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## The limited effectiveness of sanctions on Russia: Modeling loopholes and workarounds

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## The limited effectiveness of sanctions on Russia: Modeling loopholes and workarounds

### Abstract

Following Russia's invasion of Ukraine in February 2022, the US, EU, and like-minded countries swiftly imposed an expanded set of primary and secondary export restrictions on Russia. This paper assesses the effectiveness of those measures and their ongoing refinement and modification over time using a calibrated three-country dynamic general equilibrium trade model with heterogeneous firm productivities. The modeling set-up comprises a rich specification of export ban loopholes and workarounds, as well as subsequent countermeasures such as re-exports, ghost trade, and secondary extraterritorial export bans. The numerical model evaluations and the numerous policy counterfactuals highlight the challenges of export ban evasion and offer insights for effective export ban designs in the future. We show that targeted secondary extraterritorial export bans have proven an impactful policy tool in diminishing Russia's imports of critical technologies.

**Keywords:** Russia, export bans, sanctions evasion, quantitative trade model

**JEL:** F12, F13, F51, H56

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# Non-technical summary

## Focus

Following Russia's 2022 invasion of Ukraine, a coalition of like-minded countries imposed an extraordinary set of coordinated economic export controls and sanctions on Russia. Over time, Western export bans have become a cat-and-mouse game with each new restriction giving rise to additional trade diversion and sanctions work-around efforts. Despite the efforts of the sanctions coalition to close loopholes and tighten the sanctions regime, Russia has succeeded in bypassing export bans by means of trade diversion imports from non-aligned countries, direct or indirect under-the-radar re-exports, and the use of false transit schemes. Each time the sanction coalition ratchets up export controls, Russia and its partners find new ways to circumvent them.

## Contribution

Against this background of numerous sanctions evasion activities, we analyze the impact of advanced technology export bans against Russia and their limited effectiveness using a calibrated multi-country dynamic trade model. Our state-of-the-art model incorporates recent advances in the general equilibrium theory of international trade, including assumptions that firms within each sector are heterogeneous in their productivity and that international trade arises in the context of cross-border input-output relationships. Notably, international trade leads to the reallocation of resources within industries, thereby raising average industry productivity. High productivity suppliers, in turn, can then expand to enter international markets. The innovative building blocks of our model are sanctions evasion strategies such as re-export of goods and extraterritorial sanctions against non-aligned countries.

## Findings

The analysis yields four main results. First, the model simulations show that export bans on Russia lead to GDP declines in both Russia and sanctioning countries, while the GDP impacts on the rest of the world countries are positive due to traditional trade diversion effects, workarounds, and re-export activities. Second, the incentive for re-export (sanction bypassing via non-aligned countries) is particularly pronounced for high-end products. Third, a tightening of primary export controls increases the incentive for workarounds and sanctions evasion. Fourth, the model-based analysis of multi-layered export bans reveals that heightened imposition of secondary extraterritorial sanctions reduces the incentive for re-exporting and impedes Russia's access to advanced technology goods.

# 1. Introduction

Following Russia's invasion of Ukraine in February 2022, a like-minded coalition of 36 global Western countries – Canada, the 27 European Union (EU) member states, Iceland, Japan, New Zealand, Norway, South Korea, Switzerland, the United Kingdom and the United States (US) – imposed an extraordinary set of coordinated economic export controls and sanctions designed to impair Russia's military-industrial complex and curtail its access to advanced technologies. Australia also imposed its own, though largely aligned, sanctions in response to Russia's invasion of Ukraine. The export bans focus on semiconductors, computers and computing machinery, communications equipment, information security equipment, transport equipment, aircraft and spacecraft, precision and optical instruments, lasers, and sensors. The export restrictions were later extended to target dual-use technologies that could potentially be used to support Russia's war effort (Abely, 2023).

The US and the EU have continued to tighten sanctions against Russia, putting particular emphasis on preventing circumvention and evasion of export bans by applying secondary sanctions as tools of statecraft. These measures include extra-territorial sanctions on businesses in non-aligned countries that bypass trade sanctions. Recent US extraterritorial sanctions also target foreign financial institutions that support Russia's military-industrial base, including transactions undertaken outside of US jurisdiction.

Export bans today are often seen as a cat-and-mouse game in which each new restriction gives rise to new trade diversion schemes or sanctions workaround efforts. Although the sanctions coalition has renewed its efforts to close loopholes and strengthen sanctions, efforts to bypass export bans by means of trade diversion imports from non-aligned countries, direct or indirect under-the-radar re-exports, or false transit remain extensive.

Re-exports are goods imported by a company possessing short-term ownership of the goods. After clearing customs, the goods are subsequently exported without

having received any particular industrial processing. The sole objective is to circumvent the sanctions on Russia.<sup>1</sup>

As the sanction coalition ratchets up export controls, ways to bypass them have become more sophisticated. At the moment, there are rather few measures in place to prevent new intermediaries from popping up and establishing trade relations in non-aligned countries that decline to enforce Western sanctions.

Against this background of numerous sanctions evasion activities, we assess the impact of the advanced technology export bans against Russia and their limited economic effectiveness in a calibrated multi-country dynamic trade model.<sup>2</sup> Our analysis relates to the theoretical and empirical literature on the role of input-output linkages in quantitative trade models in the tradition of Caliendo and Parro (2015), Caliendo et al. (2019) and Funke and Wende (2023). The state-of-the-art models comprise several recent advances in the general equilibrium theory of international trade. Following Melitz (2003), we assume that firms within each sector are heterogeneous in their productivity and that international trade arises in the context of cross-border input-output relationships. We further assume international trade leads to reallocation of resources within industries, raising average industry productivity. High-productivity suppliers can expand and enter international markets. For the sanctions impact evaluation, evasion strategies such as the re-export of goods and extraterritorial sanctions against non-aligned countries are embedded into the aforementioned workhorse trade model as integral building blocks.

We divide countries into three groups: global Western sanctioning countries (*SC*), the Russian Federation (*RU*), and the rest of the world (*RW*) countries not

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<sup>1</sup> See Chupilkin et al. (2023) for evidence indicating the use of trade diversion via neighboring economies to circumvent sanctions on Russia. The traditional foreign trade literature looks at re-exports from several angles. One focus is on re-exporting firms reducing informational barriers and providing knowledge of markets and producers for companies using these services (Biglaiser, 1993; Rauch, 1999, 2001). Another motivation for re-export trade is tax evasion, i.e. incentives to relocate goods destined for re-exporting to countries with favorable corporate tax rates (Lawless et al., 2018).

<sup>2</sup> Views on sanction effectiveness vary. Political scientists, for example, may declare sanctions effective if they achieve declared political objectives, while economists may view sanction effectiveness in terms of economic impact. For recent economic assessments of the effectiveness of sanctions, see Felbermayr et al. (2021) and Morgan et al. (2023).

adopting sanctions against Russia. If the third-party countries provide circumvention routes or substitutes for the goods and services that sanctions aim to curtail, then the sanctions on Russia become increasingly leaky. The numerical evaluation of the multi-country trade model then allows us to assess the achievable impacts of export bans in a world with global supply chains and non-cooperative circumvention strategies.

Topically related studies include Crozet and Hinz (2020), who provide a quantitative analysis of the sanctions imposed following Russia's annexation of Crimea in 2014. Felbermayr et al. (2023, 89-90), who model a decoupling of Russia from the US and allied countries without direct reference to the current sanctions regime, employ a computable general equilibrium trade model calibrated with the Global Trade Analysis Project (GTAP) database. The policy variable considered is a non-tariff trade barrier. A study of immediate interest is that of Ghironi et al. (2024), who use a dynamic multi-country quantitative trade model to analyze sanctions imposed on Russia since the invasion of Ukraine. Their paper evaluates the ban of international trade of outputs of consumption good businesses with productivity above a certain threshold, the import ban of Russian natural gas, and a fraction of Russian agents excluded from international bond trading.

We differ from all these papers in terms of scope and approach. The trade policy evaluations in these papers do not account for the sanctions evasion strategies of Russia and its partners. It is precisely these enforcement challenges and sanction leakages are the particular focus of this paper. To this end, we aim to provide a comprehensive modeling framework by putting the capabilities and boundaries of multi-layered export bans on a rigorous model-based footing, and thereby shed light on the limited effectiveness of targeted export bans on Russia.

Our analysis yields our four main results. First, the model simulations show that export bans on Russia lead to GDP declines in Russia and the sanctioning countries, while the GDP impacts on the rest-of-the-world countries are positive due to traditional trade diversion effects and the workarounds and re-export activities carried out. Second, in the model using Melitz (2003) as the microeconomic underpinning, the incentive for re-exports and thus sanctions bypassing via non-



aligned countries is particularly pronounced for high-end products. Third, a tightening of primary export controls increases the incentive for workarounds and sanctions evasion. Fourth, our analysis includes a novel analysis of multi-layered export bans. It reveals that the heightened imposition of secondary extraterritorial sanctions reduces the incentive for re-exporting, thus limiting Russia's access to advanced technology goods.

This paper unfolds as follows. To anchor our modeling scenarios, we present stylized sanctions evasion facts in Section 2. Section 3 lays out the augmented general equilibrium modeling framework. Section 4 presents the model calibration, and Section 5 presents the numerical analyses of the multi-layered export controls and various Russian sanction evasion strategies. Section 6 summarizes and discusses gaps and avenues for further analytical and model-based work. Overall, this study provides a rigorous model-based analysis of a topical geoeconomic question.<sup>3</sup>

## 2. Stylized facts

This section presents descriptive export control circumvention facts. To this end, we present three alternative evasion strategies for sanctioned products.

The Brussels-based Bruegel think tank's Russian Foreign Trade Tracker provides disaggregated monthly trade data for the five 2-digit Standard International Trade Classification (SITC) product categories (i) office and automatic data-processing machines; (ii) telecommunications and sound recording equipment; (iii) electric machinery and parts (including semiconductors); (iv) instruments and apparatus (including lasers); and (v) and transport equipment (other than road vehicles) as a proxy measure (Darvas et al., 2022). This indicator includes five technology-intensive 2-digit SITC categories that capture a significant share of sanctioned

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<sup>3</sup> The research also contributes to the recent literature emphasizing the interplay of geopolitics and geoeconomics attracting the attention of policymakers and researchers. See, for example, Kleinman et al. (2024a), Clayton et al. (2024) and De Souza et al. (2024).

products.<sup>4</sup> Since Russia stopped releasing customs trade data at the end of February 2022, the database looks at mirror bilateral export data from our sanctioning 27 EU countries, the US, the UK, Japan, South Korea, Switzerland, and Norway, as well as our selected non-sanctioning countries China, Turkey, Kazakhstan, India, and Brazil. These 38 countries together accounted for 80% of Russia's exports and imports in 2019.

In the first row of Figure 1, the aggregated Russian imports of the five 2-digit SITC product categories from both groups of countries are shown by the solid black line. The corresponding average values before and after the *Zeitenwende* (historical turning point in global geopolitics) are displayed as dashed red lines. The comparison of the two graphs reveals a striking difference. Post-invasion, Russian imports in the aforementioned 2-digit SITC product categories from the 33 sanctioning countries fell massively and have remained at low levels ever since. In contrast, imports from the five non-sanctioning countries exhibit a significant increase, indicating that pronounced sanctions leakages have given Russian businesses access to technologies that the global sanction coalition has sought to fence off. Within the group of non-participating countries, China heads the "black knights" list by a wide margin.<sup>5</sup> It is followed by Turkey and Kazakhstan, which have both also seen booming foreign trade with Russia since the invasion of Ukraine.<sup>6</sup>

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<sup>4</sup> The broadly defined measure is less susceptible to masking tactics such as misclassified trade in dual-use goods or the sourcing of products or sub-components from multiple suppliers to disguise the true nature of the trade, as well as the mislabeling of goods. These advantages are offset by the drawback that the precise percentage of sanctioned goods in the five SITC categories remains unobserved.

<sup>5</sup> Chinese exports of advanced machine tools to Russia have soared since the invasion of Ukraine. China's businesses, for example, now dominate trade in high-precision computer-aided numerical control devices vital to Russia's military-industrial complex. See <https://www.ft.com/content/d16c688d-9579-4f1d-a84f-ca29ca2f0bc0>. In addition, China has bypassed sanctions indirectly by substantially increasing exports of sanctioned product to Central Asian countries from where they are forwarded to Russia as re-exports.

<sup>6</sup> Since the Russian invasion of Ukraine, the ex-satellite countries of the Soviet Union have become central hubs for circumventing sanctions. Tellingly, bypassing sanctions via countries in Central Asia is sometimes referred to as the "new Silk Road." See <https://www.ft.com/content/0fc846f7-aac8-4a34-a7dd-3b0615bce983>. On Russia's sensitive goods imports for its war effort in India, see <https://www.ft.com/content/101afcd6-8e6f-4b5f-89b0-98f48cd5d119>. Interesting patterns have emerged for specific products. See, for example, the Financial Times survey of the shadowy network diverting semiconductors into Russia <https://www.ft.com/content/e70467d7-9df2-4a8c-9d0f-ddc61062b745>.

The second export control circumvention measure shown in Figure 1 is based on the list of Common High Priority Goods. The list, drawn up by the European Commission in consultation with the authorities in the US, the UK and Japan, contains a total of 50 HS 6-digit products of dual-use and advanced technology items with a special significance for Russian weapon systems. The aim of the Common High Priority Goods list is to restrict Russian military industrial complex's access to critical high-technology inputs. In contrast to the Bruegel measure, this proxy is much more narrowly defined.<sup>7</sup> The corresponding analyses are shown in the second row of Figure 1. In order to ensure comparability with the Bruegel data, both country groups have been defined analogously. The Russian imports (solid black lines) and the average values (dashed red lines) in the first and second rows of Figure 1 show a qualitatively equivalent pattern. The significant decline in Russian imports of the respective products from the 33 sanctioning countries after the onset of the war contrasts with a considerable increase in imports from the five non-sanctioning countries. In addition to this qualitative comparison, the data also allow the calculation of a quantitative sanctions circumvention measure. In view of the volatility of the monthly foreign trade data, the focus here is on the underlying trend. The numerator of the sanctions circumvention score is the absolute increase in imports of products subject to export bans from the five non-sanctioning countries after the outbreak of the war (difference of the dashed red line after the invasion from the pre-war level). The denominator is the correspondingly calculated absolute before-war/post-invasion decline in imports of these product categories from the sanctioning coalition countries. The resulting evasion measurements are 45% for the Bruegel Russian Foreign Trade Tracker data and 69% percent for the Common High Priority Goods data.

