International Trade and Macroeconomic Dynamics with Sanctions

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Abstract

This paper studies international trade and macroeconomic dynamics triggered by the imposition of sanctions. We develop a two-country, two-sector model in which each country holds a comparative advantage: one (Home) in the production of differentiated consumption goods by heterogeneous firms with profits and markups, and the other (Foreign) in homogeneous intermediate goods, produced by identical firms without profits or markups. Foreign is assumed to be the target of sanctions imposed by Home. Sanctions include financial restrictions that exclude a portion of Foreign agents from international capital markets and trade bans on intermediate goods. Sanctions on consumption goods exclude a fraction of Home or/and Foreign firms from international trade. We show that sanctions trigger resource reallocation both within and across countries as production adjusts, influencing exchange rates and welfare. Welfare losses are more pronounced when sanctions target sectors where a country holds a comparative disadvantage. Focusing only on the long run and overlooking the initial dynamics results in inaccurate assessment of welfare impacts. While sanctions substantially reduce international economic comovement and contribute to global fragmentation, their effects on within-country business cycle properties are limited.

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1. Introduction

Understanding the mechanisms of international economic interdependence is crucial, especially in times of geopolitical tensions. The large-scale invasion of Ukraine by Russia on February 24, 2022, triggered an unprecedented wave of sanctions imposed by 38 countries on Russia and Belarus. These measures aimed to punish aggression, cut off critical resources, and engage in economic warfare in support of Ukraine.[1] Unlike previous episodes after World War II, in which sanctions largely targeted smaller economies, Russia is a major player, ranking 11th and 13th globally by nominal GDP and goods exports in 2021. Not since the 1930s has an economy of this size faced such sweeping restrictions. Moreover, today's global economy is more interconnected, with Russia occupying a pivotal position as one of the world's largest energy suppliers. In 2021, Russia was a net creditor, with the fourth-largest foreign exchange reserves, making it deeply embedded in global financial markets. Significant economic size and deep integration of the target country in the global economy are likely to amplify the repercussions of sanctions, not only for the sanctioned country but also for those imposing the sanctions. When the target economy is sizable, the complexity of the economic effects—both intended and unintended—increases substantially. This study aims to contribute to the understanding of interdependence in times of geopolitical tensions by developing a micro-founded model of international trade and macroeconomic dynamics under sanctions. Our goal is to provide a baseline framework and a set of benchmark results to guide future research on the macroeconomics of geoeconomic conflicts.

We extend the open-economy framework of Ghironi and Melitz (2005) to capture the economic effects of sanctions. Our model considers two countries—Home and Foreign—with comparative advantage in producing differentiated, final consumption goods (Home) and homogeneous intermediate goods (Foreign). The structure of comparative advantage that we posit is intended to reflect the pattern that characterizes trade between Western economies, which specialize in high-value industries with high monopoly power and markups, and countries that specialize in production of homogeneous commodities with lower monopoly power and markups. In our model, this implies that, under normal trade conditions, Home runs a trade surplus in consumption goods and a trade deficit in intermediate goods. Thus, while interpreting intermediate goods as energy (gas and/or oil) facilitates direct application of the model to the recent sanctions on Russia, the

[1] For historical context, see Blackwill and Harris (2016) and Mulder (2022). See also Caldara and Iacoviello (2022) on the economic effects of adverse geopolitical events.

model is broadly applicable to other contexts, such as China's specialization in homogeneous intermediate goods versus the US advantage in production of differentiated ones.

We assume that producers in the intermediate, upstream sector employ a constant returns to scale technology that combines sector-specific labor and the endowment of a natural resource to produce a tradable commodity (for instance, natural gas) that is either used domestically or exported. Under perfect competition, a representative distributor combines domestically-produced and imported amounts of this commodity to produce a homogeneous intermediate good (for instance, usable gas), which is assumed to be non-tradable due to prohibitive trade costs. In this sector, all producers are identical, and there are no markups. Producers in the final, downstream sector use the intermediate good and sector-specific labor to produce differentiated consumption goods. Firms in this sector exhibit productivity differences and operate under monopolistic competition. Monopoly power allows them to set markups over marginal cost, resulting in positive operating profits that increase in firm-specific productivity. Entry into this sector is endogenous, with potential entrants facing sunk entry costs. Under normal trade conditions, fixed trade costs imply that only the most productive firms in this sector export.

In our model, households in both countries hold bonds and shares, though only bonds are traded internationally. Households pool income from workers in both sectors. In the absence of sanctions, this leads to the existence of representative Home and Foreign households. Bond adjustment costs pin down the deterministic steady-state levels of bond holdings (which can be different after sanctions), allowing for long-run international bond imbalances. This framework enables us to examine how the size of initial international bond positions or unbalanced trade flows impact transition dynamics, welfare, and business cycles in both sanctioning and sanctioned countries.

We introduce two types of sanctions imposed by Home: financial sanctions and trade sanctions, both of which restrict access to international markets. Specifically, financial sanctions target a subset of Foreign households by excluding them from international bond trading. As a result, Foreign households are divided into two groups: sanctioned and non-sanctioned. While non-sanctioned households continue to trade bonds with Home households, sanctioned households are confined to trading bonds solely with other non-sanctioned Foreign households. In the extreme case, if all Foreign households are excluded, the economy enters a state of financial autarky.

Trade sanctions, on the other hand, can be applied to trade in the commodity and differentiated consumption goods. In the case of the commodity (for instance, the natural gas used by a distributor

to produce usable gas, intermediates), we analyze a scenario where the volume of commodity trade is restricted. A complete ban on trade is equivalent to a situation where the Home government enforces a price cap on the imported commodity, setting it below the marginal cost of production in Foreign.

For differentiated consumption goods, sanctions take the form of export bans for Home firms that exceed a government-determined productivity threshold or import bans on goods from Foreign firms whose productivity exceeds a potentially different threshold also determined by the Home government.[2] Without sanctions, all firms in Home and Foreign with productivity above a cutoff determined by fixed trade costs would export. Under sanctions, a second, higher productivity cutoff is imposed by the Home government. Only firms whose productivity falls between the two cutoffs are now allowed to engage in international trade. In the extreme case, if the sanction-imposed cutoff equals or falls below the trade-cost one, international trade in differentiated goods is completely halted. This setup is intended to capture the fact that sanctions primarily affect larger, highly productive firms, typically producing high-tech or advanced technology products.[3]

We examine the effects of sanctions over the short, medium, and long term, focusing on their impact on international relative prices, standard macroeconomic indicators, and welfare in both Home and Foreign. We begin by studying the determinants of the real exchange rate in our model. As in Ghironi and Melitz (2005), an increase in the cost of consumption-good production in Home relative to Foreign—higher relative cost of Home effective consumption-good sector labor or higher relative price of the Home intermediate good—leads to real appreciation of the Home currency. Additionally, the real exchange rate is sensitive to changes in the average productivity of exporters and shifts in the composition of consumption baskets. For example, when the average productivity of Foreign exporters decreases, the average price of Home imports rises, resulting in Home real exchange rate appreciation. Conversely, if the share of imported goods in Home's consumption basket rises, the real exchange rate depreciates, because expenditure is shifting toward relatively lower-priced goods. These theoretical results help us interpret how sanctions affect the

[2] It is worth noting that for our results, the distinction between firms ceasing exports due to government-imposed sanctions or voluntary decisions is inconsequential. In practice, companies can independently cease trade because of moral principles or public relations. These concerns are outside the scope of our model.

[3] The primary reason for not modeling sanctions on differentiated-good trade as blanket bans or imposing higher tariff costs is rooted in the nature of the sanctions imposed by Western countries on Russia. These sanctions explicitly prohibit the trade of specific goods and/or transactions with designated entities. Guidance notes issued by these Western countries provide lists of sanctioned goods, emphasizing that the sanctions are not intended as blanket bans. For instance, see https://www.consilium.europa.eu/en/policies/sanctions/ and https://crsreports.congress.gov/product/pdf/R/R45415. It is noteworthy that the industries targeted by these sanctions, when compared to non-sanctioned sectors like non-durable goods, display higher productivity levels.

real exchange rate by altering its key drivers. We use numerical simulations to further illustrate these dynamics and explore the broader macroeconomic implications of sanctions.

The numerical results show that the real exchange rate responds differently to various types of sanctions, in manners that are consistent with the analytical results and economic intuition. The effect of consumption-good trade sanctions is largely driven by their effect on the business environment for consumption-good sector firms relative to the pre-sanctions environment. Consider sanctions that prevent the most productive Home firms from exporting. All else given, this reduces the attractiveness of entry into Home's final consumption-good sector, because prospective entrants now know that, even if they were characterized by high productivity post entry into Home, they would not be able to reap the benefit of this in terms of export profits. This implies that consumption-good sector entry shifts toward Foreign. However, in the long run, a sufficient mass of consumption-good sector firms must continue to be present in this sector of the Home economy to keep at least some Home consumption-good sector labor employed. Because of this, the relative cost of Home effective consumption-good sector labor must decrease, resulting in Home real exchange rate depreciation. The responses of entry and the numbers of consumption-good producers in Home and Foreign in the short run and along the transition path ensure the working of this mechanism, shifting consumption-good sector labor demand across countries (and sectors within countries) in a manner consistent with the movement of the relative cost of effective labor in the final consumption-good sector. Since labor in this sector of the Home economy becomes relatively less expensive, the trade-cost determined cutoff for entry into the Home export sector decreases, which combines with the government-induced exclusion of top-productivity firms from exporting in producing lower average Home exporter productivity. Conversely, Foreign consumption-good sector labor becomes relatively more expensive, which pushes up the trade-cost-induced Foreign export cutoff and average Foreign exporter productivity. These effects reinforce the depreciation of Home's real exchange rate by causing higher average import prices in Foreign and lower average import prices in Home. Sanctions that prevent high-productivity Foreign firms from exporting to Home have similar, but opposite-direction effects.

Interestingly, the exchange rate effects of financial sanctions are qualitatively similar to those of sanctions on Foreign exporters. Intuitively, preventing (enough) Foreign households from accessing the international capital market reduces the resources available for financing entry into the Foreign economy, making it a less attractive environment for entry, just like sanctions that imply that high-productivity firms will not be able to export. The one situation in which the movement of

the real exchange rate does not qualitatively correspond to that of the relative cost of effective consumption-good sector labor is commodity trade sanctions. This happens because commodity trade sanctions have the largest effect on the relative price of intermediate goods at Home and in Foreign. Preventing Home from importing Foreign-produced commodity causes a large increase in the price of the Home intermediate good relative to Foreign, which dominates other effects and causes the Home real exchange rate to appreciate. Additional counterfactual analysis highlights the pivotal role of comparative advantage in driving changes in labor use across sectors in response to the different types of sanctions we analyze. When comparative advantage is removed, sectoral labor reallocations are significantly dampened, particularly over the long term.

In the context of financial sanctions on Russia, it has been argued that, for them to be effective, all Russian banks should be sanctioned instead of only a subset.[4] To keep our analysis simple, our model does not include banks. Nevertheless, the results provide some backing to the argument that target countries should be fully financially isolated for these sanctions to be effective. We find that financial sanctions significantly affect Foreign consumption and welfare only when a large share of Foreign households is excluded from international capital markets. If the sanctioned share is small, non-sanctioned households can borrow and lend on behalf of sanctioned ones, offsetting the impact of the sanctions. It is only when a large portion of Foreign households faces sanctions that the availability of resources for financing investment (in the form of domestic firm entry) in Foreign diminishes, leading to significant reduction in the number of Foreign firms and lower Foreign consumption. When many Foreign households are sanctioned, our model world economy shifts to a situation of near financial autarky, forcing near-balanced trade from the time sanctions are imposed. This implies that, despite the overall reduction in the number of Foreign consumption-good producers, the number of those that export to Home increases to ensure that trade is balanced between Home and Foreign. We also find that initial net foreign asset positions (NFAs) matter for the consequences of financial sanctions: the larger is the initial level of international bond holdings by Foreign households, the more pronounced the impact of financial sanctions, as their negative wealth effect on Foreign households is correspondingly amplified.

The combined effects of sanctions result in significant welfare losses for both Foreign and Home households. While sanctions are intended to inflict economic damage on the targeted economy, they carry significant costs when the sanctioned country is large and integrated into global markets. The effectiveness and costs of sanctions depend on the specific sector they target and each economy's

[4]See, for instance, De Luce (2022).

comparative advantage. For example, commodity-trade sanctions are particularly costly for Home because they force the economy to reallocate labor use to the less efficient commodity sector. Conversely, sanctions on trade in final consumption goods are more detrimental to Foreign, given its comparative disadvantage in that area.[5] Furthermore, our simulations highlight the importance of accounting for transition paths when assessing the effects of sanctions. Ignoring these paths leads to overestimation of Home welfare losses and underestimation of Foreign, especially for financially unsanctioned Foreign households.

Finally, while sanctions may achieve their intended geopolitical objectives or welfare losses in sanctioned economies through the impact and transmission of sanction shocks in absence of other sources of fluctuations, sanctions can also affect macroeconomic dynamics and household welfare by altering the impact and transmission of business cycle shocks. To study this possibility, we compare the business cycle properties of our model world economy before and after the imposition of sanctions. Our simulation results reveal that while sanctions cause lower international business cycle comovement by limiting trade in goods and international assets, there is a limited impact on within-country business cycle fluctuations. Sanctioned and unsanctioned economies display similar standard deviations of GDP, investment, labor, and consumption in the pre- and post-sanction scenarios. The same is true for the cyclicality (correlation with GDP) of investment, labor, and consumption. This suggests that, at least in our model, sanctions have a limited impact on welfare through their impact on business cycle fluctuations.

The large scale invasion of Ukraine by Russia has sparked a series of studies that examine the economic effects of sanctions. An incomplete list of works in this context includes Albrizio, Bluedorn, Koch, Pescatori and Stuermer (2022), Bachmann, Baqaee, Bayer, Kuhn, Löschel, Moll, Peichl, Pittel and Schularick (2022), Bianchi and Sosa-Padilla (2024), Chupilkin, Javorcik, Peeva and Plekhanov (2023), Eichengreen, Ferrari Minesso, Mehl, Vansteenkiste and Vicquéry (2023), Itskhoki and Mukhin (2022), Lorenzoni and Werning (2023), and Sturm (2023), Becko (2024). Work that pre-dates Russia's large scale attack on Ukraine includes Korhonen (2019), Van Bergeijk (2021), and references therein. These papers present quantitative, multi-country, static analyses of trade effects (for instance, Bachmann et al. 2022), analyses that abstract from extensive margin effects (for instance, Lorenzoni and Werning 2023), or small open economy, New Keynesian models that cannot address the full range of consequences of sanctioning a large economy (for instance, Itskhoki and Mukhin 2022). Our approach differs in that we present a dynamic analysis within a canonical

[5] Absence of comparative advantage leads to smaller welfare losses for both the sanctioning and sanctioned economies.

trade and macroeconomic framework with interdependence between large economies. Although our model is not explicitly quantitative or multi-country, it allows us to explore the dynamic effects of sanctions, incorporating extensive margin mechanisms that we deem crucial to capture the effects of sanctions as defined in official documents. In line with the findings of Eichengreen et al. (2023), our results confirm their conclusions that exchange rate movements reflect the type and scale of sanctions rather than measuring their success or failure. By expanding on these insights, we highlight the role of market entry and exit and firm heterogeneity in determining exchange rate fluctuations in response to sanctions.

In Ghironi, Kim and Ozhan (2024), we extend the framework of this paper by incorporating a third country and providing a quantitative analysis of the recent sanctions imposed on Russia. The extended model is calibrated to represent three key regions: an aggregate of countries imposing sanctions on Russia (the EU, the UK, and the US), Russia as the sanctioned country, and a group of third countries (China, India, and Turkey) that remain outside the sanctioning group. The analysis highlights the crucial role of third-country effects. Specifically, welfare results show that the sanctioned country's losses are substantially mitigated, while the sanctioning countries' losses are amplified, when third countries do not participate in the sanctions. These third countries, in turn, benefit from staying outside the sanctioning group, capitalizing on trade and investment opportunities redirected from the sanctioned economy. These findings underscore both the necessity and the challenges of coordinating international sanctions. The exercise in Ghironi et al. (2024) exemplifies how our baseline framework can be extended to study complex geopolitical dynamics and important policy questions.

The rest of the paper is structured as follows: Section 2 presents the model. Section 3 analyzes its implications for the real exchange rate. Section 4 details the model calibration. Section 5 introduces various types of sanctions and examines their effects on both the sanctioned and sanctioning economies. Section 6 provides a welfare analysis. Section 7 investigates how sanctions affect business cycle fluctuations. Section 8 concludes.

2. The Model

This section constructs an open macroeconomic framework with two asymmetric countries: Home and Foreign, to analyze the trade and macroeconomic dynamics under economic sanctions. Both regions consist of identical households with labor. We consider a two-sector economy with trade

between countries. The upstream sector (gas sector, indexed by G) operates under perfect competition and produces homogeneous goods (e.g., gas, commodities, low-technology industries) with constant returns to scale. It also supplies intermediate goods used in consumption goods production. Foreign is assumed to have a comparative advantage in this sector relative to Home.

