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International Economic Sanctions and Third-Country Effects

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Abstract

This paper studies international trade and macroeconomic dynamics triggered by economic sanctions, and the associated welfare losses, in a calibrated, three-country model of the world economy. We assume that there are two production sectors in each country, and the sanctioned country has a comparative advantage in production of a commodity (for convenience, gas) needed to produce final, differentiated consumption goods. We consider three types of sanctions: sanctions on trade in final goods, financial sanctions, and gas trade sanctions. We calibrate the model to an aggregate of countries currently imposing sanctions on Russia (the European Union, the United Kingdom, and the United States), Russia, and an aggregate of third countries (China, India, and Turkey). We show that, instead of reflecting the success of sanctions, exchange rate movements reflect the type of sanctions and the direction of the resulting within-country sectoral reallocations. Our welfare analysis demonstrates that the sanctioned country's welfare losses are significantly mitigated, and the sanctioning country's losses are amplified, if the third country does not join the sanctions, but the third country benefits from not joining. These findings highlight the necessity, but also the challenge, of coordinating sanctions internationally.

Topics: Economic models, Exchange rates, International topics
JEL codes: F31, F41, F42, F51

Résumé

Dans cette étude, nous étudions l'impact des sanctions économiques sur le commerce international et les variables macroéconomiques, ainsi que les pertes de bien-être associées, dans un modèle calibré à trois pays de l'économie mondiale. Nous supposons que chaque pays compte deux secteurs de production et que le pays sanctionné a un avantage comparatif dans la production d'une matière première (par commodité, le gaz naturel) requise pour fabriquer des biens de consommation finale différenciés. Nous considérons trois types de sanctions : les sanctions commerciales sur les biens de consommation finale, celles sur le gaz et les sanctions financières. Pour calibrer le modèle, nous nous basons sur un groupe de pays qui imposent actuellement des sanctions à la Russie (pays de l'Union européenne, Royaume-Uni et États-Unis), sur la Russie et sur un groupe de pays tiers (Chine, Inde et Turquie). Nous montrons que, au lieu de témoigner de l'efficacité des sanctions, les mouvements de taux de change reflètent le type de sanctions et la direction des réallocations sectorielles qui en résultent dans chaque pays. Selon notre analyse, si le groupe de pays tiers ne participe pas aux sanctions, les pertes de bien-être sont considérablement atténuées dans le pays sanctionné et sont amplifiées dans les pays qui imposent des sanctions, mais il est avantageux pour les pays tiers de ne pas prendre part aux sanctions. Ces résultats soulignent la nécessité, mais aussi la difficulté, de coordonner des sanctions à l'échelle internationale.

Sujets : Modèles économiques, Taux de change, Questions internationales
Codes JEL : F31, F41, F42, F51

1. Introduction

The debate on the effectiveness of economic sanctions as an instrument to induce policy change in targeted countries has been reinvigorated by Russia's large-scale invasion of Ukraine in February of 2022, and the imposition of severe sanctions on Russia by many Western countries.[1] Arguments in favor of sanctions (e.g., those discussed in Blackwill and Harris 2016) have been met with two main objections: First, Russia is a large enough economy, especially for its role in energy markets, that sanctions can backfire through their effects on the global economy. Second, sanctions that target Russia's trade and financial relationships with the West do not prevent Russia from replacing these relationships with stronger ties to other nations.[2] This brings us back to Friedman (1980)'s Cold-War-era claim that sanctions would ultimately result in losses for the nations imposing them because of substitution in global trade.

In this paper, we assess the effectiveness of sanctions in an interdependent global economy by using a calibrated three-country model that allows us to capture both the nature of Russia as an economy of significant size and its ability to trade with countries that are not part of the Western bloc. To this end, we calibrate the sanctioning country in our model (Home) to an aggregate of the European Union, United Kingdom, and United States, the sanctioned country (Foreign) to Russia, and the third country (RoW, for Rest of the World) to an aggregate of China, India, and Turkey. Consistent with evidence, we set parameter values so that, when measured in purchasing power parity (PPP) terms, the Gross Domestic Product (GDP) of our model-Russia represents approximately 10% of the combined GDPs of the European Union, United Kingdom, and United States. The structure of the model also allows us to capture Russia's comparative advantage and exporter role in production of mineral fuels. In this context, we show that sanctions can succeed at lowering the targeted economy's income and welfare, even when global effects and third-country behavior are taken into account.

The model that we use in our analysis shares several features with Ghironi and Melitz (2005)—henceforth, GM—which uses Melitz (2003) as the microeconomic underpinning of a two-country model of international trade and macroeconomics. We extend GM by adding an upstream energy-

[1] We take a broad view of the West as including traditional allies, for instance, Japan.

[2] Schott (2023), among others, documents that Western sanctions compelled Russia to increase its trade with some Middle Eastern and Asian nations.

production sector that combines labor with a natural resource endowment (for convenience, natural gas) to produce energy. We assume that Foreign has a comparative advantage in this sector in the form of a larger endowment of natural gas. In the downstream sector, heterogeneous, monopolistically competitive firms combine labor and usable gas to produce differentiated consumption goods. Home enjoys a comparative advantage in this sector in the form of higher productivity in production of existing goods and creation of new ones. Producers in this sector face sunk entry costs in the domestic market, and fixed and iceberg trade costs in the export market. As is well known, fixed trade costs imply that only producers whose productivity is above an endogenously determined threshold find it profitable to export. We also assume that international financial markets are incomplete, so that movements in current accounts have an impact on cross-border consumption allocations. This setup provides a rigorous environment for the assessment of international trade and macroeconomic effects of sanctions in dynamic general equilibrium.

We design trade and financial sanctions on Foreign as forced exits at extensive margins. Trade sanctions on downstream producers are introduced by forcing firms that exceed a certain productivity threshold to exit the export market. In this way, we capture the fact that sanctioned products from the West to Russia are those that require advanced technology to be produced.[3] Financial sanctions are introduced by assuming that a fraction of Foreign agents are excluded from participation in international financial markets.[4] Trade sanctions on Foreign gas exports are introduced in the form of a ban on gas trade.[5]

We find that all the sanctions we consider cause Foreign GDP and consumption to fall. The Home and RoW economies contract too, but by less than Foreign. Prohibiting the largest Home firms from exporting consumption goods to Foreign generates the most noticeable changes in Foreign GDP and consumption. This type of sanction induces Foreign to increase its production of consumption goods, even if it is less efficient at producing them. Foreign reallocates resources toward industries in which it does not have a comparative advantage, and this inefficient reallocation amplifies the effects of sanctions. The cost of producing consumption goods in Foreign rises,

[3] See https://www.consilium.europa.eu/en/policies/sanctions/ and https://crsreports.congress.gov/product/pdf/R/R45415

[4] Western nations have placed a variety of financial sanctions on Russia. These range from freezing central bank reserves to interruptions in international messaging systems such as SWIFT. A comprehensive analysis of financial sanctions necessitates modeling a more sophisticated financial sector, which is beyond the scope of this paper.

[5] This is the case for UK and US gas imports from Russia. The European Union has not stopped importing gas from Russia yet but has been taking steps in this direction. See Figure 2 in Section 4 for details.

putting upward pressure on domestic prices and causing the Foreign exchange rate to appreciate. In contrast, a ban on gas trade causes the Home exchange rate to appreciate by pushing Home to reallocate resources toward its gas sector, where it has a comparative disadvantage, and putting upward pressure on the cost of producing Home consumption goods. These findings show that the direction of exchange rate movements triggered by sanctions is associated with that of the within-country resource reallocation that sanctions cause. Moreover, our results show that exchange rate movements do not reflect the effectiveness of sanctions at generating economic contraction and welfare loss.[6]

To replicate Russia's trade flows after February 2022, we investigate a scenario in which Home imposes all three types of sanctions on Foreign, but RoW refrains from imposing sanctions. Our calibrated model shows that sanctions are effective at causing the targeted economy to contract and its households to suffer welfare losses regardless of what third countries do. The impact of the sanctions on Foreign is magnified if RoW imposes them. Additionally, if RoW joins the effort, Home GDP and welfare losses are smaller. However, RoW's GDP is higher and its welfare losses are smaller if RoW does not join Home's effort. These findings highlight the importance of international coordination of sanctions and the difficulty of accomplishing it.

Our paper mainly contributes to two strands of literature. The Russia-Ukraine war triggered a wave of papers on the effects of sanctions, including Albrizio and et al. (2022); Bachmann and et al. (2022); Bianchi and Sosa-Padilla (2022); de Souza et al. (2022); Eichengreen et al. (2022); Itskhoki and Mukhin (2022); Lorenzoni and Werning (2022).[7] Our main contribution is to develop a dynamic, general equilibrium analysis that accounts for the consequences of imposing sanctions on a large economy and for their extensive margin effects. Our paper also contributes to the literature on international trade and macroeconomics that developed following GM.[8] We contribute to this literature by using a three-country, two-sector, asymmetric framework to study the effects of sanctions.

[6]This echoes Eichengreen et al. (2022)'s and Itskhoki and Mukhin (2023)'s observation that exchange rates are not a good metric of the effectiveness of sanctions.

[7]Work that pre-dates Russia's large-scale invasion of Ukraine includes Korhonen (2019); van Bergeijk (2021), and references therein.

[8]An incomplete list includes Auray and Eyquem (2011); Bergin, Feng, and Lin (2021); Bergin and Corsetti (2019); Cacciatore (2014); Cacciatore and Ghironi (2021); Corsetti, Martin, and Pesenti (2007, 2013); Dekle, Jeong, and Kiyotaki (2015); Hamano and Zanetti (2017); Imura and Shukayev (2019); Kim (2021); Kim, Ozhan, and Schembri (2021); Lanteri, Medina, and Tan (2023); Rodriguez-Lopez (2011); Zlate (2016).

The rest of the paper is organized as follows: Section 2 presents the model. Section 3 discusses the calibration. Section 4 examines the effects of sanctions. Section 5 presents the welfare results. Section 6 concludes.

2. The Model

We consider a three-region world economy in which the regions are labeled as Home (H), Foreign (F), and the Rest of the World (RoW, R). The baseline model structure is similar to Ghironi, Kim, and Ozhan (2022), which uses Ghironi and Melitz (2005)'s monopolistic competition and heterogeneous producers framework for the microeconomic underpinning of the consumption good production sector. One important difference from GM is the asymmetry between the regions in terms of size and production structure. We index population by χ_i where $i \in \{H, F, R\}$. Home and RoW countries are populated by a unit mass of atomistic households (i.e., $\chi_H = \chi_R = 1$). However, the size of the Foreign country is smaller, i.e., $\chi_F \in (0, 1)$. There is a representative household in each country before the introduction of sanctions. The representative household consists of two types of workers. They supply labor to consumption goods producers and gas producers, accordingly. Home and RoW are importers of gas, whereas Foreign is an exporter of gas.

2.1. Household Preference

In each country $i \in \{H, F, R\}$, the household derives utility from consumption of a basket of goods, $C_{i,t}$, and disutility from supplying labor, L^i_t, to the sector that produces consumption goods and $L^i_{G,t}$ to the sector that produces gas. In specific, we assume Frisch elasicity to be one. Following Horvath (2000), we use constant elasticity of substitution specification, where the parameter, $\varrho > 0$, presents a degree of labor mobility between sectors. The expected intertemporal utility function that the household maximizes is:

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \left\{ \ln C_{i,t} - \frac{\kappa}{2} \left[(L^i_t)^{\frac{1+\varrho}{\varrho}} + (L^i_{G,t})^{\frac{1+\varrho}{\varrho}} \right]^{\frac{2\varrho}{1+\varrho}} \right\} \right], \tag{1}$$

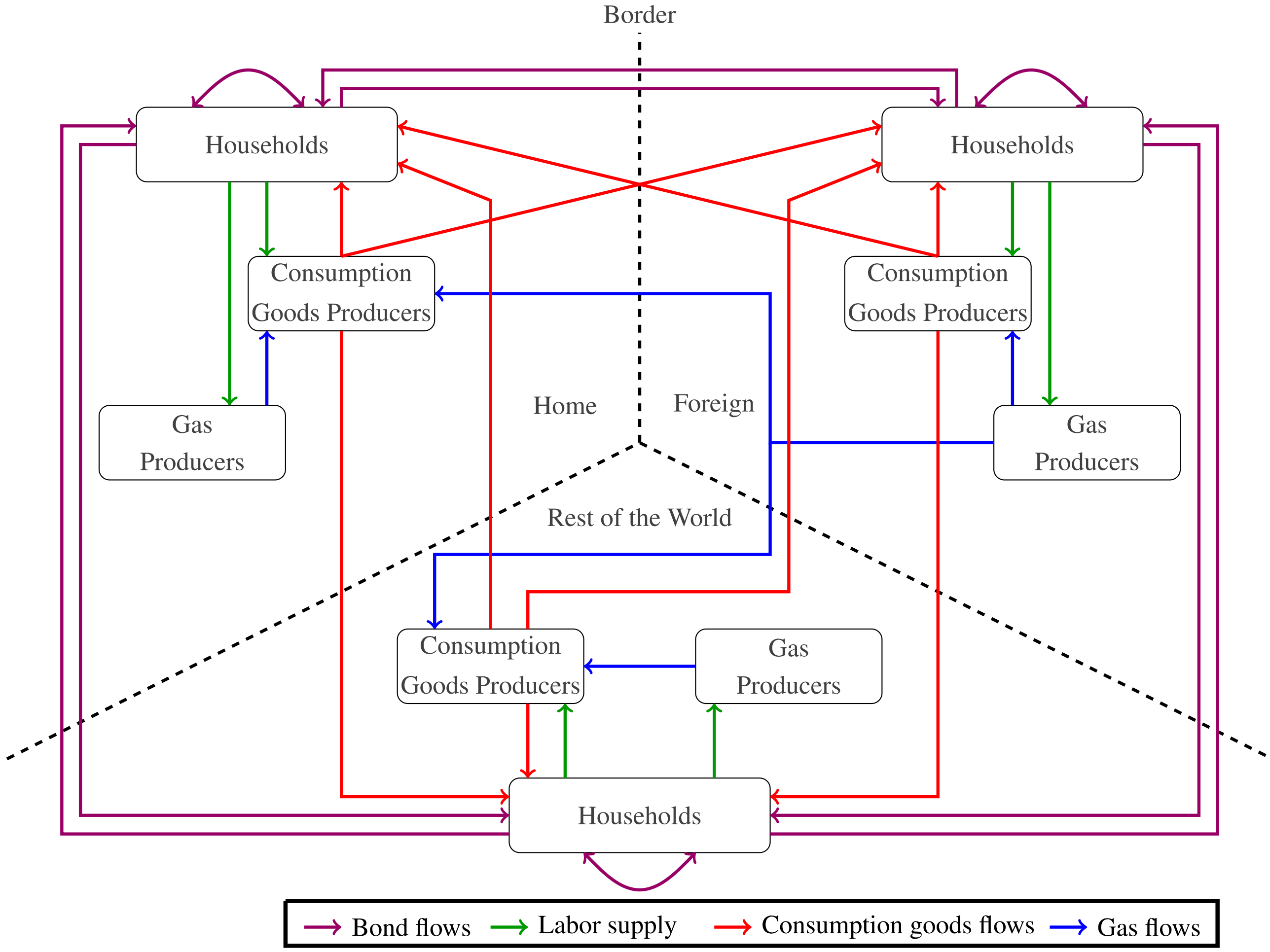


Figure 1: Model Architecture

with $\beta \in (0,1)$ and $\kappa > 0$. The consumption basket in country i is defined over a continuum of goods Ω: $C_{i,t} = \{\int_{\omega\in\Omega}[c_{i,t}(\omega)]^{\frac{\theta-1}{\theta}}d\omega\}^{\frac{\theta}{\theta-1}}$ where $\theta > 1$ is the symmetric elasticity of substitution across goods. At any time t, only a subset of goods $\Omega_{i,t} \subset \Omega$ is available in country i. Demand for individual goods in country i is $c_{i,t}(\omega) = [p_{i,t}(\omega)/P_{i,t}]^{-\theta}C_{i,t}$, where $p_{i,t}(\omega)$ is the country i currency price of a good $\omega \in \Omega_{i,t}$ and $P_{i,t} = \{\int_{\omega\in\Omega_{i,t}}[p_{i,t}(\omega)]^{1-\theta}d\omega\}^{\frac{1}{1-\theta}}$. Letting $\rho_{i,t}(\omega)$ be the price of good ω relative to the price of the basket in country i, demand for good ω is $c_{i,t}(\omega) = [\rho_{i,t}(\omega)]^{-\theta}C_{i,t}$.