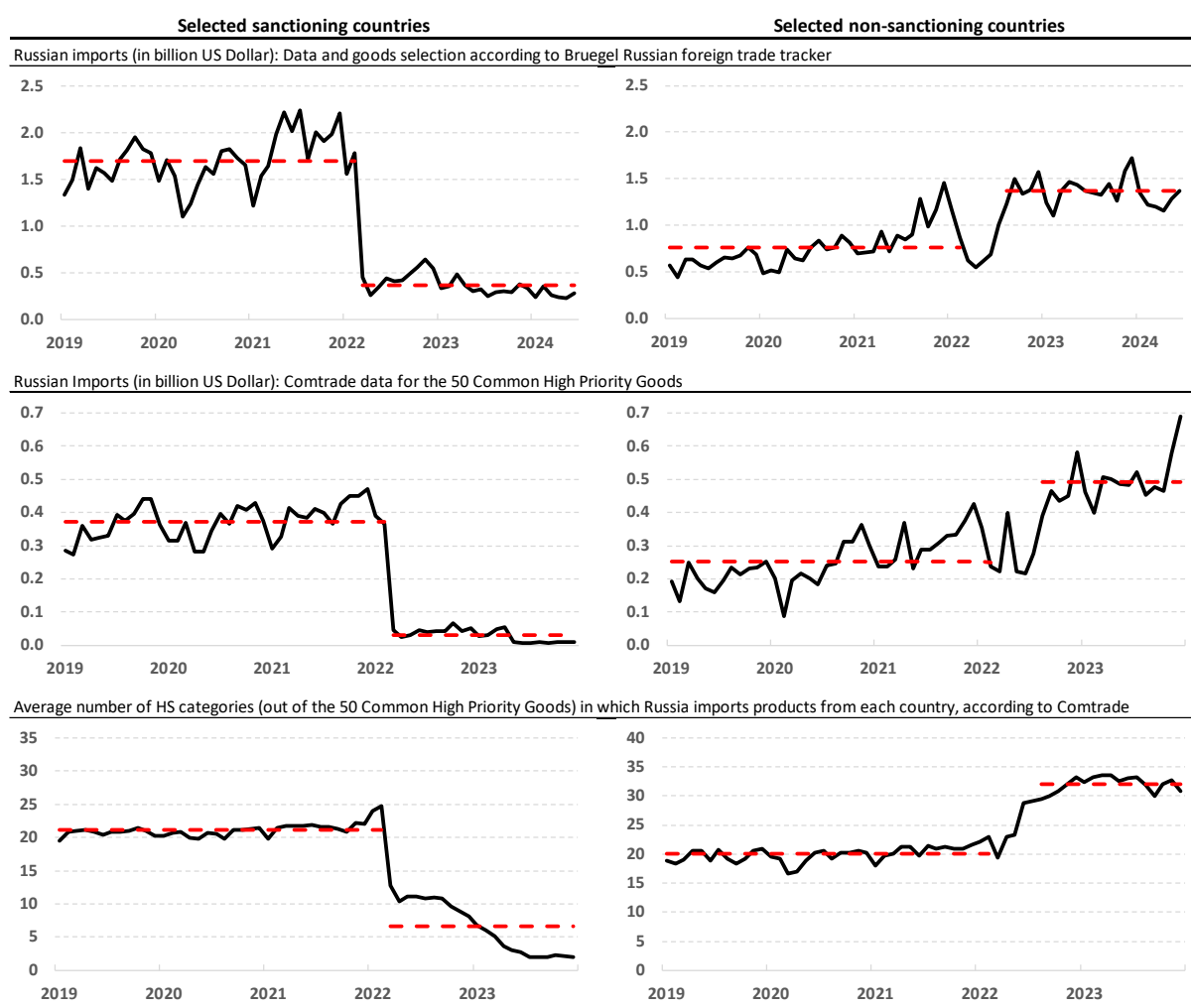
The final sanctions circumvention proxy in the third row of Figure 1 is the number of Common High Priority Goods HS 6-digit product categories in which Russia has imported from the two country groups over the sample period. For example, it can be seen that prior to the war Russia imported about 20 of the 50 HS 6-digit product categories from the non-sanctioning countries. Post-invasion, this number

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<sup>7</sup> See [https://finance.ec.europa.eu/system/files/2023-09/list-common-high-priority-items\\_en.pdf](https://finance.ec.europa.eu/system/files/2023-09/list-common-high-priority-items_en.pdf).

increases to 32. Thus, the non-sanctioning countries export more of the same products to Russia, as well as products they did not export to Russia previously. The ratio of the absolute change in average values (dashed red lines) before and after the onset of the war in both groups of countries provides a sanctions evasion score of 82%.

Figure 1. Alternative export sanctions evasion measures.



Data sources: For the Russian imports of sanctioned goods according to the Bruegel Russian Foreign Trade Tracker, see <https://www.bruegel.org/dataset/russian-foreign-trade-tracker>. The data on Common High Priority Goods are taken from the COMTRADE database (<https://comtradeplus.un.org/>). The data run to June 2024 and December 2023, respectively.

In summary, the alternative measures highlight how sanctions effectiveness has developed over time. Notwithstanding the empirical challenges and the methodological differences, all three measures indicate that the export bans are leaky and

sanctions evasion is widespread. As export controls have tightened, trade diversion, loopholes and workarounds to circumvent them have gained importance.

In the next section, we develop a modeling framework to provide clarity on the impacts of multi-layered export sanctions, loopholes, and workarounds.

### 3. The conceptual framework

This section presents the general equilibrium modeling framework with heterogeneous firm productivities that form the backbone of our analysis. The objective is to conceptualize the capabilities and boundaries of selective “smart” export sanctions on Russia. The setup builds on the work of Melitz (2003) and Ghironi and Melitz (2005) and relates to papers that use computable multi-country trade models in studying the effects of trade policy (Caliendo and Parro, 2015; Caliendo et al., 2019; Caliendo et al., 2023; Ghironi et al., 2024). These models are extended to analyze sanctions evasion.

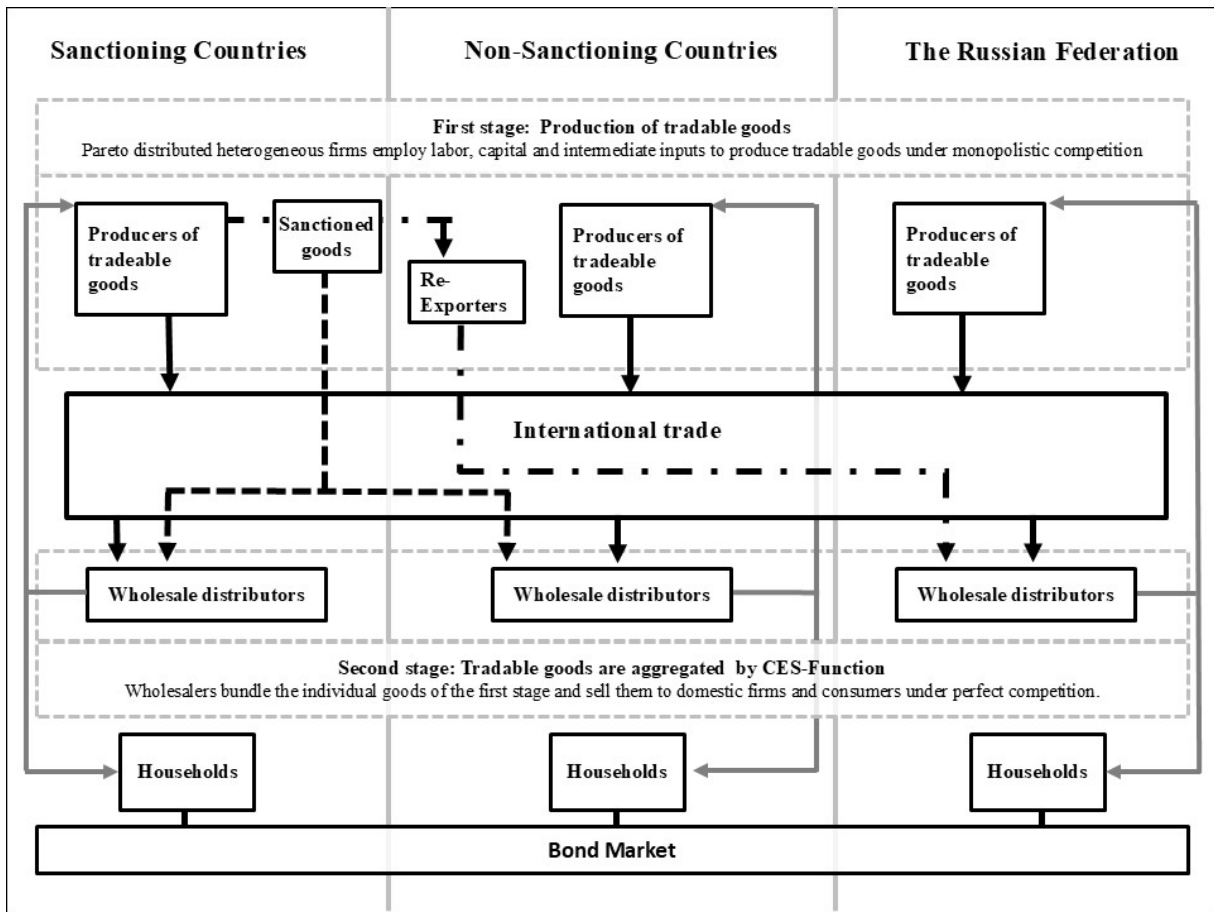
#### 3.1. General setup

We begin by outlining the general structure of the three-country model graphically sketched in Figure 2. Time is infinite and discrete. Countries are in three groups. The global Western sanction coalition, the Russian Federation, and our catch-all category for the Rest of the World are denoted by  $i \in \{SC, RU, RW\}$ . The *SC* countries impose export bans on sensitive goods in order to impair Russia’s wartime economy. Non-aligned *RW* countries serve as a bridge between the sanctions bloc and Russia bloc.

The model presumes a two-stage production process. In the first stage, heterogeneous firms use labor, capital, and final goods to produce tradable goods. These firms are differentially productive, drawing their productivity from a Pareto distribution at their birth. Only the most productive firms export their products abroad. Furthermore, the heterogeneous firms decide not only how much they produce and export, but also whether they enter the market or export at all. The tradable goods from the first stage are bought by the firms in the second stage. At the

second stage, wholesale distributors bundle the different intermediate goods available in the respective countries or country clusters. The final good bundles are then sold to domestic firms and households. The representative households of the three countries are connected via the bond market. They smooth their consumption over time, accumulate capital, and supply a fixed amount of labor. Thus, the labor force endowment is exogenous. For the sake of clarity, the governments that impose sanctions or implement sanctions evasion strategies are not shown in the schematic diagram.

Figure 2. Schematic model architecture.



To formalize sanction effectiveness, loopholes, and workarounds, we augment the benchmark dynamic multi-country trade model. First, the sanctioning global Western countries (*SC*) respond to the Russian invasion of Ukraine by imposing export bans on sensitive goods to Russia (*RU*) as tools of statecraft in the first stage of the production process. The geographically restricted international trade in

these goods is indicated in the diagram by dashed lines. Import bans on Russian products are not subject to analysis. Second, alongside the conventional trade diversion loophole, shell firms in the *RW* countries re-export imported sanctioned goods to Russia without any prior alteration or transformation in the country of transit. The interplay of the various impacts and sanction policy variables points to an efficient sanction design that impairs Russia's military-industrial complex and curtails Russia's access to advanced technologies.<sup>8</sup> Figure 2 maps the re-routing and bypassing of sanctioned goods via non-aligned third countries to Russia by the dashed-dotted line. For this newly introduced type of firm, the re-export sanction workaround is a double-edged sword. On one hand, the re-export of sanctioned items is profitable owing to the Russian military-industrial complex's inadequate supply of sensitive high-end items. Russia must pay steep premia to acquire sanctioned technology products from shadowy businesses in non-aligned countries (Simola, 2023). On the other hand, the threat of extraterritorial secondary sanctions looms.<sup>9</sup> The "ghost" trade is a special form of re-export flow. Sanctioned goods, ostensibly destined a non-aligned rest-of-the-world country never clear customs in the target country, but are "lost" while transiting Russia.<sup>10</sup>

Other regulations also aim at impeding the re-export of sanctioned goods by means of higher opportunity costs. For example, the EU has introduced the mandatory requirement for businesses to insert a "no re-export to Russia" clause in their contracts which involve any selling, supplying, or exporting to a third country that has not adopted export bans similar to those of the EU. To ensure compliance,

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<sup>8</sup> In contrast, Eaton and Engers (1992, 1999) provide a non-cooperative bargaining model for the endogenous determination of sanctions. Focusing on Markov perfect equilibria, they show how the timing and effectiveness of sanctions depend on the interacting countries' time preferences and the harms they incur from sanctions. Hausmann et al. (2024) provide theoretically grounded guidance on the design of effective export bans on Russia at the product level based on the implied economic costs.

<sup>9</sup> See <https://www.ft.com/content/7d5ed8ad-2251-47fc-835a-61f021fe12a2>. When modeling extraterritorial sanctions in a firm-specific manner, associated political foreign policy costs are ignored. Political resentment can set in when extraterritorial secondary sanctions are expanded to a point where economic losses become significant. This situation can make non-participation in the economic sanctions regime a way of signaling a country's sovereignty and cause problems for the aligned sanctioning countries in other areas of international relations.

<sup>10</sup> See <https://www.ft.com/content/76fc91b2-3494-4022-83d0-9d6647b38e3d>. In June 2023, the EU responded with a ban on transit of goods through Russia. The product categories subject to the transit prohibition include all sanctioned high-technology products.

the guidance document requires that all export contracts to non-EU entities contain “adequate remedies in the event of a breach” by the non-EU party. These remedies should be “reasonably strong” and “aim to deter non-EU operators from any breaches.” Instead of taking a very specific micro-foundation for re-exporters, we choose an objective function which maps these ancillary and mutually complementary economic, legal and political measures.<sup>11</sup> The benefit of our approach is that our results apply to a general class of sanctions-tightening.

In addition to the sanction workarounds already mentioned, our modeling framework allows for conventional sanction loopholes. Sanctioned goods can be substituted by means of non-sanctioned goods from the sanctioning countries by importing sanctioned goods from non-aligned *RW* countries, by producing the goods domestically, or both. Goods production requires investment in new firms (varieties) and physical capital. The model thus incorporates investment at the intensive and extensive margins.

To our knowledge, this is the first formal extension of general equilibrium trade models to the sanctions loophole and workaround issue. Another special feature of the modeling approach that merits highlighting is that the heterogeneous firm productivities in the set-up also allow analyzing the technology sensitivity of evasion strategies and sanctions.<sup>12</sup> When doing so, we strive to keep the augmented model with multi-layered sanctions as parsimonious as possible, ensuring maximum transparency in the transmission mechanism and interpretation of outcomes. Having introduced these conceptual model features, we next present a formal outline of the modeling framework.

## 3.2. Firms

Heterogeneous producers in region  $i$  use labor, capital, and intermediate inputs to produce and sell their individual varieties. A share of  $\Gamma_t^{ij}$  of the goods of region  $i$  is

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<sup>11</sup> See [https://finance.ec.europa.eu/document/download/7f54341b-2bf1-4142-b5d4-b1b09c93d03e\\_en](https://finance.ec.europa.eu/document/download/7f54341b-2bf1-4142-b5d4-b1b09c93d03e_en).

<sup>12</sup> For comparable modeling without reference to the circumvention strategies and workarounds, see Ghironi et al. (2024) and Funke and Wende (2023) in similar modeling frameworks.



subject to sanctions with respect to exports to country  $j$ . If goods are subject to sanctions, then exports to country  $j$  are prohibited. However, as export bans cannot be fully controlled, loopholes and workarounds exist. In the present model, the workarounds are performed by re-exporters. The middlemen businesses conduct detour trade to help Russia's war machine buy sanctioned goods from  $SC$  countries, export them to non-aligned  $RW$  countries, and re-export them to Russia ( $RU$ ). Re-exporters bear all associated trade costs, including the potential costs of extraterritorial sanctions. In the following, we describe the production and price-setting of individual producers, as well as the decision rationale of profit-maximizing re-exporters.