The downstream sector (consumption-good sector, indexed by Y) utilizes Melitz (2003)'s monopolistic competition framework with endogenous exports. Firms are heterogeneous due to firm-specific technologies, leading to variations in exports, sales, and profits. This sector requires relatively high technologies, where Home is assumed to have a comparative advantage relative to Foreign. Appendix Figure A1 depicts the model architecture, highlighting key features of supply chains within and between the two economies.

2.1. Household Preference and Labor Supply

Households maximize their expected intertemporal utility, which depends on their consumption level (C_t) and the disutility from labor supply (L_t). The utility function is assumed to be logarithmic for consumption and disutility from labor is assumed to be quadratic with a Frisch elasticity of one. The expected intertemporal utility function is:

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\left(\log C_t-\frac{\kappa}{2}L_t^2\right)\right],\quad \text{where}\quad C_t=\left\{\int_{\omega\in\Omega}[c_t(\omega)]^{\frac{\theta-1}{\theta}}d\omega\right\}^{\frac{\theta}{\theta-1}}. \tag{1}$$

The parameter $\beta\in(0,1)$ is a discount factor, and $\kappa>0$ represents disutility from labor. The consumption basket (C_t) is defined over a continuum of goods Ω, where the elasticity of substitution across goods is constant, $\theta>1$. The aggregate price index is $P_t^{1-\theta}=\int_{\omega\in\Omega_t}[p_t(\omega)]^{1-\theta}\mathrm{d}\omega$, where $\Omega_t\subset\Omega$ is a set of available goods in period t. Then, the home demand function of each consumption-good ω is $c_t(\omega)=[p_t(\omega)/P_t]^{-\theta}C_t$.

The total labor (L_t) is allocated between the two sectors (L_t^Y for differentiated goods and L_t^G for homogeneous goods) according to a constant elasticity of substitution function.

$$L_t=\left[(\gamma)^{\frac{1}{\varrho}}\left(L_t^Y\right)^{\frac{1+\varrho}{\varrho}}+(1-\gamma)^{\frac{1}{\varrho}}\left(L_t^G\right)^{\frac{1+\varrho}{\varrho}}\right]^{\frac{\varrho}{1+\varrho}} \tag{2}$$

The parameter $\varrho>0$ captures the degree of labor mobility between sectors, and the labor disutility share of sector Y is $\gamma\in(0,1)$. In addition to the imperfect substitution between sectoral labor, we introduce adjustment costs. The household incurs the adjustment costs for supplying their labor

that depends on a reference level of labor (S_t^Y and S_t^G) in each sector.

$$\text{Ladj}_t(L_t^Y, L_t^G) \equiv \sum_{i\in\{Y,G\}} 0.5\eta_L(L_t^i/S_t^i - 1)^2 w_t^i S_t^i, \tag{3}$$

where the reference levels are external and satisfy that the ratios to the reference levels (L_t^Y/S_t^Y and L_t^G/S_t^G) are equal to one in the steady state. The labor adjustment cost allows the elasticity of substitution between sectoral labor (i.e., the degree of labor mobility between sectors) to differ in short- and long-run. The positive adjustment coefficient, $\eta_L > 0$, implies short-run additional costs for changes in labor supply, leading the short-run mobility to be more limited than the long-run mobility. We set $S_t^i = L_{t-1}^i$ for $i \in \{Y, G\}$.

2.2. Upstream Sector with Homogeneous Goods (Gas, Intermediate-Good Sector)

In each country's intermediate-good sector G, there exists a continuum of identical producers and distributors on a unit interval. Both producers and distributors are price takers and face constant returns to scale in production, leading to zero profits in equilibrium.

Representative Producers. Home commodity (natural gas) producers use a technology with constant returns to scale to produce commodity ($G_{R,t}$) using labor (L_t^G) from the endowment of a natural resource (Z_t^G). Their production function is: $G_{R,t} = Z_t^G L_t^G$. Foreign is assumed to have a comparative (absolute) advantage in commodity (natural gas) production, reflected by a higher productivity parameter Z_t^{G*} compared to Z_t^G.

Given the commodity price ($\rho_{R,t}^G \equiv p_{R,t}^G/P_t$) and sectoral wage rate ($w_t^G \equiv W_t^G/P_t$), both expressed relative to the consumption-good price index (P_t), producers maximize their profits:

$$\max_{\{L_t^G, G_{R,t}\}} \rho_{R,t}^G G_{R,t} - w_t^G L_t^G, \quad \text{s.t.} \quad G_{R,t} = Z_t^G L_t^G. \tag{4}$$

The commodity can be used domestically ($G_{D,t}$) or exported ($G_{X,t}$). In equilibrium, total production must equal domestic demands and exports: $G_{R,t} = G_{D,t} + G_{X,t}$. Additionally, the commodity price equals the sectoral wage divided by productivity: $\rho_{R,t}^G = w_t^G/Z_t^G$.

Representative Distributors. Commodities cannot be directly consumed by households or used as intermediate goods in the differentiated consumption-good sector. Home distributors combine domestically produced commodity ($G_{D,t}$) with imported commodity ($G_{X,t}^*$) to produce a

homogeneous intermediate-good (usable gas, G_t). The technology exhibits constant elasticity of substitution ($\sigma > 1$) as shown in the following maximization problem:

$$\max_{\{G_t, G_{D,t}, G_{X,t}\}} \rho_t^G G_t - \rho_{R,t}^G G_{D,t} - Q_t \rho_{R,t}^{G*} G_{X,t}^*, \quad \text{s.t.} \quad G_t^{\frac{\sigma-1}{\sigma}} = (G_{D,t})^{\frac{\sigma-1}{\sigma}} + (G_{X,t}^*/\tau_t^{G*})^{\frac{\sigma-1}{\sigma}}, \quad (5)$$

where Q_t represents the consumption-based real exchange rate (units of Home consumption per unit of Foreign). Iceberg trade costs (τ_t^{G*}) are borne by Home importers (distributors) on imported Foreign commodity. The optimal decision equates marginal cost to the intermediate-good price:

$$\rho_t^G = \left[(\rho_{R,t}^G)^{1-\sigma} + (\tau_t^{G*} Q_t \rho_{R,t}^{G*})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \quad (6)$$

The demand for domestically-produced and imported commodities are determined by the relative prices: $G_{D,t} = (\rho_{R,t}^G/\rho_t^G)^{-\sigma} G_t$ and $G_{X,t}^* = (\tau_t^{G*})^{1-\sigma}(Q_t \rho_{R,t}^{G*}/\rho_t^G)^{-\sigma} G_t$. Because trade costs lead homogeneous intermediates (usable gas) not to be traded internationally, in equilibrium, the total supply (G_t) is equal to the demand as an intermediate input by the consumption-good sector.

2.3. Downstream Sector with Differentiated Goods (Final, Consumption-Good Sector)

This subsection describes the differentiated goods sector, which consists of monopolistically competitive firms subject to endogenous entry. These firms produce differentiated final consumption goods by employing labor from households and using the usable gas as an intermediate input.

Heterogeneous Producers. A firm produces output $y_t(\omega)$ of a specific good ω:

$$y_t(\omega) = z(\omega) Z_t^Y [g_t(\omega)]^\alpha [l_t^Y(\omega)]^{1-\alpha}, \quad \text{where} \quad y_t(\omega) \equiv y_{D,t}(\omega) + \tau_t^Y y_{X,t}(\omega). \quad (7)$$

The variables $y_{D,t}(\omega)$ and $y_{X,t}(\omega)$ denote the quantity of goods supplied to the domestic and export markets, respectively. τ_t^Y is an iceberg export cost of consumption goods from Home to Foreign, $g_t(\omega)$ denotes the firm's total use of the usable gas (intermediate good) purchased from domestic distributors, and $l_t^Y(\omega)$ represents the firm's labor usage in production. The parameter $0 \leq \alpha < 1$ reflects the relative importance of intermediates and labor in final consumption-good production. Firms' productivity consists of the sectoral and firm specific productivity (Z_t^Y and $z(\omega)$). It is assumed that Home has a comparative (absolute) advantage in the production of differentiated consumption goods, which is reflected by a higher sectoral productivity Z_t^Y compared to Z_t^{Y*}.

The firm chooses its prices ($\rho^Y_{D,t}(z) \equiv p^Y_{D,t}(z)/P_t$ and $\rho^Y_{X,t}(z) \equiv p^Y_{X,t}(z)/P^*_t$) and quantities of supply ($y_{D,t}$ and $y_{X,t}$) to maximize its profit:

$$\max_{\substack{\{\rho^Y_{j,t}(z), y_{j,t}(z)\}_{j=D,X} \\ l^Y_t(\omega), g_t(z)}} \rho^Y_{D,t}(z) y_{D,t}(z) + Q_t \rho^Y_{X,t}(z) y_{X,t}(z) - w^Y_t l^Y_t(z) - \rho^G_t g_t(z) - \frac{w^Y_t f_{X,t}}{Z_t} \mathbb{1}\{y_{X,t}(z) > 0\}, \tag{8}$$

subject to its production and demand functions. The indicator function, $\mathbb{1}\{\cdot\}$, takes the value of 1 if the condition inside the brackets is true, and 0 otherwise. We dropped the identifier ω and replaced it with z (productivity) to emphasize the link between firm heterogeneity and firm productivity.

Firms set prices with a constant degree of markup over marginal cost. The firm's marginal cost of production depends on the price of the homogeneous goods, real wage, and firm-specific productivity. The pricing equations are:

$$\rho^Y_{D,t}(z) = \left(\frac{\theta}{\theta - 1}\right) \frac{[\rho^G_t/\alpha]^\alpha [w^Y_t/(1-\alpha)]^{1-\alpha}}{z Z_t} \quad \text{and} \quad \rho^Y_{X,t}(z) = \frac{\tau_t}{Q_t} \rho^Y_{D,t}(z). \tag{9}$$

A firm decides to export ($y_{X,t}(\omega) > 0$) only if the profits from exporting outweigh the fixed export cost ($f_{X,t}$). This cost, measured in units of effective labor, requires $w^Y_t f_{X,t}/Z^Y_t$ units of consumption goods.[6] Therefore, the export cutoff, denoted by $\underline{z}_{X,t}$, is the level of productivity at which a firm becomes indifferent between exporting and not exporting, i.e., $d_{X,t}(\underline{z}_{X,t})$, where $d_{j,t}(z)$ represents firm z's profits in market $j = D, X$ (Home aggregate consumption-good unit). This cutoff level is determined by $\theta^{-1}[\rho^Y_{X,t}(\underline{z}_{X,t})]^{1-\theta} Q_t C^*_t = w^Y_t f_{X,t}/Z^Y_t$. A firm with productivity z greater than $\underline{z}_{X,t}$ will find exporting profitable, while firms with productivity below $\underline{z}_{X,t}$ will not.

Number of Firms, Exporters, and Their Averages. Following Melitz (2003), define the market-share weighted productivity average $\tilde{z}_D$ for all producing firms and exporters in Home:

$$\tilde{z}_D \equiv \left[\int_{z_{\min}}^{\infty} z^{\theta-1} \mathrm{d}\Phi(z)\right]^{\frac{1}{\theta-1}} \quad \text{and} \quad \tilde{z}_{X,t} \equiv \left[\frac{1}{1 - \Phi(\underline{z}_{X,t})} \int_{\underline{z}_{X,t}}^{\infty} z^{\theta-1} \mathrm{d}\Phi(z)\right]^{\frac{1}{\theta-1}} \tag{10}$$

As shown by Melitz (2003), the model can be equivalently analyzed by assuming a fixed number of firms with these average productivity levels. Specifically, the model can be viewed as if there are $N_{D,t}$ domestic firms all operating with the average productivity $\tilde{z}_D$, and $N_{X,t}$ exporting firms with

[6] We assume that fixed and sunk costs only require labor but not intermediate goods as in Grossman and Helpman (1991). See Bak, Kim and Mehra (2024) for more discussions about factor usages in variable and fixed cost function.

the average productivity $\tilde{z}_{X,t}$.

These productivity averages are linked with firm profits and price indexes. The average total profits for Home firms ($\tilde{d}_t \equiv \tilde{d}_{D,t} + [1 - \Phi(\underline{z}_{X,t})]\tilde{d}_{X,t}$) are calculated based on the average profits from domestic sales ($\tilde{d}_{D,t} \equiv d_{D,t}(\tilde{z}_D)$) and export sales ($\tilde{d}_{X,t} \equiv d_{X,t}(\tilde{z}_{X,t})$), considering the proportion of Home firms that choose to export ($N_{X,t}/N_{D,t} = 1 - \Phi(\underline{z}_{X,t})$). Similarly, the aggregate price index in the Home country (ρ_t^Y) is determined by the average relative prices charged by domestic producers ($\tilde{\rho}_{D,t}^Y \equiv \rho_{D,t}^Y(\tilde{z}_D)$) and foreign exporters ($\tilde{\rho}_{X,t}^{Y*} \equiv \rho_{D,t}^Y(\tilde{z}_X^*)$) in the Home market, along with the number of firms in each category (domestic and exporting), i.e., $(\rho_t^Y)^{1-\theta} = N_{D,t}(\tilde{\rho}_{D,t}^Y)^{1-\theta} + N_{X,t}^*(\tilde{\rho}_{X,t}^{Y*})^{1-\theta}$.

Firm Entry and Exit. There is an unbounded mass of potential entrants in each country. Entry requires using labor, with its effectiveness depending on the overall economic conditions (Z_t^Y). All potential entrants are identical and face a one-time sunk entry cost ($f_{E,t}$) to enter, measured in terms of consumption goods ($w_t^Y f_{E,t}/Z_t^Y$). Upon entry, each firm draws its productivity level (z) from distribution function $\Phi(z)$, which remains fixed thereafter.

Potential entrants look ahead and calculate the expected stream of future profits, factoring in potential economic changes. Entry occurs until this value (the average value of a new entrant, $\tilde{v}_t$) reaches the sunk entry cost (free-entry condition: $\tilde{v}_t = w_t^Y f_{E,t}/Z_t^Y$). We assume positive entry occurs in every period. All firms (new and existing, regardless of productivity) face a probability (δ) of exiting at the end of each period. We also assume a one-period time-to-build requirement. Thus, the mass $N_{D,t}$ of Home producing firms is determined by $N_{D,t} = (1 - \delta)(N_{D,t-1} + N_{E,t-1})$, where $N_{E,t-1}$ is the number of firms that entered in period $t - 1$.

2.4. The Rest of the Model

The rest of the model is standard. See Appendix A for the representative household's budget constraint and choices and the market clearing conditions.

3. The Real Exchange Rate

As mentioned in the Introduction, we begin by providing a formal analysis of real exchange rate determinants in our model. The real exchange rate, which measures the relative price of consumption baskets between countries, is a critical indicator of how sanctions affect trade and

resource allocation. As in Ghironi and Melitz (2005), we focus on a measure of the real exchange rate that purges pure variety effects on price levels that would not be captured by available price-level data. Specifically, given the Home price index P_t, which measures the price of consumption in welfare-consistent units, we follow Feenstra (1994) and adjust it to remove the pure welfare effect of product variety by using $\tilde{P}_t \equiv N_t^{1/(\theta-1)} P_t$, where $N_t \equiv N_{D,t} + N_{X,t}^*$ is the total number of products available to Home consumers. We apply a similar adjustment to the Foreign price index and compute the data-consistent, model-implied real exchange rate $\tilde{Q}_t$ using these adjusted price indexes.