2.2. Gas Production

Each country is endowed with some level of natural gas G^i_N. We assume that Foreign has a larger endowment, i.e., $G^F_N > G^H_N, G^R_N$. A perfectly competitive, upstream sector in each country produces usable gas by combining labor and natural gas.

$$G_t^i = G_N^i(\chi_i L_{G,t}^i). \tag{2}$$

This gas can be used domestically ($G_{i,t}^i$) or exported ($G_{j,t}^i$) for $i \neq j$. Hence, in equilibrium, it will be $G_N^i \chi_i L_{G,t}^i = \sum_{j=H,F,R} G_{j,t}^i$. First-order conditions for optimal labor demand in gas production yields $w_{G,t}^i = \rho_{G,t}^i G_N^i$, where $w_{G,t}^i$ is the real (per unit) wage paid to workers in this sector, and $\rho_{G,t}^i$ is the real price of usable gas in country i (both wages and prices are in units of the country's consumption basket).

Foreign exports gas to Home and RoW but does not import from them. Produced gas is perfectly substitutable, and thus their gas market price determination ensures $\rho_{G,t}^H = \tau_{G,t} Q_{F,t}^H \rho_{G,t}^F$ and $\rho_{G,t}^R = \tau_{G,t} Q_{F,t}^R \rho_{G,t}^F$, where $\tau_{G,t}$ is iceberg gas import costs, and $Q_{j,t}^i$ is the consumption-based real exchange rate (units of country i consumption per unit of country j).

2.3. Consumption Good Production

Consumption goods producer. Differentiated consumption goods are produced by monopolistic competitive firms by combining gas and labor. Home, Foreign, and RoW gas are perfect substitutes in the production of consumption goods. Firm ω in country $i \in \{H, R\}$ produces output $y_t^i(\omega)$ with the following production function:

$$y_t^i(\omega) = z Z_t^i \left\{ \alpha \left[g_{i,t}^i(\omega) + \frac{g_{i,t}^F(\omega)}{\tau_{G,t}} \right]^\rho + (1-\alpha) \left[l_t^i(\omega) \right]^\rho \right\}^{\frac{1}{\rho}}. \tag{3}$$

Hence, the elasticity of substitution between factors, ϵ, is given by $\epsilon \equiv 1/(1-\rho)$. The firm specific productivity, $z \in [z_{min}, \infty)$, is determined upon entry. $Z_t^i > 0$ is a sector-wide productivity level, $l_t^i(\omega)$ is labor, and the relative share of gas in the production function is α where $0 \leq \alpha < 1$.

We define the firm's total gas demand by $g_{i,t}(\omega) = g_{i,t}^i(\omega) + g_{i,t}^F(\omega)/\tau_{G,t}$. The demand is split between domestically produced gas and imported gas, where the latter is subject to an iceberg cost. Foreign does not import gas from other countries. Firm optimization equates the gas prices due to the perfect substitutability assumption. In country $i = H$ and R,

$$\rho^i_{G,t} = \tau_{G,t} Q^i_F \rho^F_{G,t}. \tag{4}$$

Foreign firms use only domestic gas, $G^H_{F,t}(\omega) = G^R_{F,t}(\omega) = 0$ and $G_{F,t}(\omega) = G^F_{F,t}(\omega)$.

We drop the identifier ω and replace it with the heterogeneous productivity z. Using w^i_t to denote the real wage paid to consumption-sector workers (in units of consumption), the expressions for labor and gas demand by firm z are

$$l^P_{i,t}(z) = \left(\frac{1-\alpha}{w^i_t}\right)^{\epsilon} \frac{y^i_t(z)}{\alpha^\epsilon (\rho^i_{G,t})^{1-\epsilon} + (1-\alpha)^\epsilon (w^i_t)^{1-\epsilon}}, \tag{5}$$

$$g_{i,t}(z) = \left(\frac{\alpha}{\rho^i_{G,t}}\right)^{\epsilon} \frac{y^i_t(z)}{\alpha^\epsilon (\rho^i_{G,t})^{1-\epsilon} + (1-\alpha)^\epsilon (w^i_t)^{1-\epsilon}}. \tag{6}$$

It is straightforward to express the firm's marginal cost as

$$\text{mc}^i_t(z) = \frac{1}{z Z^i_t} \left[\alpha^\epsilon (\rho^i_{G,t})^{1-\epsilon} + (1-\alpha)^\epsilon (w^i_t)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{7}$$

Given Dixit-Stiglitz preferences and iceberg trade costs, the real price charged by the firm located in country i for sales in market j is

$$\rho^i_{j,t}(z) = \left(\frac{\theta}{\theta-1}\right) \frac{\tau^i_{j,t} \text{mc}^i_t(z)}{Q^i_{j,t}}. \tag{8}$$

Exporting is costly, and producers are subject to an iceberg export cost, $\tau^i_{j,t} > 1$ for $i \neq j$ (and $\tau^i_{i,t} = 1$), and a per-period fixed export cost, $f_{X,t}$. The fixed export cost requires use of consumption-sector labor with effectiveness determined by the aggregate shock Z^i_t. We assume that $f_{X,t}$ is in units of effective labor when $i \neq j$. Hence, the fixed export cost in units of consumption is $w^i_t f_{X,t}/Z^i_t$ for firms located region i. The fixed export cost implies that only firms with sufficiently high productivity z will export. In other words, there exists a cutoff $\underline{z}^i_{j,t}$ satisfying that a firm located in country i sells its product and turns a positive profit in market j if $z > \underline{z}^i_{j,t}$, with $\underline{z}^i_{i,t} = z_{min}$.

Number of firms, exporters, and their averages. Following Melitz (2003), define the market-share weighted productivity average $\tilde{z}^i_j$ for country i's firms with non-negative sales in market j as follows.[9]

$$\tilde{z}^i_{j,t} \equiv \left[\frac{1}{\Phi(\overline{z}^i_{j,t}) - \Phi(\underline{z}^i_{j,t})} \int_{\underline{z}^i_{j,t}}^{\overline{z}^i_{j,t}} z^{\theta-1} \mathrm{d}\Phi(z)\right]^{\frac{1}{\theta-1}}, \tag{9}$$

where $\overline{z}^i_{j,t} \to \infty$ and $\Phi(\overline{z}^i_{j,t}) \to 1$. When $i = j$, the market-share weighted productivity average $\tilde{z}_D$ for all producing firms ($z^i_{i,t} = z_{min}$ and $\overline{z}^i_{i,t} \to \infty$) is

$$\tilde{z}^i_{i,t} = \tilde{z}_D \equiv \left(\int_{z_{min}}^{\infty} z^{\theta-1} \mathrm{d}\Phi(z)\right)^{\frac{1}{\theta-1}}. \tag{10}$$

As shown by Melitz (2003), the model is isomorphic to one in which $N^i_{D,t}$ firms with productivity $\tilde{z}^i_D$ produce in country i, and $N^i_{j,t}$ firms with productivity $\tilde{z}^i_{j,t}$ export to country $j \neq i$. The expression of country i's price index P^i_t then implies $\sum_{j \in H,F,R} N^i_{j,t}(\tilde{\rho}^j_{i,t})^{1-\theta} = 1$, where $\tilde{\rho}^j_{i,t} \equiv \rho^j_{i,t}(\tilde{z}^j_{i,t})$ is the average relative prices of producers of origin country j and destination country i.

Furthermore, the average profits of country i firms from market j is $\tilde{d}^i_{j,t} \equiv \theta^{-1}(\tilde{\rho}^i_{j,t})^{1-\theta} Q^i_{j,t} C_{j,t}$. Thus, average total profits of country i firms are $\tilde{d}^i_t = \sum_{j=H,F,R}[\Phi(\overline{z}^i_{j,t}) - \Phi(\underline{z}^i_{j,t})]\tilde{d}^i_{j,t}$, where $\Phi(\overline{z}^i_{j,t}) - \Phi(\underline{z}^i_{j,t})$ is the proportion of firms that export, $N^i_{j,t}/N^i_{D,t}$.

Firm entry and exit. There is an unbounded mass of potential entrants in each country. Entry requires use of consumption-sector labor with effectiveness determined by the aggregate shock Z^i_t. Prior to entry, all firms are identical and face a sunk entry cost $f_{E,t}$ in units of effective labor. Hence, the sunk entry cost in units of consumption is $w^i_t f_{E,t}/Z^i_t$. Upon entry, firms draw the firm-specific productivity level z from a cumulative distribution function $\Phi(z)$ with support $[z_{min}, \infty)$. This productivity level remains fixed thereafter. We assume that $f_{E,t}/Z^F_t > f_{E,t}/Z^H_t$, allowing for the possibility that the gas-rich country features fewer consumption-sector firms as a consequence of inefficiencies of various types that can characterize the firm creation process.

We also assume a one-period time-to-build requirement: it takes one period between the time of entry and the time when firms start producing and generating profits. All firms in the economy, incumbent and new entrants, are subject to an exogenous shock that causes them to exit with probability $\delta \in (0, 1)$ at the end of each period. Therefore, the mass $N^i_{D,t}$ of producing Home

[9] See Zlate (2016); Kim (2021) for a case with both the upper and lower bounds of exporting firms.

firms in period t is determined by $N^i_{D,t} = (1-\delta)(N^i_{D,t-1} + N^i_{E,t-1})$, where $N^i_{E,t-1}$is the number of firms that entered in period t-1.

Given these definitions, firm entry decisions are determined as follows. Prospective entrants are forward-looking and compute the expected stream of average total profits that they will generate post entry. This determines the average value of an entrant, $\tilde{v}_t$, as:

$$\tilde{v}^i_t \equiv \mathbb{E}_t \left\{ \sum_{s=t+1}^{\infty} [\beta(1-\delta)]^{s-t} \left(\frac{C_{i,s}}{C_{i,t}} \right)^{-1} \tilde{d}^i_s \right\}. \tag{11}$$

Entry occurs until this value is equated to the sunk entry cost, implying the free-entry condition $\tilde{v}^i_t = w^i_t f_{E,t}/Z^i_t$. We assume that macroeconomic shocks are never large enough to cause zero entry in any period (or $\tilde{v}^i_t < w^i_t f_{E,t}/Z^i_t$) so that the entry condition always holds with equality (in other words, there is always a positive number of entrants). Since both new entrants and incumbent firms face the same probability of exit, δ, at the end of each period regardless of their firm-specific productivity, $\tilde{v}^i_t$ is also the average value of incumbent firms after production has occurred.

2.4. Household Budget Constraint and Asset Holdings

International financial markets are incomplete as only non-contingent, riskless real bonds are traded internationally. The representative country i household's holdings of country j bonds entering period t are denoted with $B^j_{i,t}$. The household receives the risk-free real interest rate r^j_t on these bonds during period t. (Country j bonds and interest rate are in units of country j consumption). We assume that firms are fully domestically owned. Specifically, the country i representative household enters the period with share holdings x^i_t in a mutual fund of $N^i_{D,t}$ producing firms in country i. During period t, the household receives dividends from its share holdings, $\tilde{d}^i_t$ per share, and the value of selling its share portfolio at the price $\tilde{v}^i_t$ per share. Besides its financial assets and the income they generate, the representative household's resources in period t also include the income from labor supplied in the gas production sector ($w^i_{G,t} L^i_{G,t}$) and in the consumption sector ($w^i_t L^i_t$). Finally, the household also receives a lump-sum rebate of fees that it pays to financial intermediaries in order to enter period $t+1$ (these fees serve the purpose of pinning down holdings of Home and Foreign bonds at their steady-state values in the deterministic steady state of the model). During period t, the household uses its resources to buy consumption, to buy bonds with which it will enter period $t+1$ ($\{B^j_{i,t+1}\}_{j=H,F,R}$), to pay fees $\sum_{j=H,F,R} 0.5Q^i_{j,t}(B^j_{i,t+1}-B^i_j)^2$, with $\eta>0$, and to buy share holding x^i_{t+1} in a mutual fund of $N^i_t \equiv N^i_{D,t}+N^i_{E,t}$ firms. Only $1-\delta$ of these N^i_t firms will be around to produce and generate profits in period $t+1$. The household does not know which firms will be hit by the exit-inducing shock and, therefore, it finances continued operations by all currently producing firms and entry by all producers who choose to enter the market, with the risk of firm exit at the end of period t reflected in the share price that will be determined by the Euler equation for optimal share holdings. The budget constraint of the representative household in country i is thus:

$$C_{i,t}+\tilde{v}_t N^i_t x^i_{t+1}+\frac{\eta}{2}\left(x^i_{t+1}-\frac{1}{\chi_i}\right)^2+\sum_{j=H,F,R} Q^i_{j,t}\left[B^j_{i,t+1}+\frac{\eta}{2}(B^j_{i,t+1}-B^j_i)^2\right]$$
$$=w^i_{G,t}L^i_{G,t}+w^i_t L^i_t+(\tilde{d}^i_t+\tilde{v}^i_t)N^i_{D,t}x^i_t+T^f_t+\sum_{j=H,F,R} Q^i_{j,t}(1+r^i_t)B^j_{i,t}. \tag{12}$$

where $T^f_t = 0.5\eta\left[(x^i_{t+1}-\chi_i^{-1})^2+\sum_{j=H,F,R} Q^i_{j,t}(B^j_{i,t+1}-B^j_i)^2\right]$ in equilibrium.