### 3.2.1. Production

The behavior of producers is determined by their productivity  $z$  and their sanction status  $\varphi \in \{sg, ng\}$ . The export decision of producers of non-sanctioned products ( $\varphi = ng$ ) is determined by their individual productivity  $z$ . Producers of sanctioned products ( $\varphi = sg$ ) in  $SC$  countries do not export to Russia. However,  $sg$  exports can take place via re-exporters in  $RW$  countries.

Firms produce heterogenous varieties under imperfect competition. The production function of a firm in region  $i \in \{SC, RU, RW\}$  indexed by its relative productivity  $z$  and its sanction status  $\varphi$  is given by the Cobb–Douglas function

$$Y_{D,t}^i(z, \varphi) = zZ^i \left( L_t^i(z, \varphi) \right)^{\varrho_L^i} \left( K_t^i(z, \varphi) \right)^{\varrho_K^i} \left( M_t^i(z, \varphi) \right)^{\varrho_M^i}, \quad (1)$$

where  $L_t^i(z, \varphi)$ ,  $K_t^i(z, \varphi)$  and  $M_t^i(z, \varphi)$  are labor, capital and raw materials, respectively.  $\varrho_L^i$ ,  $\varrho_K^i$  and  $\varrho_M^i$  are the respective factor weights and  $Z^i$  is aggregate productivity in region  $i$ . Profit maximization yields marginal cost given by

$$MC_t^i = \left( \frac{w_t^i}{\varrho_L^i} \right)^{\varrho_L^i} \left( \frac{R_{K,t}^i}{\varrho_K^i} \right)^{\varrho_K^i} \left( \frac{1}{\varrho_M^i} \right)^{\varrho_M^i} \quad (2)$$

where  $w_t^i$  denotes the real wage in country  $i$  and  $R_{Ks,t}^i$  is the rental price of physical capital. The price of the final goods bundle used as input by firms is given by the numeraire price index and therefore equal to one. Note that the marginal cost of purchasing an additional unit of the factor input bundle, denoted as  $MC_{s,t}^i$ , is identical for all firms within the same country. In contrast, the marginal cost of producing an additional unit of output, given by  $MC_{s,t}^i/Z^i z$ , differs across firms. Price-setting under imperfect competition leads to a first-order condition in which firms choose the output price as a mark-up on marginal costs as

$$p_{D,t}^i(z, \varphi) = p_{D,t}^i(z) = \frac{p_{D,t}^{i,n}(z)}{P_t^i} = \frac{\theta}{\theta - 1} \frac{MC_t^i}{Z^i z}, \quad (3)$$

where  $\theta$  is the elasticity of substitution (see also section 3.1.7). The superscript  $n$  denotes nominal variables. If a firm in country  $i$  with productivity  $z$  exports to country  $j$ , its price in terms of the price index of the destination market is given by

$$p_{X,t}^{ji}(z, ng) = \frac{p_{X,t}^{ji,n}(z, ng)}{P_t^j} = \frac{1}{\varepsilon_t^{ij}} \tau_{X,t}^{ij} p_{D,t}^i(z), \quad (4)$$

where  $\tau_{X,t}^{ji}$  are iceberg trade costs from exporting from country  $j$  to country  $i$  and  $\varepsilon_t^{ij}$  is the real exchange rate defined as  $\varepsilon_t^{ij} = \varepsilon_t^{ij,n} P_t^j / P_t^i$ . We assume flexible nominal exchange rates. Note that  $p_{X,t}^{ji}(z, ng)$  is the price received by firm  $z$ .

If a non-sanctioned firm in country  $i$  decides to export to region  $j$ , it has to pay fixed costs of exporting  $f_{X,t}^{ij}$  in terms of effective units of its input bundle. Consequently, export profits are given by:

$$d_{X,t}^{ij}(z, ng) = \begin{cases} \frac{\varepsilon_t^{ij}}{\theta} (1 + \tau_t^{ji})^{-\theta} [p_{X,t}^{ji}(z, ng)]^{1-\theta} (P_{X,t}^{ji})^\theta Q_{X,t}^{ji} - MC_t^i \frac{f_{X,t}^{ij}}{Z^i}, & \text{if firm } z \text{ exports to } j \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

$p_{X,t}^{ji}$  is the import price index of all goods imported by country  $j$  from country  $i$  including re-exports,  $Q_{X,t}^{ji}$  is the bundle of imported goods, and  $\tau_t^{ji}$  is an ad-valorem trade tariff imposed by country  $j$  on imports from country  $i$ . For sanctioned firms, the export profits are zero, i.e.  $d_{X,t}^{ij}(z, sg) = 0$ . Total profits of a firm with productivity  $z$  and sanction status  $\varphi$  are the sum of its domestic and export profits given by  $d_t^i(z, \varphi) = \sum_{j \neq i} (d_{D,t}^i(z) + d_{X,t}^{ij}(z, \varphi))$ .

### 3.2.2. Re-exports and associated sanctions evasion costs

Detour re-exports to Russia via *RW* countries are associated with higher costs than conventional exports. These higher costs consist of additional transportation costs, tariffs, and the anticipated costs of potential extraterritorial sanctions, respectively. Extraterritorial secondary sanctions exert pressure on foreign-based businesses in *RW* countries to stop trading with Russia by threatening to block their market access to *SC* countries. The modeling presumption is that the likelihood of extraterritorial secondary sanctions and the associated knock-on costs depends on the re-export trade volume and the strategic importance of the re-exported products for the Russian military-industrial sector.<sup>13</sup>

To introduce these costs into the augmented trade model, we suppose that the re-exporters face a modified transport cost function. We conjecture that the re-export transport costs of a sanctioned good  $z$  depend on the domestic price  $p_{D,t}^i(z)$  that the re-exporter has to pay, the volume  $Q_{RX,t}^j(z, sg)$  that it buys and on the strategic importance of the product to be re-exported. The latter, in turn, is mapped by the productivity  $z$  of the business that produces the variety. In accordance with the literature, the higher the productivity  $z$ , the more important the product variety. The re-exporter sets the price in the destination market  $p_{RX,t}^{ji}(z, sg)$  to maximize its profit, which can be written in terms of the price index of region  $i$  as

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<sup>13</sup> Extraterritorial sanctions necessitate either outright blacklisting of front companies and foreign commercial banks in question or leaning on political allies to discipline the complex networks handling re-exports to Russia. Both approaches require large expenditures of diplomatic capital. The most likely outcome is half-baked secondary sanctions enforcement.

$$d_{RX,t}^{ij}(z, sg) = \varepsilon_t^{ij} p_{RX,t}^{ji}(z, sg) Q_{RX,t}^{ji}(z) - \tau_{RX,t}^{ij} [z]^{\tau_{z,t}^{ij}} p_{D,t}^i(z, sg) Q_{RX,t}^j(z, sg) - MC_t^i \frac{f_{RX,t}^{ij}}{Z^i}, \quad (6)$$

where  $Q_{RX,t}^{ji}(z, sg)$  is the quantity of the product that the re-exporter sells in region  $j$ , whereby the product was initially imported by region  $k$  from region  $i$ . Since we only model three regions, we can omit the index  $k$  in all variables with the exception of the exchange rate. In the following, we also omit sanction status as the re-exporters only re-export sanctioned goods. The term  $\tau_{RX,t}^{ij} [z]^{\tau_{z,t}^{ij}}$  denotes product and trade volume specific trade costs. The first element  $\tau_{RX,t}^{ij}$  represents iceberg trade costs. Suppose that  $0 \leq \tau_{z,t}^{ij} < 1$ . The second element  $[z]^{\tau_{z,t}^{ij}}$  then implies that trade costs are positively dependent on the productivity of the firm producing the variety, or are constant as a special case (see section 3.1.4). In economic terms, this maps the intuition that the re-export costs are higher for high-end goods under tighter international surveillance. Re-exporters also have to pay fixed costs of exporting as described below.

We assume that each re-exporter specializes in one product, which results in double marginalization, i.e. a double markup above cost. It follows that the re-exporters' price in terms of the price index of the destination market is given by

$$\begin{aligned} p_{RX,t}^{ji}(z) &= \frac{p_{RX,t}^{ji,n}(z)}{P_t^j} = \frac{1}{\varepsilon_t^{ij}} \tau_{RX,t}^{ij} [z]^{\tau_{z,t}^{ij}} \frac{\theta}{(\theta - 1)} p_{D,t}^i(z) \\ &= \frac{1}{\varepsilon_t^{ij}} \tau_{RX,t}^{ij} [z]^{\tau_{z,t}^{ij}} \left( \frac{\theta}{\theta - 1} \right)^2 \frac{MC_t^i}{Z^i} \end{aligned} \quad (7)$$

Considering the fixed costs of exporting  $f_{RX,t}^{ij}$ , the re-exporters profits are given by

$$d_{RX,t}^{ij}(z) = \begin{cases} \frac{\varepsilon_t^{ij}}{\theta} (1 + \tau_t^{ki})^{-\theta} [p_{RX,t}^{ji}(z)]^{1-\theta} (P_{X,t}^{ji})^\theta Q_{X,t}^{ji} - MC_t^i \frac{f_{RX,t}^{ij}}{Z^i}, & \text{if product } z \text{ is re-exported to } j \\ 0 & \text{otherwise} \end{cases} \quad (8)$$

Moreover, we assume that re-exports of sanctioned goods to Russia are free of customs and excise duties, such that re-exporters are only required to pay tariffs  $\tau_t^{ki}$  on the export of goods from country  $i$  to country  $k$ .<sup>14</sup> The profits of domestic companies on the domestic market are given as

$$d_{DD,t}^i(z) = \frac{1}{\theta} [p_{D,t}^i(z)]^{1-\theta} (P_{D,t}^i)^\theta Q_{D,t}^i, \quad (9)$$

where  $P_{D,t}^i$  is the domestic price index of the domestic goods bundle  $Q_{D,t}^i$ . On top of this, the profits resulting from the goods sold to the re-exporters are given by

$$d_{DRX,t}^{ij}(z) = \begin{cases} \frac{1}{\theta} (1 + \tau_t^{ki})^{-\theta} [p_{D,t}^i(z)]^{1-\theta} \left( \frac{p_{RX,t}^{ji}(z)}{P_{X,t}^{ji}} \right)^{-\theta} Q_{X,t}^{ji}, & \text{if product } z \text{ is re-exported to } j \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

The assumption here is that the re-exporters bear all transport costs. In summary, this means that domestic profits of firm  $z$  are  $d_{D,t}^i(z) = d_{DD,t}^i(z) + d_{DRX,t}^{ij}(z)$ .

### 3.2.3. Equilibrium price indices and aggregation

The aggregate domestic and import equilibrium prices of region  $i$  are given by

$$P_{D,t}^i = \left\{ \int_{z_{min}}^{\infty} [p_{D,t}^i(z, \varphi)]^{1-\theta} N_{D,t}^i g(z) dz \right\}^{\frac{1}{1-\theta}} \quad (11)$$

and

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<sup>14</sup> A sizable number of sanctions evaders are based in the Eurasian Economic Union (Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia). This integrated single market allows for free movement of goods and services. See <https://www.economist.com/europe/2024/08/19/the-mysterious-middlemen-helping-russias-war-machine>.

$$P_{X,t}^j = \left\{ \int_{z_{RX,t}^{ij}}^{\infty} [(1 + \tau_t^{ki}) p_{RX,t}^{ji}(z, sg)]^{1-\theta} \Gamma_t^{ij} N_{D,t}^i g(z) dz + \int_{z_{X,t}^{ij}}^{\infty} [(1 + \tau_t^{ji}) p_{X,t}^{ji}(z, ng)]^{1-\theta} (1 - \Gamma_t^{ij}) N_{D,t}^i g(z) dz \right\}^{\frac{1}{1-\theta}} \quad (12)$$

respectively.  $N_{D,t}^i$  is the number of firms in country  $i$ , each of which produces one variety from which a fraction of  $\Gamma_t^{ij}$  is sanctioned. Only non-sanctioned firms with a productivity cutoff value of at least  $z_{X,t}^{ji}$  will also export to region  $i$ , and only products of sanctioned firms with a productivity cut-off of  $z_{RX,t}^{ji}$  will be re-exported.

Given the cutoff productivity of firms,  $z_{min}$ , we define the average productivity of all firms as  $\tilde{z}_{D,t} = \left[ \int_{z_{min}}^{\infty} z^{\theta-1} g(z) dz \right]^{1/(\theta-1)}$ . This average productivity is normalized to be the same in all regions, but we allow for differences in aggregate productivity between regions through differences in  $Z^i$ . We also need an average productivity of firms exporting from region  $i$  to region  $j$ . This average productivity must be formed between exporters and re-exporters. In the case of re-exporters, their average productivity is the productivity of the sanctioned firms whose products they re-export. Considering the productivity-dependent cost structure of re-exporters, we define the effective average productivity as

$$\begin{aligned} \tilde{z}_{X,t}^{ij} &= \left\{ (1 - \Gamma_t^{ij}) \int_{z_{X,t}^{ij}}^{\infty} z^{\theta-1} g(z) dz + \Gamma_t^{ij} \left[ \frac{\tau_{RX,t}^{ij}}{\tau_{X,t}^{ij}} \frac{1 + \tau^{ki}}{1 + \tau^{ji}} \left( \frac{\theta}{\theta - 1} \right) \right]^{1-\theta} \int_{z_{RX,t}^{ij}}^{\infty} z^{(1+\theta_2)(\theta-1)} g(z) dz \right\}^{\frac{1}{\theta-1}} \\ &= \left\{ (1 - \Gamma_t^{ij}) (\tilde{z}_{X,t}^i)^{\theta-1} + \Gamma_t^{ij} \left[ \frac{\tau_{RX,t}^{ij}}{\tau_{X,t}^{ij}} \frac{1 + \tau^{ki}}{1 + \tau^{ji}} \left( \frac{\theta}{\theta - 1} \right) \right]^{1-\theta} (\tilde{z}_{RX,t}^{ij})^{\theta-1} \right\}^{\frac{1}{\theta-1}} \end{aligned} \quad (13)$$

The average productivities  $\tilde{z}_{D,t}^i$  and  $\tilde{z}_{X,t}^i$  are weighted means of the firms' productivity values  $z$ , where the weighting is based on the firms' output shares. The effective average productivities  $\tilde{z}_{X,t}^{ij}$  and  $\tilde{z}_{RX,t}^{ij}$  are based on the same weighting, but

also account for the costs and markup of re-exporters. Thus, aggregated prices are given by

$$P_{D,t}^i = \frac{P_{D,t}^{i,n}}{P_t^i} = (N_{D,t}^i)^{\frac{1}{1-\theta}} p_{D,t}^i(\tilde{z}_{D,t}^i) \quad (14)$$

$$P_{X,t}^{ij} = \frac{P_{X,t}^{ij,n}}{P_t^i} = (1 + \tau_t^j)(N_{D,t}^i)^{\frac{1}{1-\theta}} p_{X,t}^{ji}(\tilde{z}_{X,t}^{ij}) \quad (15)$$

Note that  $\tilde{z}_{X,t}^{ij}$  is defined in such a way that it can simply be substituted into  $p_{X,t}^{ji}(z, ng)$  from equation (4) to obtain the average price  $p_{X,t}^{ji}(\tilde{z}_{X,t}^{ij})$ .

