The Long-Run Effects of Russian Sanctions*

Joao Monteiro†

April 2023

Abstract

In this paper, I consider the effects of tariffs on Russian imports imposed by a coalition of countries. I find that a 10 percentage point increase in tariffs is enough to yield large drops in Russian exports to coalition countries which are not offset by an increase in Russian exports to other countries. This increase in tariffs also leads to a recession in Russia, with a drop in nominal wages and factor prices. Tariffs lead to a drop in Russian welfare, which is mostly driven by a worsening of Russian terms-of-trade as the price of Russian exports falls. There are no discernible welfare losses for coalition countries. I also show that imposing a higher cost of exports to Russia leads to larger drops in Russian welfare, at the cost of more significant welfare losses for coalition countries. Therefore, coalition countries face a trade-off between maximizing welfare losses for Russian and minimizing welfare losses at home.

*I thank Effi Benmelech, Marty Eichenbaum, Joao Guerreiro, Laura Murphy, and Dimitris Papanikolaou for helpful comments and discussions.

†Kellogg School of Management, Northwestern University; joao.monteiro@kellogg.northwestern.edu.

1 Introduction

The Russian invasion of Ukraine and the desire of NATO countries to impose trade sanctions on Russia has led to a discussion on how best to design these sanctions. In this paper, I approach this question through the lens of a multi-country multi-sector Ricardian trade model.

I consider a standard Ricardian trade model with many countries and many sectors like in Caliendo and Parro (2015). Each country has a representative household that consumes only domestically produced goods and supplies labor inelastically. This household has two sources of income: labor income and a lump-sum transfer from the government. This transfer corresponds to the revenue governments earn from tariffs on imports. In each sector, there is a continuum of firms producing intermediate goods and a representative producer of a composite good. Producers of intermediate goods use labor and domestically produced composite goods from all sectors in their production. Therefore, the model features a network structure which will generate amplification of the effects of trade shocks. Producers of composite goods use intermediate goods from the same sector. However, they may import intermediate goods from abroad.

In this economy, free trade is beneficial because firms are able to purchase cheaper inputs from abroad. Therefore, a decrease in the cost of trade is beneficial because it reduces marginal costs. However, trade is costly in this model. There are two costs of trade: tariffs on imports, which are rebated to households as a lump-sum transfer, and classic iceberg "melting" costs which are pure deadweight losses. I also assume that, for all countries, aggregate exports must equal aggregate imports and so trade deficits are zero.

In this model, the natural measure of welfare is real household income, which is identical to real consumption. This measure is the sum of two components: (1) a terms-of-trade effect and (2) a volume of trade effect. An improvement in terms of trade (an increase in the price of exports relative to the price of imports) increases welfare as, for the same level of exports, the country can now purchase more imports. An increase in imports (volume of trade) also yields welfare gains because it means an abundance of cheaper inputs for production and an increase in domestic tariff revenues.

I then use this model to evaluate the impact of an increase in tariffs on Russian imports. I assume that there is a coalition of countries which is strictly smaller than the full set of countries in the world. This coalition includes all E.U. countries as well as the U.S., the U.K., Canada, Turkey, Australia, Norway, Japan, South Korea and New Zealand. This coalition seeks to impose uniform tariffs on Russian imports. Therefore, all countries will impose the same tariffs and tariffs will be identical for all sectors. These two assumptions greatly simplify the analysis. In my baseline exercise, tariffs on Russian imports increase by 10 percentage points.

The increase in tariffs has very significant effects on the volume of trade. Total Russian exports decrease by around 10% in response to these sanctions. Russian exports to coalition countries fall by much more. For example, German imports of Russian goods decrease by over 55% and Italian imports of Russian goods decrease by more than 60%. There is some heterogeneity across coalition countries in terms of the reduction in imports. This heterogeneity is explained by the types of products each country imports from Russia - countries importing products with a higher trade elasticity will observe a larger decline in imports from Russia.

Russian exports to non-coalition countries increase. However, this increase is not enough to fully offset the impact of tariffs. Therefore, it is not true that, even in the long-run, Russia can simply shift its exports to other countries. This increase is also a consequence of tariffs. As coalition countries impose tariffs on Russia, demand for Russian exports declines. As a consequence, domestic demand in Russia for labor and other factors of production declines, which leads to a decline in the wage and factor prices. This leads to a decrease in marginal costs, which stimulates Russian exports. Therefore, the rise in Russian exports to non-coalition countries comes from the fact that tariffs lead to a decline in wages.

I then turn to an analysis of the impact of tariffs in welfare. First, I show that, for coalition countries, the imposition of tariffs reduces sectoral TFP (gains from trade). This decrease is larger in sectors that were very dependent on Russian imports. Therefore, one the first consequences of tariffs on coalition countries is a drop in aggregate productivity. For example, Hungary exhibits a 0.17% drop in aggregate TFP as a consequence of the imposition of tariffs. However, this drop in aggregate TFP is fully offset by the increase in tariff revenue. For example, the Netherlands display a 0.19% drop in aggregate TFP but a 0.01% increase in welfare.

Russia suffers significant welfare losses as a result of tariffs. With a 10 percentage increase in tariffs on Russian imports, Russia displays a welfare loss of 0.31%. My measure of welfare is real household income and so this can be interpreted as a 0.31% drop in real consumption for Russian households. I can decompose this change in welfare into a terms-of-trade effect and a volume of trade effect. Most of the drop in welfare (around 60%) is driven by a decrease in terms of trade as the price of Russian exports falls due to the fall in the Russian nominal wage and factor prices. The remaining effect is driven by the drop in imports. As Russian exports fall due to the tariffs, Russian imports must also decrease in order to verify the balanced trade condition. This decrease means that Russia must rely more on more expensive inputs for production and suffers a loss in tariff revenue.

The effect on the volume of trade is perhaps the most immediate when thinking about tariffs. However, the effects on terms of trade turn out to be the most important. The imposition of tariffs harm the Russian economy because it leads to a drop in demand for domestic factors which then leads to a drop in the price of exports. By imposing tariffs on Russia, coalition countries force it to export more to other countries at lower prices. This insight means that, in the long-run, we should expect to see an increase in Russian exports to other countries. However, that increase requires Russia to sell its exports at a lower price.

I then turn to an analysis of the importance of the size of the coalition. I compare tariffs imposed by a large coalition of countries with tariffs imposed by a single country (Germany). I find that a large coalition is always more effective and more beneficial. When a single country imposes tariffs on Russia, it is possible that Russian welfare actually increases because its terms of trade may improve. Russian terms of trade improve because the imposition of tariffs harms the German economy more due to the ease with which Russian can export to other countries. Therefore, the price of German exports decrease and so does the price of Russian imports. Therefore, it is better to have a large coalition imposing tariffs than a small coalition. Moreover, with a large coalition, coalition members may exhibit welfare gains due to the increase in income generated by the tariffs.

With a large coalition, a larger increase in tariffs will yield a larger drop in Russian welfare with no discernible effect on coalition welfare. Therefore, if the goal of the coalition is to maximize economic hardship for the Russian economy conditional on an acceptable welfare loss for coalition countries, the optimal level of tariffs is possibly unboundedly large. As tariffs increase, Russian welfare decreases at a decreasing rate whereas coalition welfare is flat.