The country i representative household's Euler equation for optimal holdings of country j bonds is:

$$C^{-1}_{i,t}\left[1+\eta(B^j_{i,t+1}-B^j_i)\right]=\beta\left(1+r^j_{t+1}\right)\mathbb{E}_t\left[\frac{Q^i_{j,t+1}}{Q^i_{j,t}}C^{-1}_{i,t+1}\right], \tag{13}$$

for each $j=H,F,R$. The Euler equation for optimal share holdings implies:

$$\tilde{v}^i_t\left[1+\eta\left(x^i_{t+1}-\frac{1}{\chi_i}\right)\right]=\beta\left(1-\delta\right)\mathbb{E}_t\left[\left(\frac{C_{i,t+1}}{C_{i,t}}\right)^{-1}\left(\tilde{v}^i_{t+1}+\tilde{d}^i_{t+1}\right)\right]. \tag{14}$$

Forward iteration of this equation and the relevant transversality condition imply the expression for $\tilde{v}^i_t$ in the free-entry condition of equation (11), thus establishing the general equilibrium link between firm entry decisions and household decisions regarding the financing of entry.

2.5. Market Clearing and Aggregate Accounting

The price of usable gas, $\rho^i_{G,t}$, is determined by a gas market clearing condition in a gas import country $i = H$ and R:

$$G^i_N(\chi_i L^i_{G,t}) = G^i_{i,t}, \tag{15}$$

and also, the gas demand satisfies

$$N^i_{D,t}\int_{z_{min}}^{\infty} g_{i,t}(z)\mathrm{d}\Phi(z) = G^i_{i,t} + \frac{G^F_{i,t}}{\tau_{G,t}}. \tag{16}$$

In a gas export country (F), the followings hold.

$$G^F_N(\chi_F L^F_{G,t}) = \sum_{j=H,F,R} G^F_{j,t} \tag{17}$$

$$N^i_{D,t}\int_{z_{min}}^{\infty} g_{i,t}(z)\mathrm{d}\Phi(z) = G^F_{F,t} \tag{18}$$

The labor supply decision in gas production in country i requires

$$L^i_{G,t} = \left(\frac{w^i_{G,t}}{\kappa C^i_t}\right)^{\varrho}\left[(L^i_t)^{\frac{1+\varrho}{\varrho}} + (L^i_{G,t})^{\frac{1+\varrho}{\varrho}}\right]^{\frac{\varrho(1-\varrho)}{1+\varrho}}. \tag{19}$$

Let country i be a gas importer (H or R) and $\varrho = 1$. Then, $L^i_{G,t} = \rho^i_G G^i_N/(\kappa C^i_t)$ and $L^F_{G,t} = \rho^i_{G,t} G^F_N/(\tau_{G,t}\kappa Q^i_{F,t} C_{F,t})$, where the relationships use the fact that $\rho^i_{G,t} = \tau_{G,t} Q^i_{F,t}\rho^F_{G,t}$ and $w^i_{G,t} = \rho^i_{G,t} G^i_N$. Ceteris paribus, the amount of labor employed in gas production in each country increases as the country's endowment of natural gas increases and as the the price of gas increases. Instead, labor in the gas sector decreases as the country's consumption increases, and intuitively, as the weight of the disutility of labor increases. Because a real depreciation of the country i's currency (an increase in $Q^i_{F,t}$) causes a higher real price of usable gas in gas import country i, it causes a decrease in gas-sector employment in Foreign, as there is an incentive to shift production to country i.

Market clearing for individual goods requires $y_{i,t}(z) = c_{H,t}(z) + c_{F,t}(z) + c_{R,t}(z)$ for the product of a Home firm with specific productivity z. Market clearing conditions for individual goods of

Foreign and RoW firms are analogous.

Labor market clearing in the consumption good sectors of country $i = H, F, R$ requires

$$\chi_i L_t^i = N_{D,t}^i \int_{z_{min}}^{\infty} l_{i,t}^P(z) \mathrm{d}\Phi(z) + N_{E,t}^i \frac{f_{E,t}}{Z_t^i} + \sum_{j \neq i} N_{j,t}^i \frac{f_{X,t}}{Z_t^i}, \tag{20}$$

where the labor satisfies

$$L_t^i = \left(\frac{w_t^i}{\kappa C_t^i}\right)^{\varrho} \left[(L_t^i)^{\frac{1+\varrho}{\varrho}} + (L_{G,t}^i)^{\frac{1+\varrho}{\varrho}}\right]^{\frac{\varrho(1-\varrho)}{1+\varrho}}. \tag{21}$$

Market clearing for bonds issued by country i requires $\sum_{j=H,F,R} \chi_j B_{j,t+1}^i = 0$ in every period. Stock market clearing in each country requires $x_{t+1}^i = x_t^i = 1/\chi_i$ in every period. Because costs of adjusting bond holdings are rebated back to households in equilibrium, imposing equilibrium conditions on the household budget constraint yields:

$$C_{i,t} + \tilde{v}_t^i N_{E,t}^i \chi_F^{-1} + TB_{i,t} = GDP_{i,t}, \tag{22}$$

where $TB_{i,t} = \sum_{j=H,F,R} Q_{j,t}^i [B_{i,t+1}^j - (1 + r_t^j) B_{i,t}^j]$ and $GDP_{i,t} = w_{G,t}^i L_{G,t}^i + w_t^i L_t^i + N_{D,t}^i \tilde{d}_t^i \chi_i^{-1}$ are country i's trade balance and GDP per capita, respectively.

2.6. Sanctions

We consider three types of sanctions and also their combinations. Namely, consumption good trade (export/import) sanctions, financial sanctions, and gas trade sanctions. We model sanctions in the form of exit at the extensive margin (rather than solely manipulation of the prices of existing traded goods which are utilized by the sanctioned economy).[10] We focus on the transitional dynamics in converging to the new steady state under sanctions.

We model consumption good trade sanctions by imposing exit from trade of consumption good producers with productivity above a certain threshold. The idea is that sanctions imply a reduc-

[10]The evidence shows that sanctions were in the form of exit from the Russian market. It is documented that more than 1,000 companies voluntarily curtailed operations in Russia in an attempt to add to what was being imposed by governments. See Sonnenfeld et al. (2022) and https://som.yale.edu/story/2022/over-1000-companies-have-curtailed-operations-russia-some-remain for more details and discussion.

tion in the trade of most productive producers. Our modelling approach comes from the fact that the sanctioned products from the the EU and the US to Russia are those that require sophisticated technology to be produced, such as quantum computers, sensors, lasers, space industry goods, maritime navigation goods and luxury cars.[11] We introduce financial market sanctions by modelling exclusion of a fraction of Foreign households from international bond trading. In the limit, all Foreign households are excluded. We motivate our modelling approach for financial sanctions from the Biden administration's sanctions on the trade of Russian bonds.[12] Implementation of financial sanctions by the EU and the US came in many forms, including freezing central bank reserves, restricting transactions of Russian financial institutions and restrictions on international financial messaging systems such as SWIFT. In this paper, we limit our attention on financial sanctions by focusing on the restrictions on international bond trade. With regard to gas trade sanctions, we conduct simulations with a permanent halt of gas imports from Foreign. We provide more details on the modelling of sanctions below.

Consumption good trade sanctions. We introduce sanctions on consumption good trade by imposing a productivity upper bound, $\overline{z}_S$, which we call the sanction productivity limit. Either Home consumption good producers with higher productivity levels than the sanction productivity limit level stop exporting to Foreign ($\overline{z}^H_{F,t} = \overline{z}_S$), or Home stops importing from Foreign producers with productivity levels above the sanction productivity limit ($\overline{z}^F_{H,t} = \overline{z}_S$). Under consumption good trade sanctions, the share of exporting firms from country i (sanctioning region) to country j (sanctioned region) reads as follows:

$$\frac{N^i_{j,t}}{N^i_{D,t}} = (1 - \mathbb{1}^S) + \mathbb{1}^S \Phi(\overline{z}_S) - \Phi(\underline{z}^i_{j,t}). \tag{23}$$

where $\mathbb{1}^S$ is an indicator function and takes the value 1 when sanctions are introduced and 0 under normal times. Our choice of the sanction cut-off level reflects Russia's non-mineral fuel goods

[11] See a description of the goods from the EU and the US that are subject to sanctions: http://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/#trade and "Russia's War on Ukraine Financial and Trade Sanctions," Congressional Research Service, February 22, 2023.

[12] See "Russia's War on Ukraine Financial and Trade Sanctions," Congressional Research Service, February 22, 2023.

trade flows with the European Union, the United Kingdom, and the United States after the Russian-Ukrainian war. (See Section 3 for the details.) Specifically, we pin down the threshold sanction productivity level by imposing that the top 0.5% most productive consumption good producers are participating in sanctions. Although the top 0.5% Home firms represent 78% of aggregate exports to Foreign in our model's initial steady state, there is an increase in the export participation of lower productive firms. Therefore, the total decrease in aggregate exports is less than 78%.[13] The increase in lower productivity firms entering the export market does not quantitatively affect our results. The average exporter productivity drops after the sanctions, irrespective of whether there is further entry by lower productivity firms into the export market or lack thereof.

Financial sanctions. When Home imposes financial sanctions against Foreign, a fraction $\lambda > 0$ of Foreign households are excluded from international financial markets. These households can only trade Foreign bonds and shares with RoW households and other Foreign households.[14] When the entire Foreign economy is subject to financial sanctions with $\lambda = 1$, Foreign operates under financial autarky.

The budget constraint of the representative sanctioned household reads:

$$C^{*}_{F,t} + \frac{\eta}{2}\tilde{\upsilon}^{F}_{t} N^{F}_{t}(x^{F*}_{t+1} - \chi^{-1}_{F})^{2} + \tilde{\upsilon}^{F}_{t} N^{F}_{t} x^{F*}_{t+1} + \sum_{j=F,R} Q^{j}_{F,t}\left[B^{j*}_{F,t+1} + \frac{\eta}{2}(B^{j*}_{F,t+1} - B^{j}_{F})^{2}\right]$$

$$= w^{F}_{G,t} L^{F*}_{G,t} + w^{F}_{t} L^{F*}_{t} + (\tilde{d}^{F}_{t} + \tilde{\upsilon}^{F}_{t}) N^{F}_{D,t} x^{F*}_{t} + T^{*}_{F,t} + \sum_{j=F,R}(1 + r^{j}_{t}) Q^{j}_{F,t} B^{j*}_{F,t}. \tag{24}$$

The asterisk denotes Foreign households that are subject to sanctions. The sanctioned households cannot trade Home bonds along the transitional path, and their terminal steady state holdings are zero, i.e., $B^{F,t+1}_{H} = B^{F}_{H} = 0$. If the RoW joins sanctions, the terminal steady state holdings of RoW bonds goes to zero as well, i.e., $B^{F*}_{R,t+1} = B^{F}_{R} = 0$.

[13]Due to asymmetry between Home and Foreign, the top 0.5% Foreign firms represent 60% of aggregate exports from Foreign to Home in the initial steady state. Section 3 provides the details.

[14]The resulting household structure after the introduction of financial sanctions is related to those in open economy HANK literature, such as Guo, Ottonello, and Perez (2023). This literature studies the effects of shocks given the heterogeneous structure of households, whereas our focus is on the variation of household heterogeneity along the transitional path between steady states.

The budget constraint of the representative non-sanctioned household is:

$$C_{F,t}^{**} + \frac{\eta}{2}\tilde{v}_t^F N_t^F (x_{t+1}^{F**} - \chi_F^{-1})^2 + \tilde{v}_t^F N_t^F x_{t+1}^{F**} + \sum_{j=H,F,R} Q_{F,t}^j \left[B_{F,t+1}^{j**} + \frac{\eta}{2}(B_{F,t+1}^{j**} - B_F^{j**})^2 \right]$$

$$= w_{G,t}^F L_{G,t}^{F**} + w_t^F L_t^{F*} + (\tilde{d}_t^F + \tilde{v}_t^F) N_{D,t}^F x_t^{F**} + T_{F,t}^{**} + \sum_{j=H,F,R} (1 + r_t^j) Q_{F,t}^j B_{F,t}^{j**}. \quad (25)$$

The doubled asterisk denotes non-sanctioned households. The non-sanctioned households can trade Home bonds along the transitional path, but their terminal steady state holdings are zero, i.e., $B_H^F = 0$. ($B_R^F = 0$ if the RoW joins sanctions.) Market clearing conditions for bonds and shares in the presence of financial market sanctions are as follows:

$$0 = \chi_F (1-\lambda) B_{F,t+1}^{H**} + \sum_{j=H,R} B_{j,t+1}^H \quad (26)$$

$$0 = \chi_F [\lambda B_{F,t+1}^{F*} + (1-\lambda) B_{F,t+1}^{F**}] + \sum_{j=H,R} B_{j,t+1}^F \quad (27)$$

$$1 = \chi_F [\lambda x_{t+1}^* + (1-\lambda) x_{t+1}^{**}]. \quad (28)$$

Gas sanctions. We study gas sanctions by modelling a permanent drop in gas imports from Foreign in period 1. When sanctions are imposed, market clearing for usable gas in Foreign is modified as follows:

$$G_N^F \chi_F L_{G,t}^F = \min\{\overline{G}_{H,t}^S, G_{H,t}^F\} + \min\{\overline{G}_{R,t}^S, G_{R,t}^F\} + G_{F,t}^F. \quad (29)$$

In the above equation, $\overline{G}_{H,t}^F$ and $\overline{G}_{R,t}^F$ denote the quota imposed by Home and RoW to gas imports from Foreign, respectively. We consider gas trade to completely stop under gas sanctions, i.e., $\overline{G}_{H,t}^F = 0$. If RoW participates in sanctions, the gas import quota is $\overline{G}_{R,t}^F = \overline{G}_{H,t}^F$. Otherwise, there is no quota, $\overline{G}_{R,t}^F \to \infty$.