Using optimal price setting decisions by firms, it is then possible to show that $\tilde{Q}_t$ is such that

$$\tilde{Q}_t^{1-\theta} = \frac{\frac{N_{D,t}^*}{N_t^*}\left[(TOL_t^Y)^{1-\alpha}(TOG_t)^{\alpha}\frac{\tilde{z}_D}{\tilde{z}_D^*}\right]^{1-\theta} + \frac{N_{X,t}}{N_t^*}\left[\frac{\tau_t^Y \tilde{z}_D}{\tilde{z}_{X,t}}\right]^{1-\theta}}{\frac{N_{D,t}}{N_t} + \frac{N_{X,t}^*}{N_t}\left[(TOL_t^Y)^{1-\alpha}(TOG_t)^{\alpha}\frac{\tau_t^{Y*}\tilde{z}_D}{\tilde{z}_{X,t}^*}\right]^{1-\theta}}, \tag{11}$$

where, in the terminology of Ghironi and Melitz (2005), $TOL_t^Y \equiv Q_t(w_t^{Y*}/Z_t^{Y*})/(w_t^Y/Z_t^Y)$ denotes the terms of labor (the relative cost of effective labor) in the consumption-good sector. Similarly, $TOG_t \equiv Q_t(\rho_t^{G*}/Z_t^{Y*})/(\rho_t^G/Z_t^Y)$ denotes the terms of intermediates (usable gas). Using hatted variables to denote percentage deviations from the steady-state and assuming that iceberg trade costs are constant, log-linearizing the real exchange rate equation above yields:

$$\begin{aligned}\hat{\tilde{Q}}_t \approx & \left(s_X^Y \hat{\tilde{z}}_{X,t}^* - s_X^{Y*}\hat{\tilde{z}}_{X,t}\right) + (\theta-1)^{-1}\left[\left(\frac{N_D}{N} - s_D^Y\right)\left(\hat{N}_{D,t}^* - \hat{N}_{X,t}\right) - \left(\frac{N_D^*}{N^*} - s_D^{Y*}\right)\left(\hat{N}_{D,t} - \hat{N}_{X,t}^*\right)\right] \\ & + (s_D^Y + s_D^{Y*} - 1)\left[(1-\alpha)\hat{TOL}_t^Y + \alpha \hat{TOG}_t\right],\end{aligned} \tag{12}$$

where we drop time subscripts to denote steady-state levels of variables. The Home and Foreign consumers' steady-state share of spending on domestically produced goods are s_D^Y and s_D^{Y*}, respectively. The imported good shares are $s_X^Y \equiv 1 - s_D^Y$ and $s_X^{Y*} \equiv 1 - s_D^{Y*}$. Equation (12) is the generalized version of the key real exchange rate equation in Ghironi and Melitz (2005) when we allow for intermediate goods (gas) and an asymmetric steady state for the two countries.

Considering the three key channels in equation (12) provides intuitive understanding of real exchange rate fluctuations in our model. One of their major drivers is the changes in relative import prices. For example, if the average productivity ($\hat{\tilde{z}}_{X,t}$) of Home exporters is high, the average price of Foreign final-sector imports decreases. This lowers the Foreign average price level, which in turn leads to Home real exchange rate appreciation.

The real exchange rate is also influenced by shifts in consumer spending between domestic and imported goods. Plausible parameter values imply that the share of domestic goods in available product variety in each country is larger than the share of spending on domestic goods: $N_D/N > s_D^Y$ and $N_D^*/N^* > s_D^{Y*}$). In this case, an increase in the availability of domestic products relative to imported ones leads to a higher domestic price level. This happens because, when only the more productive firms export, imported goods are relatively cheaper. Expenditure switching toward domestic goods, which include relatively more expensive non-traded goods, leads to a higher price level and appreciation of the real exchange rate.

The second line of equation (12) shows how changes in relative production costs in the consumption-good sector affect the real exchange rate. In the presence of trade costs, the share of spending on domestic goods in each country is larger than 1/2, implying $s_D^Y + s_D^{Y*} > 1$. Costly trade then implies that an increase in relative effective labor costs and/or intermediate-good prices causes the real exchange rate to appreciate.

To further understand the relationship between intermediate-good prices and the real exchange rate it is useful to decompose the terms of intermediates TOG_t as:

$$T\hat{O}G_t \equiv (\hat{Q}_t + \hat{\rho}_t^{G*} - \hat{\rho}_t^G) - (\hat{Z}_t^{Y*} - \hat{Z}_t^Y) \approx (s_D^G + s_D^{G*} - 1)T\hat{O}L_t^G - (\hat{Z}_t^{Y*} - \hat{Z}_t^Y), \tag{13}$$

where $TOL_t^G \equiv Q_t(w_t^{G*}/Z_t^{G*})/(w_t^G/Z_t^G)$ denotes the terms of labor in the commodity-producing sector. This equation tells us that the relative cost of effective labor in commodity production influences the real exchange rate through its impact on the relative price of intermediate goods used in final-sector production. For example, if the Foreign economy mostly produces the commodity and imports very little of it ($s_X^{G*} = 1 - s_D^{G*} \approx 0$), while Home imports a significant amount of commodity ($s_D^G \gg 0$), an increase in the relative cost of Home effective commodity-sector labor will lead to appreciation of the real exchange rate by pushing up the price of the intermediate good in Home, $\hat{\rho}_t^G$, relative to Foreign.

The mechanisms at work in equation (12) will be central to the effects of sanctions in our model. Having understood how these mechanisms affect the real exchange rate will thus prove useful to understand the broader effects of sanctions in the model.

4. Model Calibration

An essential feature of our model involves the asymmetry between the two countries. We depart from the symmetric two-country standard parameterization by introducing differences in sectoral productivities across the border and a (long-run) non-zero NFA position. In this benchmark setting, the sanctioned country (Foreign) exhibits a comparative advantage in the intermediate-good sector and maintains a positive NFA position in the initial steady-state (without sanctions).

We assume that the countries differ in terms of their consumption-good sector productivity and intermediate-good sector productivity. The consumption-good sector in Home is more efficient than in Foreign, characterized by higher productivity and lower cost of firm entry (i.e., $Z_t^Y > Z_t^{Y*}$ and $f_{E,t}/Z_t^Y < f_{E,t}^*/Z_t^{Y*}$). Home commodity production is less productive than in Foreign (i.e., $Z_t^G < Z_t^{G*}$). Home is a net importer of commodity, while Foreign is a net exporter of commodity. Specifically, we set $Z_t^Y = 1.5$ and $Z_t^{G*} = 1.5$, where $Z_t^{Y*} = 1$ and $Z_t^G = 1$ are normalized. This calibration implies that Home GDP is about 53% larger than Foreign GDP in the initial steady-state, i.e., without sanctions.

We calibrate the initial value of Foreign Households' holdings of Home bonds to be 137% of Foreign GDP, and the Foreign NFA position to 48% of GDP, which will reflect the financial imbalances related with commodity exporters. This is accomplished by setting $B_H = -5$ and $B_H^* = 3$. The scale parameter for the costs of adjusting bond and share holdings, η, is set at 0.0025, a value with negligible impact on model dynamics, except for pinning down the non-stochastic steady-state and ensuring mean reversion after transitory shocks.

The discount factor, β, and firm exit rate, δ, are set to their standard values in the literature, at 0.99 and 0.025, respectively. Following Kim, Ozhan and Schembri (2021), the cost share of intermediates in consumption-good production, α, is set at 0.1. The disutility parameter from working, κ, is set to 8.9, which normalizes the labor supply in the consumption-good sector, L^Y, to 1. This implies that total labor supply in the initial steady-state is $L = 0.32$. The cross-sector labor elasticity parameter follows Horvath (2000), with $\varrho = 1$. The share parameter of intermediate-good sector labor (gas labor) in disutility, $1 - \gamma$, is set to 0.1, leading to Home and Foreign initial steady-state gas labor shares in total labor being $L_0^G/(L_0^Y + L_0^G) = 0.06$ and $L_0^{G*}/(L_0^{Y*} + L_0^{G*}) = 0.12$, respectively. The short-run labor adjustment cost parameter, η_L, is set to 1, implying the short-run elasticity of labor between the two sectors is half of the long-run elasticity.

Following Ghironi and Melitz (2005), the cost of entry in Home and Foreign ,$f_{E,t}$ and $f_{E,t}^*$,

are normalized to 1, and the elasticity of substitution across varieties, θ, is set to 3.8. Firm-level productivity, z, follows a Pareto distribution with a lower bound, $z_{\min}$, of 1 and a shape parameter of 3.4. This calibration for the firm-level productivity distribution results in a Pareto shape parameter of 1.21 for the (domestic) sales distribution. Additionally, the top 5% exporters (top 1% firms) contribute to 60% of total exports when 20% of firms export. This aligns with empirical observations, as reported by Mayer and Ottaviano (2008) for various countries.[7] The fixed cost of exporting ($f_{X,t} = f^*_{X,t}$) is set at 0.0085, ensuring that in the initial steady-state, 18% and 25% of Home and Foreign firms export their products, respectively. This calibration ensures that the lower bound of firm-level productivity, $z_{\min}$, is smaller than the export cutoffs, $\underline{z}_{X,t}$ and $\underline{z}^*_{X,t}$. Iceberg costs for consumption-good trade are set at 30% ($\tau^Y_t = \tau^{Y*}_t = 1.3$), while there are smaller costs for commodity trade ($\tau^G_t = \tau^{G*}_t = 1.1$), suggesting relatively smoother international transactions for commodities in the absence of sanctions. Our calibration implies Home and Foreign export-GDP ratios to be 20% and 37%, respectively. Additionally, Home and Foreign commodity export-GDP ratios are 0.36% and 6.0%, respectively.

5. The Sanctions

This section introduces three primary types of sanctions: trade sanctions for differentiated consumption goods, trade sanctions for homogeneous intermediate goods (gas), and financial sanctions. These sanctions are imposed on Foreign by Home. We simulate the economy under each type of sanctions, studying their short-, medium-, and long-term effects.

First, consumption-good trade sanctions imply trade restrictions on the goods produced by the larger, more productive firms. This is achieved by excluding firms that exceed a specific, government-determined productivity threshold from international trade. The idea is that, for instance, when the Home government forces its top exporters to quit exporting to Foreign, the goal is to curtail export of high-tech goods, which are typically produced by large, high-productivity firms. Second, financial sanctions exclude a portion of the target country's households from international financial markets. In the extreme, these sanctions lead to complete financial autarky, where all Foreign households are excluded from international financial markets. Third, commodity-trade (gas) sanctions involve a complete ban on trade. In our model, this is equivalent to imposing a price cap below the marginal cost of commodity production in Foreign, effectively halting

[7] According to Mayer and Ottaviano (2008), the share of top 5% exporters in total exports is 81, 73, 69, 59, 73, and 81% in Germany, France, UK, Italy, Belgium, and Norway, respectively.

commodity exports.

The simulations track the effects of the economic system's switch from the no-sanction equilibrium to the equilibrium with sanctions in time period $t = 1$, when sanctions are imposed, and beyond. The simulations continue until the economy reaches a new steady-state at time $t = 201$. This simulation length is sufficient time for the economy to adjust and reach a new steady-state equilibrium.

5.1. Consumption-Good Export and Import Sanctions

We implement sanctions on the trade of consumption goods by introducing another productivity cutoff for Home or Foreign exporters, $\bar{z}_X$ or $\bar{z}_X^*$, respectively. These cutoffs are determined by the Home government.[8] These sanctions take two forms: When export sanctions are imposed, Home differentiated goods producers with productivity exceeding the cutoff ($\bar{z}_X$) are no longer allowed to export to the Foreign country. Import sanctions prohibit imports from the most productive Foreign final-sector producers (those exceeding the cutoff $\bar{z}_X^*$).

Sanctions affect the average productivity of exporting firms. Sanctions of consumption-good trade imply that the expressions for the average productivitities of Home and Foreign final-sector exporters become:

$$\tilde{z}_{X,t} = \left[\frac{N_{X,t}}{N_{D,t}} \int_{\underline{z}_{X,t}}^{\bar{z}_X} z^{\theta-1} \mathrm{d}\Phi(z)\right]^{\frac{1}{\theta-1}} \quad \text{and} \quad \tilde{z}_{X,t}^* \equiv \left[\frac{N_{X,t}^*}{N_{D,t}^*} \int_{\underline{z}_{X,t}^*}^{\bar{z}_X^*} z^{\theta-1} \mathrm{d}\Phi(z)\right]^{\frac{1}{\theta-1}}, \tag{14}$$

where $N_{X,t}/N_{D,t} = \Phi(\bar{z}_X) - \Phi(\underline{z}_{X,t})$ and $N_{X,t}^*/N_{D,t}^* = \Phi(\bar{z}_X^*) - \Phi(\underline{z}_{X,t}^*)$. Hence, the relative share of exported goods in the total number of products is now determined by both the trade-cost-induced cutoff and the sanction cutoff, which will lead to changes in firm entry into the export market.

When introducing sanctions, we drop the top 1% productive Home or Foreign firms from international trade. The top 1% of Home firms account for a significant share of total exports (around 60%); however, as we explain shortly, export sanctions lower the endogenous, trade-cost-induced export cutoff, causing lower productivity firms to begin exporting. In terms of the change in the volume of exported goods, this implies a decrease of less than 60% of total export volume.[9]

Figure 1 depicts the dynamics after the introduction of consumption-good trade sanctions.

[8] In this paper, we assume an exogenous government choice of sanction cutoffs. We leave studying the optimal determination of these cutoffs for future research.

[9] For a comparison of the productivity-based sanctions of this paper to a random exclusion approach, see Ghironi et al. (2024).

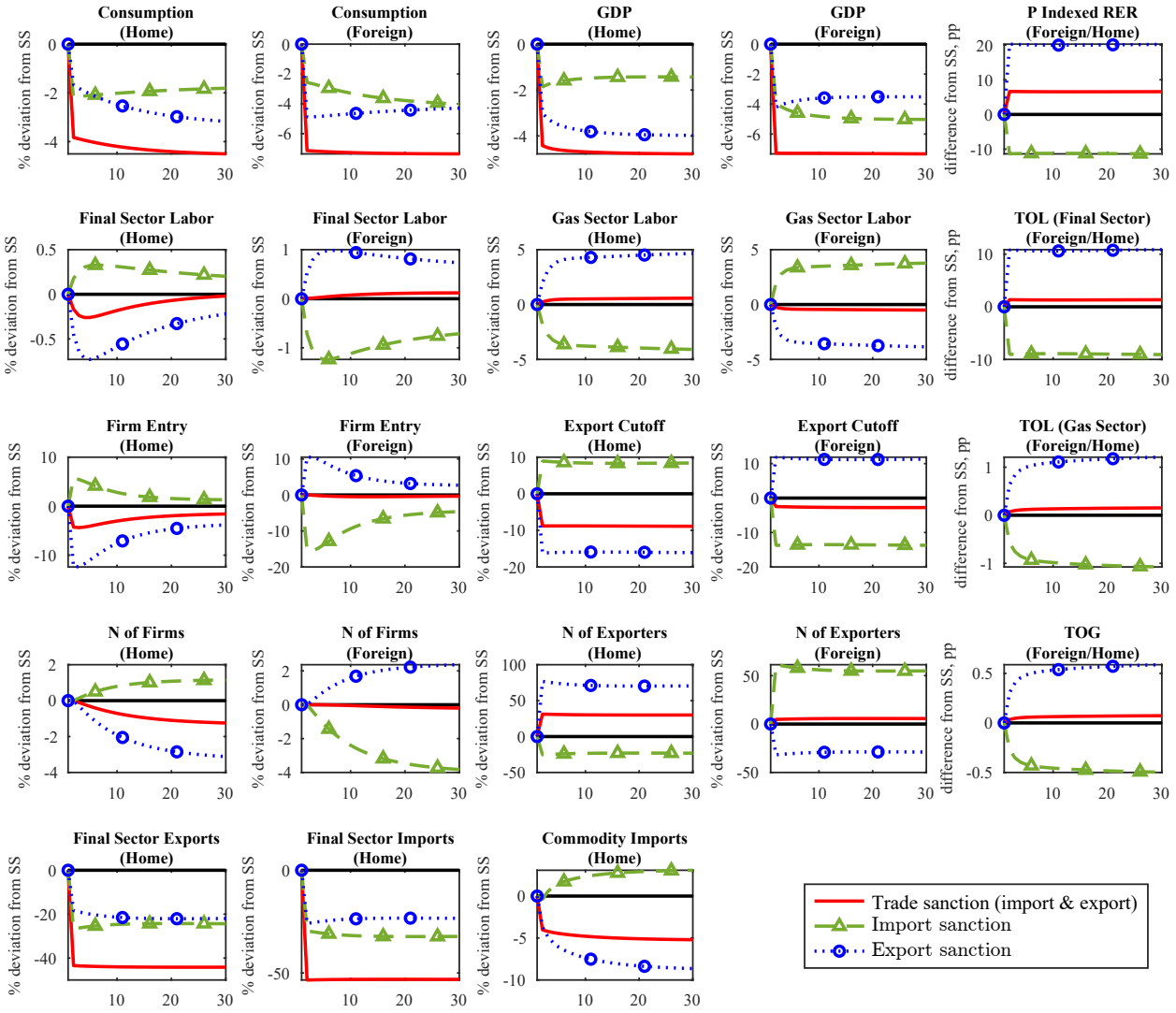

Figure 1: Transition dynamics after consumption-good trade sanctions Notes: The green dashed lines with triangles, blue dashed lines with circles, and red solid lines represent the transitional dynamics when differentiated consumption-good import, export, and trade sanctions (both export and import) are imposed at $t = 1$. All deviations, except for the figures of price indexed real exchange rate (RER), terms of labor and gas (TOL and TOG), are measured in units of percent deviation from the initial steady-state without sanctions ($t = 0$), i.e., $100 \times (x_t/x_0 - 1)$. The figures of RER, TOL, and TOG express deviations in units of percentage points from the initial steady-state, i.e., $100 \times (x_t - x_0)$.