I also consider the possibility that a large coalition imposes tariffs on all products but oil and gas. This is particularly relevant due to the reluctance of some European countries to impose tariff on energy products. I find that, under these new tariffs, Russian exhibits much smaller welfare losses (0.05% which is less that one fifth of the losses under uniform tariffs) and its real wage increases. The difference is mostly driven by terms of trade. Russian terms of trade improve under this new set of tariffs and most of its exports are oil and gas and demand for these is mostly unaffected. Moreover, welfare changes are not very different for coalition countries when compared with the case where tariffs uniform. Therefore, it is always better to impose tariffs on all products than to exclude oil and gas.

This model does not feature any adjustment frictions or nominal/real rigidities. There is no market power and so prices equal marginal costs. Therefore, the model is suited to understand the impact of tariffs on a long-run version of the economy. In order to simulate a short-run version of this economy, I will consider an equilibrium in which trade elasticities are low. This insight follows from well-known Le Chatelier principle, which states that short-run elasticities are smaller than long-run elasticities, and from the empirical findings in Boehm et al. (2020). I define the short run as an economy in which elasticities are low. In the short run, it is possible that Russia may display welfare gains in response to tariffs as its terms-of-trade improve. This effect is larger the smaller are the tariffs. Therefore, if policymakers are concerned that in the short run tariffs might be relatively more harmful for coalition countries than they are for Russia, it is better to impose larger sanctions. With large sanctions, the terms of trade effect is always negative, even in the very short run, and so the Russian economy always displays large welfare losses.

I also consider an alternative type of sanction, in which coalition countries make their exports to Russia more expensive. I model this increase as an increase in iceberg costs. Under these sanctions, coalition exports to Russia decline and, despite the fact that exports from non-coalition countries to Russia increase, Russian imports decline. For a 10 percentage point increase in iceberg costs, Russian imports decline by almost 10 percent.

This type of sanction has similarly size effects on trade flows but imposes much larger welfare losses on the Russian economy. I find that Russian real household income declines by over 1 percent for a 10 percentage point increase in iceberg costs. However, this higher effectiveness of sanctions comes with a cost as welfare losses for coalition countries are also larger. This finding suggest that coalition countries face an important trade-off: if their goal is to maximize the damage to the Russian economy, they should choose to impose sanctions on exports. If they wish to minimize welfare losses in their own economies, they should choose tariffs on imports.

In Section 2, I describe the structure of the model. Section 3 describes the consequences of tariffs on Russia. Section 4 considers an alternative method of sanctions, where coalition countries increase the cost of their exports to Russia. Section 5 concludes.

1.1 Related literature

This paper is related to a literature on the effects of tariffs on trade, and on welfare. Since the seminal work of Eaton and Kortum (2002), there has been a large of body of research devoted to using Ricardian models of trade to understand the effect of tariffs on welfare. Recently, Caliendo and Parro (2015) have used a multi-sector multi-country Ricardian trade model to evaluate the effects of NAFTA on the U.S., Canada and Mexico. They find significant welfare gains.

This paper also related to a fast growing literature which focuses on the imposition of sanctions on Russia. For example, Bachmann et al. (2022) study the possible impacts of a complete cut-off of the Germany economy from Russian energy imports. They find that the effects, while substantial, are manageable. In related work, Sturm et al. (2022) study the design on optimal tariffs on Russian energy imports. They rely on insights in Sturm (2022), who shows that tariffs and other types of sanctions can be viewed as case of terms-of-trade manipulation. In a more general setting, Baqaee et al. (2022) study the general equilibrium consequences of a stop of energy imports on the E.U. .

2 Model

In this Section, I will write a Ricardian trade model in the spirit of Caliendo and Parro (2015) to evaluate the impact of tariffs on Russia. I will consider a model with many countries and many sectors. A subset of countries, which I will call the coalition, will impose tariffs on imports from Russia. For simplicity, I will assume that the coalition will consider only uniform tariffs, i.e. tariffs that are identical for all products and countries.

2.1 Model setup

The model is static. There are N countries indexed by either n or i and, within each country, there are J sectors indexed by j or k. Throughout the description of the model, subscripts will always denote countries and superscripts will always denote sectors. In this model, trade exists because firms want to purchase the cheapest inputs for production. Households will not consume foreign goods. There are two types of goods within each sector: composite goods and intermediate goods. Composite goods use intermediates from their sector in their production and are nontradable. Producers of composite goods may import intermediates. Intermediate goods use domestic composite goods from all sectors and labor in production and may be tradable.

2.1.1 Households and preferences

In each country, there is a representative household with preferences

$$U\left(C_n\right) = C_n = \prod_{j=1}^{J} \left(C_n^j\right)^{\alpha_n^j}, \quad \sum_{j=1}^{J} \alpha_n^j = 1,$$

where C_n^j is the consumption of sector j composite goods by the representative household and C_n is aggregate consumption. The share parameters $\alpha_n^j \geq 0$ may vary by country and, from the Cobb-Douglas assumption, will capture the share of expenditure by the representative household one each sector. The household only consumes domestic goods, i.e. C_n^j is produced domestically. Therefore, I am abstracting from love-of-variety causes of international trade (Krugman (1979), Melitz (2003)). Given this structure, the domestic CPI is given by

$$P_n = \prod_{j=1}^{J} \left(\frac{P_n^j}{\alpha_n^j}\right)^{\alpha_n^j},$$

where P_n^j is the price of the composite good j in country n.

The household has three sources of income. First, the representative household is endowed with L_n units of labor which it supplies inelastically at a wage w_n.[1] Second, the household receives a lump-sum transfer from the government with the proceeds from tariffs imposed on imports. Third, the household also receives transfers from the rest of the world in the form of trade deficits.[2]

[1] I am therefore assuming that there is free labor mobility across sectors within a particular country but that there is no labor mobility across countries.

[2] In this model, national trade deficits will be exogenous. Therefore, I will think of trade deficits as transfers from countries with

2.1.2 Production

Intermediate goods: in each sector-country (j, n) there is a continuum of intermediate goods $\omega^j \in [0,1]$. Note that this specification implies that the variety ω^j exists in all countries. Production requires two types of factors: labor and materials. Materials are composite goods from all sectors in the country. Therefore, an intermediate producer in country n and sector j may use composite goods from all sectors in country n. Each intermediate producer has a productivity $z_n^j(\omega^j)$. Production takes the form

$$q_n^j\left(\omega^j\right) = z_n^j\left(\omega^j\right)\left(l_n^j\left(\omega^j\right)\right)^{\gamma_n^j}\prod_{k=1}^{J}\left(m_n^{kj}\left(\omega^j\right)\right)^{\gamma_n^{kj}}, \quad \gamma_n^j + \sum_{k=1}^{J}\gamma_n^{kj} = 1$$

where l_n^j is labor and m_n^{kj} is materials from sector k used in production. The parameter $\gamma_n^j \geq 0$ represents the share of value added in production and γ_n^{kj} represents the share of production that is allocated to inputs from sector k. The factors shares and the share of value added are allowed to vary across sectors and countries.