3. Calibration

The model is calibrated by using the conventional values in the international trade and macroeconomics literature and through matching the steady-state values of several variables to the data.

Table 1: A Priori Parameters

Parameter	Notation	Value	Target
Mass of Foreign households	χ_F	0.2	Russian (relative) labor force size
Disutility from working	κ	0.75	Normalize $L_0^H = 1$
Sectoral labor mobility	ϱ	1	Labor mobility in the US
Discount factor	β	0.99	4% annual interest rate
Firm exit probability	δ	0.025	10% annual firm exit rate
Elasticity of substitution across products	θ	3.8	Markups
Pareto distribution			
Lower bound	z_{min}	1	Normalized
Shape	k	3.4	Firm domestic sales distribution shape
Production function (consumption goods sector)			
Gas share	α	0.05	Energy factor cost share
Elasticity of substitution (gas & labor)	ϵ	0.3	Elasticity b/w energy & other factors
Productivity (gas sector)			
Sunk entry costs	$f_{E,t}$	1	Normalized
Fixed Export costs	$f_{X,t}$	0.0045	Fraction of exporters in US manufacturers

Steady-state values of Foreign GDP, Foreign exports and Foreign imports are matched to replicate the average of 2020-2021 Russian annual data, and the steady-state values of Home GDP, Home exports and Home imports are matched to replicate the combination of EU27, the UK, and the US averages in 2020-2021. We also match the Russian net foreign position and the amount of Russian external assets when setting the steady-state bond holdings of Foreign.

We first calibrate some parameters directly from the data or from the previous literature (Table 1). This approach allows us to assess the implications of sanctions without the risk of our findings being the product of an unusual calibration. We normalize the mass of Home households to one and set the mass of Foreign households to match the relative size of Russia's labor force. The data indicates that the relative size of Russian labor force is approximately 20% of the combination of EU27, the UK, and the US.[15] Therefore, we set χ_F to 0.20.

Following Kim, Ozhan, and Schembri (2021), we set the cost share of gas to $\alpha = 0.05$ and we set a low elasticity of substitution between gas and labor, ϵ, to 0.3. The latter is in line with the suggested estimates in Bachmann and et al. (2022). We set the discount factor and firm exit rates to $\beta = 0.99$ and $\delta = 0.025$, respectively. The former implies a steady-state real interest

[15] According to the World Bank's World Development Indicators, the 15-64 aged population of Russia is the 71% of the aggregates of EU27, the UK, and the US in 2020 and 2021. Labor force participation rates in total (% of total population ages 15+, modeled ILO estimate) are 61.9 (62.2), 56.6 (56.9), 62.8 (62.1), and 61.3 (62.2) in Russia, EU27, the UK, and the US, respectively, in 2020 (2021).

rate of 4% per annum. The latter is set using Ghironi and Melitz (2005), among others in this literature. The disutility parameter from working, κ, is set to 0.75 to normalize the consumption goods sector labor supply to one. We follow the sectoral labor mobility parameter of Horvath (2000).[16] The scale parameter for the costs of adjusting bond/share holdings, η, is 0.025, which is sufficient to induce stationarity. This value pins down the non-stochastic steady state. Again, following Ghironi and Melitz (2005), we set the elasticity of substitution between varieties, θ, to 3.8. As in Melitz (2003), we assume that firm-level productivity z is drawn from a Pareto distribution with lower bound z_{min} and shape parameter k. We set k to 3.4 and normalize z_{min} and f_E to 1. Hence, the Pareto shape parameter of (domestic) sales distribution is 1.21. Our choice of calibration implies that the top 1% productive exporters constitute 71% of total exports when 35% of firms export. According to Mayer and Ottaviano (2008), the share of top 1% exporters in total exports is 81%, 73%, 69%, 59%, 73%, and 81% in Germany, France, the UK, Italy, Belgium, and Norway, respectively. Our model generates values that are within the range of their estimates.

We set the fixed cost of exporting to be $f_X = 0.0045$, which yields that the percent of Home producers that export their goods to RoW is 34 in the initial steady state. Because of the small market size of Foreign, only 2% of Home firms export to Foreign. The percent of Foreign firms exporting to Home is 9 in the initial steady state.

As previously highlighted, an important dimension of our model is the asymmetry between the three regions. We calibrate the consumption goods sector productivity, gas endowment, and trade cost of each region to reflect their respective economic sizes and export patterns before the Russia sanctions, as shown in the Panel B of Table 2.

Without loss of generality, we normalize Foreign productivity and Home natural gas endowments to one; $Z_t^F = 1$ and $G_N^H = G_N^R = 1$. Home and RoW are gas importers and Foreign is a gas exporter. We set Foreign gas endowment, G_N^F, to 1.2, and Home and RoW aggregate productivity of consumption good production, $Z_t^H = Z_t^R$, to 1.2. In the gas sector, Foreign has a comparative advantage, while Home and RoW have a comparative advantage in the consumption goods sec-

[16]See Cantelmo and Melina (2023) for more information on our parameter selection and the sectoral mobility literature.

Table 2: Parameters from (Initial) Steady State Matching: GDP and Trade

Panel A. Calibrated Parameter	Notation	Value
Natural gas endowments (gas sector productivity)		
Home	$G^H_{N,t}$	1.0
RoW	$G^R_{N,t}$	$G^H_{N,t}$
Foreign	$G^F_{N,t}$	1.2
Productivity (consumption goods sector)		
Home	Z^H_t	1.2
RoW	Z^R_t	Z^H_t
Foreign	Z^F_t	1.0
Export (iceberg) costs (consumption goods)		
between Home & RoW	$\tau^H_R = \tau^R_H$	1.2
from Home & RoW to Foreign	$\tau^H_F = \tau^R_F$	1.3
from Foreign to Home & RoW	$\tau^F_H = \tau^F_R$	3.0
Gas import (iceberg) costs	$\tau_{G,t}$	1.3

Panel B. Target	Data	Model
GDP ratio of Home to Foreign	10.09%	10.30%
Home exports/GDP	26.7%	29.6%
Foreign exports/GDP	28.2%	34.6%
Foreign gas export share in total exports	57.2%	64.5%

Notes: In Panel B's second column (data), we collect Russia, European Union, UK, and US data from the World Bank's World Development Indicators–DataBank. The GDP ratio of Foreign to Home is calculated by dividing the sum of the GDPs of the EU27, the UK, and the US by the GDP of Russia (PPP, current international $). Home and Foreign export to GDP ratios are from the USD nominal values of annual exports and GDP of the three countries (EU27, UK, and US) and Russia, respectively. We calculate the Foreign gas export share by dividing Russia's monthly mineral fuel exports by total goods exports, using data from Zsolt Darvas, Luca Lery Moffat, Catarina Martins, and Conor McCaffrey's Russian Foreign Trade Tracker (17 May 2023). All numbers are the average of 2020 and 2021. The third column reports the model values at the initial state without sanctions.

tor.[17] Our calibration implies that the Home GDP is roughly ten times larger than the Foreign GDP in the initial steady state, absent sanctions. According to the World Bank's World Development Indicators–DataBank, this value is similar to the ratio of combined GDPs at purchasing power parity (PPP) of EU27, the UK, and the US to Russian GDP at PPP in 2020 and 2021. There is a small discrepancy between the model implied steady state and the data between the combined GDPs of EU27, the UK, and the US (indicative for Home) versus China, India, and Turkey (indicative for RoW). In the data, the former is 1.2 times larger than the latter, whereas, in the model, these

[17] In addition to comparative advantages from endowments and productivities, Home and RoW tend to be concentrated in the consumption goods sector because of their large market sizes. According to the home market effects of Krugman (1980), countries with large market sizes are more appealing as a firm location for producing differentiated goods and economies of scale. For further recent discussion on the home market effects of product differentiation, trade costs, and economies of scale, see Hanson and Xiang (2004); Bak, Kim, and Mehra (2022), and many others.

regions are equal in size.

The calibration of iceberg trade costs enables us to match the export-to-GDP ratios of the steady state of the model to data. We set the iceberg trade costs to 30%, i.e., $\tau^H_{F,t} = \tau^R_{F,t} = \tau_{G,t} = 1.3$. The calibration of these parameters is within the estimates that are widely used in the literature.[18] We set lower trade costs between Home and RoW, i.e., $\tau^H_R = \tau^R_H = 1.2$, in order to match the model's Home exports-to-GDP ratio and the fraction of Home exporters to those of data.[19] Finally, the cost of trade for Foreign exporters is relatively higher in our calibration, i.e., $\tau^F_{H,t} = \tau^R_{H,t} = 3.0$. These values are higher with respect to trade costs between Home and RoW, but Foreign being subject to higher trade costs helps to match the Russian low exports of non-mineral fuel goods to our model's steady state, specifically, exports-to-GDP ratio and the share of gas exports in total exports. See Table 2 for the related data.

The fact that Russia is a net creditor on global markets is a crucial characteristic of the Russian economy. Therefore, to set the initial steady state net foreign asset holdings of Foreign, we target the value of Russian net foreign position (NFA) and external assets.[20] In the data, the former is approximately 30% of Russian GDP in 2021, and the latter is approximately equal to the Russian GDP in 2021. Table 3 summarizes our calibration of steady state asset holdings.

Parameters related with sanctions. We end this section by explaining the calibration related with sanctions. We set the sanction productivity limit for consumption good trade to match the observed changes in Russia's trade flows of goods (excluding mineral fuels) after the war that began in February 2022. (See Figure 2 for the data.) The implied sanction productivity limit ($\overline{z}_S$) is $0.005^{-1/k}$, which translates into exclusion of the top 0.5% firms from export markets. Regarding financial and gas sanctions, our choices are suggestive. We set the percentage of Foreign households that are excluded from international bond trade after financial sanctions, λ, to 0.9. For gas sanctions, we consider a complete stop of gas imports from Foreign ($\overline{G}^S_{H,t} = 0$), which is in line

[18] Anderson and van Wincoop (2004) summarizes the literature on the estimation of tariff equivalent trade costs (i.e., iceberg trade costs) and our values are within the range provided in their paper as well, i.e., between 10% and 40%.

[19] Setting low trade costs between Home and RoW is not an unusual calibration. The EU is Turkey's largest trade partner, the US is India's largest trade partner, and the EU and the US are the top two largest trade partners of China in 2021.

[20] According to the International Monetary Fund's International Investment Position database, Russia's foreign assets are 1,569 billion USD in 2020 and 1,652 billion USD in 2021. In 2020 and 2021, its net foreign asset positions are 517 and 485 billion USD, respectively.

Table 3: Parameters from (Initial) Steady State Matching: External Assets

Panel A. Calibrated Parameter	Notation	Value
Foreign initial bond holdings		
Home bond	B_F^H	$1/\chi_F$
Foreign bond	B_F^F	$-1.3/\chi_F$
RoW bond	B_F^R	B_F^H
Home initial bond holdings		
Home bond	B_H^H	$-\chi_F B_F^H$
Foreign bond	B_H^F	$-\chi_F B_F^F/2$
RoW bond	B_H^R	0
RoW initial bond holdings		
Home bond	B_R^H	B_H^R
Foreign bond	B_R^F	B_H^F
RoW bond	B_R^R	B_H^H

Panel B. Target	Data	Model
Foreign's NFA/GDP	31.0%	29.4%
Foreign's External Assets/GDP	99.1%	98.8%

Notes: In the second column of Panel B, we collect Russia's annual external assets and net foreign assets (NFA) data for 2020 and 2021 from the International Monetary Fund's International Investment Position database. Russia's annually nominal GDP USD values for 2020 and 2021 are taken from the World Bank's World Development Indicators–DataBank. We compute the ratios for each year and average them. The third column reports the model values at the initial state without sanctions.

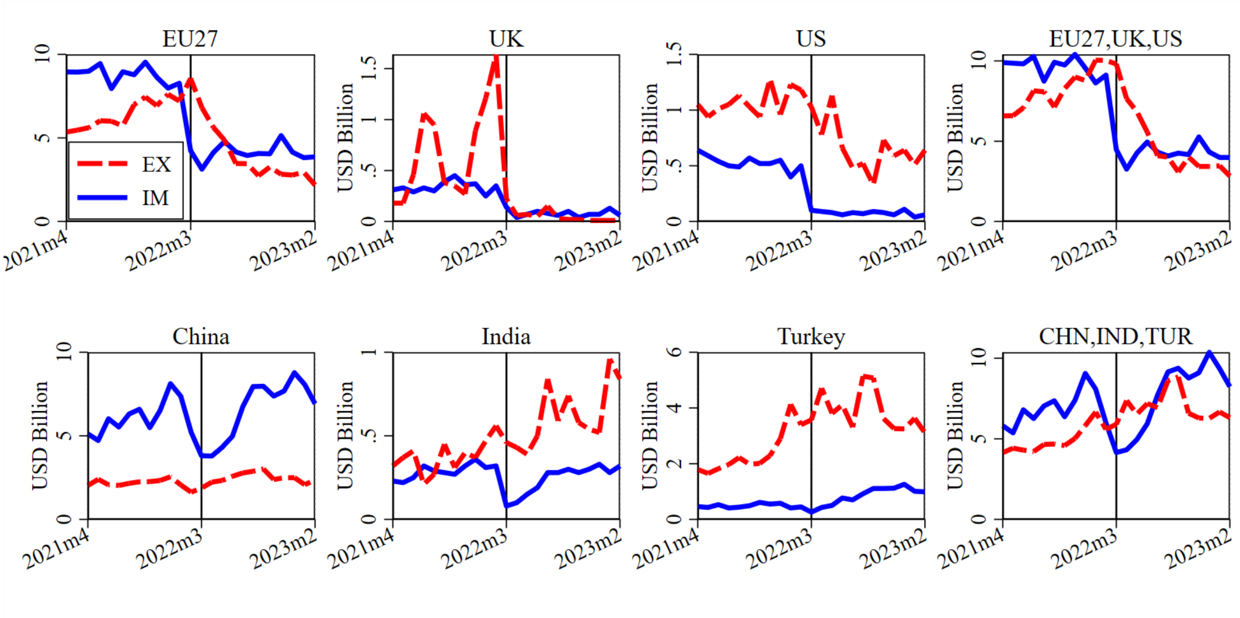
with the data of the UK and the US mineral fuel imports from Russia in Figure 2.[21]

Figure 2 illustrates the movement in Russia's exports (red dashed lines) and imports (blue solid lines) of goods excluding mineral fuels after the sanctions (in USD). Following the sanctions, Russia's non-mineral exports and imports with the EU, the UK, and the US decreased by 66% and 55%, respectively (in terms of year-to-year growths on average for December 2022–February 2023). Our choice of the sanction productivity limit ($\overline{z}_S$) is to match these values. In our calibrated model, when Home applies all of the sanctions without RoW's participation, the new steady-state values of Foreign exports and imports with Home are 62% and 64% lower than the initial values in terms of Home currency.[22] The corresponding sanction cut-off, $\overline{z}_S$, translates into the exclusion of the top 0.5% firms from export markets.