Green lines with triangles denote responses to import sanctions where the top 1% productive Foreign firms can no longer export to Home, i.e., $\Phi(\bar{z}_X^*) = 0.99$. Blue lines with circles represent responses to export sanctions where the top 1% productive Home firms must quit exporting to Foreign, i.e., $\Phi(\bar{z}_X) = 0.99$. Red lines denote responses to the imposition of both import and export sanctions simultaneously (labeled as "Trade sanction").

The effect of consumption-good trade sanctions is largely driven by their effect on the business environment for consumption-good sector firms relative to the pre-sanctions environment. Consider the case of export sanctions (the blue lines with circles). All else given, this reduces the attractiveness of entry into Home's final consumption-good sector, because prospective entrants now know that, even if they were characterized by high productivity post entry into Home, they would not be able to earn export profits. This implies that consumption-good sector entry shifts toward Foreign. However, in the long run, a sufficient mass of consumption-good sector firms must continue to be present in Home to keep at least some Home consumption-good sector labor employed. Because of this, the relative cost of Home effective consumption-good sector labor TOL_t^Y must decrease, resulting in Home real exchange rate depreciation, consistent with the intuition in Section 3. The responses of entry and the numbers of consumption-good producers in Home and Foreign in the short run and along the transition path ensure the working of this mechanism, shifting consumption-good sector labor demand across countries (and sectors within countries) in a manner consistent with the movement of the relative cost of effective final-sector labor.

Since Home final-sector labor becomes relatively less expensive, the trade-cost determined cutoff for entry into the Home export sector decreases, which combines with the government-determined exclusion of top-productivity firms from exporting to generate lower average Home exporter productivity. Conversely, Foreign consumption-good sector labor becomes relatively more expensive, as increased entry and number of firms put upward pressure on labor demand. This pushes up the trade-cost-determined Foreign export cutoff and average Foreign exporter productivity. Consistent with Section 3, these effects reinforce the depreciation of Home's real exchange rate by causing higher average import prices in Foreign and lower average import prices in Home.

Reduced entry, number of firms, and export volume by the Home firms also imply less intermediate-good usage in Home, leading to a decrease in commodity imports from Foreign. This contributes to the shift in Foreign labor usage from commodity production to consumption-good production, the relative increase in the cost of Foreign effective final-sector labor, and relative

decrease in the price of the intermediate good (usable gas) in Home (TOL_t^G rises). As explained in Section 3, this further contributes to the depreciation of Home's real exchange rate.

Sanctions that prevent the top 1% Foreign firms from exporting to Home (import sanctions) have similar, but opposite-direction effects. Now it is the attractiveness of entry into the Foreign final sector that is reduced relative to the pre-sanction environment. Entry shifts toward Home, leading to a gradual increase in the number of Home firms, and fueling appreciation of Home's final-sector terms of labor. This is the primary driver of Home's real exchange rate appreciatio in this scenario. The appreciation is then amplified by the fact that higher final-sector labor cost causes a higher trade-cost-induced cutoff for export by Home firms (conversely, the trade-cost-induced export cutoff in Foreign becomes lower). Mirroring the export sanction scenario, the higher (lower) average export productivity in Home (Foreign) contributes to lower (higher) average import prices in Foreign (Home), which strengthens Home's real exchange rate appreciation. The increase in entry also results in higher intermediate-good demand from the Home consumption-good sector, prompting the Foreign economy to reallocate production toward its commodity sector. In turn, these effects drives up the Home price of the intermediate good relative to Foreign. TOL_t^G appreciates, and this contributes to the appreciation of $\tilde{Q}_t$. Like in the case of export sanctions, all the effects and mechanisms are consistent with the analysis in Section 3.

The fact that the responses to export and import sanctions do not exactly mirror each other quantitatively is explained by our assumptions about comparative advantage and the implied asymmetry of initial positions. This also explains why the joint introduction of export and import sanctions (red responses) produces trade and macroeconomic responses similar to those of export sanctions, rather than import sanctions. Home's comparative advantage in producing consumption goods implies that the effect of forcing top Home firms to quit exporting dominates the effect of terminating trade with top Foreign final-sector exporters.

5.2. Financial Sanctions

We model financial sanctions by excluding a portion of Foreign agents from participating in international bond markets. When Home imposes financial sanctions on Foreign, a fraction $\lambda \in [0, 1]$ of Foreign households is excluded from participating in international financial markets. After the imposition of sanctions, these households can only trade Foreign bonds and shares with other Foreign households. In the extreme case where all Foreign households are sanctioned ($\lambda = 1$), Foreign operates under financial autarky.

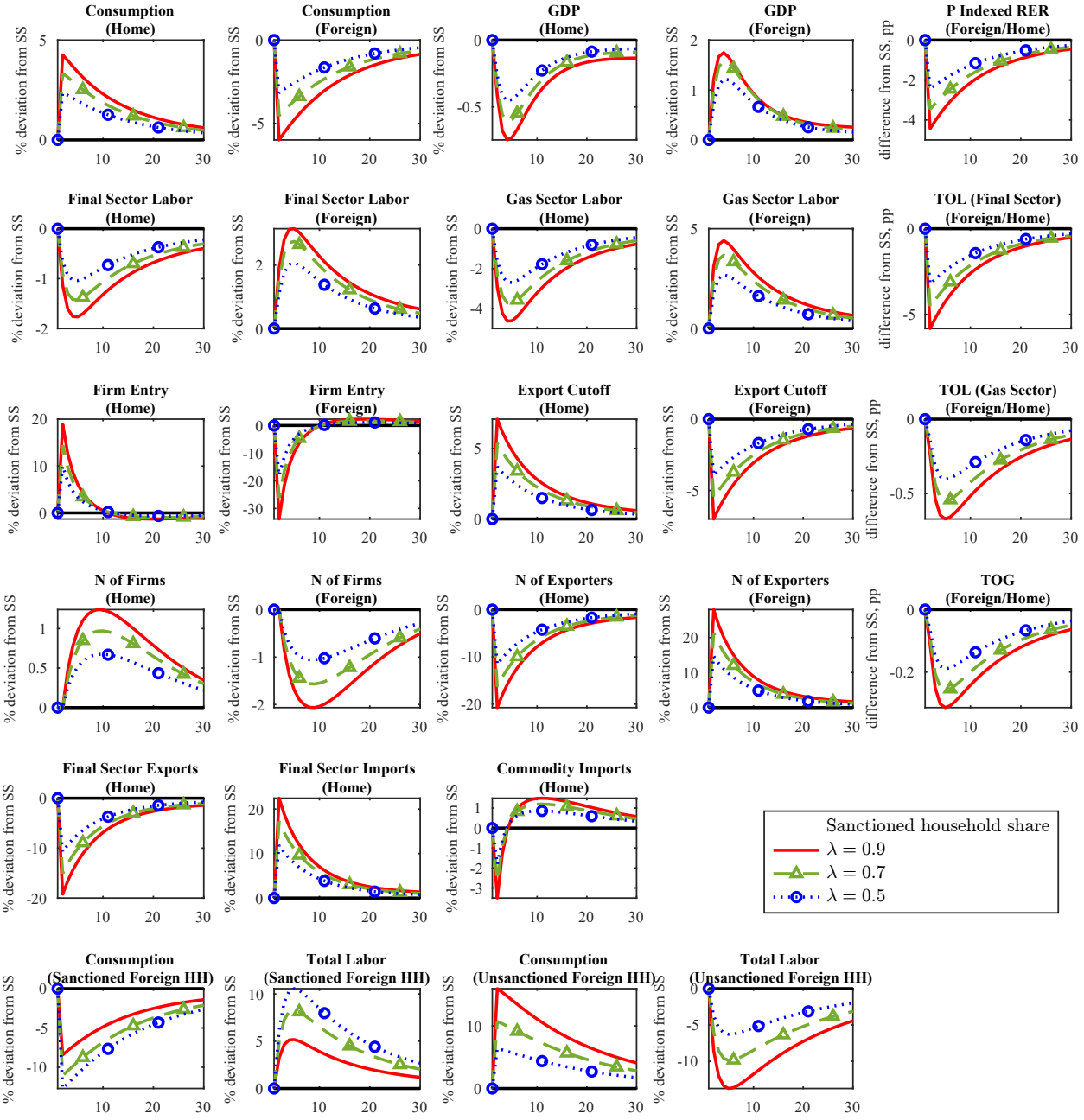

Figure 2: Transition dynamics after financial sanctions with different shares of sanctioned households
Notes: The red solid lines, green dashed lines with triangles, and blue dashed lines with circles depict the model transition dynamics when financial sanctions are imposed at $t = 1$, with the fraction of sanctioned Foreign households $\lambda = 0.9$, 0.7, and 0.5. All deviations, except for the figures of price indexed real exchange rate (RER), terms of labor and gas (TOL and TOG), are measured in units of percent deviation from the initial steady-state without sanctions ($t = 0$), i.e., $100 \times (x_t/x_0 - 1)$. The figures of RER, TOL, and TOG express deviations in units of percentage points from the initial steady-state, i.e., $100 \times (x_t - x_0)$. All Foreign variables are aggregates except for the last row. The total labor in the last row is the sum of sectoral labor supplies $(L_t^Y + L_t^G)$ for each type of Foreign household.

Once financial sanctions are imposed, the Foreign population is divided into two groups of households: λ who are subject to the sanctions and $1-\lambda$ who are not. The budget constraint for the representative sanctioned household becomes:

$$\begin{aligned} &C^*_{S,t} + B^*_{S,F,t+1} + \tilde{v}^*_t N^*_t x^*_{S,t+1} + 0.5\eta\big[(B^*_{S,F,t+1} - B^*_{S,F})^2 + \tilde{v}^*_t N^*_t (x^*_{S,t+1} - 1)^2\big] + \text{Ladj}_t(L^{Y*}_{S,t}, L^{G*}_{S,t}) \\ &= (1 + r^*_t) B^*_{S,F,t} + w^*_{G,t} L^*_{S,G,t} + w^*_t L^*_{S,t} + (\tilde{d}^*_t + \tilde{v}^*_t) N^*_{D,t} x^*_{S,t} + T^{*f}_{S,t}, \end{aligned} \tag{15}$$

for period $t \geq 1$. The subscript S denotes households that are subject to sanctions. The sanctioned households lose the Home-issued bonds ($B_{S,F,1} = B_F = -B_H > 0$), and thus, they cannot receive any returns from them at $t = 1$. Additionally, they cannot trade Home bonds for the entire duration after the sanctions ($B_{S,F,t+1} = 0$ for $\forall t \geq 1$). However, they can still trade Foreign bonds with unsanctioned Foreign households, but their terminal steady-state level is zero ($B^*_{S,F} = 0$).

After the imposition of financial sanctions, the budget constraint for the representative non-sanctioned household remains unchanged:

$$\begin{aligned} &C^*_{NS,t} + \frac{B_{F,t+1}}{Q_t} + B^*_{NS,F,t+1} + \tilde{v}^*_t N^*_t x^*_{NS,t+1} \\ &\quad + 0.5\eta\big[Q_t^{-1}(B_{NS,F,t+1} - B_{NS,F})^2 + (B^*_{NS,F,t+1} - B^*_{NS,F})^2 + \tilde{v}^*_t N^*_t (x^*_{NS,t+1} - 1)^2\big] + \text{Ladj}_t(L^Y_t, L^G_t) \\ &= (1 + r_t)\frac{B_{NS,F,t}}{Q_t} + (1 + r^*_t) B^*_{NS,F,t} + w^*_{G,t} L^*_{NS,G,t} + w^*_t L^*_{NS,t} + (\tilde{d}^*_t + \tilde{v}^*_t) N^*_{D,t} x^*_t + T^{*f}_{NS,t}, \end{aligned} \tag{16}$$

where the subscript NS denotes non-sanctioned households, who retain the ability to trade bonds during the transition. In the terminal steady-state, the bond holdings of non-sanctioned Foreign households remain unchanged after financial sanctions, specifically $B_{NS,F} = B_F = -B_H$ and $B_{NS,F} = B^*_F = -B^*_H$.

The Home and Foreign bond markets clear: $B_{H,t} + (1-\lambda) B_{NS,F,t} = 0$ and $B^*_{H,t} + (1-\lambda) B^*_{NS,F,t} + \lambda B^*_{S,F,t}$, respectively. Also, the market clearing for shares in Home and Foreign implies $x_t = 1$ and $\lambda x^*_{S,t} + (1-\lambda) x^*_{NS,t} = 1$. Because financial sanctions enforce zero bond holdings for sanctioned Foreign households, the new steady-state bond holdings for Home and Foreign are $-(1-\lambda) B_{NS,F}$ and $-(1-\lambda) B^*_{NS,F}$, respectively.

Figure 2 presents the transition dynamics under varying fractions of exclusion: 90%, 70%, and 50% with the benchmark initial bond holdings ($B_H = -5$ & $B^*_H = 3$) where the Foreign's NFA is positive. The red solid line plots these dynamics when 90% of Foreign households are excluded from international financial transactions, representing a 90% asset freeze. The impact of

financial sanctions on Foreign consumption is more pronounced in the short to medium term when a larger proportion of Foreign households is affected. Only a fraction of the Foreign population is subjected to financial sanctions, allowing the sanctioned group to mitigate the effects by engaging in transactions with those in Foreign who still have access to international financial markets.

The qualitative effects of financial sanctions are in many ways similar to those of final-sector sanctions that exclude the top Foreign exporters from trade (import sanctions). The reason is that, just like import sanctions, financial sanctions reduce the attractiveness of entry into the Foreign consumption-good sector relative to the pre-sanction world. In the case of import sanctions, this happens because prospective entrants know that, even if they have high productivity post entry, they will not benefit from it in terms of export profits. In the case of financial sanctions, it is reduced access to entry finance in the form of borrowing from Home that makes entry into Foreign less appealing, and shifts entry toward Home. Then, once again, the effects on the real exchange rate can be interpreted easily by referring to the mechanisms in Section 3.

In Figure 3, the red solid lines depict the model transition dynamics with the benchmark initial bond holdings ($B_H = -5$ & $B_H^* = 3$). To understand the role of initial bond holdings in financial sanctions, we introduce two counterfactual scenarios. The green lines with triangles represent the first counterfactual scenario with half the initial bond holdings ($B_H = -5/2$ & $B_H^* = 3/2$), representing a less financially linked world economy. In the second counterfactual scenario (blue lines with circles), we set $B_H^* = 0.6997$ with $B_H = -5/2$ maintaining the same NFA-GDP ratio as the benchmark but with a lower initial level of international bond holdings.

Upon the imposition of financial sanctions, we observe a sharp short-term decline in Foreign consumption, exceeding its long-term reduction. This is primarily due to wealth effects arising from the loss of Home bond holdings. These wealth effects significantly determine the negative impacts of financial sanctions on Foreign consumption. Therefore, the impact of financial sanctions on Foreign consumption is more pronounced when a larger amount of bonds are traded internationally initially. A negative wealth effect in Foreign generates an increase in Foreign labor supply. Consequently, Foreign terms of labor in all sectors depreciate (low labor costs), contributing to a depreciation of the Foreign real exchange rate.