Markets are perfectly competitive and so producers of intermediate goods will price their goods at the marginal cost which is $c_n^j / z_n^j\left(\omega^j\right)$ where

$$c_n^j = \Upsilon_n^j w_n^{\gamma_n^j}\prod_{k=1}^{J}\left(P_n^k\right)^{\gamma_n^{kj}}, \tag{1}$$

and where $\Upsilon_n^j = \left(\gamma_n^j\right)^{-\gamma_n^j}\prod_{k=1}^{J}\left(\gamma_n^{kj}\right)^{-\gamma_n^{kj}}$ is a constant that varies across sectors and countries. I will interpret c_n^j as the unit cost of the production bundle.

Composite goods: producers of composite goods in sector j and country n supply a quantity Q_n^j according to the production function

$$Q_n^j = \left[\int_0^1 \left(h_n^j\left(\omega^j\right)\right)^{1-1/\sigma^j} d\omega^j\right]^{\sigma^j/\left(\sigma^j-1\right)}, \quad \sigma > 0$$

where $\sigma > 0$ is the elasticity of substitution across intermediate goods and $h_n^j\left(\omega^j\right)$ is the demand for intermediate good ω^j by composite good producer j in country n. Cost minimization yields the following demand for intermediates

$$h_n^j\left(\omega^j\right) = \left(\frac{p_n^j\left(\omega^j\right)}{P_n^j}\right)^{-\sigma^j} Q_n^j,$$

where $p_n^j\left(\omega^j\right)$ is the price of the intermediate good and P_n^j is the unit price of the composite good which is given by

$$P_n^j = \left[\int_0^1 \left(p_n^j\left(\omega^j\right)\right)^{1-\sigma^j} d\omega^j\right]^{\frac{1}{1-\sigma^j}}.$$

Producers of composite goods may purchase each intermediate ω^j from any country. I will assume that they will choose the lowest cost supplier.

trade surpluses to countries with trade deficits.

2.1.3 Trade costs and prices

In this model, trade is costly. There are two different costs of trade: (1) iceberg costs, and (2) tariffs. Iceberg costs are standard: delivering one unit one good j from country n to country i requires shipping $d_{ni}^{j} \geq 1$ units of this good, where $d_{nn}^{j} = 1$ for all j, n. I will also consider ad-valorem flat-rate tariffs: goods imported by country n from country i have to pay a tariff $\tau_{in}^{j} \geq 0$ applicable over unit prices, and where $\tau_{nn}^{j} = 0$ for all j, n. I can combine these two trade costs in a single factor κ_{ni}^{j} which multiplies unit costs:

$$\kappa_{ni}^{j} = d_{ni}^{j} \times \left(1 + \tau_{ni}^{j}\right).$$

In this model, iceberg costs are a deadweight loss. Producing $d_{ni}^{j} - 1$ requires the use of inputs and this quantity disappears or "melts". In contrast, tariffs are rebated as a lump-sum transfer to the representative household.

Prices of intermediate goods: producers of composite goods may purchase intermediate goods from any country, and they choose the lowest cost supplier. In the presence of trade costs, a unit of an intermediate good ω^{j} produced in country i is available in country n at a price $c_{i}^{j}\kappa_{in}^{j}/z_{i}^{j}\left(\omega^{j}\right)$. Therefore, the cost to the composite good producer of purchasing the lowest price intermediate ω^{j} is

$$p_{n}^{j}\left(\omega^{j}\right) = \min_{i} \left\{ \frac{c_{i}^{j}\kappa_{in}^{j}}{z_{i}^{j}\left(\omega^{j}\right)} \right\}.$$

If sector j is a non-tradable sector, I set $\kappa_{in}^{j} = \infty$ for all $i \neq n$ and this implies that $p_{n}^{j}\left(\omega^{j}\right) = c_{n}^{j}/z_{n}^{j}\left(\omega^{j}\right)$ as the lowest cost supplier is the domestic producer.

Following Eaton and Kortum (2002) and Caliendo and Parro (2015), I will adopt a probabilistic representation of productivities. In particular, I will assume that the productivity of producing an intermediate good ω^{j} in country n is the realization of a Fréchet distribution with a location parameter $\lambda_{n}^{j} \geq 0$ and a shape parameter $\theta^{j} \geq 0$. I will also assume that the distribution of productivities is independent across goods, sector and countries and that $1 + \theta^{j} \geq \sigma^{j}$. This representation also allows to independently vary absolute and comparative advantages. The location parameter λ_{n}^{j} represents absolute advantage, as a higher λ_{n}^{j} increases average productivity. The shape parameter θ^{j} represents comparative advantage as a smaller θ^{j} implies a higher dispersion of productivities. With this distributional assumption, I can then compute the sectoral price index.

Proposition 1. *The price of the composite good j in country n is given by*

$$P_{n}^{j} = A^{j} \left[\sum_{i=1}^{N} \lambda_{i}^{j} \left(c_{i}^{j}\kappa_{in}^{j} \right)^{-\theta^{j}} \right]^{-1/\theta^{j}}, \tag{2}$$

where A^{j} is a constant. For a non-tradable sector where $\kappa_{in}^{j} = \infty$ for all $i \neq n$, $P_{n}^{j} = A^{j}\left(\lambda_{n}^{j}\right)^{-1/\theta^{j}} c_{n}^{j}$.

2.1.4 Expenditure shares and market clearing

I can define total expenditure on sector j goods in country n as X_{n}^{j}. Now, define X_{in}^{j} as the expenditure in country n of goods from sector j coming from country i. Using these two terms, I can write the share of country i in country n's expenditure of sector j goods as $\pi^j_{in} = X^j_{in}/X^j_n$. Using the properties of the Fréchet distribution, I can then express this share as a function of unit costs, trade costs and exogenous parameters.

Corollary 1. *The share of country i in country n's expenditure of sector j goods can be written as*

$$\pi^j_{in} = \frac{\lambda^j_i \left[c^j_i \kappa_{in}\right]^{-\theta^j}}{\sum_{h=1}^N \lambda^j_h \left[c^j_h \kappa^j_{hn}\right]^{-\theta^j}}, \tag{3}$$

and for a non-tradable sector where $\kappa^j_{in} = \infty$ for all $i \neq n$, $\pi^j_{nn} = 1$.

With this result, I can now write the gravity equation of this model:

$$X^j_{in} = \frac{\lambda^j_i \left[c^j_i \kappa_{in}\right]^{-\theta^j}}{\sum_{h=1}^N \lambda^j_h \left[c^j_h \kappa^j_{hn}\right]^{-\theta^j}} X^j_n, \tag{4}$$

which is going to depend on demand in the destination country X^j_n as well as productivity across all possible countries (λ^j_h), marginal costs across all countries (c^j_h), trade costs κ^j_{hn} and the dispersion of the distribution of productivities θ^j. This term appears in the same fashion as trade elasticities appear in Armington models.