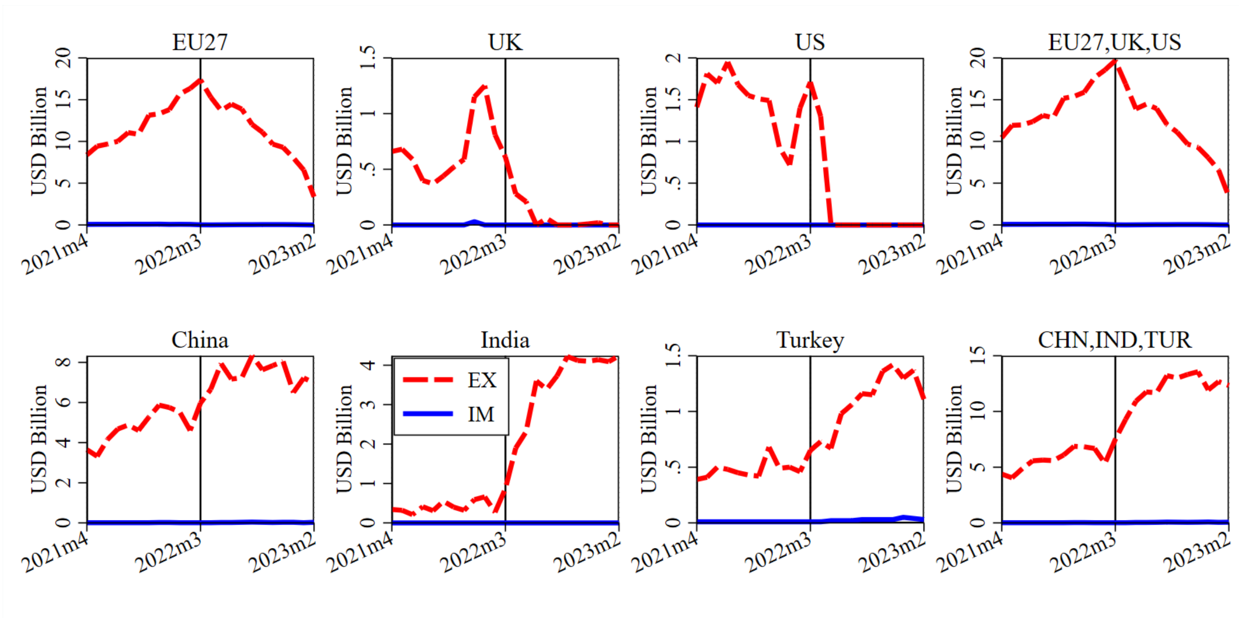
In contrast, Russia raises its non-mineral fuel exports and imports (USD) with China, India, and Turkey by 7% and 23%, respectively, in terms of year-to-year growth rates on average during

[21]The EU27 mineral fuel imports from Russia did not fall to zero after the war, although there has a substantial decrease in these imports.

[22]Note that Figure 6 plots exports in terms of destination currency (consumption good unit).



(a) Goods Other than Mineral Fuels



(b) Mineral Fuels

Figure 2: Russia's Exports and Imports of Goods

Notes: The figure plots Russia's monthly exports of goods to the selected countries from April 2021 to February 2023, as well as its monthly imports of these goods from those countries (blue solid lines and red dashed lines, respectively). Date source: Zsolt Darvas, Luca Lery Moffat, Catarina Martins, and Conor McCaffrey's Russian Foreign Trade Tracker (17 May 2023).

December 2022-February 2023 (Figure 2's subfigure a). Despite not being targeted, our model is successful in generating similar behavior, i.e., an increase in imports of the sanctioned economy from a third region in response to uncoordinated sanctions. Our model generates an increase of 23% (Home currency value) in Foreign imports from RoW after the uncoordinated sanctions imposed by Home. Following these sanctions, Foreign economy's imports from RoW and domestic productions of consumption goods increase to replace the sanctioned Home products. Increased domestic demand in Foreign implies reduction in exports to RoW. Furthermore, Foreign raises labor employment in firm entry and production to extensively and intensively boost final consumption good production.

According to the model, Foreign's final consumption good imports from RoW increase by 23% (Home currency value) after the Home imposes combined sanctions without RoW coordination. Following the imposition of sanctions, the Foreign economy's access to Home produced goods has been constrained, leading to an increase in imports from RoW and an increase in final consumption goods production to replace Home products. Increased foreign demand for its domestically produced goods causes Foreign firms to sell domestically rather than export to RoW. Furthermore, Foreign raises labor employment in firm entry and production to extensively and intensively boost final consumption good production. Wages, prices, and currency grow as a result, causing them to lose competitiveness in the RoW consumption goods market. Therefore, Foreign firms considerably reduce exports to RoW. Because of Foreign (and also RoW) currency appreciation, the value of exports from Foreign to RoW in terms of Home currency drops by just 4 percentage points, contradicting the data's modest increase of Russia's exports to China, India, and Turkey. Wages, prices, and currency grow as a result, causing them to lose competitiveness in the RoW consumption goods market. Therefore, Foreign experiences trade deficit with RoW.[23] As shown in the subfigure (a) of Figure 2, Russia's imports from Turkey, China, and India are rising more than its exports to those countries.

In Figure 2, the red dashed lines of the subfigure (b) illustrate that sanctions have reduced UK and US imports of mineral fuels from Russia to near-zero since the war. While European economies continue to import mineral fuels from Russia, their value has also steadily declined. China, India, and Turkey, on the other hand, increased their imports of mineral fuels from Russia.

[23]Foreign currency appreciation dampens this channel.

Specifically, Russia's mineral fuel exports (in USD) to the EU27, the UK, and the US fell by 65% year-on-year, but its mineral fuel exports (in USD) to China, India, and Turkey rose by 99%. We replicate these numbers in calibration of gas sanctions in our model. Our model generates that gas exports from Foreign to Home and RoW drop by –100% and 64%, respectively, in terms of Home currency. Note that our model does not allow Home or RoW to export gas because all six countries have zero or minimal exports of mineral fuels to Russia, as shown in the data.

4. The Impact of Sanctions

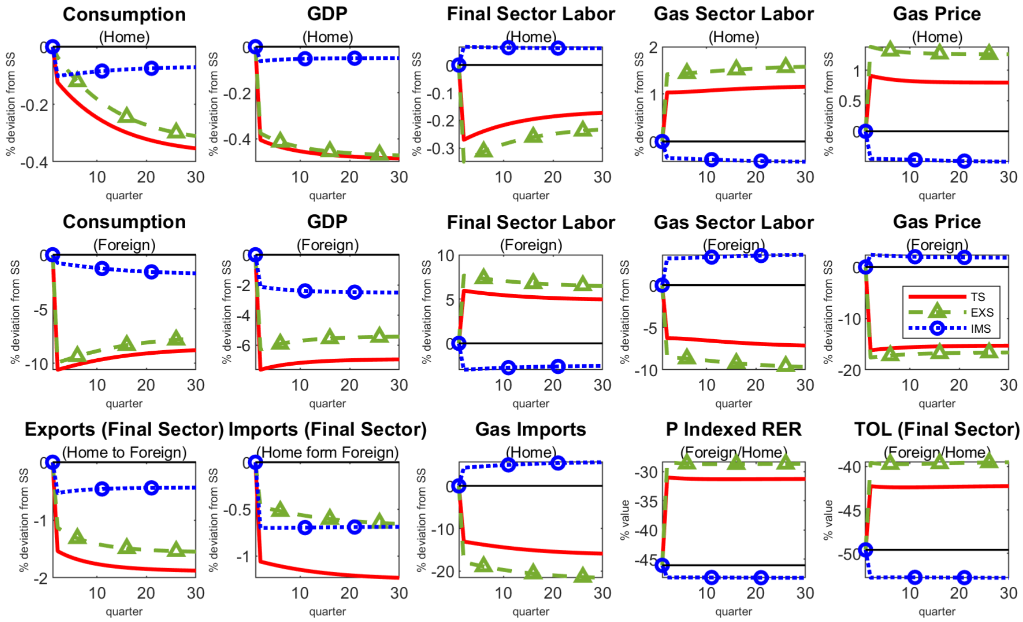
We solve our model numerically to investigate the short-, medium-, and long-term effects of sanctions. To be precise, at $t = 0$, the model is at the no-sanction equilibrium. Sanctions are introduced in $t = 1$ and the model converges to a new equilibrium, which we call the sanction equilibrium.[24] In the first subsection, we first consider that Home and RoW impose sanctions against Foreign together. This exercise is reminiscent of simulations in a two-region setting. To highlight the deviation from the two-region setting, later in the second subsection, we present and discuss dynamics when Home sanctions Foreign and the RoW does not join the sanctions.

4.1. Types of Sanctions

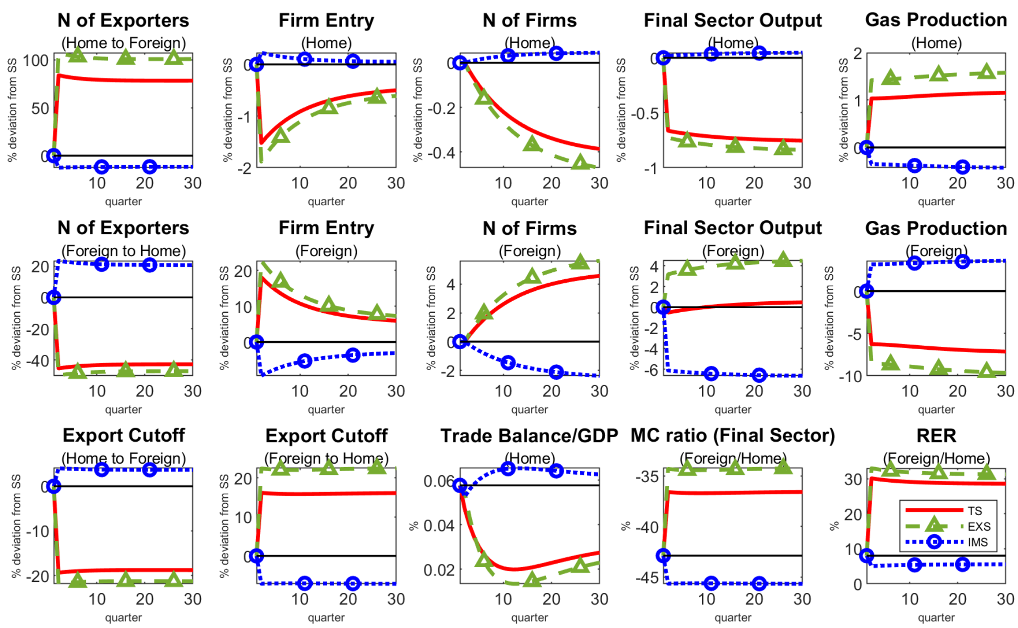
We study three different types of sanctions: financial sanctions, trade sanctions on consumption goods, and trade sanctions on gas. All of the sanctions generate a fall in Home and RoW consumption and GDP, although the fall is not as large as in Foreign. The impact of consumption good export sanctions generates the most pronounced changes. We also find that real exchange rate movements are shaped by sectoral reallocations, but do not indicate effectiveness of sanctions.

Consumption good trade sanctions. Figure 3 shows the transitional dynamics from the no-sanction equilibrium to the sanction equilibrium of several macroeconomic and trade variables after the introduction of consumption good trade sanctions at $t = 1$. Green dashed lines with triangles represent simulations in which the top 0.5% of productive Home and RoW firms stop

[24] Using Dynare's nonlinear equation solver with line search, we solve the model as a nonlinear, forward-looking, deterministic system.



(a) Main Macro Variables



(b) Extensive Margins and Other Variables

Figure 3: Transitional Dynamics uner Trade Sanctions

Notes: The red solid lines plot the model transition dynamics when trade sanctions (TS, export and import sanctions) are imposed at $t = 1$. The green dashed lines with triangles plot the model transition dynamics when export sanctions (EXS) are imposed at $t = 1$. The blue dashed lines with circles plots the model transition dynamics when import sanctions (IMS) are imposed at $t = 1$. All deviations except for the last three figures are in units of percent deviation from the initial steady state without sanctions ($t = 0$). The last two figures, titled P indexed RER and TOL (Final Sector) in subfigure (a) and Trade Balance/GDP, MC ratio (Final Sector), and RER in subfigure (b), are in units of percent deviation from one, i.e., $100 * (x - 1)$.

exporting to Foreign markets after the introduction of export sanctions (labeled EXS). Blue dashed lines with circles indicate the simulations in which the top 0.5% of productive Foreign firms stop exporting to both Home and RoW (labeled IMS). Simulations with simultaneous import and export sanctions are shown with red solid lines, labeled trade sanctions (TS).

In response to import sanctions (IMS), less productive Foreign producers begin to export, indicating a decline in the least productive Foreign exporter's cutoff productivity level. The decline in the average productivity of Foreign exporters translate into more expensive Foreign consumption good exports. Increase in the Home consumption price index, due to more expensive imports from Foreign, generates an appreciation of Home real exchange rate as shown in Figure 3. The drop in the supply of exported consumption goods of Foreign implies lower demand for labor in the consumption good sector. In turn, the number of producers in Foreign decreases. Resources in the Foreign economy is reallocated towards the gas sector to compensate for the loss of export revenues. Therefore the labor demand in Foreign gas sector goes up. The increase in the gas production of Foreign reduces the price of gas in Home and RoW.