When sanctions are imposed, Foreign sanctioned households experience a negative transitory income shock and face limited opportunities for savings through Home bonds. This leads to a decrease in Foreign consumption demand, including its demand for imports from Home. The reduction in Foreign imports results in fewer Home exporters accessing the Foreign market,

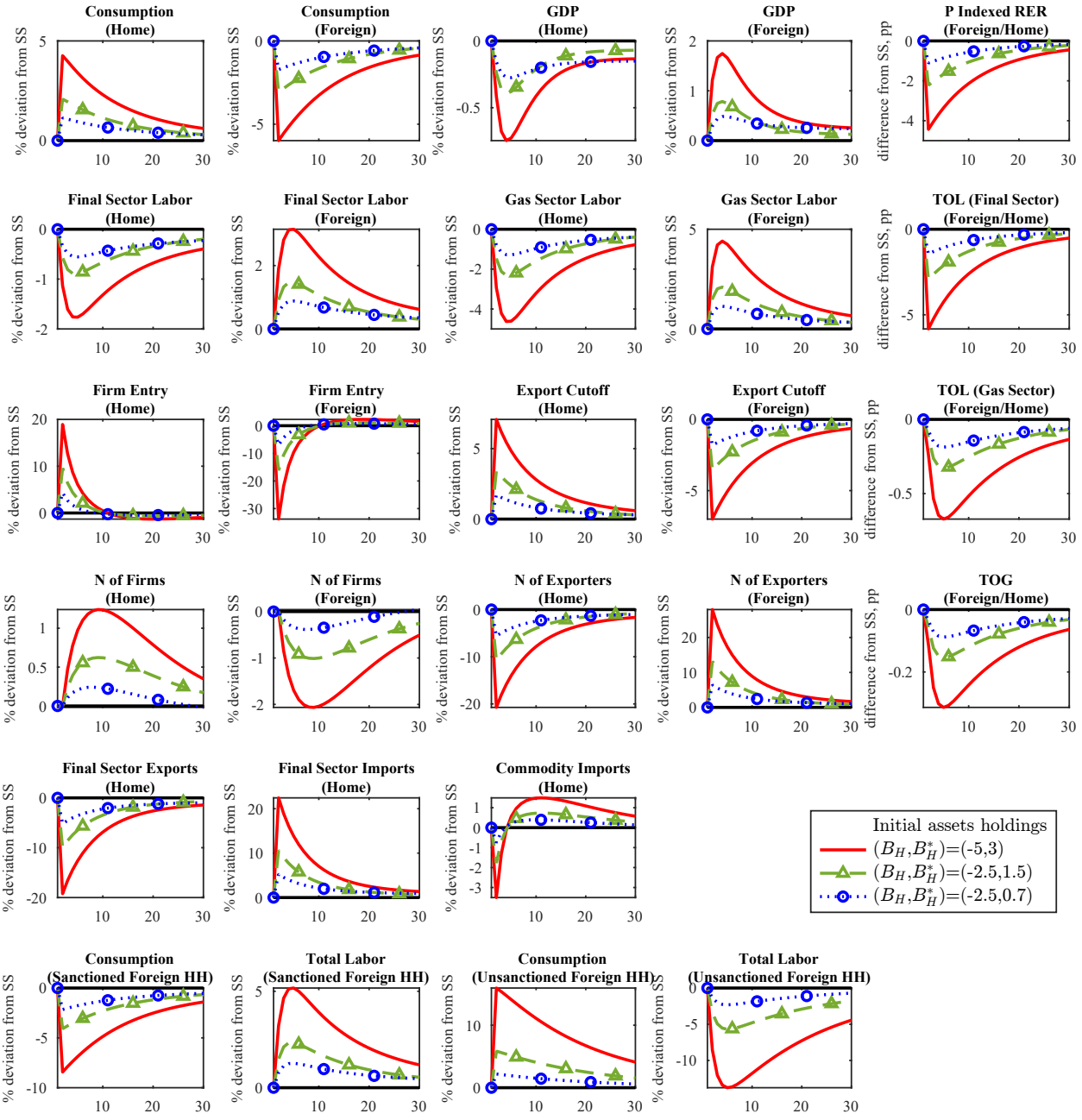

Figure 3: Transition dynamics after financial sanctions with different initial asset holdings Notes: The red solid lines, green dashed lines with triangles, and blue dashed lines with circles depict the model transition dynamics when financial sanctions are imposed at $t = 1$, with the benchmark initial bond holdings ($B_H = -5$ & $B_H^* = 3$), the counterfactual initial bond holdings ($B_H = -5/2$ & $B_H^* = 3/2$ and $B_H = -5/2$ & $B_H^* = 0.6997$). The first counterfactual implies a low initial level of international bond holdings. The second counterfactual implies a low initial level of Foreign household Home-issued bond holdings while the level of NFA-GDP ratio is identical to the benchmark scenario (47.5%). All deviations, except for the figures of price indexed real exchange rate (RER), terms of labor and gas (TOL and TOG), are measured in units of percent deviation from the initial steady-state without sanctions ($t = 0$), i.e., $100 \times (x_t/x_0 - 1)$. The figures of RER, TOL, and TOG express deviations in units of percentage points from the initial steady-state, i.e., $100 \times (x_t - x_0)$. All Foreign variables are aggregates except for the last row. The total labor in the last row is the sum of sectoral labor supplies $(L_t^Y + L_t^G)$ for each type of Foreign household.

raising their export threshold. This, in turn, lowers the average Home export price and causes an appreciation of the Home real exchange rate.

The last row of Figures 2 and 3 show significant heterogeneity between sanctioned and unsanctioned Foreign households. Sanctioned households respond to the fall in their financial income by increasing their labor supply in both the consumption- and intermediate-good production sectors. This surge in labor supply results in lower wages, contributing to the depreciation of the Foreign terms of labor and real exchange rate, along with an increase in the trade surplus. In contrast, unsanctioned households decrease their labor supply in both sectors and benefit from non-labor incomes by trading bonds with Home households and sanctioned households. This indicates that (almost) all Foreign households should be sanctioned for financial sanctions to be effective.

5.3. Commodity Trade Sanctions

We explore commodity trade sanctions by implementing a permanent ban on commodity (gas) trade starting from period $t = 1$. This is equivalent to imposing a permanent price cap on traded commodity, effective from period $t = 1$ onward. The price cap is set below marginal costs of commodity production, causing Foreign to cease commodity exports to Home in response to the commodity trade sanction.

Under commodity trade sanctions, a ban on commodity (natural gas) trade ($G^*_{X,t} = G_{X,t} = 0$) means that the intermediate-good (usable gas) price equation (6) no longer holds. In the new equilibrium, Home and Foreign commodity markets are separated, and market clearing conditions in Home and Foreign are $Z^G_t L^G_t = G_{D,t} = G_t$ and $Z^{G*}_t L^{G*}_t = G^*_{D,t} = G^*_t$, respectively. Moreover, Home and Foreign intermediate-good prices equal their marginal costs of commodity production: $\rho^G_t = \rho^G_{R,t} = w^G_t / Z^G_t$ and $\rho^{G*}_t = \rho^{G*}_{R,t} = w^{G*}_t / Z^{G*}_t$, respectively.

Figure 4 plots the transition dynamics in response to the implementation of commodity trade sanctions (blue lines with circles). For comparative analysis, we include the dynamics under consumption-good trade sanctions (red solid lines). Because the initial steady-state Home commodity exports to Foreign are small, we also include the dynamics under consumption goods import sanctions (green lines with triangles) for a clearer comparative analysis. commodity trade sanctions are not as impactful as the sanctions on consumption-good trade in reducing Foreign consumption. While consumption-good sanctions lead to a more significant drop in Foreign consumption compared to Home consumption, commodity sanctions create more consumption drops in Home than Foreign. This observation is crucial in understanding welfare losses due to sanctions, comparative

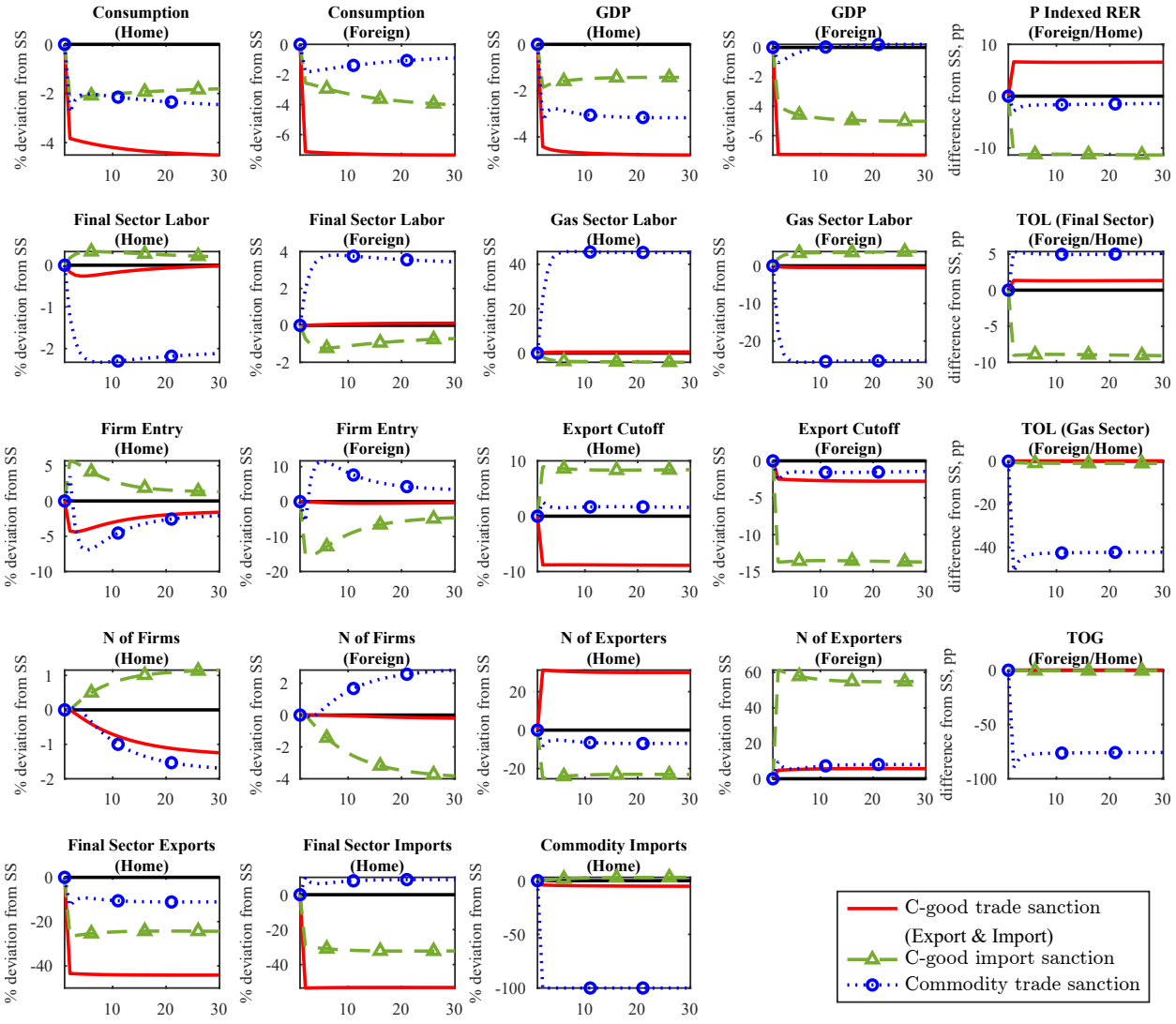

Figure 4: Transition dynamics after commodity and consumption-good trade sanctions Notes: The blue dashed lines with circles depicts the transitional dynamics when commodity trade sanctions are imposed at $t = 1$. The green dashed lines with triangles and red solid lines depict the transitional dynamics when consumption-good sector import and trade sanctions, respectively, are imposed at $t = 1$. All deviations, except for the figures of price indexed real exchange rate (RER), terms of labor and gas (TOL and TOG), are measured in units of percent deviation from the initial steady-state without sanctions ($t = 0$), i.e., $100 \times (x_t/x_0 - 1)$. The figures of RER, TOL, and TOG express deviations in units of percentage points from the initial steady-state, i.e., $100 \times (x_t - x_0)$.

advantages, and their relationship, which will be discussed in detail in the following section 6.

The decrease in demand for Foreign commodities (natural gas) reduces commodity production in Foreign, leading to an increase in the price of intermediate goods (usable gas) in Home. Since domestically produced and imported commodities are highly substitutable, and Foreign holds a comparative advantage in commodity production, the Home economy heavily depends on Foreign commodities. As a result, commodity trade sanctions drastically appreciate the terms of gas (the relative price of intermediates) because Home must replace cheaper imported commodities with domestically produced ones, which have higher production costs. This also raises labor supply to commodity production and decreasing labor supply to the consumption-good production, further driving up the terms of labor in the intermediate goods (gas) sector.

The intermediate-good price increase is driven by consumption-good producing firms, which demand more domestic commodity to compensate for the lost imported commodity. As the price of intermediate good increases, the marginal cost of production in the Home consumption-good sector also rises. This cost escalation is reflected in fewer entrants in Home, leading to a decline in the total number of producers.

In contrast, the Foreign economy undergoes a rebalancing in the opposite direction. To offset the loss of commodity exports, the economy shifts towards increased production in the consumption-good sector and higher imports of final consumption goods. Consumption-good producers in Foreign increase their demand for labor, resulting in rising wages. Concurrently, the decrease in commodity production reduces the need for labor in the intermediate-good (gas) sector, leading to a decline in wages. This economic shift encourages more entrants into the consumption-good sector. Consequently, the number of producers in the Foreign consumption-good sector increases. To counter the loss of commodity exports, more firms in the consumption-good sector begin exporting, and the cutoff productivity level for the least efficient exporter in Foreign decreases. This adjustment in Foreign exporter productivity cutoff translates into higher average Home final consumption-good import prices, appreciating the Home real exchange rate.

5.4. Combined Sanctions

This subsection presents the combined impact of all sanctions introduced simultaneously. Figure 5 shows the dynamics of our benchmark model when all combinations of sanctions are in place (red solid lines). To understand the role of comparative advantage, we consider a counterfactual scenario where Home and Foreign have no comparative advantage (green lines with triangles,

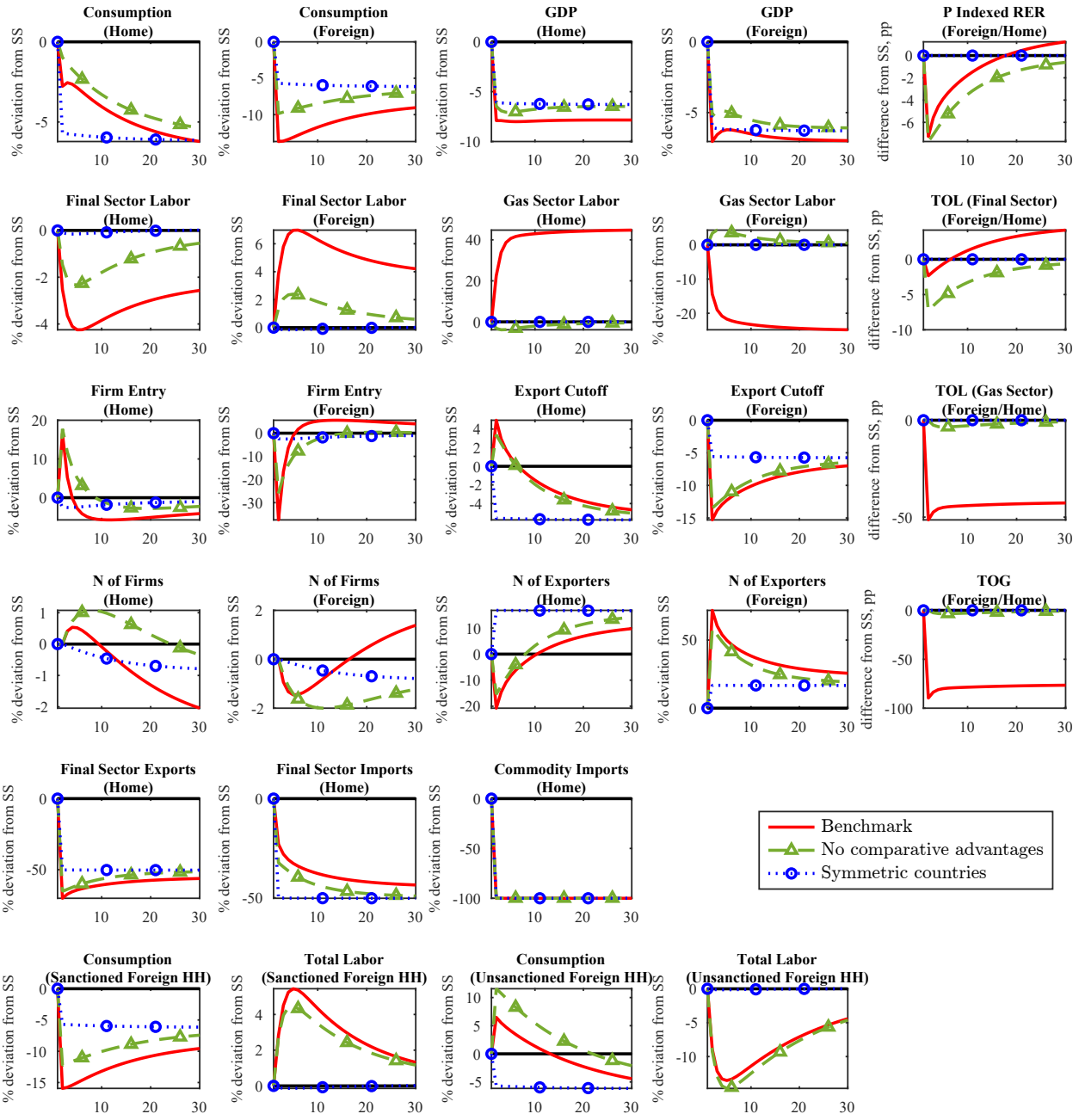

Figure 5: Transition dynamics with combinations of sanctions Notes: The red solid lines and green dashed lines with triangles depict the transitional dynamics of the benchmark and counterfactual scenarios when all sanctions are imposed at $t = 1$. Under the counterfactual scenario, there is no comparative advantage ($Z_t^Y = Z_t^{Y*} = Z_t^G = Z_t^{G*} = 1.25$) instead of the benchmark calibration ($Z_t^Y = 1.5 = Z_t^{G*}$ and $Z_t^{Y*} = 1 = Z_t^G$). All deviations, except for the figures of price indexed real exchange rate (RER), terms of labor and gas (TOL and TOG), are measured in units of percent deviation from the initial steady-state without sanctions ($t = 0$), i.e., $100 \times (x_t/x_0 - 1)$. The figures of RER, TOL, and TOG express deviations in units of percentage points from the initial steady-state, i.e., $100 \times (x_t - x_0)$. The total labor in the last row is the sum of sectoral labor supplies ($L_t^Y + L_t^G$) for each type of Foreign household.