### 3.2.4. Distributional assumptions and firm averages

We assume that firm productivity  $z$  is distributed according to the Pareto distribution. The cumulative distribution function is then given by  $G(z) = 1 - (z_{min}/z)^k$  with lower bound  $z_{min}$  and shape parameter  $k$ , which must be greater than  $\theta - 1$  so that average firm size does not become infinite. Combined with *CES*, the Pareto distribution delivers closed-form solutions and thus plays a crucial role in the result of the trade model. Given this distribution function, the average productivity of firms in country  $i$  takes the form

$$\tilde{z}_{D,t}^i = \left[ \frac{k}{k - \theta + 1} \right]^{\frac{1}{\theta-1}} z_{min} \quad (16)$$

and the average productivities of firms in country  $i$  that decide to export non-sanctioned products to country  $j$  and of firms whose sanctioned products are re-exported to country  $j$  via a third country by re-exporters are given by

$$\tilde{z}_{XX,t}^{ij} = \left( \frac{k}{k - (\theta - 1)} \right)^{\frac{1}{(\theta-1)}} z_{XX,t}^{ij}; \quad \tilde{z}_{RX,t}^{ij} = \left( \frac{k}{k - (\theta - 1)} \right)^{\frac{1}{(\theta-1)}} z_{RX,t}^{ij}. \quad (17)$$

We have also defined the simple average productivity of re-exporters, which we will use later. Their effective average productivity is given by

$$z_{XS,t}^{ij} = \left( \frac{k}{k - (1 - \tau_{z,t}^{ij})(\theta - 1)} \right)^{\frac{1}{(\theta-1)}} (z_{RX,t}^{ij})^{1-\tau_{z,t}^{ij}}. \quad (18)$$

We now combine the above and firm profits, equations (5) and (8), to solve for the productivity cutoffs that distinguish exporters as profitable or nonprofitable exporters, and re-export opportunities as profitable or non-profitable. Non-sanctioned firms that draw a productivity above the export cutoff  $z_{X,t}^{ij}$  will supply the market, and the varieties of sanctioned firms will only be bought by re-exporters if their productivity draw is above  $z_{RX,t}^{ij}$ . Finally, we can rearrange terms to obtain the two productivity cut-off values

$$z_{X,t}^{ij} = \tau_{X,t}^{ij} \left( \frac{\theta}{\theta - 1} \right) \left( \frac{(1 + \tau_t^{ji})MC_t^i}{\varepsilon_t^{ij} Z_t^i P_{X,t}^{ji}} \right)^{\frac{\theta}{\theta-1}} \left( \frac{\theta f_{X,t}^{ij}}{Q_{X,t}^{ji}} \right)^{\frac{1}{\theta-1}} \quad (19)$$

and

$$z_{RX,t}^{ij} = \left[ \tau_{RX,t}^{ij} \left( \frac{\theta}{\theta - 1} \right)^2 \left( \frac{(1 + \tau_t^{ji})MC_t^i}{\varepsilon_t^{ij} Z_t^i P_{X,t}^{ji}} \right)^{\frac{\theta}{\theta-1}} \left( \frac{\theta f_{RX,t}^{ij}}{Q_{X,t}^{ji}} \right)^{\frac{1}{\theta-1}} \right]^{\frac{1}{1-\tau_{z,t}^{ij}}} \quad (20)$$

Unsurprisingly,  $z$  increases with both  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$ . For  $\tau_{z,t}^{ij} = 1$ , there is no productivity cut-off that separates exporters from non-exporters, because productivity advantages are exactly offset by cost disadvantages in this case. Thus, businesses either export or do not export.

The aforementioned productivity cut-offs, in conjunction with the corresponding average productivity, permit the calculation of both the average prices and the average profits.



### 3.2.5. Firms and the decision to export

There are  $N_{D,t}$  home firms in sector  $s$  from which  $N_{X,t}$  firms decide to export if they are allowed to do so. If there are no sanctions,  $G(z_{X,t}^{ij})$  is the probability that a firm will not export to sector  $s$  in country  $j$ . Consequently, the proportion of domestic firms both permitted and selected to conduct export activities is

$$\frac{N_{X,t}^{ij}}{N_{D,t}^i} = (1 - \Gamma_t^{ij}) (1 - G(z_{X,t}^{ij})) = (1 - \Gamma_t^{ij}) (z_{min}/\tilde{z}_{X,t}^{ij})^k \left( \frac{k}{k - \theta + 1} \right)^{\frac{k}{\theta-1}} \quad (21)$$

The share of home firms whose products are bought by re-exporters is given by

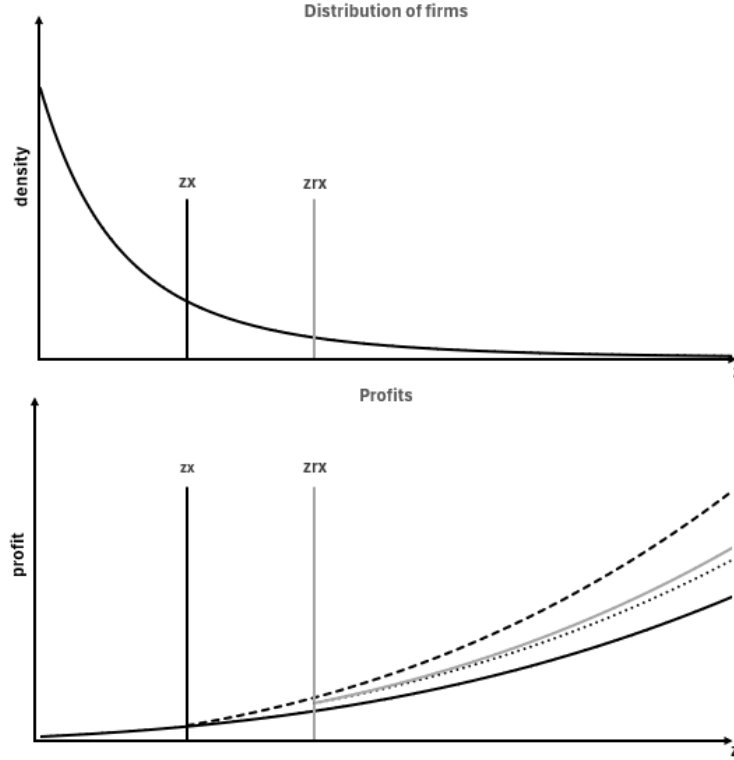
$$\begin{aligned} \frac{N_{RX,t}^{ij}}{N_{D,t}^i} &= \Gamma_t^{ij} (1 - G(z_{RX,t}^{ij})) \\ &= \Gamma_t^{ij} (z_{min})^k (\tilde{z}_{RX,t}^{ij})^k \left( \frac{\tau_{z,t}^{ij} k}{\tau_{z,t}^{ij} - 1} \right)^k \left( \frac{k}{k - (1 - \tau_{z,t}^{ij})(\theta - 1)} \right)^{\frac{k}{(\theta-1)(1-\tau_{z,t}^{ij})}} \end{aligned} \quad (22)$$

As a result, a share of  $(1 - G(z_{X,t}^i)) - N_{X,t}^{ij}/N_{D,t}^i - N_{RX,t}^i/N_{D,t}^i$  of the varieties are no longer exported to region  $j$  due to the sanctions.

Figure 3 illustrates the model features. The upper panel shows the inverse relationship between the number of firms and the productivity level  $z$ . Only firms with productivity above the cut-off,  $zx$ , export. If firm varieties are sanctioned,  $zx$ -firms cease exporting to Russia and  $zrx$ -firms continue re-exporting to Russia. The lower panel depicts the positive dependence of firm profits on firm productivity  $z$ . The solid black line shows the domestic profits of all businesses. Firms with productivity beyond  $zx$  gain additional profits from exporting as shown by the vertical distance between the solid black and the dashed black lines. Sanctioned firms in the productivity bracket  $zx < z < zrx$  forgo their exporting profits. Only beyond the  $zrx$ -cutoff do exports to re-exporters become profitable. The resulting profits are represented by the vertical distance between the solid black line and the dotted

black line. The profits of re-exporters, in turn, are represented by the distance between the dotted black line and the solid gray line. The accurate shapes of the curves are given by the cost parameters introduced earlier.

Figure 3. The distribution of firms and profits depending on firm-level productivity.



### 3.2.6. Firm entry and exit decisions

Following Ghironi and Melitz (2005), we assume that for market entry the expected stream of profits  $\tilde{v}_t^i$  must be equal to the costs of entry, so that

$$\tilde{v}_t^i = \frac{MC_t^i f_E^i}{Z_t^i} \quad (23)$$

$N_{E,t}^i$  new entrants in period  $t$  start to produce in period  $t + 1$  and survive every period with an exogenous probability  $(1 - \delta)$ . The stock of firms  $N_{D,t}^i$  in period  $t$  is then given by:

$$N_{D,t}^i = (1 - \delta)(N_{D,t-t}^i + N_{E,t-1}^i) \quad (24)$$

### 3.2.7. Substitution between varieties

For further use as a consumption or intermediate product, the different varieties must be aggregated. This bundling of goods of region  $i$  in period  $t$  is given by the following constant elasticity of substitution (CES) aggregator:

$$Q_t^i = \left( (1 - \alpha^i)^{\frac{1}{\omega}} (Q_{D,t}^i)^{\frac{\omega-1}{\omega}} + (\alpha^i)^{\frac{1}{\omega}} (Q_{X,t}^i)^{\frac{\omega-1}{\omega}} \right)^{\frac{\omega}{\omega-1}}, \quad (25)$$

where  $\alpha^i$  is the degree of openness, and  $\omega$  is the macro elasticity, i.e., the elasticity of substitution between the domestically produced bundle of varieties and that produced abroad. The former is given by  $Q_{D,t}^i = \left( \int_z (Q_{D,t}^i(z))^{\frac{\theta-1}{\theta}} dz \right)^{\theta/(\theta-1)}$  where  $Q_{D,t}^i(z)$  represent the demand for domestic variety  $z$ , and the foreign produced bundle is denoted  $Q_{X,t}^i$ . The foreign bundle is given by:

$$Q_{X,t}^i = \left( \sum_{j \neq i} (\kappa^{ij})^{\frac{1}{\theta}} (Q_{X,t}^{ij})^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \quad (26)$$

where  $\kappa^{ij}$  denotes the utility weight of the CES index, the bundle of varieties imported from country  $j$  is  $Q_{X,t}^{ij} = \left( (1 - \Gamma_t^{ij}) \int_z (Q_{X,t}^{ij}(z))^{\frac{\theta-1}{\theta}} dz + \right.$

$\left. \Gamma_t^{ij} \int_z (Q_{RX,t}^{ij}(z))^{\frac{\theta-1}{\theta}} dz \right)^{\theta/(\theta-1)}$  and  $\theta$  is the micro-elasticity of substitution, which

is the same for all goods. The introduction of these two distinct substitution elasticities follows Feenstra et al. (2018). The CES-based final price index is given by

$$P_t^i = \left[ (1 - \alpha^i) (P_{D,t}^{i,n})^{1-\omega} + \alpha^i (P_{X,t}^{i,n})^{1-\omega} \right]^{\frac{1}{1-\omega}}, \quad (27)$$

where  $P_{X,t}^{i,n} = \left( \sum_{j \neq i} \kappa^{ij} (P_{X,t}^{ij,n})^{1-\theta} \right)^{1/(1-\theta)}$ .  $P_{D,t}^{i,n}$  and  $P_{X,t}^{ij,n}$  are the above defined nominal aggregate equilibrium price indices of the domestic and of imported varieties, respectively. Dividing equation (25) by  $P_t^i$ , we obtain the following relationship between real domestic import price indices

$$1 = (1 - \alpha^i)(P_{D,t}^i)^{1-\omega} + \alpha^i(P_{X,t}^i)^{1-\omega} \quad (28)$$

As with the prices of individual firms, all price indices are divided by the  $P_t^i$  to define all real prices relative to the numeraire price index.

### 3.3. Households

The representative household  $h$  in country  $i \in \{SC; RU; RW\}$  maximizes its utility

$$V_0 = E_0 \left( \sum_{t=0}^{\infty} \beta^t \frac{(C_{h,t}^i)^{1-\gamma}}{1-\gamma} \right), \quad (29)$$

where  $E_0$  is the rational expectations operator,  $\beta$  is the discount factor and  $\gamma$  is the inverse elasticity of intertemporal substitution with regard to consumption  $C_{h,t}^i$ .<sup>15</sup> Consumption of every country has a mass relative to the size of the SC economy  $\xi^{SC}$ . Therefore, all absolute quantities represent aggregates relative to the sanctioning countries. Due to symmetry, consumption and labor supply are the same for every household and, thus,  $C_{h,s,t}^i = \frac{\xi^{SC}}{\xi^i} C_{s,t}^i$ . The aggregated budget constraint of all households in country  $i$  is given by

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<sup>15</sup> In principle, the representative household presumption can be used not only for positive analyses but also for normative analyses, such as evaluating the optimality of equilibria (Schmitt-Grohé and Uribe, 2007). However, the utility function does not encompass the profound geopolitical challenges often referred to as a *Zeitenwende*, a historic turning point. Export bans are never considered from the perspective that they might help liberal democracies survive expansionist autocratic ambitions. Put another way, economic models consistently take peace and order for granted, a tacit premise unjustified by current events. Therefore, standard economic welfare calculations as a supplement to positive analyses are waived in the paper.