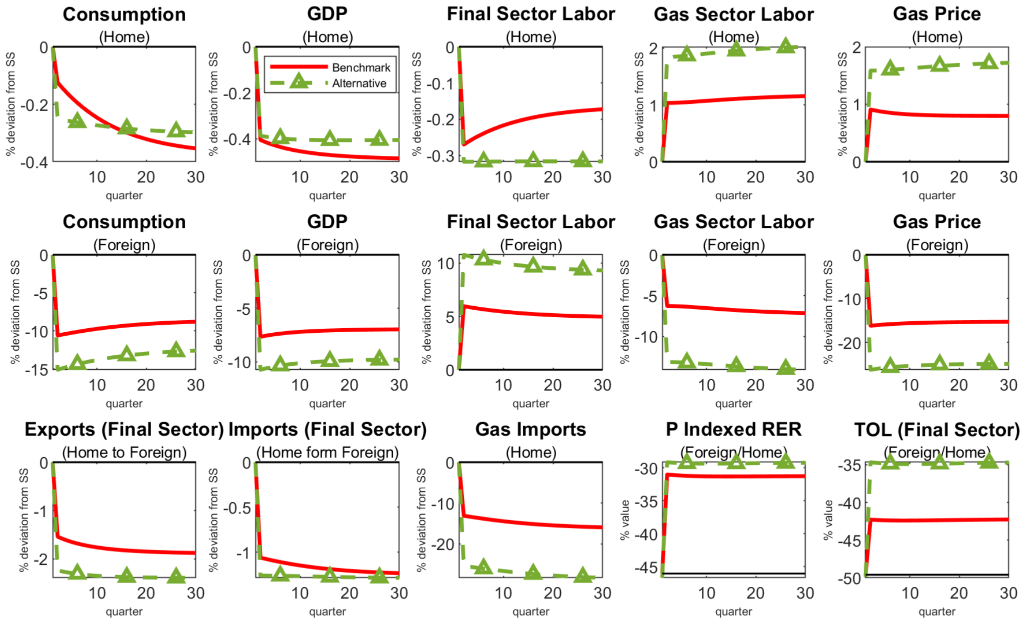
In response to export sanctions (EXS), Foreign economy reallocates its resources from the gas sector to the final good sector. The resource allocation works in the opposite direction when compared with import sanctions (IMS). Foreign economy rebalances itself to produce more consumption goods in compensation to loss of imports from Home and RoW. In returns, labor demand in Foreign consumption good sector rises and entry in the consumption sector increases. The decrease in the labor supply towards gas production in Foreign implies an increase in the price of gas in Home and RoW due to lower global supply of gas. Foreign starts to import more from lower productivity firms in Home and RoW, which translates into a higher consumption price index. The latter generates the depreciation of Home real exchange rate.

When we focus on the effects of export and import sanctions on GDP and per capita consumption, we observe that Foreign suffers more than Home and RoW combined in the short-, medium- and long-term.[25] Moreover, export sanctions (EXS) always generate a more pronounced drop in per capital consumption and GDP in comparison with import sanctions (IMS). The asymmetric production structure in between the regions is at the heart of our results. Home and RoW has com-

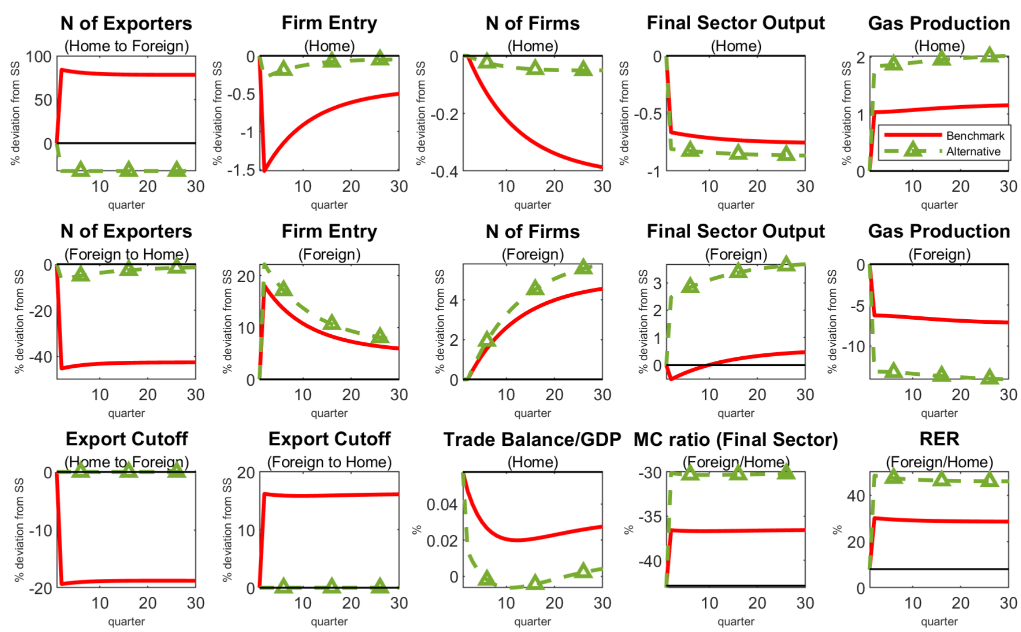
[25] It is important to note that Home and RoW combined is approximately 10 times larger than Foreign in size and this result is valid both for aggregate and per capita consumption dynamics.

parative advantage in producing consumption goods, and therefore, they rely on imported goods less than Foreign households. Losing the imports from Home and RoW forces the Foreign to move resources to its less advantageous sector and implies a loss of advantage in producing usable gas. This inefficient resource allocation squeezes the size of the Foreign economy. When we look at the combined effect of import and export sanctions, we also observe that the effects of export sanctions dominate due to the above reason (for instance, Foreign economy experiences an appreciation of real exchange rate and terms of labor under combined trade sanctions).

We conduct an additional simulation in Figure 4 to understand the importance of entry into export markets by lower productivity consumption good producers after the sanctions. To the best of our knowledge, there is no firm-level data for Russian exporters for the period after sanctions and this exercise serves the purpose of understanding the impact of entry into export markets in assessing the overall impact of trade sanctions. The solid red lines indicate dynamics of the combined trade sanctions as before (TS in Figure 3). The green dashed lines with triangles indicate dynamics when there is no changes in the export productivity cutoff of firms following trade sanctions. We label the former "Benchmark" and the latter "Alternative." We turn off the entry into export markets by fixing Home and RoW exporter productivity cutoff (lower bound) at the initial steady state level. Thus, only Home and RoW producers with productivity between $\underline{z}_{F,0}^{H}$ and $\overline{z}_{S}$ export after the sanctions (i.e., $\underline{z}_{F,t}^{i} = \underline{z}_{F,0}^{i}$ and $\overline{z}_{F,t}^{i} = \overline{z}_{S}$ for $i = H, R$ and $t \geq 1$). Shutting down the movements in the lower bound of the export margin has no qualitative impact on our simulations. The average exporter productivity still drops when the most productive producers exit from the export market due to sanctions. Therefore, the responses of the prices and the exchange rate move in the same direction with the previous exercise. However, we see a significant amplification of the responses when we turn off entry into export markets by lower productivity producers. The reason is that the collapse in aggregate trade becomes more significant when we rule out the entry margins into export market by lower productivity firms. This trade collapse, in return, is reflected into other aggregates such as Foreign consumption and GDP. The only variable with a milder response under invariant exporter entry is Home GDP. The response is caused by the significant increase of wages in the gas sector. A more significant trade collapse in Foreign generates an amplified resource reallocation towards consumption good sector, which diminishes the gas exports of Foreign more significantly. Therefore, the Home and RoW gas sectors demand more labor to produce their own gas,



(a) Main Macro Variables



(b) Extensive Margins and Other Variables

Figure 4: Transitional Dynamics under Trade Sanctions with Invariant Exporter Productivity Cutoffs

Notes: The red solid lines plot transitional dynamics in the benchmark model under combined trade sanctions. The green dashed lines with triangles plot transitional dynamics in the alternative model with invariant exporter entry under combined trade sanctions. Sanctions are imposed at $t = 1$. All deviations except for the last three figures are in units of percent deviation from the initial steady state without sanctions ($t = 0$). The last two figures, titled P indexed RER and TOL (Final Sector) in subfigure (a) and Trade Balance/GDP, MC ratio (Final Sector), and RER in subfigure (b), are in units of percent deviation from one, i.e., $100 * (x - 1)$.

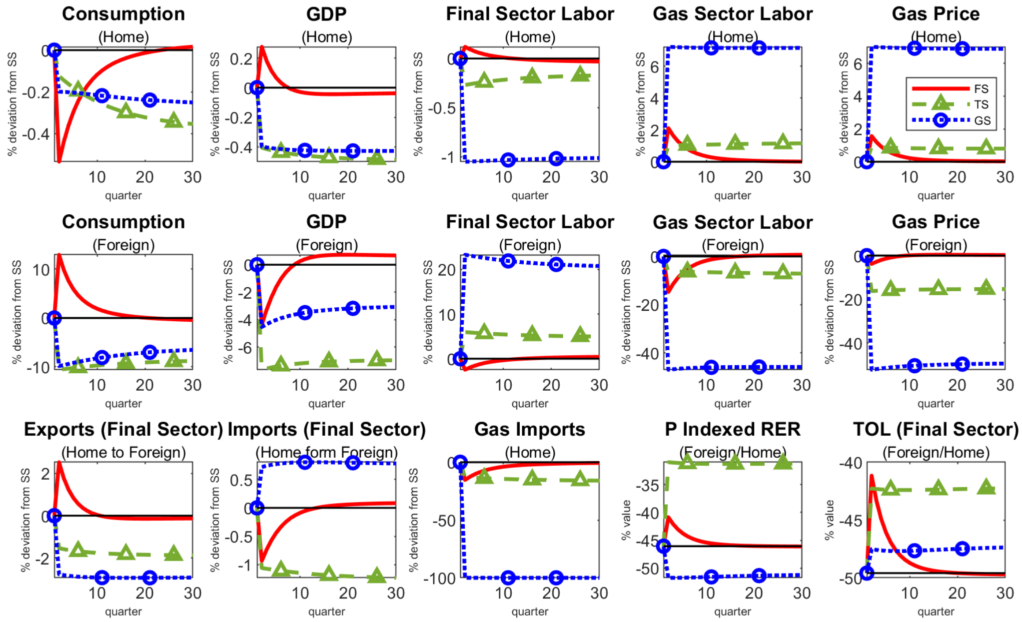
which translates into higher wages and a lower drop in GDP.

Gas sanctions. Blue dashed lines with circles in Figure 5 plot the transitional dynamics of several variables under gas sanctions. Halting gas imports from Foreign implies a big negative demand shock to Foreign usable gas producers. Foreign gas sector gets smaller and reduces its labor demand. Labor supply shifts towards consumption good production sector. Foreign economy rebalances itself towards consumption goods production and generating more export revenue in this sector to compensate for the loss of export revenue in the gas production sector. The rebalancing economy facilitates higher entry in consumption good production sector and lower exporter entry cutoff. Less productive producers entering into Foreign consumption good export market implies a decrease in the average productivity of Foreign exporters, which translates into a higher consumption price index in Home and RoW. Therefore, Foreign real exchange rate depreciates against Home and RoW.

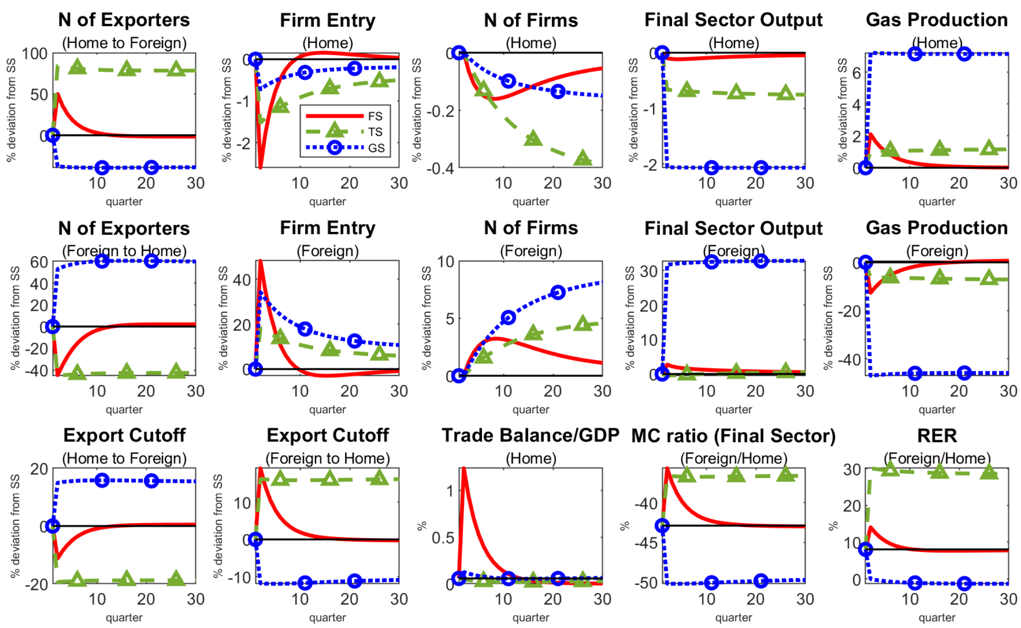
The fall in demand for Foreign gas induces a drop in gas production in Foreign and a subsequent jump in gas prices in Home and RoW. The gas price in Home and RoW economies rises because consumption good producing firms demand more domestic gas to replace the lost imported gas. A high gas price reduces the profitability of a firm, which discourages new entrants into the market and reduces the total number of producers in Home. As a result, Home households increase labor supply to gas production and decrease labor supply to consumption good production.

Financial sanctions. Red solid lines in Figure 5 indicate transitional dynamics under financial sanctions, i.e., 90% of Foreign households are excluded from international bond trade. In the initial, no-sanction equilibrium, Foreign has a positive net foreign asset position, whereas under the sanction equilibrium, Foreign has zero net foreign asset position.

Our initial observation is that, in response to financial sanctions, Foreign consumption goes up in the short run and reverts back in the long run. Wealth effects are at the center of this behavior. After the sanction hits, Foreign cashes in its bond holdings and this generates a positive transitory income shock with limited opportunity of savings. Therefore, Foreign consumption demand increases, including the demand on exports from Home and RoW. The increase in Foreign imports facilitates exporter entry in Home and RoW, affecting the average export price and generating a



(a) Main Macro Variables



(b) Extensive Margins and Other Variables

Figure 5: Transitional Dynamics under Trade Sanctions with Invariant Exporter Productivity Cutoffs

Notes: Red solid lines, green dashed lines with triangles, and blue dashed lines with circles plot the transitional dynamics under financial (FS), consumption good sector trade (TS), and gas sanctions (GS), respectively. Sanctions are imposed at $t = 1$. All deviations except for the last three figures are in units of percent deviation from the initial steady state without sanctions ($t = 0$). The last two figures, titled P indexed RER and TOL (Final Sector) in subfigure (a) and Trade Balance/GDP, MC ratio (Final Sector), and RER in subfigure (b), are in units of percent deviation from one, i.e., $100 * (x - 1)$.