I now turn to market clearing.Consider sector j in country n with a value of production X^j_n. This production is used both for final consumption of households in country n and as materials by intermediate producers in country n. Given the Cobb-Douglas assumption I made for the utility function of the representative household, production used for household consumption is $\alpha^j_n I_n$, where I_n is the income of the representative household. What about intermediate producers? From the Cobb-Douglas assumption in the production function, each intermediate good producer in sector k will use a share γ^{jk}_n of its production to purchase composite goods from sector j. In turn, total production of these intermediate goods will be sold to all sectors k in all countries. Therefore, I can write the market clearing condition as

$$X^j_n = \alpha^j_n I_n + \sum_{k=1}^J \gamma^{jk}_n \sum_{i=1}^N X^k_i \frac{\pi^k_{ni}}{1+\tau^k_{ni}}, \tag{5}$$

where $\sum_{i=1}^N X^k_i \pi^k_{ni}/(1+\tau^k_{ni})$ represents total production of intermediates in sector k in country n. Note that in equation (5), I am removing tariffs from total expenditure. I do this because firms only receive the unit costs, not the tariffs and I don't do this for iceberg costs or interest rates because the value of these frictions is a deadweight loss and is not distributed to households. [3]

Households derive income from three sources: (1) labor income $w_n L_n$, where w_n is the wage and L_n is the exogenous labor endowment in country n, (2) tariff revenue R_n, and (3) exogenous trade deficits D_n. Therefore, household income is given by $I_n = w_n L_n + R_n + D_n$. As tariffs are imposed on all tariffs, tariff revenue can be written as

$$R_n = \sum_{j=1}^J \sum_{i=1}^N \tau^j_{in} X^j_n \frac{\pi^j_{in}}{1+\tau^j_{in}},$$

[3] For example, for most of the model in Eaton and Kortum (2002), tariffs are also deadweight losses and are not distributed to households. In that case, I would need to remove the tariffs in equation (5).

which is jus the sum of the value of the ad-valorem flat rate tariffs imposed on unit costs (which is why I need to divide the shares π_{in}^j by the tariffs). National trade deficits are given by $D_n = \sum_{j=1}^J D_n^j$, where D_n is exogenous but D_n^j is an equilibrium object. Sectoral deficits are given by

$$D_n^j = \sum_{i=1}^N X_n^j \frac{\pi_{in}^j}{1+\tau_{in}^j} - \sum_{i=1}^N X_i^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j}, \tag{6}$$

which is the difference between imports and exports. I can use the definition of national deficits together with (6) to write the balanced trade equation

$$\sum_{j=1}^J \sum_{i=1}^N X_n^j \frac{\pi_{in}^j}{1+\tau_{in}^j} - D_n = \sum_{j=1}^J \sum_{i=1}^N X_i^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j}, \tag{7}$$

in which the left hand side is the value of exports minus the exogenous national trade deficit and the right hand side is the value of imports.[4]

2.1.5 Equilibrium

I can now define an equilibrium under policies $\left\{\tau_{ni}^j\right\}$.

Definition 1. Given $L_n, D_n, \lambda_n^j, \theta^j$ and d_{ni}^j, and equilibrium under policy $\{\tau\}$ is a wage vector $\boldsymbol{w} \in \mathbb{R}_{++}^N$ and prices $\left\{P_n^j\right\}_{j=1,n=1}^{J,N}$ that satisfy equilibrium conditions (1), (2), (3), (5) and (7) for all j, n.

Instead of solving for an equilibrium under a policy $\{r, \tau\}$ and then solving for another equilibrium under a new policy $\{\tau'\}$, I will use the exact hat algebra method of Dekle et al. (2008) to solve for the equilibrium in relative changes. In this method, instead of computing two equilibria and then computing the changes, I can compute the changes directly. This method is appealing for two reasons. First, I can identify the effect on equilibrium outcomes from a pure change in tariffs. Second, I can solve the model without needing to estimate parameters which may be difficult to identify. For example, this method implies that I do not need to specify the level of iceberg costs. I will now define the equilibrium in changes of the model under a new policy $\{\tau'\}$ relative to an old policy $\{\tau\}$.

Definition 2. Let $(\boldsymbol{w}, P)$ be an equilibrium under policy $\{\tau\}$ and let $(\boldsymbol{w}', P')$ be an equilibrium under policy $\{\tau'\}$. Define $\left(\hat{\boldsymbol{w}}, \hat{P}\right)$ as an equilibrium under policy $\{\tau'\}$ relative to $\{\tau\}$, where for a variable x $\hat{x} = x'/x$. Using equations (1), (2), (3), (5) and (7) the equilibrium conditions in relative changes satisfy:

Cost of the input bundles:

$$\hat{c}_n^j = (\hat{w}_n)^{\gamma_n^j} \prod_{k=1}^J \left(\hat{P}_n^k\right)^{\gamma_n^{kj}}. \tag{8}$$

Price index:

$$\hat{P}_n^j = \left[\sum_{i=1}^N \pi_{in}^j \left(\hat{\kappa}_{in}^j \hat{c}_i^j\right)^{-\theta^j}\right]^{-1/\theta^j}. \tag{9}$$

[4] I have not specified market clearing for the labor market. I don't need to do this because market clearing in each sector-country together with the balanced trade equation yields market clearing for the labor market in each country. In order to see this, I can add equation (5) across all sectors, use the expression for household income and then substitute into the balanced trade equation (7) to obtain

$$w_n L_n = \sum_{j=1}^J \gamma_n^j \sum_{i=1}^N X_i^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j}.$$

Bilateral trade shares:

$$\hat{\pi}_{in}^{j} = \left(\frac{\hat{c}_i^j \hat{\kappa}_{in}^j}{\hat{P}_n^j} \right)^{-\theta^j}. \tag{10}$$

Total expenditure in each country n and sector j:

$$X_n^{j\prime} = \alpha_n^j I_n^\prime + \sum_{k=1}^{J} \gamma_n^{jk} \sum_{i=1}^{N} X_i^{k\prime} \frac{\pi_{ni}^{k\prime}}{1+\tau_{ni}^k}. \tag{11}$$

Trade balance:

$$\sum_{j=1}^{J} \sum_{i=1}^{N} X_n^{j\prime} \frac{\pi_{in}^{j\prime}}{1+\tau_{in}^j} - D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} X_i^{j\prime} \frac{\pi_{ni}^{j\prime}}{1+\tau_{ni}^j}, \tag{12}$$

where $\hat{k}_{in}^j = \left(1+\tau_{in}^{j\prime}\right) / \left(1+\tau_{in}^j\right)$ and $I_n^\prime = \hat{w}_n w_n L_n + D_n + \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{in}^j X_n^{j\prime} \frac{\pi_{in}^{j\prime}}{1+\tau_{in}^j}$.

Therefore, if I have a change in interest rates I can then compute the equilibrium changes by solving equations (8)-(12), and without relying on estimates of productivity or transport costs. I only need data on bilateral trade shares π_{in}^j, the share of value added in production γ_n^j, value added $w_n L_n$, the share of intermediate consumption γ_n^{kj} and the sectoral dispersion of productivity θ^j. I will obtain the share of each sector in final demand α_n^j from these data.