$Z_t^Y = Z_t^{Y*} = Z_t^G = Z_t^{G*} = 1.25$). The differences between the red solid lines and green lines with triangles reveal the role of comparative advantages in the dynamics arising from sanctions. Additionally, we consider a symmetric country scenario (blue lines with circles) where Home and Foreign have zero initial bond holdings ($B_H = B_H^* = 0$) alongside the identical productivities. and identical productivities. Thus, the differences between the green lines with triangles and the blue lines with circles represent the role of international asset positions. In the symmetric scenario, the blue lines for Home and Foreign variables have identical dynamics, and relative variables such as real exchange rates and terms of labor do not respond to sanctions.

In Figure 5, the labor transition dynamics in the Home and Foreign consumption-good and intermediate-good (gas) sectors show that comparative advantages play a key role in production reallocation across sectors. Under the benchmark, both countries experience significant labor reallocation towards comparative advantage sectors: Home labor shifts from the consumption-good sector to the intermediate-good sector, while Foreign labor shifts from the intermediate-good sector to the consumption-good sector. When we remove comparative advantages, these reallocations are significantly dampened, especially in the long run.

In contrast, firm entry and export cutoff dynamics of the red lines and green lines with triangles are similar, implying a limited role of comparative advantages in the within-consumption-good sector's extensive margins in domestic and export markets. However, the red and green lines significantly differ from the blue lines with circles, highlighting the important role of foreign asset holdings in transition dynamics reacting to sanctions. As discussed, the impact of financial sanctions depends on initial asset holdings. With zero international bond holdings, financial sanctions do not affect asset prices (bonds and shares), limiting their impact on the value of entrants and thus firm entries. Additionally, zero international bond holdings prevent financial sanctions from creating positive and negative wealth effects in Home and Foreign, respectively. However, all three models provide similar levels of firm entries and export cutoffs under sanctions in the long run because the long-run firm entries and export cutoffs are primarily affected by the discount factor (β) and trade balance of the new steady-state.

6. Welfare Analysis

In this section, we explore the welfare effects of sanctions on both the imposing and targeted economies. To measure welfare, we consider lifetime utility from consumption and disutility from

labor. The effect of sanctions is incorporated from the first period ($t = 1$), and we analyze the transition dynamics until $t = 200$, accounting for the terminal impact at $t = 201$.

The lifetime utility used to measure welfare without sanctions is given by $\mathcal{U}_0 \equiv (\log C_0 - 0.5\kappa L_0^2)/(1-\beta)$, where C_0 and L_0 are Home household's consumption and labor supply, respectively, at the (initial) steady-state without sanctions. Similarly, the lifetime utility at the new steady-state after sanctions is: $\mathcal{U}_{201}^{\text{sanc}} \equiv (\log C_{201} - 0.5\kappa L_{201}^2)/(1-\beta)$, where C_{201} and L_{201} are Home household's consumption and labor supply, respectively, at the (terminal) steady-state with sanctions. Then, the welfare with sanctions and transition paths can be expressed as:

$$\mathcal{U}_0^{\text{sanc}} = \sum_{t=0}^{200} \beta^t \left(\log C_t - \frac{\kappa}{2} L_t^2 \right) + \beta^{201} \mathcal{U}_{201}^{\text{sanc}}. \tag{17}$$

To measure aggregate Foreign welfare under sanctions, we calculate the weighted average of welfare for sanctioned and non-sanctioned households: $\mathcal{U}_0^{\text{sanc}*} = \lambda \mathcal{U}_{S,0}^{\text{sanc}*} + (1-\lambda)\mathcal{U}_{NS,0}^{\text{sanc}*}$, where the subscripts S and NS indicate financially sanctioned and unsanctioned Foreign households.

We then calculate the welfare gain in initial consumption-equivalent terms:

$$\mathcal{U}_0^{\text{sanc}} = \frac{1}{1-\beta} \left\{ \log[(1+\Delta)C_0] - \frac{\kappa}{2} L_0^2 \right\}, \tag{18}$$

where Δ measures lifetime welfare gains in (initial steady-state) consumption-equivalent terms. After some algebra, it can be expressed as $\Delta = \exp[(1-\beta)(\mathcal{U}_0^{\text{sanc}} - \mathcal{U}_0)] - 1$.[10] To compare welfare with and without dynamics, we calculate the welfare gain in consumption-equivalent terms from comparative statistics between the initial and new steady-states:

$$\mathcal{U}_{201}^{\text{sanc}} = \frac{1}{1-\beta} \left\{ \log[(1+\Delta_{ss})C_0] - \frac{\kappa}{2} L_0^2 \right\}, \tag{19}$$

where Δ_{ss} can be expressed as $\Delta_{ss} = \exp[(1-\beta)(\mathcal{U}_{201}^{\text{sanc}} - \mathcal{U}_0)] - 1$.[11]

Table 1 presents the calculated welfare effects in Home and Foreign resulting from different sanctions. The welfare gains without dynamics are presented in parentheses. To understand the role of comparative advantage and international asset holdings in the welfare effects of sanctions, we consider three counterfactual scenarios: 1) no initial state bond holdings, $B_H = B_H^* = 0$, 2)

[10] The aggregate Foreign welfare gains are calculated by $\Delta^* = \exp[(1-\beta)(\mathcal{U}_0^{\text{sanc}*} - \mathcal{U}_0^*)] - 1$, where $\mathcal{U}_0^{\text{sanc}*} = \lambda \mathcal{U}_{S,0}^{\text{sanc}*} + (1-\lambda)\mathcal{U}_{NS,0}^{\text{sanc}*}$ and $\mathcal{U}_0^* = \lambda \mathcal{U}_{S,0}^* + (1-\lambda)\mathcal{U}_{NS,0}^*$.

[11] The aggregate Foreign welfare gains are calculated by $\Delta_{ss}^* = \exp[(1-\beta)(\mathcal{U}_{201}^{\text{sanc}*} - \mathcal{U}_0^*)] - 1$, where $\mathcal{U}_{201}^{\text{sanc}*} = \lambda \mathcal{U}_{S,201}^{\text{sanc}*} + (1-\lambda)\mathcal{U}_{NS,201}^{\text{sanc}*}$ and $\mathcal{U}_0^* = \lambda \mathcal{U}_{S,0}^* + (1-\lambda)\mathcal{U}_{NS,0}^*$.

Table 1: The welfare effects of sanctions

		(1) Benchmark	(2)	(3) Long-run zero foreign assets	(4)	(5) No comparative advantages	(6)	(7) Symmetric countries	(8)
		Panel A. Benchmark and counterfactual exercises							
		Home	Foreign	Home	Foreign	Home	Foreign	Home	Foreign
Non-domestic issued bond holdings (steady-state)									
without financial sanctions		3	5	0	0	3	5	0	0
with financial sanctions		$3(1-\lambda)$	$5(1-\lambda)$	0	0	$3(1-\lambda)$	$5(1-\lambda)$	0	0
Productivity level	C-goods	1.5	1	1.5	1	1.25	1.25	1.25	1.25
	Commodity	1	1.5	1	1.5	1.25	1.25	1.25	1.25
		Panel B. Change in welfare after sanctions (%, initial consumption)							
Type of sanctions	Household	Δ	$[\Delta_{ss}]$	Δ	$[\Delta_{ss}]$	Δ	$[\Delta_{ss}]$	Δ	$[\Delta_{ss}]$
Commodity trade	Home	-2.57	$[-2.74]$	-2.55	$[-2.72]$	-0.39	$[-0.39]$	-0.39	$[-0.39]$
	Foreign	-0.70	$[-0.47]$	-0.73	$[-0.49]$	-0.39	$[-0.39]$	-0.39	$[-0.39]$
C-good export	Home	-3.15	$[-3.49]$	-3.22	$[-3.55]$	-3.60	$[-3.96]$	-3.66	$[-4.00]$
	Foreign	-4.25	$[-4.08]$	-4.09	$[-3.94]$	-2.86	$[-2.72]$	-2.75	$[-2.63]$
C-good import	Home	-1.78	$[-1.68]$	-1.71	$[-1.62]$	-2.85	$[-2.72]$	-2.75	$[-2.63]$
	Foreign	-3.97	$[-4.34]$	-4.13	$[-4.49]$	-3.50	$[-3.84]$	-3.66	$[-4.00]$
C-good trade	Home	-4.46	$[-4.62]$	-4.46	$[-4.62]$	-5.76	$[-5.89]$	-5.71	$[-5.84]$
	Foreign	-7.28	$[-7.36]$	-7.26	$[-7.36]$	-5.67	$[-5.79]$	-5.71	$[-5.84]$
Financial	Home	$+1.02$	$[+0.34]$	0	[0]	$+1.26$	$[+0.48]$	0	[0]
	Foreign	-1.57	$[-0.50]$	0	[0]	-1.30	$[-0.48]$	0	[0]
	Sanctioned	-2.31	$[-0.56]$	0	[0]	-2.05	$[-0.53]$	0	[0]
	Unsanctioned	$+5.35$	[0]	0	[0]	$+5.70$	$[+0.01]$	0	[0]
Commodity trade	Home	-1.56	$[-2.40]$	-2.55	$[-2.72]$	$+0.87$	$[+0.09]$	-0.39	$[-0.39]$
+ Financial	Foreign	-2.29	$[-0.99]$	-0.73	$[-0.49]$	-1.68	$[-0.87]$	-0.39	$[-0.39]$
	Sanctioned	-3.03	$[-1.05]$	-0.74	$[-0.49]$	-2.42	$[-0.92]$	-0.39	$[-0.39]$
	Unsanctioned	$+4.58$	$[-0.45]$	-0.70	$[-0.49]$	$+5.23$	$[-0.38]$	-0.39	$[-0.39]$
C-good trade	Home	-3.42	$[-4.30]$	-4.46	$[-4.62]$	-4.47	$[-5.39]$	-5.71	$[-5.84]$
+ Financial	Foreign	-8.82	$[-7.83]$	-7.26	$[-7.36]$	-7.00	$[-6.28]$	-5.71	$[-5.84]$
	Sanctioned	-9.46	$[-7.88]$	-7.27	$[-7.36]$	-7.71	$[-6.34]$	-5.71	$[-5.84]$
	Unsanctioned	-2.54	$[-7.38]$	-7.25	$[-7.36]$	-0.34	$[-5.80]$	-5.71	$[-5.84]$
Commodity trade	Home	-5.92	$[-6.90]$	-6.92	$[-7.21]$	-4.85	$[-5.77]$	-6.08	$[-6.21]$
+ C-good trade	Foreign	-9.41	$[-8.24]$	-7.87	$[-7.78]$	-7.35	$[-6.65]$	-6.08	$[-6.21]$
+ Financial	Sanctioned	-10.10	$[-8.30]$	-7.88	$[-7.78]$	-8.06	$[-6.70]$	-6.08	$[-6.21]$
	Unsanctioned	-2.96	$[-7.74]$	-7.85	$[-7.78]$	-0.72	$[-6.17]$	-6.08	$[-6.21]$

Notes: The table reports the welfare (lifetime utility) gains of sanctions in terms of initial consumption, Δ in equation (18). In brackets, we report the welfare gains of sanctions through comparative statistics (ignoring transition paths) between the initial and terminal points ($t = 0$ and $t = 201$), Δ_{ss} in equation (19). The Foreign (aggregate) welfare gains are calculated from the weighted sum of financially sanctioned and unsanctioned Foreign households' welfare.

identical productivity levels across countries, $Z_t^Y = Z_t^{Y*} = 1.25$ and $Z_t^G = Z_t^{G*} = 1.25$, and 3) symmetric countries with zero initial bond holdings and identical productivities.

The first part of Panel B reports the welfare gains in response to individual sanctions. Both consumption goods export and import sanctions lead to more pronounced welfare losses in Foreign than in Home. commodity trade sanctions, while causing more significant welfare losses in Home compared to Foreign, have a smaller quantitative impact than consumption-good trade sanctions. Notably, financial sanctions generate a small but positive welfare gain in Home due to wealth effects arising from the transition from a negative NFA position to having no external debt.

As discussed in the previous section, the economies' rebalancing toward different sectors plays a crucial role in the effect of sanctions. Table 1 shows that sanctioning the comparative disadvantage sector (consumption goods) in Foreign results in more significant welfare losses in Foreign compared to Home because the Foreign economy must reallocate resources towards this sector. Conversely, under sanctions on the comparative advantage sector (intermediate goods, commodity) in Foreign, Home welfare losses are significantly higher than Foreign. The comparison between the benchmark and counterfactual economies (Columns 1–2 and 5–6) shows that comparative advantages create significant heterogeneity in the welfare losses across countries and amplify the welfare effects of sanctions. For example, when all sanctions are introduced, the benchmark economy's welfare losses are larger in both Home and Foreign than in the counterfactual economies without comparative advantages: –5.92 and –9.41% in Column (1) vs. –4.85 and –7.35% in Column (5).

The differences between the benchmark and counterfactual economies (Columns 1–2 and 3–4) reveal the role of foreign asset holdings in the welfare effects of sanctions. The initial international asset position has a limited role in the welfare effects of individual sanctions on commodity and consumption-good trade. By the design of financial sanctions, Foreign's positive NFAs lead to positive but negative welfare gains for Home and Foreign, respectively, through wealth effects. Under combined sanctions, the differences between the benchmark and counterfactual economies with zero foreign assets are around 1% and –1.5% in Home and Foreign, respectively, which are similar to the differences observed when only financial sanctions are implemented.

The welfare analysis in Table 1 highlights the importance of considering transition paths when evaluating the effect of sanctions. Comparing Δ and $[\Delta_{ss}]$ reveals that Home welfare losses from the combined sanctions are overvalued, while Foreign welfare losses are undervalued, when transition paths are ignored. These discrepancies arise due to the sluggish convergence of Home consumption to the new steady-states and the short-term sharp decline in Foreign consumption, driven by the

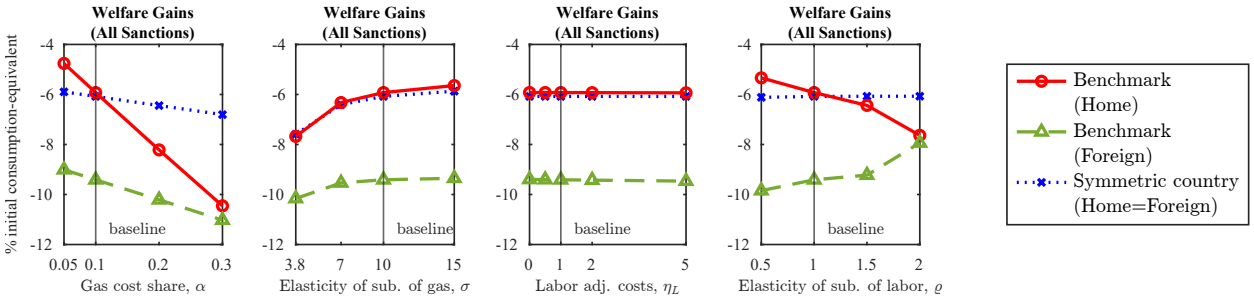

Figure 6: The welfare effects of sanctions with alternative calibrations Notes: The figure plots the welfare (lifetime utility) gains of sanctions in terms of initial consumption, Δ in equation (18), across various parameter values. The Foreign (aggregate) welfare gains are calculated from the weighted sum of financially sanctioned and unsanctioned Foreign households' welfare. The blue lines with circles depict the welfare gains from the symmetric country counterfactual model with zero steady-state international bond holdings and identical productivities ($Z_t^Y = Z_t^{Y*} = Z_t^G = Z_t^{G*} = 1.25$).

loss of income from Home bonds at $t = 1$, as illustrated in Figures 2.

The mismeasurements are even more pronounced when focusing on financially unsanctioned Foreign households. Table 1 shows that comparative statistics between the initial and new steady-states tend to significantly overestimate their welfare losses. For instance, combined commodity trade and financial sanctions lead to welfare gains for unsanctioned households ($\Delta^*_{NS} = 4.58\%$ in Column 1), while the welfare measure without transition paths indicates a decrease ($\Delta^*_{NS,ss} = -0.45\%$ in Column 2). This discrepancy arises because comparative statistics cannot account for short-run advantages through the ability to trade Home and Foreign bonds in domestic and international markets, advantages that diminish in the long run. As shown in Figure 2, unsanctioned Foreign households experience short-run increases in consumption and income but decreases in labor, which are not captured by comparative statistics.

To understand the mechanisms underlying our welfare results and assess their robustness, Figure 6 presents the welfare impacts of sanctions under alternative calibrations. The red lines with circles and green lines with triangles plot Home and Foreign welfare effects when all sanctions are imposed. The blue lines with crosses plot the counterfactual welfare effects of symmetric countries with zero initial bond holdings, resulting in identical Home and Foreign welfare gains.