Foreign real exchange rate appreciation.

Due to limited saving opportunity in Foreign, households increase their labor supply to generate more income. Foreign gas sector accommodates the increase in labor supply better due to its relative size in the Foreign economy. The movements in the labor supply translates into lower wages and therefore a decline in Foreign GDP.

Finally, we observe that, in the long run, financial sanctions bite less. The reason is that only a fraction of the population in Foreign is subject to financial sanctions and therefore the sanctioned fraction can overcome the sanctions through engaging in transactions with those in Foreign who preserve their access to international financial markets.

4.2. Combined Sanctions With(out) International Coordination

To account for the total impact of sanctions imposed on Russia, we study the impact of combined sanctions. We particularly focus on the changes to the impact, when sanctions are uncoordinated (only Home imposing sanctions) or coordinated (Home and RoW imposing sanctions together). Although the EU, the UK, and the US placed a wide range of sanctions against Russia, China, India, and Turkey did not follow.

We conduct simulations when Home imposes all of the sanctions mentioned in the previous subsection on Foreign, but RoW does not join in sanctioning. We label this scenario "uncoordinated sanctions." Then, we compare this outcome with the case in which RoW and Home sanctions Foreign together, which we label as "coordinated sanctions."

Figures 6 and 7 present the transition dynamics between the no-sanction and the sanction steady states. Green dashed lines with triangles indicate dynamics when only Home sanctions Foreign (called uncoordinated sanctions), whereas red solid lines indicate dynamics when both Home and RoW sanction Foreign (called coordinated sanctions).

Under uncoordinated sanction, Home and Foreign consumption fall while RoW consumption increases. RoW GDP increases in response to uncoordinated sanctions because of the substitution effects. RoW reallocates its economy towards consumption good production to match the additional demand coming from Foreign. Moreover, RoW expands exports to Foreign while increasing its gas imports from Foreign. It is important to note that Foreign still suffers from Home's sanctions even though RoW does not join sanctioning. The sanctioned imports from Home are partially

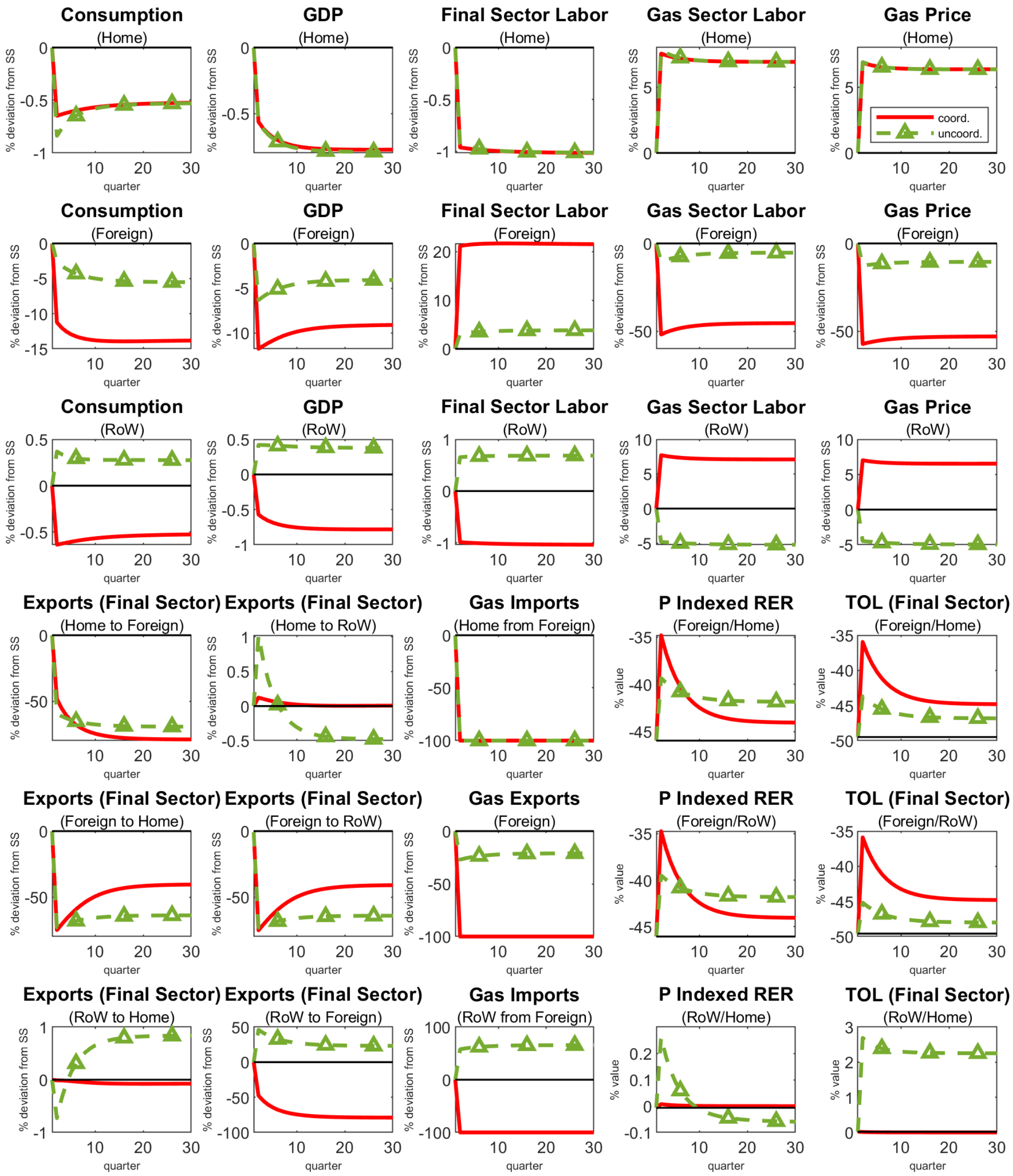


Figure 6: Transition Dynamics after the (Un-)Coordinated Sanctions: Main Macro Variables

Notes: The red solid lines (labeled coord.) plot the model transition dynamics when all sanctions are imposed by Home and RoW at $t = 1$. The green dashed lines (labeled uncoord.) with triangles plot the model transition dynamics when all sanctions are imposed by Home at $t = 1$, while the RoW does not participate in sanctions. All deviations except for the figures of ratio variables are in units of percent deviation from the initial steady state without sanctions ($t = 0$). The figures of ratios, titled P indexed RER and TOL (Final Sector), are in units of percent deviation from one, i.e., $100 * (x - 1)$. See Appendix Figure 7 for the other variables' responses.

substituted with RoW imports, but exporters in RoW have to pay fixed trade costs to be able to enter the export market. It is easier for Foreign to move factors of production to its relatively disadvantageous consumption good production sector. Inefficient resource allocation (in comparison with the initial steady state) in Foreign still makes sanctions bite.

Coordination of sanctions helps Home to share the burden of sanctions with RoW while amplifying the impact of sanctions against Foreign. The loss in Foreign consumption and GDP, in both short and long term, are almost doubled. However, RoW consumption and GDP suffer from the sanctions as in Home. Under coordinated sanctions, RoW rebalances its economy towards gas production. Convergence towards zero net foreign asset position implies that Home exporters substitute towards RoW, generating a positive trade balance. An important question is whether the additional cost on RoW is greater than the additional impact of coordinated sanctions against Foreign. To provide an answer to this question, we focus on welfare in the next section.

5. Welfare

We calculate welfare as the lifetime utility from consumption and disutility from labor. We incorporate the impact of sanctions after they are imposed in the first period, i.e., $t = 1$, include transition dynamics until $t = 201$, and the terminal impact. Simulating our model for 200 periods is enough for the economy to reach its new steady state. In particular, we compute the lifetime uitility to measure the welfare with sanctions as follows.

$$\begin{aligned}\mathcal{W}_i^{Sanction} =& \sum_{t=0}^{200} \beta^t \left\{ \ln C_{i,t} - \frac{\kappa}{2} \left[(L_t^i)^{\frac{1+\varrho}{\varrho}} + (L_{G,t}^i)^{\frac{1+\varrho}{\varrho}} \right]^{2\frac{\varrho}{1+\varrho}} \right\} \\ &+ \frac{\beta^{201}}{1-\beta} \left\{ \ln C_{i,201} - \frac{\kappa}{2} \left[(L_{201}^i)^{\frac{1+\varrho}{\varrho}} + (L_{G,201}^i)^{\frac{1+\varrho}{\varrho}} \right]^{2\frac{\varrho}{1+\varrho}} \right\}. \end{aligned} \tag{30}$$

When there is no sanction, the welfare is

$$\mathcal{W}_i^{NoSanction} = \frac{1}{1-\beta} \left\{ \ln C_{i,0} - \frac{\kappa}{2} \left[(L_0^i)^{\frac{1+\varrho}{\varrho}} + (L_{G,0}^i)^{\frac{1+\varrho}{\varrho}} \right]^{2\frac{\varrho}{1+\varrho}} \right\}, \tag{31}$$

where C_0^i, L_0^i, and $L_{G,0}^i$ are country i households' consumption, consumption good labor supply, and gas sector labor supply without sanctions, respectively. Now, we calculate the welfare loss in consumption equivalent terms:

$$\mathcal{W}_i^{Sanction} = \frac{1}{1-\beta}\left\{\ln[(1-\Delta_i)C_{i,0}] - \frac{\kappa}{2}\left[(L_0^i)^{\frac{1+\varrho}{\varrho}} + (L_{G,0}^i)^{\frac{1+\varrho}{\varrho}}\right]^{2\frac{\varrho}{1+\varrho}}\right\}, \tag{32}$$

where Δ_i can measure country i's lifetime welfare losses in consumption per capita equivalent terms. After some algebra, it can be expressed by

$$\Delta_i = 1 - \exp\left((1-\beta)[\mathcal{W}_i^{Sanction} - \mathcal{W}_i^{NoSanction}]\right). \tag{33}$$

Foreign consists of two different types of households. To measure their aggregate welfare losses, we calculate Δ_i of equations (33) by using the weighted average of welfare of sanctioned and non-sanctioned households indexed by S and NS, for example, $\mathcal{W}_F^{Sanction} = \lambda\mathcal{W}_{F,S}^{Sanction} + (1-\lambda)\mathcal{W}_{F,NS}^{Sanction}$ and $\mathcal{W}_F^{NoSanction} = \lambda\mathcal{W}_{F,S}^{NoSanction} + (1-\lambda)\mathcal{W}_{F,NS}^{NoSanction}$.

Table 4 presents welfare losses and changes of GDP per capita in Home, Foreign, and RoW under sanctions. Panels A and B provide the numbers under individual and combined sanctions, respectively. As expected, sanctions generate welfare losses in the sanctioning and sanctioned economies. Because of Home's larger size, welfare loss and the fall in GDP per capita are smaller than in Foreign under all scenarios.

The difference between coordinated and uncoordinated scenarios highlights the importance of international coordination in sanctions in Table 4. Coordinated sanctions result in significantly greater welfare losses in Foreign in comparison to unilateral sanctions. In most cases, coordination dampens the Home's negative effect of sanctions. The required rebalancing of Home economy in response to sanctions is smaller when RoW joins sanctions (see the section above). This translates into smaller welfare and GDP losses in Home under sanctions when RoW joins. On the other hand, uncoodinated sanctions result in little welfare loss for RoW while simultaneously increasing its GDP per capita. Joining sanctions always come at a cost for RoW, both in terms of welfare and GDP.

The effects of coordinated versus uncoordinated sanctions differ more in Foreign than in Home. In particular, under gas sanctions, the impact of coordinated sanctions against Foreign is more than double the impact of uncoordinated sanctions. This is due to the fact that the foreign economy is gas-intensive and dependent on gas exports because of the small size of the Foreign country and

Table 4: Change in Welfare and GDP after Sanctions

Type of Sanctions	International Coordination	% Welfare Loss (Δ)			% Change of GDP per capita		
		Home	Foreign	RoW	Home	Foreign	RoW
Panel A. Individual Sanctions							
Gas	Yes	1.17	5.80	1.17	–0.43	–2.98	–0.43
	No	1.14	2.02	0.67	–0.39	–1.20	0.29
C-good export	Yes	1.18	7.99	1.18	–0.48	–5.40	–0.48
	No	1.31	4.20	0.69	–0.62	–2.83	0.24
C-good import	Yes	0.96	1.90	0.96	–0.06	–2.53	–0.06
	No	0.96	1.06	0.87	–0.04	–1.24	0.00
C-good trade	Yes	1.22	9.03	1.22	–0.48	–6.92	–0.48
	No	1.36	4.73	0.69	–0.64	–3.66	0.23
Financial	Yes	0.88	0.44	0.88	–0.04	0.61	–0.04
	No	0.89	0.30	0.88	–0.04	0.30	0.01
Panel B. Sanction Combinations							
Gas + Financial	Yes	1.16	6.13	1.16	–0.47	–2.12	–0.47
	No	1.13	2.23	0.66	–0.43	–0.75	0.29
C-good trade + Financial	Yes	1.21	9.13	1.21	–0.50	–6.66	–0.50
	No	1.30	4.64	0.73	–0.52	–3.39	0.12
Gas + C-good trade + Financial	Yes	1.42	13.37	1.42	–0.77	–9.07	–0.77
	No	1.44	5.58	0.59	–0.79	–4.09	0.38
Panel C. Sanction Combinations under the Model Version with Invariant Export Cutoff							
C-good trade + Financial	Yes	1.16	12.92	1.16	–0.40	–9.65	–0.40
	No	1.33	5.45	0.70	–0.52	–4.09	0.15
Gas + C-good trade + Financial	Yes	1.44	14.44	1.44	–0.80	–9.73	–0.80
	No	1.46	6.28	0.57	–0.80	–4.70	0.40

Notes: The first three columns present the welfare (lifetime utility) loss of sanctions in terms of per-capita consumption defined in equation (33). The last columns present the percent change of GDP per capita from the initial period GDP per capita ($t = 0$) to the terminal period GDP per capita ($t = 201$). The Foreign welfare losses and GDP per-capita changes are calculated from the weighted sum of financially sanctioned and unsanctioned foreign households. The changes in welfare and GDP are calculated in Panel C by preventing less productive firms entering the export market in response to trade sanctions.

its comparative advantage in the gas sector.