2.1.6 Relevant quantities

Proposition 2. *Total production in sector j in country n can be written as*

$$\frac{Y_n^j}{P_n^j} = \frac{c_n^j}{P_n^j} \left(L_n^j\right)^{\gamma_n^j} \prod_{k=1}^{J} \left(M_n^{kj}\right)^{\gamma_n^{kj}},$$

where $Y_n^j = \int \left(c_n^j / z_n^j \left(\omega^j\right)\right) q_n^j \left(\omega^j\right) d\omega^j$ is the value of production in sector j and country n, L_n^j is total labor used in the sector and M_n^{kj} is total usage of materials from sector k in sector n.

According to this representation, I can think of the ratio c_n^j / P_n^j as a multiplicative TFP factor. In fact, this term captures gains from trade in this model. To see this, note that in autarky, $\hat{P}_n^j = \hat{c}_n^j$ and so changes in marginal costs of domestic production move one-to-one with changes in price of the good j in country n. With trade, an increase in marginal costs $\hat{c_n}^j$ no longer causes the same increase in the price, as this term will be dampened by the share of own consumption $\hat{\pi}_{nn}^j$. Therefore, in the presence of trade, increases in the cost of domestic production do not fully pass-through into the cost of the good in country n. Therefore, I shall call this ratio $\mathcal{A}_n^j = c_n^j / P_n^j$ and will interpret it as productivity in sector j in country n. I can further use equation (10) to write changes in productivity as

$$\log \hat{\mathcal{A}}_n^j = -\frac{1}{\theta^j} \log \hat{\pi}_{nn}^j, \tag{13}$$

which implies that I only need to know two quantities to identify changes in productivity: (1) the trade elasticity and (2) the share of own consumption. [5]Suppose that there is a shock that increases the share of

[5]Note that, for non-tradable goods, $\pi_{nn}^j = 1$ and so productivity is fixed at $A_n^j = \left(A^j\right)^{-1} \left(\lambda_n^j\right)^{1/\theta^j}$.

own consumption. In that case, marginal costs increase because firms are no longer importing the cheap intermediates from abroad and are instead relying on the more expensive domestically produced intermediates. Therefore, production becomes more expensive and productivity decreases. This representation of gains from trade as a function of these two quantities is very general. In fact, Arkolakis et al. (2012) show that in most trade models either of the Ricardian or the Krugman-Melitz type, gains from trade can be summarized by the elasticity of imports with respect to variable trade costs (which in this model is the trade elasticity) and the share of expenditure on domestic goods. In their seminal paper, the Ricardian model written by Eaton and Kortum (2002) displays this characterization, as does the Caliendo and Parro (2015) model. In our model, all of effects on welfare and other relevant quantities will be a function of these two statistics.

This representation also has some important implications for the design of tariffs. The goal of the coalition is to inflict maximum damage in the Russian economy. In order to do, they must induce large drops in productivity. Therefore, tariffs should be designed such that there is a negative correlation between trade elasticities and $\hat{\pi}^j_{nn}$. Therefore, optimal tariffs are the ones that inflict large changes in the share of own consumption in sectors where trade elasticities are low. Hence, optimal tariffs must follow a type of the inverse elasticity rule.

I now turn to the real wage. This will be an important component of welfare. In order to see this, note that welfare in this model is given by $W_n = I_n / P_n$ and that, using the household's budget constraint, I can write

$$d \log W_n = \frac{w_n L_n}{I_n} d \log \frac{w_n}{P_n} + \frac{R_n}{I_n} d \log \frac{R_n}{P_n},$$

which depends on the real wage and on real transfers. The next Proposition shows that I can write the real wage as a weighted average of gains from trade and relative prices.

Proposition 3. *The changes in the real wage in country n can be written as*

$$\begin{aligned}\log \frac{\hat{w}_n}{\hat{P}_n} &= \sum_{j=1}^{J} \alpha^j_n \log \hat{\mathcal{A}}^j_n + \sum_{j=1}^{J} \alpha^j_n \frac{1-\gamma^j_n}{\gamma^j_n} \log \hat{\mathcal{A}}^j_n - \sum_{j=1}^{J} \frac{\alpha^j_n}{\gamma^j_n} \sum_{k=1}^{J} \gamma^{kj}_n \log \left(\frac{\hat{P}^k_n}{\hat{P}^j_n} \right) \\ &= - \sum_{j=1}^{J} \frac{\alpha^j_n}{\theta^j} \log \hat{\pi}^j_{nn} - \sum_{j=1}^{J} \frac{\alpha^j_n}{\theta^j} \frac{1-\gamma^j_n}{\gamma^j_n} \log \hat{\pi}^j_{nn} - \sum_{j=1}^{J} \frac{\alpha^j_n}{\gamma^j_n} \sum_{k=1}^{J} \gamma^{kj}_n \log \left(\frac{\hat{P}^k_n}{\hat{P}^j_n} \right) \end{aligned} \tag{14}$$

In order to build intuition for this result, let us consider each term individually. Suppose first that $\gamma^j_n = 1$ for all j and n and intermediate goods are produced using only labor. In this case, the change in average productivity, which is the real wage, is just the weighted average of the change in sectoral productivities, and where the weights are the consumption shares. The effect will depend on each sector's trade elasticity and on how π^j_{nn} changes. If the shock increase the own share of consumption, then sectoral productivities decrease and so does the average productivity. Moreover, note that the correlation between α^j_n / θ^j and $\hat{\pi}^j_{nn}$ is of first order importance. If the sectors where $\hat{\pi}^j_{nn}$ is large are also the sectors where the trade elasticity is high, then the overall effect on the real wage will be muted. Therefore, even if the shock is uniform across sectors, accounting for heterogeneity across sectors in terms of the elasticity is important to obtain an accurate picture of the consequences of the shock.

Consider now the situation where $\gamma^j_n < 1$ but $\gamma^{jj}_n = 1 - \gamma^j_n$ for all j and n. In this world, intermediate goods producers use labor and materials from the same sector to produce the goods, but there are no sectoral interrelations. Consider an increase in the costs of trade. This shock will lead to an increase in the price of intermediate goods which in turn leads to an increase in the price of composite goods. However, this last increase also represents an increase in the marginal costs of intermediate goods producers as their inputs have become more expensive. How big is this effect? In the expression, it appears multiplied by γ_n^{jj}/γ_n^j which is simply the share of intermediate goods relative to the value added share. Therefore, this additional term is captured by $\sum_{j=1}^{J} \frac{\alpha_n^j}{\theta^j} \frac{1-\gamma_n^j}{\gamma_n^j} \log \hat{\pi}_{nn}^j$.

I now turn to the general model, which allows for sectoral interrelations. The term $\sum_{k=1}^{J} \gamma_n^{kj} \log \hat{P}_n^k$ captures the effect of a change in the price of composite good k on real wages in sector j through changes in the marginal cost of production. Suppose I have a shock such that $\hat{P}_n^k > 1$. In this case, the effect on marginal costs increases with the share parameter γ_n^{kj}. Therefore, the larger γ_n^{kj} is, the more relevant are the fluctuations in sector k price for marginal costs in sector j. This term will therefore capture the network structure of the economy. The full term is simply a weighted average of the change in the relative price of materials. In this economy, the only way this component is zero is if all price behave in the exact same way.