$$\begin{aligned}
& \sum_{j \neq i} B_{i,t}^i + \sum_{j \neq i} \varepsilon_t^{ij} B_{j,t}^i + \tilde{v}_t^i N_t^i x_t^i + I_{k,t}^i \sum_{j \neq i} B_{i,t}^i + \sum_{j \neq i} \varepsilon_t^{ij} B_{j,t}^i + \tilde{v}_t^i N_t^i x_t^i + I_{k,t}^i + C_{h,t}^i \\
& = \\
& \sum_{j \neq i} R_{t-1}^i B_{i,t-1}^i + \sum_{j \neq i} R_{j,t-1}^i \varepsilon_t^{ij} B_{j,t-1}^i + R_{Ks,t}^i K_{s,t-1}^i + (\tilde{d}_t^i + \tilde{v}_t^i) N_t^i x_{t-1}^i + w_t^i L^i + \Psi_t^i,
\end{aligned} \tag{30}$$

where  $B_{i,t}^i$  are bonds denoted in domestic currency,  $B_{j,t}^i$  are bonds denoted in a foreign currency, and  $\varepsilon_t^{ij} = \varepsilon_t^{ij,n} P_t^j / P_t^i$  is the real exchange rate.  $R_{t-1}^i$  is the interest rate of bonds denoted in domestic currency and  $R_{j,t-1}^i$  is the interest rate of bonds denoted in the currency of country  $j$ .  $w_t^i$  is the real wage,  $L^i$  is labor supply, and  $\Psi_t^i$  is a lump-sum rebate of the import tariff revenue. During period  $t$ , households buy  $x_t^i$  shares in an investment fund from  $N_t^i \equiv N_{D,t}^i + N_{E,t}^i$  domestic firms and in this way invest at the extensive margin. The price of the shares is equal to the above-mentioned present value of the expected stream of average profits of the domestic firms  $\tilde{v}_t^i$ . The dividends paid to the shareholders in period  $t$  are again equal to average profits  $\tilde{d}_t^i$ . Moreover, households can consume  $C_t^i$  or invest  $I_{k,t}^i$  of the final good (at the intensive margin). In previous periods accumulated capital,  $K_{s,t-1}^i$  provides a real return  $R_{Ks,t}^i$  to the household. Furthermore, we assume convex investment adjustment costs. Therefore, the utility maximization problem of the household is also subject to

$$K_t^i = (1 - \delta_K) K_{t-1}^i + I_{k,t}^i \left( 1 - \frac{\phi}{2} \left( \frac{I_{k,t}^i}{I_{k,t-1}^i} - 1 \right)^2 \right), \tag{31}$$

where  $\phi$  is an investment adjustment cost parameter and  $\delta_K$  is the depreciation rate of capital. The aggregate marginal value of consumption is given as

$$\lambda_t^i = \left( \frac{\xi^{SC}}{\xi^i} C_{h,t}^i \right)^{-\gamma}, \tag{32}$$

where  $\lambda_t^i$  is the Lagrangian multiplier of the budget constraint. The remaining first-order conditions common to all countries are:

$$R_t^i = \frac{1}{\beta} E_t \left( \frac{\lambda_t^i}{\lambda_{t+1}^i} \right) \quad (33)$$

$$R_{j,t}^i = \frac{1}{\beta} E_t \left( \frac{\varepsilon_t^{ij}}{\varepsilon_{t+1}^{ij}} \frac{\lambda_t^i}{\lambda_{t+1}^i} \right) \quad (34)$$

$$q_t^i = \beta E_t \left( \frac{\lambda_{t+1}^i}{\lambda_t^i} \left( R_{K,t+1}^i + q_{t+1}^i (1 - \delta_K) \right) \right) \quad (35)$$

$$\begin{aligned} q_t^i = 1 + q_t^i \frac{\phi}{2} \left( \frac{I_{k,t}^i}{I_{k,t-1}^i} - 1 \right)^2 + \phi q_t^i \left( \frac{I_{k,t}^i}{I_{k,t-1}^i} - 1 \right) \frac{I_{k,t}^i}{I_{k,t-1}^i} \\ - \beta \phi E_t \left( q_{t+1}^i \frac{\lambda_{t+1}^i}{\lambda_t^i} \left( \frac{I_{k,t+1}^i}{I_{k,t}^i} - 1 \right) \left( \frac{I_{k,t+1}^i}{I_{k,t}^i} \right)^2 \right) \end{aligned} \quad (36)$$

$$\tilde{v}_t^i = \beta(1 - \delta) E_t \left( \frac{\lambda_{t+1}^i}{\lambda_t^i} (\tilde{d}_{t+1}^i + \tilde{v}_{t+1}^i) \right) \quad (37)$$

Equations (33) and (34) are the usual Euler equations for trading in domestic and foreign bonds. The ratio of the Lagrange multipliers is denoted  $q_t^i$ , which corresponds to the marginal value of a unit of installed capital (marginal Tobin's  $q$ ). Its development is determined by the equations (35) and (36). Finally, equation (37) is the Euler equation for shareholdings.

### 3.4. Government transfers

After characterizing the producer and consumer optimization problems, we now characterize the government. To maintain analytical clarity, we model the government in a simplified way, limiting its responsibility to trade policy. It collects tariffs and transfers all tariff revenues to households in the form of lump-sum transfers. The lump-sum transfer is given by

$$\Psi_t^i = \sum_{j \neq i} \tau_t^{ij} \varepsilon_t^{ij} N_{X,t}^{ji} \tilde{r}_{X,t}^{ji} + \sum_{j \neq i} \tau_t^{ij} \varepsilon_t^{ij} N_{RX,t}^{jk} \tilde{r}_{RX,t}^{jk}, \quad (38)$$

where  $\tilde{r}_{X,t}^{ji} = \theta (\tilde{d}_{X,t}^{ji} + MC_t^j [f_X^{ji}/Z^j])$  are average export revenues from intermediate firms in country  $j$  exporting to country  $i$ . Similarly,  $\tilde{r}_{RX,t}^{jk} = \theta (\tilde{d}_{RX,t}^{jk} + MC_t^j [f_{RX}^{jk}/Z^j])$  are average re-export revenues from re-exporters that purchase goods in country  $j$  exporting to region  $i$  and re-export to  $k$ . Consequently, these re-exporters are required to pay tariffs in country  $i$ .

### 3.5. Market clearing

Market clearing is defined as a sequence of allocations such that households maximize utility, firms maximize profits, all constraints are satisfied, and all markets clear. The market equilibrium for bonds denominated in the currency of country  $i$  is given by

$$B_{i,t}^{SC} + B_{i,t}^{RU} + B_{i,t}^{RW} = 0 \quad (39)$$

To obtain a unique steady state, we follow Schmitt-Grohé and Uribe (2003), assuming a convex risk premium that depends on the difference between the actual bond holdings  $B_{i,t}^j$  and their steady state

$$R_{i,t}^j = R_t^i + \Upsilon e^{\bar{B}_i^j - B_{i,t}^j} \quad (40)$$

The functional form in equation (37) implies that the risk premium sensitivity depends upon the parameter  $\Upsilon$ . Next, market clearing in the sector of tradable intermediates requires

$$(L^i)^{q_L^i} (K_t^i)^{q_K^i} (M_t^i)^{q_M^i} = \frac{(\theta - 1)}{MC_t^i} \left( N_{D,t}^i \tilde{d}_{DD,t}^i + \sum_{j \neq i} N_{X,t}^{ij} \tilde{d}_{X,t}^{ij} + \sum_{j \neq i} N_{RX,t}^{ij} \tilde{d}_{DRX,t}^{ij} \right) + \frac{1}{Z_t^i} \left( \theta \left[ \sum_{j \neq i} N_{XS,t}^{ij} f_X^{ij} \right] \right) \quad (41)$$

Turning to the goods markets, the aggregate resource constraints are given by

$$Q_t^i = C_t^i + M_t^i + I_t^i, \quad (42)$$

where  $I_t^i = I_{k,t}^i + N_{E,t}^i f_E^i$ . Moreover, to close the model the net assets of two out of the three countries must be used. In the case of the sanctioning countries, market clearing requires

$$\begin{aligned} & B_{SC,t}^{SC} + \varepsilon_t^{SCRU} B_{RU,t}^{SC} + \varepsilon_t^{SCRW} B_{RW,t}^{SC} \\ &= \frac{1}{2} \left[ R_{SC,t-1}^{SC} B_{SC,t-1}^{SC} - \sum_{j \neq SC} R_{SC,t-1}^j B_{SC,t-1}^j \right. \\ &+ \varepsilon_t^{SCRU} \left( R_{RU,t-1}^{SC} B_{RU,t-1}^{SC} - \sum_{j \neq SC} R_{RU,t-1}^j B_{RU,t-1}^j \right) \\ &+ \varepsilon_t^{SCRW} \left( R_{RW,t-1}^{SC} B_{RW,t-1}^{SC} - \sum_{j \neq SC} R_{RW,t-1}^j B_{RW,t-1}^j \right) \\ &+ w_t^{SC} L^{SC} + \Psi_t^{SC} + R_{K,t}^{SC} K_{t-1}^{SC} + N_{D,t}^{SC} \tilde{d}_t^{SC} - I_t^{SC} - C_{h,t}^{SC} \\ &\left. - \sum_{j \neq SC} \varepsilon_t^{SCj} \left( w_t^j L^j + \Psi_t^j + \sum_s R_{Ks,t}^j K_{s,t-1}^j + N_{D,t}^j \tilde{d}_t^j - I_t^j - C_{h,t}^j \right) \right] \end{aligned} \quad (43)$$

### 3.6. Numerical model evaluation

Before proceeding with the model calibration, we briefly discuss the numerical solution method. Since the model is highly nonlinear, we employ the Dynare perfect foresight solver. The details of the algorithm can be found in Juillard (1996). This completes the model representation. In the next section, we map the theoretical model step-by-step onto the data.<sup>16</sup>

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<sup>16</sup> The underlying “theory with numbers” methodology is similar in spirit to the modeling approach articulated by Costinot and Rodríguez-Clare (2014).



## 4. Model calibration

The three-country dynamic general equilibrium trade model is calibrated to represent the sanctioning countries (SC), the Russian Federation (RU) and the non-sanctioning countries (RW), respectively. Time is measured in quarters. The calibration is conducted in two stages. Initially, the values of several parameters are set in accordance with the literature or directly obtained from observed data. The remaining parameters are determined numerically to match steady-state model moments with corresponding moments in the data. The approach corresponds to that of Kehoe et al. (2018) and Steinberg (2019). By means of this approach, a perfect match is achieved for all moments for which actual data is available. For parameters without direct observations, their plausibility is ensured.

Table 1. Baseline parameters

Parameter	Definition	Value
Trade elasticities		
$\theta$	Micro elasticity	3.8
$\omega$	Macro elasticity	1.9
Production, costs and capital		
$\varrho_L$	Labor, capital and material share in the production function	0.5
$\varrho_K$		0.2
$\varrho_M$		0.3
$\delta$	Exit probability of firms	0.025
$\delta_K$	Capital depreciation	0.025
$f_E^i$	Entry cost	1
$Z^i$	Aggregate productivity	1
$\tau_{RX,t}^{SCRU}$	Shipping cost parameters	0.9
$\tau_{z,t}^{SCRU}$		0.3
Households		
$\beta$	Discount factor	0.99
$\gamma$	Coefficient of relative risk aversion	2
Firm distribution and other structural parameters		
$z_{min}$	Minimum relative productivity	1
$k$	Pareto shape parameter	3.4
$\phi$	Investment adjustment cost parameter	8
$\Upsilon$	Risk premium parameter	0.001

In terms of sanctions at the outset, the benchmark calibration mirrors the half-hearted and ultimately ineffective sanctions imposed against Russia in the aftermath of the illegal annexation of the Crimean Peninsula and the hybrid warfare between the Ukrainian military and Russian-backed separatist rebels in the Donbass in 2014. Sanctions at that time included only few restrictions on the export and re-export of technology for the Russian defense sectors, so most high-end technology exports were exempt from trade restrictions. Since the sanctions at that time *de facto* had no effect on essential goods exports, we assume  $\Gamma_t^{SCRU} = 1\%$  as our baseline.<sup>17</sup>

The tabular summary of the baseline parameters in stage one is given in Table 1. Most parameter values are conventional in the literature, and we here use the same values as in Funke and Wende (2022). The trade elasticities subdivided into micro and macro elasticities are particularly important. We set the micro elasticity  $\theta$  to 3.8 as in Ghironi and Melitz (2005), and, as determined in the meta study of Bajzik et al. (2020), as the median estimate. We assume the macro elasticity  $\omega$  to be 1.9, half the micro elasticity. This is a common approach and roughly in line with the estimates of Feenstra et. al. (2018). Tariff rates  $\tau_t^{SCRW} = \tau_t^{SCRU} = \tau_t^{RWSC} = \tau_t^{RWRU} = 0.032$  and  $\tau_t^{RUSC} = \tau_t^{RURW} = 0.053$  are taken from the WTO data (<https://stats.wto.org/>). We use MFN trade-weighted average duties (3.2% for the EU and China, 5.3% for Russia).

In the second stage, we calibrate a range of parameters to fit either the empirical moments shown in Table 2 or a plausibly chosen value. We calibrate the country weights such that the regions match their share of world GDP, setting  $\xi^{SC}$  to 1. To match key trade figures, we use the degree of openness,  $\alpha^i$ , as well as the country weights  $\kappa^{ij}$ . For the trade balance as share of GDP we use steady state bond holdings. For the sake of simplicity, we assume that all debt claims are denominated in US dollars. Moreover, the fixed costs of exporting are calibrated such that somewhat more than 20% of Russian firms export to both other regions and 10 percent of firms from the other two regions export in all foreign regions. The weight

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<sup>17</sup> For the economic footprint of layered sanctions following Russia's warfare against Ukraine in 2014, see Ashford (2016) and Bělin and Hanousek (2021).

of disutility of labor  $v^i$  is set to match a  $\frac{\xi^{SC}}{\xi^{Li}} = 0.2$ . The quantitative model evaluation in the following section illustrates the quantitative properties and takeaways of the model and includes counterfactual policy analyses.

Table 2. Actual data

Country	Sanctioning Countries (SC)	Russian Federation (RU)	Non-Sanctioning Countries (RW)
	Share of GDP in World GDP		
	0.579	0.019	0.402
	Openness: Share of Imports in Total Domestic Demand		
	0.049	0.110	0.058
	Import Shares		
SC	---	0.492	0.945
RU	0.048	---	0.055
RW	0.952	0.508	---
	Trade Balance as a Share of GDP		
	-0.001	0.075	-0.001

*Notes:* All moments are calculated by the authors using the 2019 edition of the EU inter-country supply, use, and input-output tables (Remond-Tierrez and Rueda-Cantuche, 2019). This ensures that the baseline calibration is not influenced by the large shocks related to the Covid-19 pandemic.

## 5. Model dynamics

Our modeling framework provides a laboratory for the analysis of primary and secondary sanctions. In addition to our focus on sanctions evasion, we also conduct various policy experiments and robustness checks. The experiments serve as a tool for policymakers seeking actionable insights into their own country's multi-layered sanction policy strategy.

There are four parameters in the model that control sanction effectiveness. The share of sanctioned export goods  $\Gamma_t^{ij}$  on the part of the SC countries is an exogenous policy parameter. The parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  influence the re-exporters' costs for each unit shipped via the RW countries. The fixed costs of re-exporters are given by  $f_{RX,t}^{ij}$ .

The two cost parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  mirroring extraterritorial secondary sanctions are not immediate policy parameters, but rather proxies for extraterritorial

secondary sanctions of various kinds. Their varying modes of action are evident from the price equation for re-exports to Russia given by

$$p_{RX,t}^{ji}(z) = \frac{1}{\varepsilon_t^{ij}} \tau_{RX,t}^{ij}(z)^{\tau_{z,t}^{ij}} \left( \frac{\theta}{\theta - 1} \right)^2 \frac{MC_t^i}{Z^i z} \quad (44)$$

The parameter  $\tau_{RX,t}^{ij}$  represents productivity-independent unit shipment costs and thus impacts the re-exports of all product varieties evenly. In contrast, the cost parameter  $\tau_{z,t}^{ij}$  has a twofold impact. On the one hand, any changes of  $\tau_{z,t}^{ij}$  also cause changes in costs and thus alter the incentives for re-exports overall. Beyond that, however, the cost changes are  $z$ -dependent and thus particularly pronounced for high-end varieties. In terms of the sanctions effectiveness, this entails that larger  $\tau_{z,t}^{ij}$  parameters penalize cutting-edge re-exports in particular. Hence, larger  $\tau_{z,t}^{ij}$  parameters can act as a proxy for more stringent extraterritorial measures aimed at deterring high-technology exports to Russia.

