed so-called smart sanctions targeting strategically important companies and individuals after the Crimean crisis and found their impacts had been neutralized by shielding actions by the Russian government.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jpolmod.2023.04.001.

References

Ahn, D. P., & Ludema, R. D. (2020). The sword and the shield: The economics of targeted sanctions. *European Economic Review, 130*, Article 103587. https://doi.org/10.1016/j.euroecorev.2020.103587

Armington, P.S., 1969. A theory of demand for products distinguished by place of production. IMF Staff Papers. https://doi.org/10.2307/3866403.

Burfisher, M.E., Lambert, F., & Matheson, T. (2019). NAFTA to USMCA: What is gained? IMF Working Papers. https://doi.org/10.5089/9781498303286.001.

Chepeliev, M. (2020). GTAP- Power database: Version 10. *Journal of Global Economic Analysis, 5*(2), 110–137. https://doi.org/10.21642/JGEA.050203AF

Chepeliev, M., Hertel, T., & van der Mensbrugghe, D., (2022, March 9). Cutting Russia's fossil fuel exports: Short-term pain for long-term gain. VOXEU. https://voxeu.org/article/cutting-russia-s-fossil-fuel-exports-short-term-pain-long-term-gain.

Dalheimer, B., Herwartz, H., & Lange, A. (2021). The threat of oil market turmoils to food price stability in Sub-Saharan Africa. *Energy Economics, 93*, Article 105029. https://doi.org/10.1016/j.eneco.2020.105029

Dhingra, S., Huang, H., Ottaviano, G., Paulo Pessoa, J., Sampson, T., & van Reenen, J. (2017). The costs and benefits of leaving the EU: Trade effects. *Economic Policy, 32*(92), 651–705. https://doi.org/10.1093/epolic/eix015

Dreger, C., Kholodilin, K. A., Ulbricht, D., & Fidrmuc, J. (2016). Between the hammer and the anvil: The impact of economic sanctions and oil prices on Russia's ruble. *Journal of Comparative Economics, 44*(2), 295–308. https://doi.org/10.1016/J.JCE.2015.12.010

Felbermayr, G., Morgan, T. C., Syropoulos, C., & Yotov, Y. v (2021). Understanding economic sanctions: Interdisciplinary perspectives on theory and evidence. *European Economic Review, 135*, Article 103720. https://doi.org/10.1016/j.euroecorev.2021.103720

Hosoe, N. (2018). Impact of border barriers, returning migrants, and trade diversion in Brexit: Firm exit and loss of variety. *Economic Modelling, 69*, 193–204. https://doi.org/10.1016/j.econmod.2017.09.018

Hosoe, N. (2020). Impact of tighter controls on Japanese chemical exports to Korea. *Economic Modelling, 94*, 631–648. https://doi.org/10.1016/j.econmod.2020.02.006

Hosoe, N. (2022). Economic de-integration in North America and foreign direct investment from Japan. *Japan and the World Economy, 61*, Article 101114. https://doi.org/10.1016/J.JAPWOR.2021.101114

Hosoe, N., Gasawa, K., & Hashimoto, H. (2010). *Textbook of computable general equilibrium modelling: Programming and simulations.* Palgrave Macmillanhttps://doi.org/10.1017/CBO9781107415324.004

Iwasaki, I., Maurel, M., & Meunier, B. (2016). Firm entry and exit during a crisis period: Evidence from Russian regions. *Russian Journal of Economics, 2*(2), 162–191. https://doi.org/10.1016/J.RUJE.2016.06.005

Kumagai, S., Hayakawa, K., Gokan, T., Isono, I., Keola, S., & Tsubota, K. (2022). Impact of economic sanctions against Russia on the global economy using the IDE-GSM. *IDE Policy Briefing, 148*.

Kumagai, S., Hayakawa, K., Isono, I., Gokan, T., Keola, S., Tsubota, K., & Kubo, H. (2023). Simulating the decoupling world under Russia's invasion of Ukraine: An application of IDE-GSM. *IDE Discussion Paper, 874*.

Nikkei Asia, (2022, March 31). Japan will not abandon Sakhalin-2 LNG stake, Kishida says.

Nivorozhkin, E., & Castagneto-Gissey, G. (2016). Russian stock market in the aftermath of the Ukrainian crisis. *Russian Journal of Economics, 2*(1), 23–40. https://doi.org/10.1016/J.RUJE.2016.04.002

Ortiz Valverde, G., & Latorre, M. C. (2020). A computable general equilibrium analysis of Brexit: Barriers to trade and immigration restrictions. *The World Economy, 43*(3), 705–728. https://doi.org/10.1111/twec.12881

Sedrakyan, G. S. (2022). Ukraine war-induced sanctions against Russia: Consequences on transition economies. *Journal of Policy Modeling, 44*(5), 863–885. https://doi.org/10.1016/j.jpolmod.2022.08.003

Shin, S., & Balistreri, E. J. (2022). The other trade war: Quantifying the Korea–Japan trade dispute. *Journal of Asian Economics, 79*, Article 101442. https://doi.org/10.1016/J.ASIECO.2022.101442

Takahara, K. (2022). Japan to revoke Russia's most favored nation trade status. *The Japan Times*. March 16 ⟨https://www.japantimes.co.jp/news/2022/03/16/national/russia-most-favored-nation-status-revoke/⟩.

United States International Trade Commission (USITC), (2019). U.S.-Mexico-Canada trade agreement: likely impact on the U.S. economy and on specific industry sectors. Investigation Number: TPA 105–003. ⟨https://www.usitc.gov/publications/332/pub4889.pdf⟩.