The first column of Figure 6 demonstrates that input-output linkages amplify the negative welfare effects of sanctions. When the intermediate-good share (α) in consumption-good production increases, both Home and Foreign welfare losses increase, with Home experiencing a more pronounced rise due to its comparative disadvantage in commodity production. This highlights the significant harm caused by the commodity trade ban when intermediates are intensively used

in consumption-good production. The second column shows that the elasticity of substitution (σ) between imported and domestically produced commodities also influences welfare losses. When imported commodity can be more easily replaced by domestic commodity, the welfare losses from commodity trade sanctions are mitigated.

Additionally, we consider different levels of sectoral labor mobility. In this model, sectoral reallocations are the key mechanism in reacting to sanctions. Therefore, the economy's ability to move labor between the consumption-good and intermediate-good sectors determines the level of welfare effects of sanctions. Surprisingly, the third column of Figure 6 indicates that welfare gains do not change quantitatively with short-run labor adjustment costs (η_L). In contrast to the limited impact of the short-run elasticity, the last column reveals that long-run elasticity (ϱ) plays a crucial role. When long-run sectoral mobility increases, Foreign losses decrease, but Home welfare losses surprisingly increase. Under symmetric countries, the absence of comparative advantage leads to limited sectoral reallocations as shown in Figure 5. Consequently, different levels of labor mobility in both the short- and long-run do not generate significant differences, as evidenced by the green lines with triangles in the last two columns of Figure 6.

7. The International Business Cycle

This section investigates how sanctions affect the propagation of shocks and the cyclical comovements between countries. By comparing sanctioned and unsanctioned economies, we aim to uncover the mechanisms through which sanctions alter cross-country resource allocations and comparative advantages, ultimately influencing business cycle fluctuations. Through this lens, we will explore the broader economic interactions that emerge under sanctions, shedding light on their unintended macroeconomic consequences.

7.1. Impulse Responses under Sanctions

In this subsection, we analyze the impulse responses of key model variables to a one-time, transitory home aggregate productivity shock in the consumption-good sector. Specifically, we consider a scenario without international spillovers, ensuring that all comovements are endogenously generated. The productivity shock follows an autoregressive process as specified by $\ln Z_t^Y = 0.01 \ln Z_{ss}^Y + 0.99 \ln Z_{t-1}^Y + e_t$, where Z_{ss}^Y is the steady-state level of Home consumption-good sector productivity. As in the previous section, we set $Z_{ss}^Y = 1.5 = Z_{ss}^{G*}$ and $Z_{ss}^{Y*} = 1 = Z_{ss}^G$.

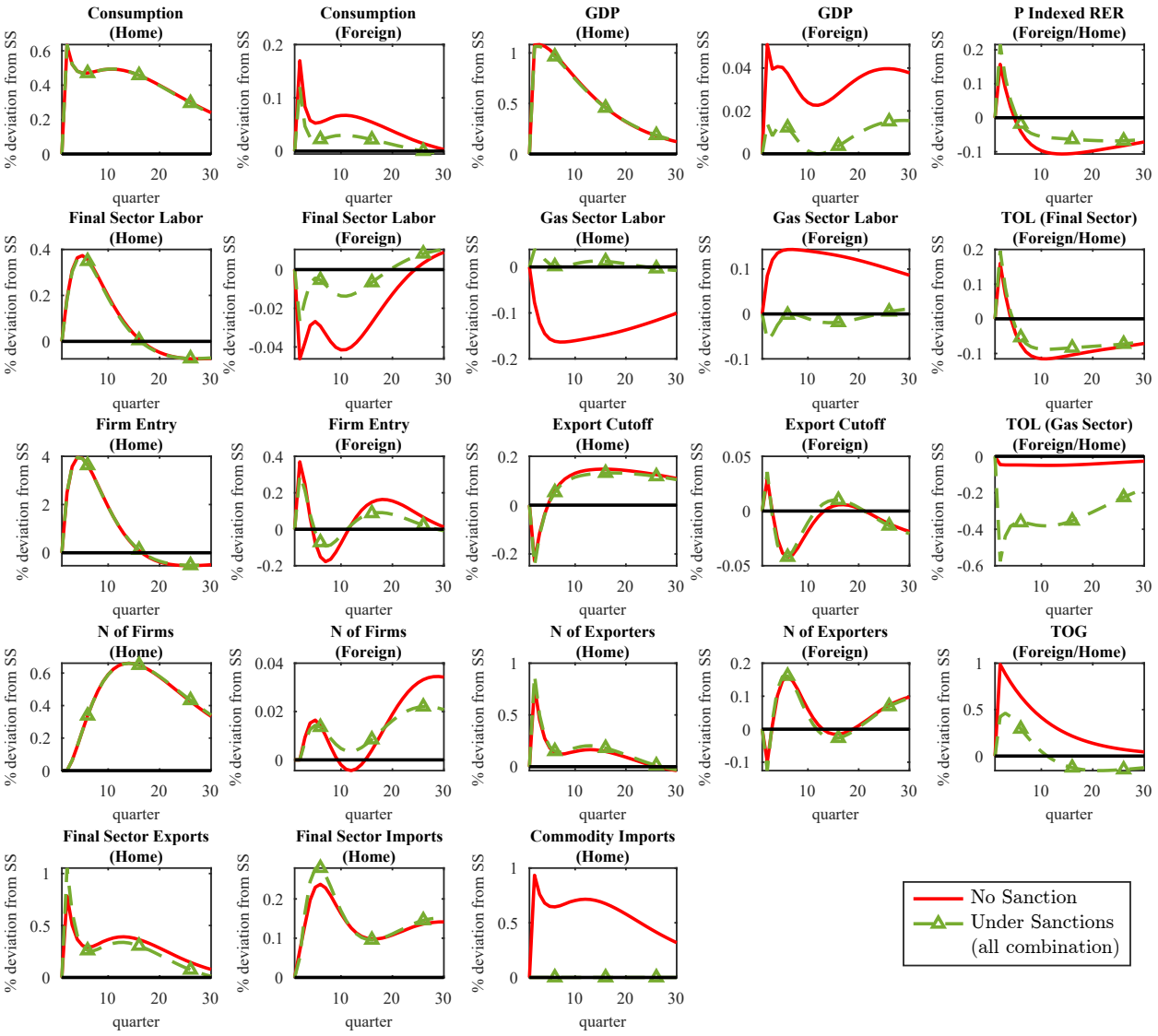

Figure 7: Responses to a 1% productivity shock in Home consumption-good sector Notes: The red solid lines and green dashed lines with triangles represent the unsanctioned and sanctioned model's responses to the productivity shock of the Home consumption-good sector (Z_t^Y) at $t = 1$: 1% increase in the shock innovation with 0.99 autoregressive coefficient. All deviations are expressed in units of percent log difference from the steady-state. All Foreign variables are aggregates.

Figure 7 illustrates the model responses to a 1% productivity shock ($e_1 = 0.01$) in the Home consumption-good sector at time $t = 1$. Sanctions act by disrupting the efficient allocation of resources between countries, primarily through restrictions on trade and asset flows. These disruptions are captured in the model through labor adjustments, both within and across sectors, and are reflected in the impulse response functions presented in the figure. The solid red lines and green lines with triangles plot the impulse responses of the unsanctioned and sanctioned economies (all sanctions), respectively. Notably, the two lines are indistinguishable in the Home consumption-good sector, Home consumption-good sector labor, firm entry, and export cutoffs. This indicates that sanctions have a limited impact on within-country business cycle properties.

While sanctions do not meaningfully affect within-country variables, they significantly mitigate Foreign responses to the Home favorable shock. In the absence of sanctions, comparative advantages create cross-country comovements and within-country labor allocations across sectors. The shock leads Home and Foreign to concentrate in the consumption- and intermediate-good sectors, as illustrated by the red lines in labor variables. Also, the demand for intermediates rises due to increased consumption, which moderates price fluctuations and promotes commodity imports.

Sanctions, on the other hand, suppress these reallocation channels between- and within-country, mitigating international comovements, labor reallocations, and boosting the Home intermediate-good price. Consequently, sanctions isolate economies, dampening Foreign consumption and GDP increases and leading to higher Home intermediate price during a Home boom.

7.2. The Business Cycle Properties under Sanctions

This subsection presents the international business cycle properties of the model with and without sanctions. For simulation, we define data-consistent variables using CPIs (i.e., price-indexed variables) as in Ghironi and Melitz (2005). The data-constant variable of x_t is defined as $x_{R,t} = (1/N_t)^{1/(\theta-1)} x_t$. To calculate model-generated moments, we use HP filtered variables with a smoothing parameter of 1,600.

Recent open economy macro studies have documented a highly persistent shock (near unit root) with zero transmission across countries. Following Kim (2021)'s heterogeneous two-sector model calibration, we set the home and foreign industry productivities to follow the AR(1) process

for each industry $i \in \{Y, G\}$:

$$\begin{bmatrix} \ln Z_t^i - \ln Z_{ss}^i \\ \ln Z_t^{i*} - \ln Z_{ss}^{i*} \end{bmatrix} = \begin{bmatrix} 0.99 & 0 \\ 0 & 0.99 \end{bmatrix} \begin{bmatrix} \ln Z_{t-1}^i - \ln Z_{ss}^i \\ \ln Z_{t-1}^{i*} - \ln Z_{ss}^{i*} \end{bmatrix} + 0.8 \begin{bmatrix} e_t^A \\ e_t^{A*} \end{bmatrix} + 0.2 \begin{bmatrix} e_t^i \\ e_t^{i*} \end{bmatrix}, \quad (20)$$

where there exist aggregate and industry-specific shocks. The home and foreign shock innovations are the sum of aggregate and industry shock innovations with weights 80% and 20%. The shock innovations $\{e_t^A, e_t^{A*}, e_t^Y, e_t^{Y*}, e_t^G, e_t^{G*}\}$ are multi-normally distributed with zero mean and variance-covariance matrix $\mathbf{\Sigma}$:

$$\mathbf{\Sigma} = \sigma_Z^2 \begin{bmatrix} \mathbf{\Sigma}_C & \mathbf{0}_{2\times 4} \\ \mathbf{0}_{4\times 2} & \begin{bmatrix} \mathbf{\Sigma}_C & \mathbf{0}_{2\times 2} \\ \mathbf{0}_{2\times 2} & \mathbf{\Sigma}_C \end{bmatrix} \end{bmatrix} \quad \text{where} \quad \mathbf{\Sigma}_C = \begin{bmatrix} 1 & 0.1 \\ 0.1 & 1 \end{bmatrix}. \quad (21)$$

The aggregate and industry-specific shock innovations are uncorrelated, but we allow 10% cross-country correlation of shock innovations, representing the advanced countries' pairwise correlations of TFP (Ambler, Cardia and Zimmermann 2004). We choose the standard deviations of shock innovations as $\sigma_Z = 0.013$. See Kim (2021) for more discussions.

Table 2 reports the unsanctioned vs. sanctioned model-generated business cycle properties, with the last columns showing the business cycle properties of the symmetric countries model. The results reveal that while the standard deviations of GDP, consumption, investment, and labor are similar across both sanctioned and unsanctioned environments, cross-country correlations drop significantly under sanctions. This suggests that sanctions may not increase volatility in individual economies, but they do reduce economic integration, making the global economy more fragmented.

To understand the mechanisms underlying our welfare results and verify their robustness, we consider different parameter values for intermediate cost share, elasticity of imported and domestic commodities, labor adjustment costs, and elasticity of substitution of labor between two sectors. The first observation is that comparative advantages and international bond holdings play a limited role in shaping the sanctioned economy's business cycle properties. In all subfigures of Figure 8, the benchmark model-generated moments (illustrated by the blue dashed lines with crosses) are indistinguishable from the counterfactuals (illustrated by the blue dashed lines with circles) when all sanctions are imposed.

While sanctioned and unsanctioned economies have similar standard deviations of Home GDP

Table 2: International business cycles

	(1) Data	(2) Model-generated moments	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Benchmark without sanctions		Benchmark with sanctions		Symmetric countries without sanctions		Symmetric countries with sanctions	
Variables		Home	[Foreign]	Home	[Foreign]	Home	[Foreign]	Home	[Foreign]
St. dev. of GDP (%)	1.54	1.63	[1.55]	1.65	[1.61]	1.61	[1.60]	1.64	[1.62]
St. dev. relative to GDP									
Consumption	0.82	0.64	[0.66]	0.65	[0.65]	0.65	[0.65]	0.65	[0.65]
Investment	4.20	3.56	[4.25]	3.42	[3.70]	3.82	[3.84]	3.54	[3.55]
Labor	0.62	0.23	[0.23]	0.21	[0.21]	0.22	[0.22]	0.21	[0.21]
Correlation with GDP									
Consumption	0.86	0.99	[0.99]	0.99	[0.99]	0.99	[0.99]	0.99	[0.99]
Investment	0.91	0.95	[0.92]	0.97	[0.95]	0.94	[0.94]	0.96	[0.96]
Labor	0.81	0.96	[0.96]	0.96	[0.96]	0.96	[0.96]	0.96	[0.96]
Cross-country correlation									
GDP	0.22	0.172		0.118		0.164		0.117	
Consumption	0.14	0.167		0.083		0.132		0.082	

Notes: The table reports the model-generated moments of price-indexed variables consistent with the data. All variables are HP-filtered. Columns (6)–(9) present the model-generated moments with zero steady-state international bond holdings and identical steady-state productivities ($Z^Y_{ss} = Z^{Y*}_{ss} = Z^G_{ss} = Z^{G*}_{ss} = 1.25$). The standard deviations and GDP correlations are from Table F.9 of Kim (2021), and the cross-country correlation data are from the first column of Table 1 in Ambler et al. (2004).

shown in the first row of Figure 8, there are notable differences in their cross-country comovements as discussed in Table 2. The Home and Foreign GDP and consumption more strongly comove together when interemediate goods are more intensively used in consumption-good production. Such increases become smaller when the model has no comparative advantages. This is because the high intermediate-good share (α)—a high degree of input-output linkage—causes more specialization and resource allocations within and between countries. When imported commodity is more easily substitutable to domestic commodity, such specialization and reallocations are less required. Thus, the international comovements shrink with high elasticity (σ) of substitution of imported and domestically-produced commodities. However, this channel is quantitatively small in our simulation exercises.

The last two columns of Figure 8 illustrate the role of sectoral labor mobility in our calibrated model business cycle fluctuations. More flexible labor allocations across sectors lead to stronger cross-country production reallocations toward a more productive economy over the business cycle. This implies increased GDP volatility with a high elasticity (ϱ) of substitution of labor across sectors

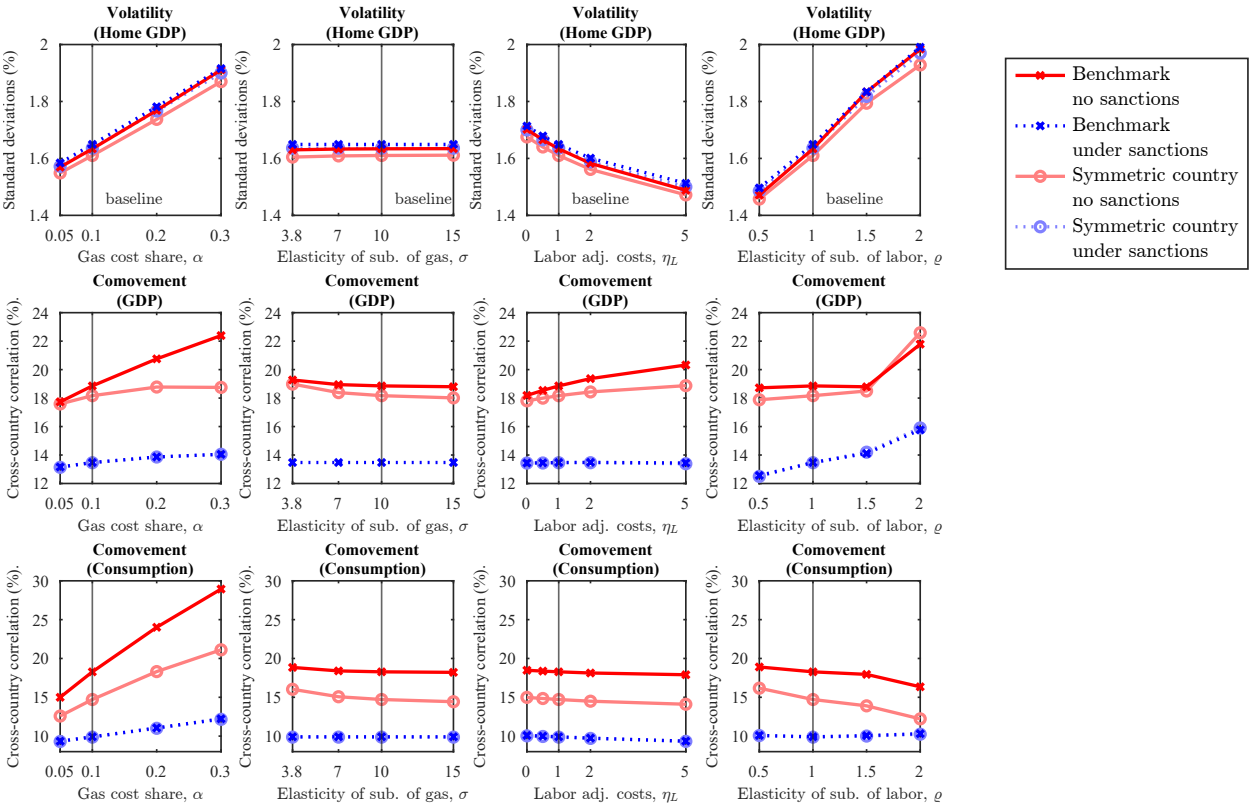

Figure 8: International business cycles with alternative calibrations Notes: The figure plots the model-generated moments of price-indexed variables (consistent with the data) across various parameter values. All variables are HP-filtered. The red and blue lines with circles depict the model-generated moments with zero steady-state international bond holdings and identical steady-state productivities ($Z^Y_{ss} = Z^{Y*}_{ss} = Z^G_{ss} = Z^{G*}_{ss} = 1.25$). The vertical lines represent the baseline calibration values for each parameter. See Appendix Figure A2 for the Foreign GDP volatility.

and low sectoral labor adjustment costs (η_L).