Next, we provide a quantitative evaluation of the effects of export sanctions, sanction loopholes, and workarounds bypassing export sanctions by means of impulse response functions (IRFs). The IRFs allow us to open up the model to closer scrutiny. In the first model evaluation step, the impact of alternative shares of sanctioned exports to Russia are presented. Subsequently, the effects of alternative counterfactual policy scenarios are examined step by step.<sup>18</sup>

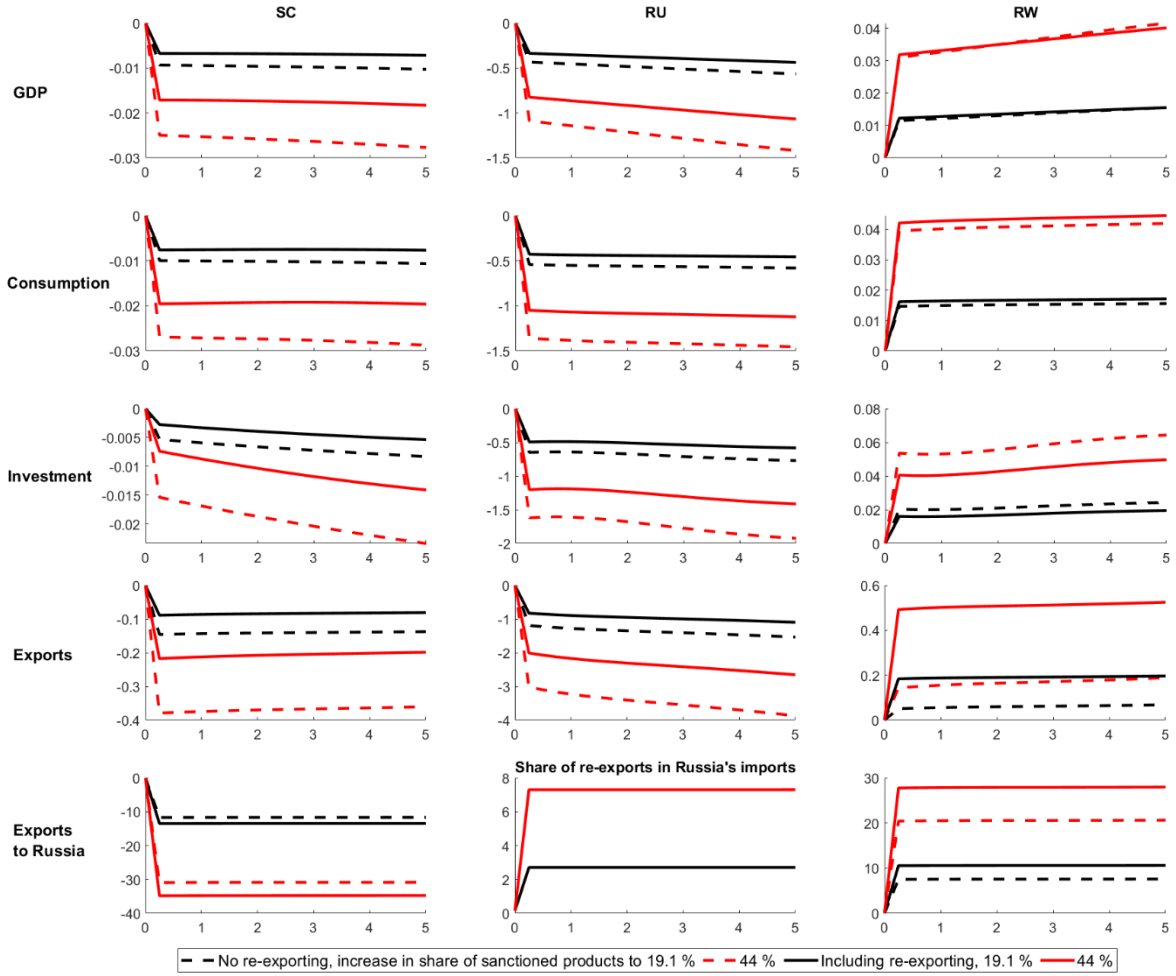
Figure 4 illustrates the SC export sanction impacts for two  $\Gamma_t^{ij}$  parameters, and thus two primary export ban coverages. The IRFs are shown for both model variants without and with induced re-exports for given levels of  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$ , and thus the benchmark level of secondary extraterritorial sanctions. Figure 4 is split into two parts with regard to the variables shown. The top three rows display the IRFs for GDP, consumption, and investment for the three country groups. The bottom

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<sup>18</sup> In all sanction designs analyzed, we take the current SC coalition as given. While we concede this is not the most promising approach for improving the efficiency of export bans, the aim of such analysis should be to establish that a persuasive case exists that would allow other countries as well to embrace the appropriateness and legitimacy of sanctions (a case that is probably not politically tenable at present).

two rows illustrate total exports, exports to RU, and the share of re-exports in Russia's imports, thus highlighting induced loopholes and workarounds.

Figure 4. The sanctions regime of the global Western coalition.



*Notes:* The IRFs show the percentage deviations of the variables from their initial steady state for increments of the  $\Gamma_t^{ij}$  parameter to values of  $\Gamma_t^{ij} = 0.191$  (black lines) and  $\Gamma_t^{ij} = 0.440$  (red lines), respectively. The share of re-exports is shown in percentage points. The baseline cost parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{Z,t}^{ij}$  are 0.90 and 0.30 throughout. Years are drawn on the horizontal axis.

In terms of sanctions coverage, Hausmann et al. (2024, p.122) show that 19.1% of all HS-6 items are currently sanctioned by both the EU and the US. In addition, 17.5% of all HS-6 items are currently sanctioned only by the EU and 7.4% only by the US. Taken together, this means that primary export bans and controls affect 44% of all HS-6 items at least in part. In the following, we thus simulate export

ban scenarios for  $\Gamma_t^{ij} = 0.191$  and  $\Gamma_t^{ij} = 0.440$ . In terms of the economic policy assessment,  $\Gamma_t^{ij} = 0.191$  represents the overlap of the EU vs. the US sanctions lists and thus most likely the present global sanctions intensity. In contrast,  $\Gamma_t^{ij} = 0.440$  represents the counterfactual scenario if the EU and the US would upgrade their differing sanctions lists to the respective more stringent levels in a coordination process.

The black lines in Figure 4 represent the benchmark export ban scenario assuming  $\Gamma_t^{ij} = 0.191$ . In detail, the solid (dashed) lines indicate the IRFs including (excluding) the triggered re-exports via the RW countries. In this benchmark scenario, 67.7% of the sanctioned varieties are re-exported.<sup>19</sup> The steady-state GDP changes including re-exports in the RU, SC and RW countries amount to -0.609%, -0.013% and 0.018%, respectively. Supplementary to this, the solid (dashed) red lines in Figure 4 illustrate the hypothetical case of  $\Gamma_t^{ij} = 44.0\%$  sanctioned export goods to RU with (without) induced re-exports bypassed via the RW countries. As expected, stricter export bans lead to larger steady-state GDP changes of -1.491%, -0.032% and 0.048% in the RU, SC and RW countries, respectively. In this case, 76.2% of the sanctioned varieties are re-exported via the RW countries bolstering GDP growth in Russia.<sup>20</sup> Seven findings in Figure 4 deserve mention.

- Export controls impose macroeconomic costs on both Russia and the like-minded SC coalition countries imposing the sanctions.
- The impact size differences between Russia and the sanctioning SC coalition result from the asymmetrical mutual significance. The SC countries are an important sourcing origin for Russia, whereas Russia is not an important exporting destination for SC countries.

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<sup>19</sup> The order of magnitude is in line with the findings in Astrov et al. (2024, p.13), who claim two-thirds of sanctioned Russian imports are offset by various sanctions-evasion channels. The numerical model results are underpinned by synthetic control method evasion estimates in Mancini et al. (2024), which highlight the fact that high-technology exports from non-sanctioning countries to Russia substantially exceed those under the hypothetical no-war counterfactual.

<sup>20</sup> The results are in the same ballpark as those of Felbermayr et al. (2023, pp. 89-93), who analyze several scenarios in which trade barriers entail a *de facto* decoupling between Russia and the sanctioning countries in a standard Caliendo and Parro (2015) framework. The modeling framework makes no distinction between industries with different technology intensities and the export controls that targeted them.

- The GDP increase in RW countries is due to traditional trade diversion effects and their re-export business bypassing sanctions.
- The declining number of Russian businesses and the dwindling capital stock over the course of the adjustment process lead to an amplifying sanctions impact on Russia over time.<sup>21</sup>
- In the case of overall exports and exports to RU, the mirror image of the pattern in SC and RW countries, is striking. While SC exports are falling, RW exports are rising in tandem.
- With a tightening of the primary export ban intensity  $\Gamma_t^{ij}$  for a given scope of secondary extraterritorial sanctions, the economic incentive for the re-routing of sanctioned goods to Russia via front businesses in RW countries increases significantly.
- The significant share of re-exports in total Russian imports illustrates the leakage losses of the primary export controls. Admittedly, the primary export controls impede Russia's military production and make it more expensive. On their own, however, they do not engender decisive choke points or disruptions in Russian supply chains.<sup>22</sup> In fact, the enhanced workarounds in the case of tightened primary export controls unravel the complexity of export controls and indicate the necessity to jointly stipulate primary export bans and secondary extraterritorial sanctions to make smart export sanctions bite.

A much-discussed question in the context of modeling the Russian invasion of Ukraine and the increasing fragmentation of the global economy is the size of substitution elasticities as time is passing (Baqaei et al., 2023; Moll et al., 2023). According to the Le Chatelier principle, the elasticities of substitution are increasing over time (Milgrom and Roberts, 1996). This is because markets react and moderate the impact. High prices induce more supply and blocking international trade

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<sup>21</sup> Albeit with the opposite sign, the underlying mechanism operates in accordance with Ravikumar et al. (2019). In a dynamic trade model with capital accumulation, the authors show that the short-term welfare gains of trade liberalization are significantly smaller than the steady state welfare gains.

<sup>22</sup> The GDP impacts represent the *ceteris paribus* impact of the export bans. For the sake of brevity and clarity, we abstract from other complexities such as the seizing of Russian central bank reserves, extraterritorial sanctions on financial institutions in the RW countries, fossil fuel import bans from Russia, and the withdrawal of foreign businesses from Russia.

spurs the creation of detour routes. The flip side of increasing substitution elasticities over the course of time is that the sanctions' effectiveness will inevitably be eroded. When modeling sanctions, it is thus important to carefully measure the entire adjustment process over time. Relying on short-run substitution elasticities can potentially overstate the long-run impact. While one would expect markets to adjust in the long-run, focusing on long-run estimates could have the opposite effect, e.g., the stated initial effectiveness of sanctions exhibits a downward bias. Thus, it is important to account for the time-varying adjustment process when tracing the effectiveness of sanctions.

The following approximation of time-varying substitution elasticities via a time-delayed adjustment of the goods bundle is inspired by Alessandria et al. (2021). The model extension still provides closed-form expressions mapping the re-routing of sanctioned export goods via non-aligned RW countries. The re-specified CES bundle in country  $i$  at time  $t$  in the augmented modeling set-up is given by

$$Q_{X,t}^i = \left( \sum_{j \neq i} (g_t^{ij} \kappa^{ij})^{\frac{1}{\theta}} (Q_{X,t}^{ij})^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \quad (45)$$

where

$$g_t^i = (g_{t-1}^{ij})^{\rho_g} \left( \left( 1 - v_g \left| \frac{Q_{X,t}^{ij}/Q_{X,t}^{ji}}{Q_{X,t-1}^{ij}/Q_{X,t-1}^{ji}} - 1 \right| \right) \right)^{1-\rho_g}. \quad (46)$$

The adjustment dynamics in the augmented model are governed by the parameters  $\rho_g$  and  $v_g$ . The adjustment persistence is steered by  $\rho_g$ , and  $v_g$  determines the initially lower  $g_t^i$  value.<sup>23</sup>

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<sup>23</sup> In contrast to Alessandria et al. (2021), the augmented model assumes it is more difficult for Russia to substitute sanctioned SC good varieties with those of non-sanctioning RW countries over the short term. This is a focal point of the paper. In Alessandria et al. (2021), by contrast, the substitution of domestic goods with foreign goods is modeled by means of a time-lagged adjustment process. This is accomplished in the present model by means of the lower macro elasticity in the trade model.



Figure 5 illustrates the GDP, consumption and investment impacts of the SC export controls to Russia in the augmented modeling set-up.<sup>24</sup> Mirroring Figure 4, the IRFs are again displayed for export ban increases to  $\Gamma_t^{ij} = 0.191$  (black lines) and  $\Gamma_t^{ij} = 0.440$  (red lines) of the originally imported Russian product varieties. To mitigate the uncertainty that surrounds the model calibration, we moreover rely on robustness analyses and analyze and project the future path of the three economies for two alternative  $\nu_g$  parameters.

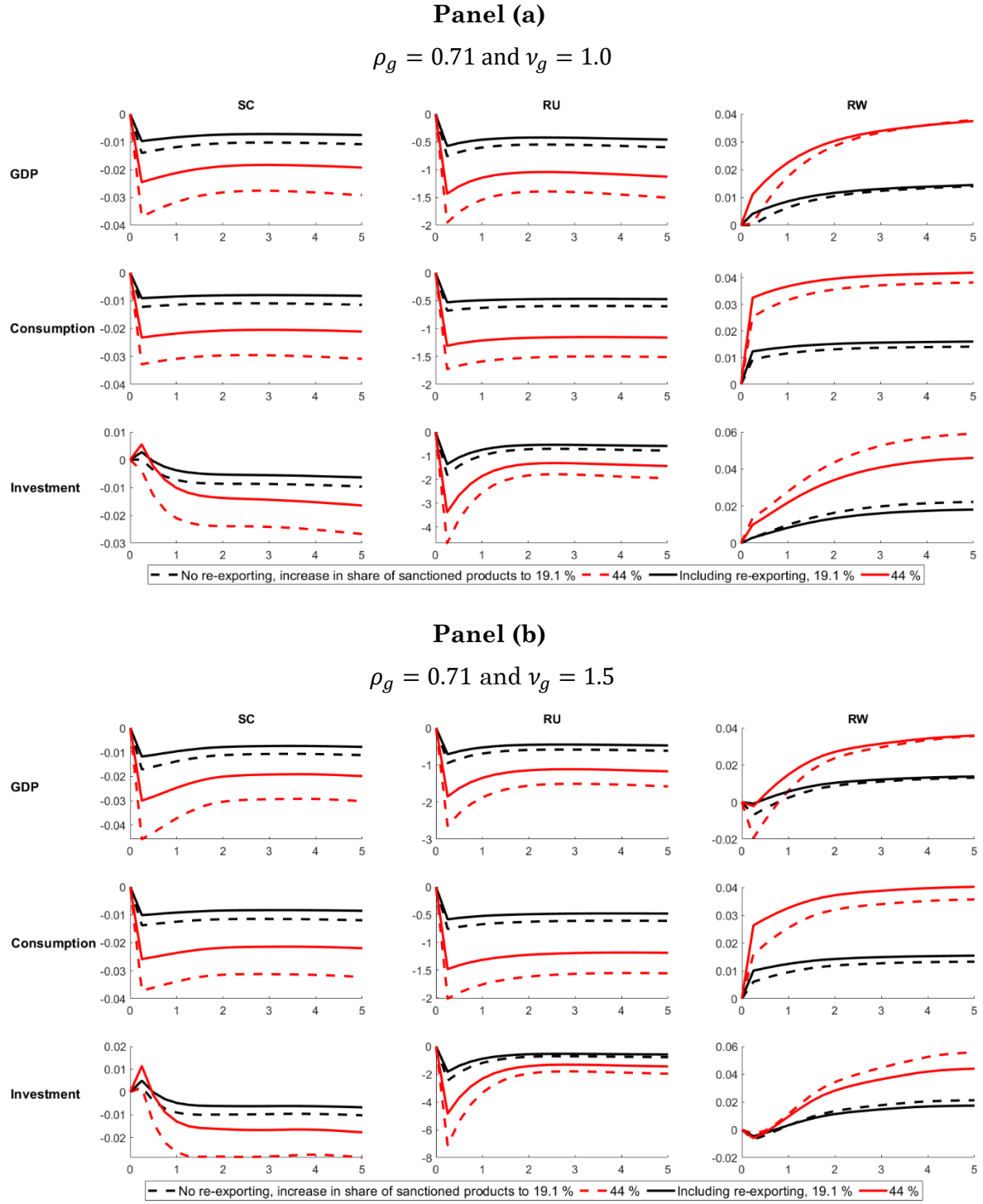
We offer three observations about the augmented model evaluation in Figure 5.