Finally, I can present a useful decomposition of the change in welfare into terms of trade and volume of trade.

Proposition 4. *The changes in welfare in country n can be decomposed as*

$$d \log W_n = \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \left(E_{ni}^j d \log c_n^j - M_{in}^j d \log c_i^j \right) + \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{in}^j M_{in}^j \left(d \log M_{in}^j - d \log c_i^j \right) \tag{15}$$

where $E_{ni}^j = X_i^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j}$ *are country n's exports of sector j goods to country i and* $M_{in}^j = X_n^j \frac{\pi_{in}^j}{1+\tau_{in}^j}$ *are country n's imports of country i's sector j products.*

The first term measures the change in terms of trade. This term is a weighted average of domestic and foreign marginal costs (which are the prices of exports and imports respectively net of trade costs), weighted by exports and imports. If the trade shock increases the domestic marginal cost with no change in the foreign marginal cost then the domestic country experiences an improvement in terms of trade as the relative price of exports increases and this increases welfare. The second term is the change in the volume of trade, which is the change in the value of imports minus the change in the price of imports. Therefore, an increase in the volume of trade contributes positively to welfare.

2.1.7 Discussion

I have presented a multi-sector multi-country Ricardian trade model. In this model, trade is welfare improving because it allows firms to purchase cheaper intermediate goods to use in product. However, this is not the only possible gain from trade. In the Krugman-Melitz tradition, trade has another benefit - it allows household to consume a larger variety of goods. In that world, not all countries produce the same goods and so trade allows households to consume goods that cannot be produced domestically. Therefore, the model I have outline exhibits supply-side gains from trade whereas a Krugman-Melitz type model would exhibit demand-side gains from trade.

Both supply and demand side gains from trade are potentially relevant. In the case of Russia, it is reasonable to assume that there are some goods that cannot be produced by Russian firms and therefore need to be imported. For example, there is some evidence that Russian manufacturing was highly dependent on high-tech components that came from the U.S..[6] However, it is difficult to say whether this dependence comes from the fact that the goods cannot be produced in Russia or that it is cheaper to buy them from abroad. The former implies a productivity level of zero, whereas the latter merely suggests the existence of a comparative advantage. As the goal of this paper is to focus on the long-run effects of sanctions and, in particular, of those effects on the ability of the Russian economy to generate wealth, it seems better to focus on the supply-side impacts. However, it should be noted that imposing sanctions on Russia may also prevent Russian households from consuming certain goods, which will also lead to further welfare losses.

This model also abstracts from short-time considerations. In particular, by assuming that firms can freely adjust their import mix, I am assuming that there are no frictions in input sourcing. If there were frictions and firms could not freely adjust their input sourcing, the impact of sanctions on Russia would be smaller. Coalition firms would still have to purchase inputs from Russia, but at a higher price. Therefore, domestic marginal costs would increase, which would lead to a fall in exports in coalition countries. Therefore, introducing frictions in input sourcing would shift some of the costs of sanctions from Russia to coalition countries.

There is a political economy dimension in sanctions which I am also abstracting from. Coalition countries have different incentives, and face different costs, when it comes to imposing sanctions on Russia. For example, a country like Hungary which is very dependent on Russian oil and gas, would be more reluctant to impose sanctions on Russia than Canada or New Zealand. I am assuming that sanctions, which take the form of a tariff policy, are exogenous. There is a possibly very rich game-theoretic model from where these tariffs could arise. Within a coalition, there is certainly a bargaining process in which countries choose tariffs. Moreover, all coalition members may deviate from the chosen tariff policy by leaving the coalition. [7]Therefore, in order to implement the sanctions I am taking as exogenous, coalition countries would need to agree on a set of transfers from countries more willing to impose sanctions to countries which are less willing to do so. Moreover, the size of the coalition is also probably endogenous.

2.1.8 Calibration and solution

Before describing the data sources I employ to calibrate the model, I need to specify the number of countries and sectors. I will set $N = 32$ and so I will have 32 countries: 31 countries and one constructed rest of the world. I will consider $J = 40$ sectors of which 20 are tradable. I follow the list of countries and sectors in Caliendo and Parro (2015). These choices maximize the number of countries and sectors covered in our sample conditional to obtaining reliable data. I will use 2018 as the base year. I now briefly describe the data sources.[8]

The main advantage from solving the model in changes is that I can avoid calibrating certain parameters of the model like iceberg costs. In fact, in order to calibrate the model I only need four sources of data: (1) bilateral trade flows X_{in}^j, (2) value added by sector and country V_n^j, (3) gross production by sector Y_n^j, and (4) I-O tables to identify the coefficients of the production function of intermediates. Using these data I can then calculate the data counterparts of π_{in}^j, γ_n^j,γ_n^{kj} and α_n^j.

I begin by obtaining bilateral trade flows from Comtrade for all countries. I obtain gross output and value added from three different sources: (1) the OECD STAN database for industrial analysis, (2) the Industrial Statistics Database INDSTAT2 and (3) the OECD Input-Output database. I use I-O tables from

[6]https://www.bloomberg.com/news/articles/2022-04-21/u-s-allies-cut-bulk-of-russia-high-tech-imports-raimondo-says

[7]This deviation also does not need to be public. For example, coalition countries who wish to import from Russia could do so via a third country. This type of deviation is a hidden action which is not present in my model.

[8]I present these sources in greater detail in Appendix A, along with some summary statistics.

the World Input-Output Database (WIOD) and the OECD Input-Output Database. I obtain data on tariffs for the year 2018 from the United Nations Statistical Division, Trade Analysis and Information System. Finally, I use the estimated trade elasticities from Caliendo and Parro (2015).

In order to compute the bilateral trade shares π_{in}^{j} I begin by calculating domestic sales in each country as the difference between gross production and total exports: $X_{nn}^{j} = Y_{n}^{j} - \sum_{i \neq n}^{N} X_{ni}^{j}$. Define M_{in}^{j} as the trade flows I obtain from Comtrade, which exclude tariffs. I compute the expenditure of country n in sector j goods from country i as $X_{in}^{j} = M_{in}^{j}\left(1 + \tau_{in}^{j}\right)$. I then obtain the shares by computing $\pi_{in}^{j} = X_{in}^{j} / \sum_{h=1}^{N} X_{ih}^{j}$. The share of sector j's spending on sector k goods, γ_{n}^{kj}, is directly computed from the I-O matrix as the share of intermediate consumption of sector k in sector j over the total intermediate consumption of sector j minus the share of value-added. I compute the share of value added by dividing value added by gross production and so $\gamma_{n}^{j} = V_{n}^{j}/Y_{n}^{j}$. I calculate the final consumption share by taking the total expenditure of sector j goods and subtracting the intermediate goods expenditure and dividing the result by income and so $\alpha_{n}^{j} = \left(Y_{n}^{j} + D_{n}^{j} - \sum_{k=1}^{J} \gamma_{n}^{jk} Y_{n}^{k}\right) / I_{n}$, which just follows from the market clearing condition (5). I compute trade deficits in each sector j and country n as $D_{n}^{j} = \sum_{i=1}^{N} M_{in}^{j} - \sum_{i=1}^{N} M_{ni}^{j}$.