These findings hold important implications for policymakers considering the use of sanctions as an economic tool. While sanctions may achieve their intended geopolitical objectives, they also come with macroeconomic costs in terms of reduced global economic synchronization. While sanctions desynchronize GDP and consumption comovements, they do not significantly alter within-country business cycle properties, particularly standard deviations of consumption and GDP flows. This implies that sanctions would not create additional welfare costs through business cycle fluctuations.

Our findings echo those of previous open macroeconomic studies, which highlight the limited impact of international frictions on within-country volatility. The within-country business cycle properties in Ghironi and Melitz (2005) are similar to those in Bilbiie, Ghironi and Melitz (2012), the closed economy version of Ghironi and Melitz (2005). Additionally, Kim (2021) documents

that adding two sectors with heterogeneous production technologies causes only slight changes in the model's within-country business cycle properties while helping to reproduce the observed cross-country comovements.

8. Conclusions

In this paper, we provided an international trade and macroeconomic framework to study the effects of economic sanctions in an interdependent world economy. Our analysis focused on how sanctions operate and propagate, and their effects on relative prices, standard macroeconomic indicators, and welfare. A key feature of our framework is the treatment of sanctions as exclusion of households and/or firms from international financial and goods markets, distinguishing it from models that treat sanctions as tariff increases, and in which the adjustment to sanctions takes place primarily along the intensive margin of existing trade relationships.

The transmission of sanctions (imposed by Home on Foreign) in our model emphasizes extensive margin effects and firm heterogeneity. For instance, when sanctions prevent the highest-productivity final-sector Home firms from exporting to Foreign, Home becomes a less attractive environment for firm entry into the final sector relative to the pre-sanction world. Final-sector entry shifts toward Foreign, and the relative cost of effective Home final-sector labor decreases, leading to Home real exchange rate depreciation. This is amplified by the increase in the average price of imports faced by Foreign consumers as a consequence of forced market exit of the most productive Home exporters, and by the effect of higher Foreign demand of domestically produced goods. In contrast, commodity-trade sanctions, which block trade in those goods, cause the Home real exchange rate to appreciate. This occurs because commodity-trade sanctions force Home to reallocate resources (labor) toward commodity production and Foreign toward final-good production. The number of Foreign final-good exporters increases, but their average productivity decreases, which pushes up the average price of Home imports. Most important, the price of intermediate goods in Home rises substantially relative to Foreign, and this dominates all other effects in determining Home real exchange rate appreciation. These examples demonstrate why the exchange rate is not a reliable measure of the effectiveness of sanctions: it may depreciate or appreciate depending on the nature of the sanction and the resource reallocations that follow.

Our welfare analysis reveals that sanctions on consumption-good trade lead to the largest welfare losses for the targeted economy, as they compel a shift toward the less efficient production

sector, where the country is at a comparative disadvantage. Counterfactual exercises demonstrate that comparative advantage is key to shaping the welfare effects of sanctions on trade of commodities or final-sector goods, while initial foreign asset positions are key to the welfare effects of financial sanctions. Additionally, accounting for transition paths is crucial in accurately assessing welfare effects in both sanctioning and sanctioned economies.

When analyzing the effects of sanctions on business cycle fluctuations, we find that sanctions reduce international business cycle comovement by restricting international trade in goods and assets. However, their impact on within-country business cycles is small. Both Home and Foreign exhibit similar volatility and cyclicality of key macroeconomic variables in the pre- and post-sanction scenarios. This suggests that, at least in our model, sanctions do not have large welfare effects through their impact on business cycles.

As the literature that followed Ghironi and Melitz (2005) demonstrates, our framework is easily amenable to extensions in several directions, and thus it opens several promising avenues for future research. We explored one—third-country effects—in Ghironi et al. (2024). Others include optimal determination of sanctions by the governments of sanctioning countries and of responses by the governments of targeted economies; the effects of sanctions on the budgets of targeted-country governments, particularly when fiscal revenues are highly dependent on international trade, and how these governments can use fiscal policy to ameliorate the effects of sanctions; finally, the roles of central banks once the model is extended to incorporate nominal rigidity. Currency appreciation may seem attractive to monetary policymakers in sanctioning countries, particularly if sanctions end up causing inflation, yet the same events that prompt governments to impose sanctions could trigger economic downturns that call for expansionary monetary responses.[12] These topics present intriguing questions that we will explore in our future work.

[12] Long-lasting sanctions may also affect neutral interest rates, further complicating policy decisions.

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Appendix

A. The Rest of the Model

A.1. Household Budget Constraint, Asset Holding, and Labor Supply Decisions

International financial markets are incomplete, as only non-contingent, riskless real bonds are traded internationally. The representative household in the Home country holds domestic bonds (denoted by $B_{H,t}$) and earns the risk-free real interest rate (r_t) on them during period t. They also hold foreign real bonds ($B^*_{H,t}$) denominated in foreign consumption units and pay the foreign risk-free real interest rate (r^*_t), in which Foreign bonds and interest rate are in units of Foreign consumption. We assume that domestic firms are fully owned by domestic households. Specifically, the household enters period t with holdings (x_t) in a mutual fund representing all $N_{D,t}$ domestic producing firms. During period t, they receive dividends ($\tilde{d}_t$ per share) and can sell their entire shareholding at the price of $\tilde{v}_t$ per share. The household incurs quadratic adjustment costs for holding domestic and foreign bonds and shares. These costs are denoted by $0.5\eta(B_{H,t+1} - B_H)^2$, $0.5\eta Q_t(B^*_{H,t+1} - B^*_H)^2$, and $0.5\eta\tilde{v}_t N_t(x_{t+1} - 1)^2$, where η is a positive parameter.

In addition to income from financial assets, the household's resources in period t include labor income from the consumption-good and intermediate-good sectors ($w^Y_t L^Y_t$ and $w^G_t L^G_t$). Then, the budget constraint of the representative Home household is:

$$\begin{aligned} C_t + B_{H,t+1} + Q_t B^*_{H,t+1} + \tilde{v}_t N_t x_{t+1} + 0.5\eta\big[(B_{H,t+1} - B_H)^2 + Q_t(B^*_{H,t+1} - B^*_H)^2 + \tilde{v}_t N_t(x_{t+1} - 1)^2\big] \\ = (1 + r_t)B_{H,t} + Q_t(1 + r^*_t)B^*_{H,t} + (\tilde{d}_t + \tilde{v}_t)N_{D,t}x_t + w^Y_t L^Y_t + w^G_t L^G_t - \text{Ladj}_t(L^Y_t, L^G_t) + T_t. \end{aligned} \tag{A1}$$

where the adjustment costs transfer to the household, $T_t = 0.5\eta(B_{H,t+1} - B_H)^2 + 0.5\eta Q_t(B^*_{H,t+1} - B^*_H)^2 + 0.5\eta\tilde{v}_t N_t(x_{t+1} - 1)^2 + \text{Ladj}_t(L^Y_t, L^G_t)$.

The intertemporal decision rules for home and foreign bonds and share holdings are

$$1 + \eta(B_{H,t+1} - B_H) = \beta\mathbb{E}_t\left[\mathcal{M}_{t,t+1}\right](1 + r_{t+1}), \tag{A2}$$

$$1 + \eta(B^*_{H,t+1} - B^*_H) = \beta\mathbb{E}_t\left[\mathcal{M}_{t,t+1}\frac{Q_{t+1}}{Q_t}\right](1 + r^*_{t+1}), \tag{A3}$$

$$\tilde{v}_t[1 + \eta(x_{t+1} - 1)] = \beta(1 - \delta)\mathbb{E}_t\left[\mathcal{M}_{t,t+1}(\tilde{v}_{t+1} + \tilde{d}_{t+1})\right], \tag{A4}$$

where the discount factor is $\mathcal{M}_{t,t+1} = (C_{t+1}/C_t)^{-1}$. The decision rules for labor supply to the consumption-good and intermediate-good sectors are

$$\frac{w_t^Y}{C_t} = \frac{\kappa\gamma^{\frac{1}{\varrho}} L_t^{1-\frac{1}{\varrho}} (L_t^Y)^{\frac{1}{\varrho}}}{1-\eta_L(L_t^Y/S_t^Y-1)} \quad \text{and} \quad \frac{w_t^G}{C_t} = \frac{\kappa(1-\gamma)^{\frac{1}{\varrho}} L_t^{1-\frac{1}{\varrho}} (L_t^G)^{\frac{1}{\varrho}}}{1-\eta_L(L_t^G/S_t^G-1)}. \tag{A5}$$

A.2. Market Clearing and Aggregate Accounting

In the intermediate-good sector, the market clearing condition for Home commodity is

$$Z_t^G L_t^G = G_{R,t} = G_{D,t} + G_{X,t} = \left[\rho_t^G/(w_t^G/Z_t^G)\right]^\sigma G_t + \tau_{G,t}^{1-\sigma}\left[Q_t\rho_t^{G*}/(w_t^G/Z_t^G)\right]^\sigma G_t^*, \tag{A6}$$

where the equilibrium price $\rho_{R,t}^G = w_t^G/Z_t^G$. The market clearing condition for Home intermediate good (usable gas) is

$$\rho_t^G G_t = \alpha(\theta-1)\left[N_{D,t}\tilde{d}_t + N_{X,t}(w_t^Y f_{X,t}/Z_t^Y)\right]. \tag{A7}$$

The consumption-good sector's labor demand is

$$L_t^Y = (1-\alpha)(\theta-1)\left[N_{D,t}(\tilde{d}_t/w_t^Y) + N_{X,t}(f_{X,t}/Z_t^Y)\right] + N_{X,t}(f_{X,t}/Z_t^Y) + N_{E,t}(f_{E,t}/Z_t^Y), \tag{A8}$$

which equals to the labor supply (equation A5) in equilibrium. The consumption goods market clearing is

$$C_t = \theta\left[N_{D,t}\tilde{d}_t + N_{X,t}(w_t^Y f_{X,t}/Z_t^Y)\right]. \tag{A9}$$

Market clearing for bonds issued by Home requires $B_{H,t+1} + B_{F,t+1} = B_{H,t} + B_{F,t} = 0$ in every period, and for bonds issued by Foreign: $B_{H,t+1}^* + B_{F,t+1}^* = B_{H,t}^* + B_{F,t}^* = 0$ in every period. Stock market clearing in each country requires $x_{t+1} = x_t = 1$ and $x_{t+1}^* = x_t^* = 1$ in every period. Since costs of adjusting bond holdings away from zero are rebated back to households in equilibrium, imposing equilibrium conditions on the household budget constraint yields:

$$C_t + \tilde{v}_t N_{E,t} + B_{H,t+1} + Q_t B_{H,t+1}^* = (1+r_t)B_{H,t} + Q_t(1+r_t^*)B_{H,t}^* + GDP_t, \tag{A10}$$

where we define GDP by the total Home income from labor and dividends $GDP_t = w_t^G L_t^G +$

$w_t^Y L_t^Y + N_{D,t}\tilde{d}_t$. The budget constraints of Home and Foreign households together, and bond market equilibrium, imply that Home foreign assets obey the law of motion:

$$\begin{aligned} B_{H,t+1} + Q_t B^*_{H,t+1} =& (1+r_t)B_{H,t} + Q_t(1+r^*_t)B^*_{H,t} \\ &+ 0.5\big[(GDP_t - Q_t GDP^*_t) - (C_t - Q_t C^*_t) - (\tilde{v}_t N_{E,t} - Q_t \tilde{v}^*_t N^*_{E,t})\big]. \end{aligned} \tag{A11}$$

Home's current account is determined by:

$$CA_t \equiv B_{H,t+1} + Q_t B^*_{H,t+1} - (B_{H,t} + Q_t B^*_{H,t}) = r_t B_{H,t} + Q_t r^*_t B^*_{H,t} + TB_t, \tag{A12}$$

where TB_t is the trade balance:

$$TB_t = 0.5\big[(GDP_t - Q_t GDP^*_t) - (C_t - Q_t C^*_t) - (\tilde{v}_t N_{E,t} - Q_t \tilde{v}^*_t N^*_{E,t})\big]. \tag{A13}$$

Home and Foreign current accounts and trade balances are such that

$$CA_t + Q_t CA^*_t = TB_t + Q_t TB^*_t = 0. \tag{A14}$$

B. Additional Figures and Tables

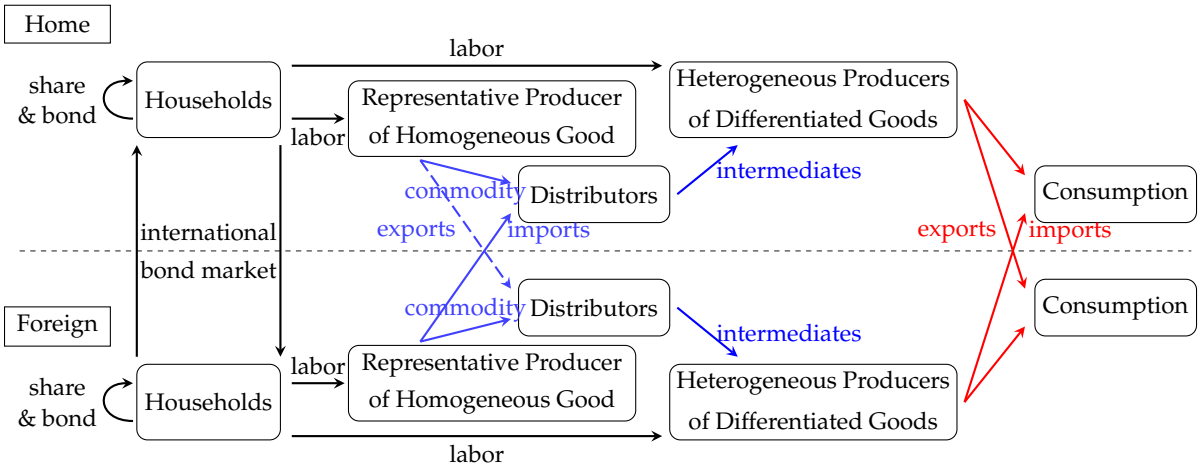

Figure A1: Model architecture

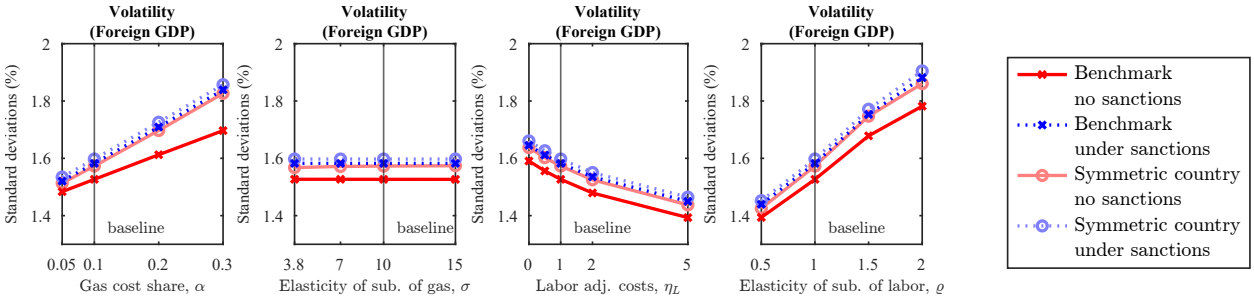

Figure A2: Foreign GDP volatility with alternative calibrations Notes: The figure plots the model-generated moments of price-indexed variables (consistent with the data) across various parameter values. All variables are HP-filtered. The red and blue lines with circles depict the model-generated moments with zero steady-state international bond holdings and identical steady-state productivities ($Z^Y_{ss} = Z^{Y*}_{ss} = Z^G_{ss} = Z^{G*}_{ss} = 1.25$).