- Relative to the benchmark model, the sanctions in the augmented model initially inflict higher economic pain on Russia. The model extension thus mirrors the Le Chatelier prediction that the cross-country substitution elasticities are initially smaller and then increase over the course of time. This conjecture resonates with recent empirical findings.
- As expected, the temporary sanction impact overshooting as compared to the steady state is more pronounced for higher  $\nu_g$  parameters.
- The implication for sanctions design is that deploying export bans requires a long-term commitment and stepped-up enforcement over time to uphold the sanction impact. Without these, the effectiveness of the sanctions erodes over time.

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<sup>24</sup> Alessandria et al. (2021) set  $\rho_g = 0.25$  for annual data. This corresponds to  $\rho_g = 0.71$  for quarterly data.

Figure 5. Export sanction dynamics in the augmented trade model.



*Notes:* The IRFs show the percentage deviations of the variables from their initial steady state for increments of the  $\Gamma_t^{ij}$  parameter to values of  $\Gamma_t^{ij} = 0.191$  (black lines) and  $\Gamma_t^{ij} = 0.440$  (red lines), respectively. The share of re-exports is shown in percentage points. The baseline cost parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  are 0.90 and 0.30 throughout. Years are drawn on the horizontal axis.

In the next steps of the analysis, we delve deeper into the transmission channels of multi-layered sanctions. The special focus here is on the *modus operandi* of differently designed secondary sanctions. In other words, we analyze differently designed coercive extraterritorial secondary sanctions in tandem with the introduction of primary export bans amounting to  $\Gamma_t^{ij} = 0.191$  (black lines) and  $\Gamma_t^{ij} = 0.440$  (red lines), respectively. The extraterritorial secondary sanction changes are modeled by varying the two parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  one at a time. To ensure the compatibility of both secondary sanction layouts, the two proxies for extraterritorial secondary sanctions are altered in the IRFs in such a way that their respective changes increase the average costs of re-exporters to the same degree. The analysis then turns to determining the extent to which this uniform average cost increase conceals different effects in detail. While the increase in  $\tau_{RX,t}^{ij}$  leads to an undifferentiated cost increase for all goods, the increase in  $\tau_{z,t}^{ij}$  leads to an above-average cost increase for high productivity goods. In all model simulations, we assume that the specific changes of  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  can actually be carried out. This presupposes that the sanctioning countries can swiftly respond to newly emerging circumvention pathways in nonaligned RW countries.<sup>25</sup> Lastly, the time-varying modeling of the substitution capabilities as modeled in equations (45) and (46) in the augmented model is retained.

Figures 6 and 7 cast a spotlight on the impact and the transmission channels of multi-layered sanctions. Three IRFs are displayed in each sub-graph. The solid black (red) lines correspond to the benchmark cases in the previous Figures and thus illustrate primary export ban increases to  $\Gamma_t^{ij} = 0.191$  (Figure 6) and  $\Gamma_t^{ij} = 0.440$  (Figure 7), respectively. In doing so, constant extraterritorial secondary sanction parameters  $\tau_{z,t}^{ij} = 0.30$  and  $\tau_{RX,t}^{ij} = 0.90$  are assumed. The remaining two IRFs in each sub-graph display the dynamics after increasing the two proxies for extraterritorial secondary sanctions. The dashed blue line shows an increase of  $\tau_{RX,t}^{ij}$  by

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<sup>25</sup> This requirement is frequently hampered by effective governmental enforcement agencies needed to impede export control circumvention networks outside domestic jurisdiction. A multitude of sanctioning coalition countries still rely on leaky corporate compliance provisions to prevent the export or re-export of sanctioned products and critical cutting-edge technologies. Therefore, the effects shown must be regarded as an upper bound.

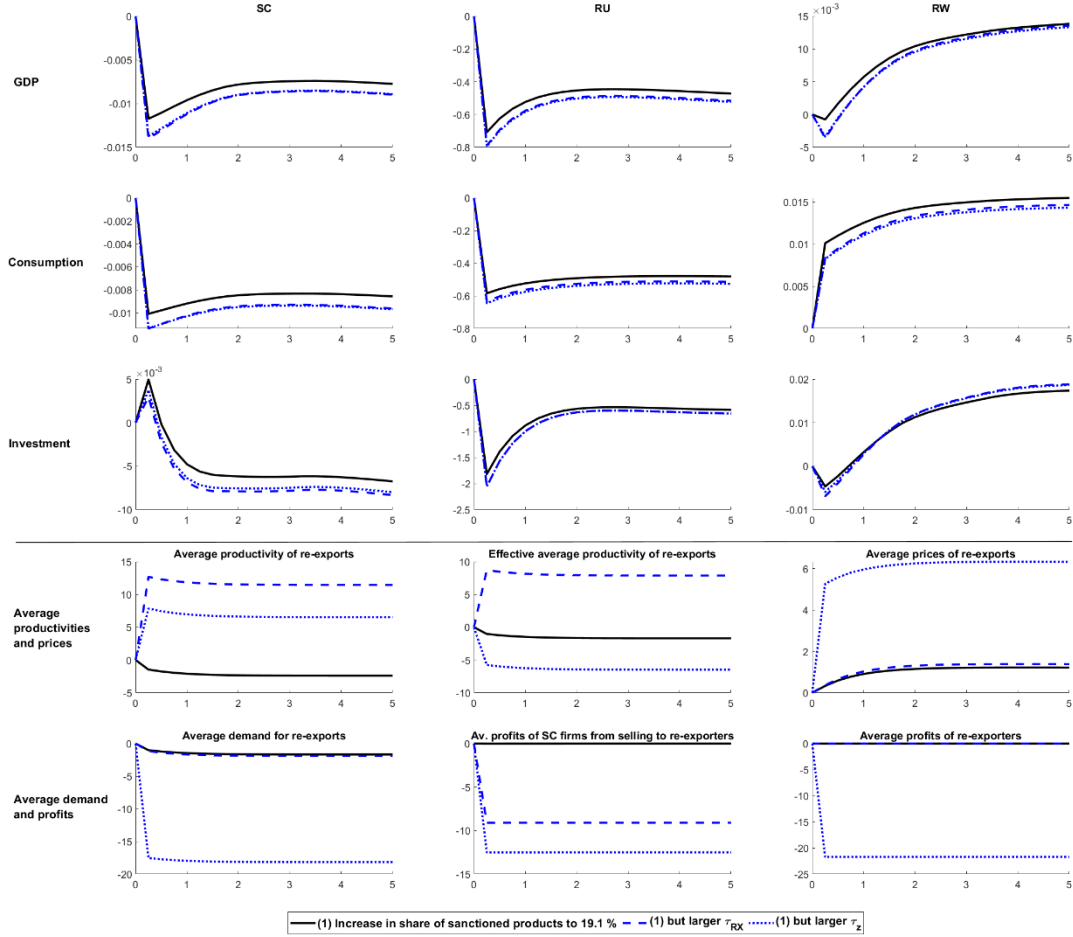
10%. The resulting increase in the average costs of re-exporters amounts to 10% as well. The dotted blue line shows an increase in  $\tau_{z,t}^{ij}$  of 24.5%. This leads to an average cost increase for re-exporters of 14%, taking into account that unproductive re-exporters leave the export market. Given this standardized average cost increase, two counterfactual scenarios can be compared. In the first, an undifferentiated increase in the intensity of secondary sanctions countering Russian sanctions evasion is considered. In the second, the effects of a smart increase in secondary sanctions with a high-end productivity profile are shown.

We highlight three findings regarding the impact upon the macroeconomic variables GDP, consumption and investment.

- The multi-layered sanction IRFs illustrate that tightened secondary sanctions as a supplement to primary sanctions are an impactful policy tool for increasing economic pain on Russia.
- The boost from secondary sanction attenuates the positive primary sanction impact on RW countries owing to reduced sanctions evasion.
- A standardized average cost increase of 10% for re-exporters leads to roughly similar macroeconomic knock-on impacts for both secondary sanction tools.

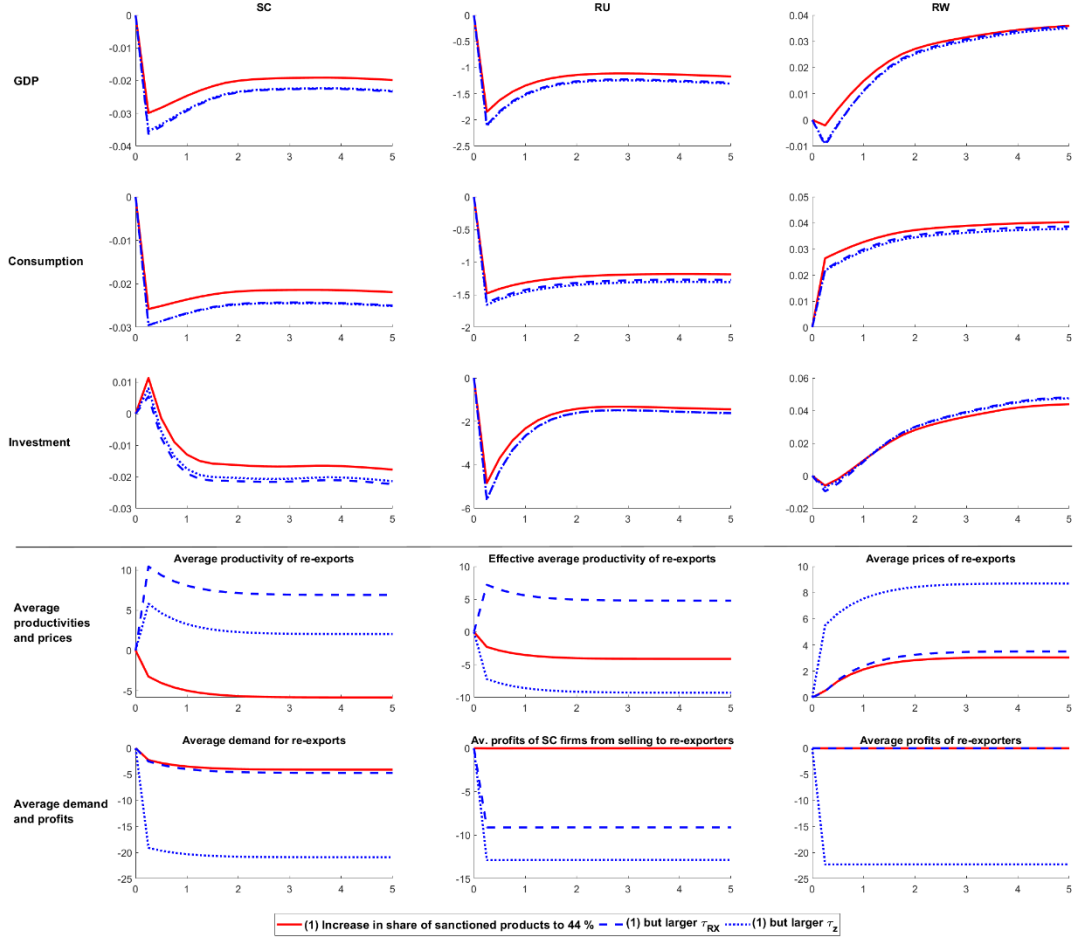
The lower six IRFs in Figures 6 and 7 provide additional insights regarding the heterogeneous impacts of both secondary sanction tools and illustrate the different modes of action behind the macroeconomic results. A concomitant benefit is that the numerical model evaluations offer guidance on how to implement multi-layered sanctions effectively.

Figure 6. The impact of a primary export ban amounting to  $\Gamma_t^{ij} = 0.191$  coupled with a uniform increase in secondary sanctions compared to a high-productivity-focused sanctions increase.



*Notes:* The solid black lines show the percentage deviations of the variables from their initial steady state for an increment of the export ban parameter to  $\Gamma_t^{ij} = 0.191$  presuming the benchmark parameters  $\tau_{RX,t}^{ij} = 0.90$  and  $\tau_{z,t}^{ij} = 0.30$ . The dashed (dotted) blue lines show the IRFs for the 10% (24.5%) increase of  $\tau_{RX,t}^{ij}$  ( $\tau_{z,t}^{ij}$ ). With regard to the modeling of time-varying substitution elasticities,  $\rho_g = 0.71$  and  $\nu_g = 1.5$  is assumed. Years are drawn on the horizontal axis.

Figure 7. The impact of a primary export ban amounting to  $\Gamma_t^{ij} = 0.440$  coupled with a uniform increase in secondary sanctions compared to a high-productivity-focused sanctions increase.



*Notes:* The solid black lines show the percentage deviations of the variables from their initial steady state for an increment of the export ban parameter to  $\Gamma_t^{ij} = 0.440$  presuming the benchmark parameters  $\tau_{RX,t}^{ij} = 0.90$  and  $\tau_{z,t}^{ij} = 0.30$ . The dashed (dotted) blue lines show the IRFs for the 10% (24.5%) increase of  $\tau_{RX,t}^{ij}$  ( $\tau_{z,t}^{ij}$ ). With regard to the modeling of time-varying substitution elasticities,  $\rho_g = 0.71$  and  $\nu_g = 1.5$  is assumed. Years are drawn on the horizontal axis.

The IRFs have an intuitive interpretation in terms of underlying economic mechanisms. At first the average productivity of the re-exported goods is shown. An increase in both secondary sanction cost parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  causes the least productive goods not to be re-exported any more. In consequence of the altered export bundle structure, the average productivity of the goods still exported increases in both cases. In addition, the change in the effective average productivity  $\bar{z}_{X,t}^{ij}$  of the re-exporters remaining in the market as given in equation (13) is shown

in the second sub-graph. In the event of an increase of  $\tau_{z,t}^{ij}$ , the effective average productivity of the remaining re-exporters in the market falls because sensitive high-end productivity goods are now subject to disproportionately rising costs, and this impact is not offset by the market exit of the least productive goods. Consequently, the re-exporters remaining in the market increase their average prices, as can be seen in the third sub-plot. In contrast, in the case of a tightened  $\tau_{RX,t}^{ij}$  parameter, the average prices remain almost the same because the uniform increase in costs is offset by the market exit of the varieties with the lowest productivity. In sum, targeting extraterritorial secondary sanctions towards high-technology variety businesses more effectively deprives Russia of sophisticated technologies needed to power advanced weaponry. The underlying reason is the higher price of these products, which leads to lower imports along the intensive margin.