I solve the model following the algorithm in Caliendo and Parro (2015). I begin by guessing a vector of wage changes $\hat{w}$. Given this vector I can solve equations (8) and (9) to obtain the changes in unit costs and sectoral prices which are consistent with our guess. I can then use the changes in unit costs, the changes in sectoral prices and the shares in the base year to solve for the new shares $\pi_{in}^{j\prime}$ using equation (10). I then use equation (11) to compute total expenditure which is consistent with our initial guess for the change in wages. Substituting all of these terms in the balanced trade equation (12), I can check if this equilibrium condition holds. If it does not, I adjust our guess for the wage changes and iterate until convergence.[9]

3 Effect of Tariffs on Russia

Consider a coalition of countries which imposes an increase on tariffs on Russian imports. This coalition contains Australia, Austria, Canada, Denmark, Finland, France, German, Greece, Hungary, Ireland, Italy, Japan, South Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, the U.K. and the U.S. . I will assume that these countries coordinate on a single value for the increase on tariffs, which will be identical for all tradable sectors.

3.1 Effect on Russian exports

I will start with a baseline value of 10 percentage points increase on tariffs imposed by the coalition countries. In Table I, I present the change in imports from Russia and the change in total imports for all countries in our sample. Both of these measures are in nominal terms.

[9] The Appendix of Caliendo and Parro (2015) describes the algorithm in greater detail.

TABLE I. Effect on Russian exports

This table presents the effect of the increase on tariffs imposed by coalition countries on Russian imports. I present, for each country, the change in imports from Russia and the change in total imports.

Coalition countries			Non-coalition countries		
	Imports from Russia (%)	Total imports (%)		Imports from Russia (%)	Total imports (%)
Australia	-43.58	-0.05	Argentina	2.67	-0.25
Austria	-42.37	0.02	Brazil	1.83	-0.54
Canada	-37.27	-0.30	Chile	3.35	-0.05
Denmark	-44.45	-0.17	China	7.40	-0.12
Finland	-48.13	-1.40	India	4.05	-0.15
France	-48.06	-0.06	Indonesia	4.07	-0.41
Germany	-55.51	-0.12	Mexico	2.12	-0.40
Greece	-54.22	-1.03	South Africa	4.72	0.00
Hungary	-59.36	0.00			
Ireland	-43.72	-0.04			
Italy	-61.03	-0.23			
Japan	-60.98	-0.62			
Korea	-54.87	-0.23			
Netherlands	-55.15	-0.15			
New Zealand	-53.91	-0.01			
Norway	-34.87	0.15			
Portugal	-56.33	-0.09			
Spain	-48.00	-0.09			
Sweden	-50.09	-0.11			
Turkey	-40.10	-0.73			
U.K.	-44.04	-0.24			
U.S.	-34.77	-0.14			

The first conclusion we can draw is that, for coalition countries, a 10 percentage point increase on tariffs has very significant effects on imports from Russia. For example, Italian imports from Russia fall over 60%. However, if we look at the U.S., this drop is only 35%. Therefore, there is substantial heterogeneity in terms of the effect on imports from Russia. If we look at non-coalition countries, we see that imports from Russia actually increase. Thus Russia is able to substitute some of its exports to non-coalition countries, but not all of them. In fact, overall Russian exports decrease by over 10% as a result of the imposition of tariffs. I will now explain both the heterogeneity across coalition countries and the increase in Russian exports to non-coalition countries.

In order to explain the heterogeneity of the effects across coalition countries, it is useful to inspect the gravity equation of this model. Let n be a coalition country and i be Russia. For a given sector j, I can write the change in imports from Russia to coalition country n as

$$\begin{aligned} d\log X_{in}^j = & \underbrace{d\log X_n^j}_{\text{domestic demand}} \\ & \underbrace{-\theta^j d\log c_i^j}_{\text{marginal cost}} \underbrace{-\theta^j d\log \kappa_{in}^j}_{\text{trade cost}} \\ & \underbrace{-d\log\left(\sum_{h=1}^{N} \lambda_h^j \left[c_h^j \kappa_{hn}^j\right]^{-\theta^j}\right)}_{\text{substitution}}, \end{aligned}$$

which is the sum of four components: (1) changes in demand in the coalition country, (2) changes of marginal costs in Russia, (3) changes in trades costs and (4) possible changes in marginal costs and trade costs in other countries. In our setting I only allow tariffs on Russia to change so the last term is zero. Numerically, I can show that the trade cost effect dominates and so the change in imports from Russia is determined by the trade elasticity and by the change in tariffs. Let the uniform change in tariffs be ζ. The change in total imports from Russia by coalition country n is approximately given by

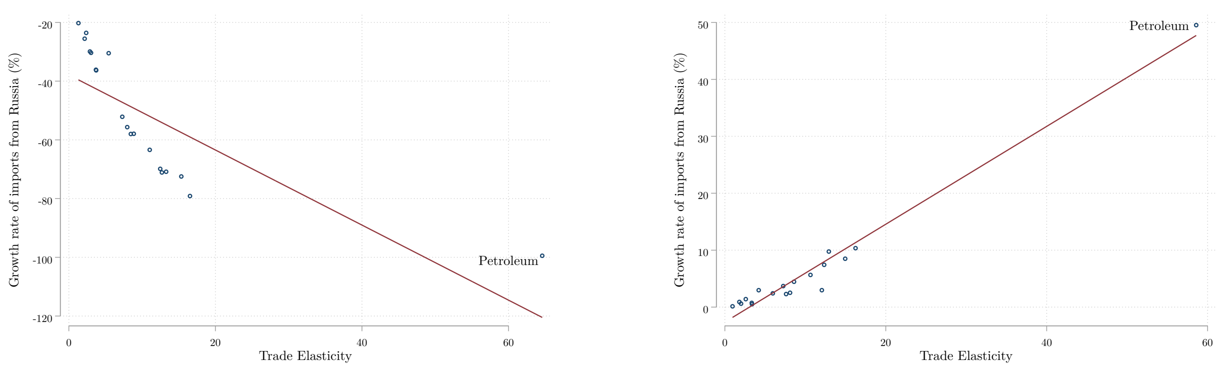
$$d\log X_{in} = d\log\left(\sum_{j=1}^{J} X_{in}^{j}\right) = -\zeta \times \sum_{j=1}^{J} \frac{X_{in}^{j}}{X_{in}}\theta^{j} = -\zeta \times \widetilde{\theta}_{in}^{j},$$

which is the product of the uniform tariff change and the "effective" trade elasticity of imports from Russia. Therefore, a coalition country n that imports very elastic products from Russia will exhibit a larger drop in imports from Russia when compared with a country that imports very inelastic products from Russia. We can see this graphically with a binned scatterplot. I plot in Figure 1 the change in imports from Russia of each sector-country for all countries against the trade elasticity of that sector.