In Panel C of Table 4, we evaluate welfare and GDP changes under a model version that does not allow the export cutoff to move in response to sanctions (labeled "alternative trade sanctions"). To be more precise, we assume that an invariant export productivity cutoff (lower bound) for the the countries (or country) that impose(s) sanctions. Under the model with alternative trade sanctions, the collapse in trade is more significant due to the limit on exporter entry, and therefore the resource allocation in each country is stronger. Hence, we observe greater welfare losses and a more significant drop in the GDPs of all regions vis-a-vis the outcome from the baseline model.

6. Conclusions

Geopolitical tensions have become a major challenge for the world economy. In this paper, we contribute to the understanding of how economic sanctions affect international relative prices, macroeconomic aggregates, and welfare. We calibrate a three-country, two-sector model of the world economy in which a sanctioning bloc (the European Union, the United Kingdom, and the United States) targets Russia with trade and financial sanctions, and a third bloc (China, India, and Turkey) does not impose sanctions. In our calibrated model, sectoral reallocation and real exchange rate fluctuations are central to the transmission of sanctions, as are changes in producer entry into domestic and export markets. However, exchange rate movements are not a good criterion to assess the success or failure of sanctions. The direction of movement of the exchange rate is tied to how economies rebalance themselves by shifting resources between sectors in response to sanctions.

The welfare analysis of the calibrated model shows that, when sanctions are imposed, coordination with the third bloc nearly doubles the welfare losses in Russia. Additionally, coordinated imposition of sanctions reduces their negative effects on Western countries. However, because of the lost gains from substitution when sanctions are imposed only by the West, coordination is costly for the third bloc. This highlights the importance and difficulty of coordinating sanctions across countries.

There are several directions in which we plan to extend our analysis in future work. Especially important among them will be to study sanctions of uncertain, state-dependent duration, as well as the endogenous determination of the optimal menu of sanctions and policy responses in an explicitly game theoretic setting.

References

Albrizio, Silvia, John C Bluedorn, Christoffer Koch, Andrea Pescatori and Martin Stuermer, 2022, "Market size and supply disruptions: Sharing the pain of a potential gas shut-off to the European Union," IMF Working Paper No. 2022/143 (Washington, DC, International Monetary Fund).
https://www.imf.org/en/Publications/WP/Issues/2022/07/18/Market-Size-and-Supply-Disruptions-Sharing-the-Pain-of-a-Potential-Russian-Gas-Shut-off-to-520928

Anderson, James E. and Eric van Wincoop, 2004, "Trade costs," Journal of Economic Literature, Vol 42, No. 3, pp. 691-751.
https://doi.org/10.1257/0022051042177649

Auray, Stephane and Aurelien Eyquem, 2011, "Endogenous entry, international business cycles, and welfare," GATE Working Paper No. 1114.
http://dx.doi.org/10.2139/ssrn.1800748

Bachmann, Rudiger, David Baqaee, Christian Bayer, Moritz Kuhn, Andreas Loschel, Benjamin Moll, Andreas Peichl, Karen Pittel and Moritz Schularick, 2022, "What if? The economic effects for Germany of a stop of energy imports from Russia" (unpublished, University of Notre Dame).

Bak, Nahyeon, Daisoon Kim, and Mishita Mehra, 2022, "Home market effects and increasing returns with non-constant marginal costs" (unpublished, North Carolina State University).

Bergin, Paul, and Giancarlo Corsetti, 2019, "Beyond competitive devaluations: The monetary dimensions of comparative advantage," American Economic Journal: Macroeconomics, Vol. 12, No. 4, pp. 246-86.
http://dx.doi.org/10.1257/mac.20160094

Bergin, Paul, Ling Feng and Ching-Yi Lin, 2021, "Trade and firm financing," Journal of International Economics, Vol. 131. No. 103461.
https://doi.org/10.1016/j.jinteco.2021.103461

Bianchi, Javier, and Cesar Sosa-Padilla, 2022, "On wars, sanctions and sovereign default" (unpublished, University of Notre Dame).

Blackwill, Robert D., and, Jennifer M. Harris, 2016, War by other means: geoeconomics and statecarft (Cambridge, Massachusetts, Harvard University Press).

Cacciatore, Matteo, 2014, "International trade and macroeconomic dynamics with labor market frictions," Journal of International Economics, Vol. 93, pp. 17-30.
https://doi.org/10.1016/j.jinteco.2014.01.008

Cacciatore, Matteo, and Fabio Ghironi, 2021, "Trade, unemployment, and monetary policy," Journal of International Economics, Vol. 132, No. 103488.
https://doi.org/10.1016/j.jinteco.2021.103488

Cantelmo, Alessandro and Giovanni Melina, 2023, "Sectoral labor mobility and optimal monetary policy," Macroeconomic Dynamics, Vol. 27, No.1, pp. 1-26.
https://doi.org/10.1017/S1365100520000577

Corsetti, Giancarlo, Philippe Martin and Paolo Pesenti, 2007, "Productivity, terms of trade and the 'home market effect'," Journal of International Economics, Vol. 73, pp. 99-127.
https://doi.org/10.1016/j.jinteco.2006.08.005

Corsetti, Giancarlo, Philippe Martin and Paolo Pesenti, 2013, "Varieties and the transfer problem," Journal of International Economics, vol. 89, pp. 1-12.
https://doi.org/10.1016/j.jinteco.2012.05.011

Dekle, Robert, Hyeok Jeong and Nobuhiro Kiyotaki, 2015, "Dynamics of firms and trade in general equilibrium," USC-INET Research Paper No. 15-12 (Los Angeles, Califonia, USC Dornsife INET Research).
http://dx.doi.org/10.2139/ssrn.2574454

de Souza, Gustavo, Naiyuan Hu, Haishi Li, and Yuan Mei, 2022, "(Trade) War and peace: How to impose international trade sanctions," unpublished manuscript.

Eichengreen, Barry, Massimo Ferrari Minesso, Arnaud Mehl and Isabel Vansteenkiste, 2022, "Sanctions and the exchange rate in time," CEPR Discussion Paper No. 17641 (London, UK, CEPR).
https://cepr.org/publications/dp17641

Friedman, Milton, 1980, "Economic sanctions," Newsweek, 21 January 1980, pp. 76 (New York City, New York, Newsweek).

Ghironi, Fabio, and Marc Melitz, 2005, "International trade and macroeconomic dynamics with heterogeneous firms," The Quarterly Journal of Economics, Vol. 120, pp. 865-915. https://doi.org/10.1093/qje/120.3.865

Ghironi, Fabio, Daisoon Kim, Galip Kemal Ozhan, 2022, "International trade and macroeconomic dynamics with sanctions," unpublished manuscript, University of Washington.

Guo, Xing, Pablo Ottonello, and Diego Perez, 2023, "Monetary policy and redistribution in open economies," Journal of Political Economy Macroeconomics, Vol.1 No.1, pp. 191-241.
https://doi.org/10.1086/723410

Hamano, Masashige, and Francesco Zanetti, 2017, "Endogenous product turnover and macroeconomic dynamics," Review of Economic Dynamics, Vol. 26, pp. 263-279.
https://doi.org/10.1016/j.red.2017.06.003

Hanson, Gordon H., and Chong Xiang, 2004, “The home-market effect and bilateral trade patterns,” American Economic Review, Vol. 97, No. 4, pp. 1108-1129.
https://doi.org/10.1257/0002828042002688

Horvath, Michael, 2000, “Sectoral shocks and aggregate fluctuations,” Journal of Monetary Economics, Vol. 45, No. 1, pp. 69-106.
https://doi.org/10.1016/S0304-3932(99)00044-6

Imura, Yuko and Malik Shukayev, 2019, “The extensive margin of trade and monetary policy,” Journal of Economic Dynamics and Control, Vol. 100, Pages 417-441.
https://doi.org/10.1016/j.jedc.2019.01.002

Itskhoki, Oleg, and Dmitry Mukhin, 2022, “Sanctions and the exchange rate,” NBER Working Paper No. 30009 (Cambridge, Massachusetts, National Bureau of Economic Research).
https://doi.org/10.3386/w30009

Itskhoki, Oleg, and Dmitry Mukhin, 2023, “International sanctions and limits of Lerner symmetry,” AEA Papers and Proceedings, Vol. 113, pp. 33-38.
https://doi.org/10.1257/pandp.20231043

Kim, Daisoon, 2021, “Economies of scale and business cycles,” Journal of International Economics, Vol. 131, No. 103459.
https://doi.org/10.1016/j.jinteco.2021.103459

Kim, Daisoon, Galip Kemal Ozhan and Larry Schembri, 2021, “Monetary policy, trade, and commodity price fluctuations,” (unpublished, Bank of Canada).

Korhonen, Iikka, 2019, “Economic sanctions on Russia and their effects,” CESifo Forum, Volume 20, No. 4, pp. 19-22.
https://www.cesifo.org/en/publications/2020/article-journal/economic-sanctions-russia-and-their-effects

Krugman, Paul, 1980, “Scale economies, product differentiation, and the pattern of trade,” American Economic Review, Vol. 70, No. 5, pp. 950-959.
https://www.jstor.org/stable/1805774

Lanteri, Andrea, Pamela Medina, and Eugene Tan, 2023, “Capital-reallocation frictions and trade shocks,” American Economic Journal: Macroeconomics Vol. 15, No. 2, pp. 190-228.
https://doi.org/10.3386/w29929

Lorenzoni, Guido, and Ivan Werning, 2022, “A minimalist model for the Ruble during the Russian invasion of Ukraine,” NBER Working Paper No. 29929 (Cambridge, Massachusetts, National Bureau of Economic Research).
https://doi.org/10.3386/w29929

Mayer, Thierry and Gianmarco I. P. Ottaviano, 2008, “The happy few: The internationalisation of European firms,” Intereconomics, Vol. 43, pp. 135-148.
https://doi.org/0.1007/s10272-008-0247-x

Melitz, Marc, 2003, "The impact of trade on intra-industry reallocations and aggregate industry," Econometrica, Vol. 71, pp. 1695-1725.
https://doi.org/10.1111/1468-0262.00467

Mulder, Nicholas, 2022, "The economic weapon: The rise of sanctions as a tool of modern war," (New Haven, Connecticut, Yale University Press).

Rodriguez-Lopez, Jose Antonio, 2011, "Prices and exchange rates: A theory of disconnect," The Review of Economic Studies, Vol. 78, pp. 1135-1177.
https://doi.org/10.1093/restud/rdq031

Sonnenfeld, Jeffrey, Steven Tian, Franek Sokolowski, Michal Wyrebkowski and Mateusz Kasprowicz, 2022, "Business retreats and sanctions are crippling the Russian economy," (unpublished, Yale School of Management).
http://dx.doi.org/10.2139/ssrn.4167193

Schott, Jeffrey J., 2023, "Economic sanctions against Russia: How effective? How durable?" Peterson Institute for International Economics Policy Brief No. 23-3 (Washington, DC, Peterson Institute for International Economics Policy).
https://www.piie.com/publications/policy-briefs/economic-sanctions-against-russia-how-effective-how-durable

van Bergeijk, Peter A.G., 2021, "Introduction to the Research Handbook on Economic Sanctions," in Research Handbook on Economic Sanctions, ed by Peter A.G. Bergeijk (Cheltenham, UK: Edward Elgar Publishing).
https://doi.org/10.4337/9781839102721.00006

Zlate, Andrei, 2016, "Offshore Production and Business Cycle Dynamics with Heterogeneous Firms," Journal of International Economics, Vol. 100, pp. 34-49.
https://doi.org/10.1016/j.jinteco.2016.01.004

Appendix

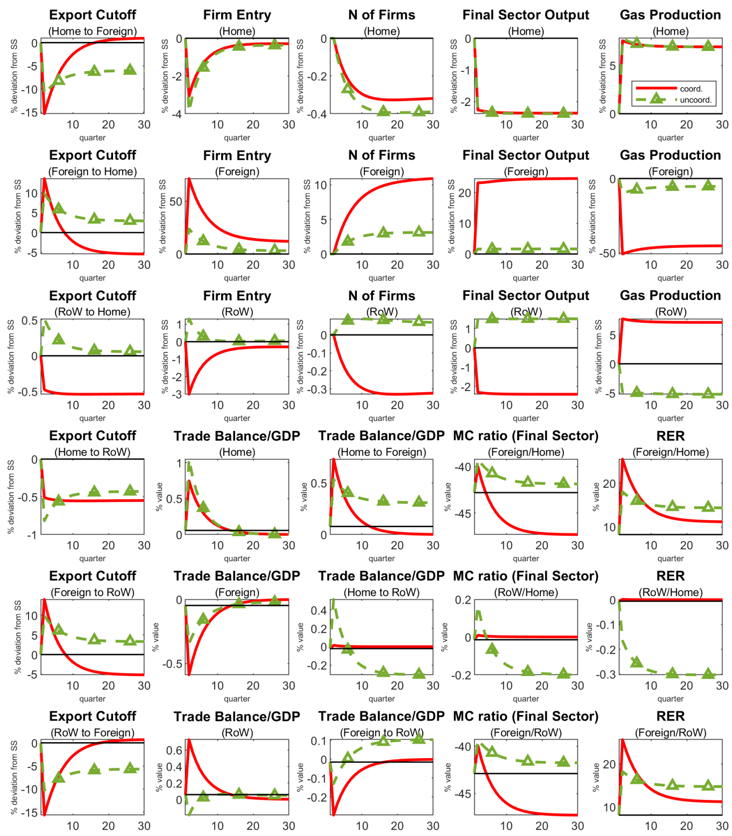


Figure 7: Transition Dynamics after the (Un-)Coordinated Sanctions: Extensive Margins and Other Variables

Notes: The red solid lines (labeled coord.) plot the model transition dynamics when all sanctions are imposed by Home and RoW at $t = 1$. The green dashed lines (labeled uncoord.) with triangles plots the model transition dynamics when all sanctions are imposed by Home at $t = 1$, however, RoW does not participate in. All deviations except for the figures of ratio variables are in units of percent deviation from the initial steady state without sanctions ($t = 0$). The figures of ratios, titled Trade Balance/GDP, MC ratio (Final Sector) and RER, are in units of percent deviation from one, i.e., $100 * (x - 1)$. See Appendix Figure 6 for the other variables' response.