The selected re-export graphs provide further insights. The demand for re-exports runs inversely to their prices and thus tightened extraterritorial sanction  $\tau_{z,t}^{ij}$  lead to a reduction in re-exports. In addition to re-export demand, the sanctions are also impacting re-exporters' supply. The last two sub-plots display the profits and thus the incentives to circumvent sanctions. On the one hand, an increase in the two parameters  $\tau_{RX,t}^{ij}$  and  $\tau_{z,t}^{ij}$  lowers the profits of the SC firms from trade with the re-exporters in the RW countries. The comparably greater impact of an increase in  $\tau_{z,t}^{ij}$  arises because it specifically affects the exports of highly productive firms. The final sub-plot illustrates the changing profits of re-exporters. Equation (8) and the Pareto distribution assumption for firm productivity yield the average profits of re-exporters in equilibrium as

$$\tilde{d}_{RX,t}^{ij} = \left[ \left( \frac{k}{k - (1 - \tau_{z,t}^{ij})(\theta - 1)} \right) - 1 \right] MC_t^i \frac{f_{RX,t}^{ij}}{Z^i} \quad (47)$$

As in the model of Ghironi and Melitz (2005), the average profits are not dependent on  $\tau_{RX,t}^{ij}$ . An increase in  $\tau_{RX,t}^{ij}$  lowers the profit of the affected firms, but since the least productive firms leave the export market, average profits remain constant. In contrast, in the present model the costs of exporting and thus average profits

also depend on  $\tau_{z,t}^{ij}$ . An increase in  $\tau_{z,t}^{ij}$  disproportionately increases the cost of re-exporting highly productive goods relative to goods with lower productivity. Exporters abandon the market and average profits decline. In contrast to the case of an untargeted secondary sanctions strategy, extraterritorial sanctions targeting high-tech products more specifically lower the incentives to re-export these product categories.

The overall lesson from the numerical model simulations seems to be that increasing smartness by focusing on high-tech extraterritorial sanctions makes sanctions bite and can play a key role in enforcing existing export bans. The flip side, of course, is dealing with the increased complexity involved in the implementation and control of targeted extraterritorial sanctions in a turbulent market environment.

## 6. Conclusions

The Russian invasion of Ukraine has disrupted the global economic and political landscape, making manifest the geopolitical risks of dependence on an autocracy with aggressive ambitions. The outbreak of the war has also challenged the notion that trade tends to pacify relations between countries, raising the opportunity costs associated with conflict and creating a state of interest that prefers peace to war.<sup>26</sup> One consequence of Russia's invasion of Ukraine is that like-minded global Western countries have imposed a sequence of comprehensive sanctions to deter Russia. Consequently, export controls have once again gained the spotlight in economic policy debates.

Against this background, our evaluations of a calibrated three-country dynamic general equilibrium trade model with heterogeneous firm productivities explored the effectiveness of export sanctions on Russia, including a novel model-based analysis of multi-layered export bans on strategically relevant products. Various

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<sup>26</sup> For the literature on economic statecraft, increasing international economic interdependence, and political alignment, inter alia see Chen (2021), Farrell and Newman (2019) and Kleinman et al. (2024a).



sanctions-evasion strategies and the associated enforcement challenges were also modeled. Notably, the economic set-up is tractable and amenable to theoretical analysis of its properties.<sup>27</sup> This theoretically grounded modeling environment informs four aspects of the policy debate:

- The initial assessments in 2022 of the impact of sanctions on Russia were overly optimistic as they failed to anticipate the foreseeable loopholes and disguised workaround strategies subsequently implemented.
- The effectiveness of sanctions depends on both the *overall scope* of the export restrictions and the *ability to pinpoint* strategically important products.
- Effective sanctions require the readiness of global Western countries to significantly expand the scope of extraterritorial against sanctions evading businesses in non-aligned countries.
- The interplay of action and reaction provides an understanding of the disruptive economic landscape and the leaky sanctions regime.

On a positive note, our modeling results demonstrate that export restrictions can succeed with constant monitoring, stringent enforcement, and regular fine-tuning. Sanctions policymakers can leverage these diverse findings to improve their design of sanctions policies.

More empirical research is desirable to better understand the costs and benefits of smart sanctions, as well as their ongoing refinement and modification over time. It would be valuable to examine the impact of the coerced and voluntary withdrawals of multinational businesses from Russia. As of summer 2024, around 400 businesses had curtailed their local operations in Russia or divested part of the business to a local Russian entity. Another 1,200 or so businesses had officially announced plans to completely shut down or temporarily reduce operations in Russia.<sup>28</sup> For these businesses, sanctions had made activities in Russia difficult and

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<sup>27</sup> As Mohr and Trebesch (2024, p. 19) point out in their review of the burgeoning geoeconomics literature, “...the theoretical literature on sanctions has been lagging behind. Future work should build on recent advances to better understand the costs, trade-offs, and effectiveness of sanctions and other tools such as export and investment controls. Moreover, the literature would benefit from a more holistic view that examines not just one tool, but the entire ‘poison cabinet’ of geoeconomic policy instruments.”

<sup>28</sup> See <https://www.ft.com/content/88b047e9-8cad-426a-b649-265ff6582db0>.

the reputational damage from staying was not worth the risk. In contrast, 2,200 companies had decided to continue operating in Russia. One reason for the wait-and-see attitude is that the Russian government has progressively raised the cost of departure, imposing a mandatory 50% discount on assets from “unfriendly” countries sold to Russian entities and a minimum 15% liquidation tax.<sup>29</sup> At the modeling layer, this requires the upgrading of the coherent modeling framework to an integrated trade and foreign direct investment model allowing for foreign-ownership of firms.

Future research could also involve long-term growth analyses of differently designed fragmentation and sanctions scenarios akin to the one presented in Kleinman et al. (2024b).<sup>30</sup> By how much will export controls ultimately degrade Russia’s manufacturing base and reduce the country future long-term growth potential? A corollary to this would be modeling Russia’s emigration-related human capital loss, a talent drain that with long-term ramifications.

Finally, the *Zeitenwende* shifts in the geopolitical landscape are large and unprecedented, provoking wide uncertainty about future protectionist trade measures. While we anchor the scenarios against the backdrop of international trade data, we are mindful of the inevitable degree of uncertainty surrounding our presented scenarios and estimates.

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<sup>29</sup> For more on the Russian government’s response to business exit plans, see <https://www.ft.com/content/88b047e9-8cad-426a-b649-265ff6582db0>.

<sup>30</sup> Kleinman et al. (2024b) use a versatile open-economy version of the neoclassical growth model to explore the implications of various counterfactual decoupling and fragmentation scenarios.

## References

- Abely, C. (2023). *The Russia Sanctions – The Economic Response to Russia's Invasion of Ukraine*, Cambridge (Cambridge University Press).
- Alessandria, G., Choi, H. and K.J. Ruhl (2021). “Trade Adjustment Dynamics and the Welfare Gains from Trade,” *Journal of International Economics* 131, 103458.
- Ashford, E. (2016) “Not-So-Smart Sanctions: The Failure of Western Restrictions Against Russia,” *Foreign Affairs* 95, No. 1, 114-123.
- Astrov, V., Kochnev, A., Scheckenhofer, L., Stamer, V. and F. Teti (2024) “Monitoring the Impact of Sanctions on the Russian Economy”, EconPol Policy Report No. 46, Munich.
- Bajzik, J., Havranek, T., Irsova, Z. and J. Schwarz (2020) “Estimating the Armington Elasticity: The Importance of Study Design and Publication Bias”, *Journal of International Economics* 127, 103383.
- Baqaei, D., Hinz, J., Moll, B., Schularick, M., Teti, F.A., Wanner, J. and S. Yang (2023) “What if? The Effects of a Hard Decoupling from China on the German Economy,” *Kiel Institute for the World Economy*, Kiel.
- Bělin, M. and J. Hanousek (2021). “Which Sanctions Matter? Analysis of the EU/Russian Sanctions of 2014,” *Journal of Comparative Economics* 49, 244-257.
- Biglaiser, G. (1993). “Middlemen as Experts,” *Rand Journal of Economics* 24, 212-223.
- Caliendo, L., Dvorkin, M., and F. Parro (2019). “Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock,” *Econometrica* 87, 741-835.
- Caliendo, L., Feenstra, R.C., Romalis, J. and A.M. Taylor (2023). “Tariff Reductions, Heterogeneous Firms, and Welfare: Theory and Evidence for 1990-2010,” *IMF Economic Review* 71, 817-851.
- Caliendo, L. and F. Parro (2015). “Estimates of the Trade and Welfare Effects of NAFTA,” *Review of Economic Studies* 82, 1-44.
- Chen, F.R. (2021). “Extended Dependence: Trade, Alliances, and Peace,” *Journal of Politics* 83, 246-259.

- Chupilkin, M., Javorcik, B. and A. Plekhanov (2023). "The Eurasian Roundabout: Trade Flows into Russia Through the Caucasus and Central Asia," EBRD Working Paper No. 276, London.
- Clayton, C., Maggiori, M. and J. Schreger (2024). "A Framework for Geoeconomics," NBER Working Paper No. 31852, Cambridge (Mass.).
- Costinot, A. and A. Rodríguez-Clare (2014). "Trade Theory with Numbers: Quantifying the Consequences of Globalization," in: Gopinath, G., Helpman, E. and K. Rogoff (eds.), *Handbook of International Economics*, Vol. 4, New York (Elsevier), 197-261.
- Crozet, M. and J. Hinz (2020). "Friendly Fire: The Trade Impact of the Russia Sanctions and Counter-Sanctions," *Economic Policy* 35, 97-146.
- Darvas, Z., Martins, C., McCaffrey, C. and L. Léry Moffat (2022). "Russian Foreign Trade Tracker," Brussels.
- De Souza, G., Hu, N., Li, H. and Y. Mei (2024). "(Trade) War and Peace: How to Impose International Trade Sanctions," *Journal of Monetary Economics*, 103572 (forthcoming).
- Eaton, J. and M. Engers (1992). "Sanctions," *Journal of Political Economy* 100, 899-928.
- Eaton, J. and M. Engers (1999). "Sanctions: Some Simple Analytics," *American Economic Review* 89, 409-414.
- Farrell, H. and A.L. Newman (2019). "Weaponized Interdependence: How Global Economic Networks Shape State Coercion," *International Security* 44, 42-79.
- Feenstra, R.C., Luck, P., Obstfeld, M. and K.N. Russ (2018). "In Search of the Armington Elasticity," *Review of Economics and Statistics* 100, 135-150.
- Felbermayr, G., Kirilakha, A., Syropoulos, C., Yalcin, E. and Y.V. Yotov (2020). "The Global Sanctions Data Base," *European Economic Review* 129, 103561.
- Felbermayr, G., Mahlkow, H. and A. Sandkamp (2023). "Cutting through the Value Chain: The Long-Run Effects of Decoupling the East from the West," *Empirica* 50, 75-108.
- Felbermayr, G., Morgan, T.C., Syropoulos, C. and Y.V. Yotov (2021). "Understanding Economic Sanctions: Interdisciplinary Perspectives on Theory and Evidence," *European Economic Review* 135, 103720.

- Funke, M. and A. Wende (2022). "Modeling Semiconductor Export Restrictions and the US-China Trade Conflict," Bank of Finland BOFIT Discussion Paper No. 13/2022, Helsinki.
- Funke, M. and A. Wende (2023). "The US-China Phase One Trade Deal: An Economic Analysis of the Managed Trade Agreement," *Canadian Journal of Economics* 56, 758-786.
- Ghironi, F., Kim, D. and G.K. Ozhan (2024). "International Trade and Macroeconomic Dynamics with Sanctions," *IMF Economic Review* 72, 611-652.
- Ghironi, F. and M.J. Melitz (2005). "International Trade and Macroeconomic Dynamics with Heterogeneous Firms," *Quarterly Journal of Economics* 120, 865-915.
- Hausmann, R., Schetter, U. and M.A. Yildirim (2024). "On the Design of Effective Sanctions: The Case of Bans on Exports to Russia," *Economic Policy* 39, 109-153.
- Juillard, M. (1996). "Dynare: A Program for the Resolution and Simulation of Dynamic Models with Forward Variables through the use of a Relaxation Algorithm," CEPREMAP Working Paper No. 9602, Paris.
- Kehoe, T.J., K.J. Ruhl, and J.B. Steinberg (2018). "Global Imbalances and Structural Change in the United States," *Journal of Political Economy* 126, 761-796.
- Kleinman, B., Liu, E. and S.J. Redding (2024a). "International Friends and Enemies," *American Economic Journal: Macroeconomics* 16, 350-385.
- Kleinman, B., Liu, E., Redding, S.J. and M. Yogo (2024b). "Neoclassical Growth in an Interdependent World," NBER Working Paper No. 31951, Cambridge (Mass.).
- Lawless, M., McCoy, D., Morgenroth, E.L.W. and C.M. O'Toole (2018). "Corporate Tax and Location Choice for Multinational Firms," *Applied Economics* 50, 2920-2931.
- Mancini M., Conteduca, F.P. and A. Borin (2024). "The Real-Time Impact of the War on Russian Imports: A Synthetic Control Method Approach," *World Trade Review* 23, 1-15.
- Melitz, M.J. (2003). "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica* 71, 1695-1725.
- Melitz, M.J., and S. Redding (2014). "Heterogeneous Firms and Trade," in: Gopinath, G., Helpman, E. and K. Rogoff (eds.), *Handbook of International Economics* 4, 1-54.

- Milgrom, P. and J. Roberts (1996). "The Le Chatelier Principle," *American Economic Review* 86, 173-179.
- Moll, B., Schularick, M. and G. Zachmann (2023). "The Power of Substitution: The Great German Gas Debate in Retrospect," *Brookings Papers on Economic Activity*, Fall 2023, 395-455.
- Mohr, C. and C. Trebesch (2024). "Geeconomics," CESifo Working Paper No. 11564, Munich (*Annual Review of Economics*, forthcoming).
- Morgan, T.C., Syropoulos, C. and Y.V. Yotov (2023). "Economic Sanctions: Evolution, Consequences, and Challenges," *Journal of Economic Perspectives* 37, 3-30.
- Rauch, J.E. (1999). "Networks versus Markets in International Trade," *Journal of International Economics* 48, 7-35.
- Rauch, J.E. (2001). "Business and Social Networks in International Trade," *Journal of Economic Literature* 39, 1177-1203.
- Ravikumar, B., Santacreu, A.M. and M. Sposi (2019). "Capital Accumulation and Dynamic Gains from Trade," *Journal of International Economics* 119, 93-110.
- Remond-Tierrez, I. and J.M. Rueda-Cantuche (2019). *Inter-Country Supply, Use and Input-Output Tables: Full International and Global Accounts for Research in Input Output Analysis (FIGARO)*, Brussels.
- Schmitt-Grohé, S. and M. Uribe (2003). "Closing Small Open Economy Models," *Journal of International Economics* 61, 163-185.
- Schmitt-Grohé, S. and M. Uribe (2007). "Optimal Simple and Implementable Monetary and Fiscal Rules," *Journal of Monetary Economics* 54, 1702-1725.
- Simola, H. (2023). "Latest Developments in Russian Imports of Sanctioned Technology Products," Bank of Finland, BOFIT Policy Brief No. 15/2023, Helsinki.
- Steinberg, J.B. (2019). "Brexit and the Macroeconomic Impact of Trade Policy Uncertainty," *Journal of International Economics* 117, 175-195.

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