FIGURE 1. Importance of Trade Elasticities

This figure is a binned scatterplot of the change in imports from Russia of each sector-country for all coalition countries against the trade elasticity of each sector. In panel (a), I present the plot for all coalition countries and, in panel (b) I present the plot for non-coalition countries.

(a) Coalition countries | (b) Non-coalition countries



In panel (a), which presents the change in imports for coalition countries we immediately see that the larger the trade elasticity, the larger the drop in imports. For example, countries importing a lot of Petroleum products from Russia like Germany will exhibit a larger decline exports when compared to countries like Canada which does not import a significant amount of goods from this sector. [10]

In panel (b), we see the opposite: the higher the trade elasticity, the larger the increase in imports from Russia. In order to understand this, I again need to turn to the gravity equation. Let Russia be country i and let country n be a non-coalition country. As before, the domestic demand and substitution effects are very small.[11] Non-coalition countries do not increase tariffs on Russian imports and so the trade cost effect is zero. Therefore, it must be that Russian marginal costs decline and that this explains the increase in imports from Russia.

In order to understand this effect, I will present the change in Russian exports by sector (decomposing it into the change in exports to coalition countries and the change in exports to non-coalition countries), as

[10] This sector contains only refined oil and coke products. It does not include unrefined oil or natural gas. These products are in the Mining sector.

[11] The substitution effect is small mostly because there is no change in tariffs on imports from countries other than Russia.

well as the trade elasticity of that sector along with the change in Russian marginal costs.

TABLE II. Effect on Russian exports by sector

This table presents the effect of the increase on tariffs imposed by coalition countries on Russian imports. I present, for each tradable sector, the change on Russian exports to coalition countries, the change on Russian exports to non-coalition countries, the change in total Russian exports, the trade elasticity of each tradable sector and the change in Russian marginal costs by sector.

Sector	Change in Russian exports (%)			Trade elasticity	Change in marginal costs (%)
	To coalition countries	To non-coalition countries	Total		
Agriculture	-55.5	5.14	2.12	9.11	-0.56
Mining	-70.1	9.61	-12.1	13.53	-0.74
Food	-22.2	1.33	-6.87	2.62	-0.50
Textiles	-53.2	4.42	-5.06	8.1	-0.54
Wood	-66.3	6.59	-8.24	11.5	-0.56
Paper	-79.0	10.3	-8.37	16.52	-0.58
Petroleum	-99.6	50.8	-1.23	64.85	-0.68
Chemicals	-29.8	1.82	-8.58	3.13	-0.60
Rubber	-21.0	0.87	-4.95	1.67	-0.52
Other non-metals	-25.6	1.67	-3.67	2.41	-0.65
Basic metals	-30.3	2.26	-15.8	3.28	-0.66
Metal products	-51.2	1.89	-4.80	6.99	-0.23
Machinery	-19.8	0.87	-2.31	1.45	-0.57
Office	-71.3	8.03	-4.17	12.95	-0.59
Electrical	-71.7	2.74	-7.62	12.91	-0.19
Communication	-36.2	1.49	-0.20	3.95	-0.35
Medical	-58.0	3.15	-13.5	8.71	-0.35
Auto	-55.1	3.71	-1.70	8.22	-0.42
Other transport	-56.4	2.33	-18.8	8.22	-0.26
Manufacturing and recycling	-36.5	1.21	-8.18	3.98	-0.29

As I had argued, for coalition countries, Russian exports are larger when the trade elasticity is larger. For example, Russian exports of Petroleum to coalition countries effectively disappear. For non-coalition countries, sectors with high trade elasticities exhibit an increase in imports from Russia. This is driven by a decline in marginal costs in Russia as a result of the increase in tariffs. For example, marginal costs for Petroleum decline by around 0.7% and the trade elasticity is 65 so the effect of the marginal cost is an increase of Russian exports of Petroleum to coalition countries of around 45%, which explains most of the change in exports I observe in Table II.

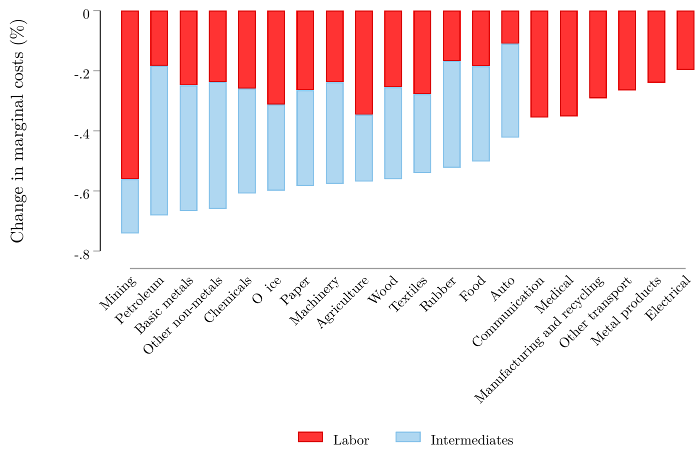
Why do marginal costs decline? In order to understand this, I can use equation (1) to write the change in marginal costs as

$$d \log c_n^j = \gamma_n^j d \log w_n + \sum_{k=1}^{J} \gamma_n^{kj} d \log P_n^k,$$

and so the change in marginal costs comes from the change in the nominal wage w_n and the change in the prices of inputs. For Russia, the model predicts a decrease of 0.8%. Moreover, the model also predicts a drop in sector prices P_n^k for Russia. I can can decompose the change in marginal costs into two components: (1) effects of the wage $\gamma_n^j d \log w_n$, (2) effects coming from the change in prices $\sum_{k=1}^{J} \gamma_n^{kj} d \log P_n^k$. I present the results of this decomposition in Figure 2.

FIGURE 2. Decomposition of Russian marginal costs

This figure presents a decomposition of the change in marginal costs for Russia by tradable sector. I decompose the change in marginal costs into two components: (1) effects from the nominal wage and (2) effects from the change of prices of intermediates.



We can see that, with the exception of Mining which does not use many intermediate inputs, most of the sectors that exhibit larger drops in marginal costs are also sectors where most the change is driven by the change in the price of intermediates. However, that is only the direct effect: for example, Petroleum uses a lot of intermediates from mining and so the true effect of the nominal wage will be the direct effect plus a term which is the product of the effect of the nominal wage on the price of mining and the share of mining goods consumed by Russian firms which are produced in Russia.

Therefore, I need to explain two phenomena: (1) the drop in nominal wages and (2) the drop in sector prices. I will start with nominal wages. When coalition countries impose tariffs on Russian imports, overall demand for Russian goods abroad decreases. Therefore, Russian firms will demand less labor at home. However, labor supply is fixed and in order to have equilibrium in the labor market, any drop in demand is fully accommodated by a drop in the nominal wage. A similar mechanism explains the drop in sector prices. As demand for composite goods declines, so does the price of these composite goods. This drop is not as pronounced as the one for the nominal wage because the supply of these goods is more inelastic. There is another effect, which comes from households. As the nominal wage falls in Russia, so does household income. Therefore, households will cut back on consumption, and this will also lead to a decrease in the price of composite goods.

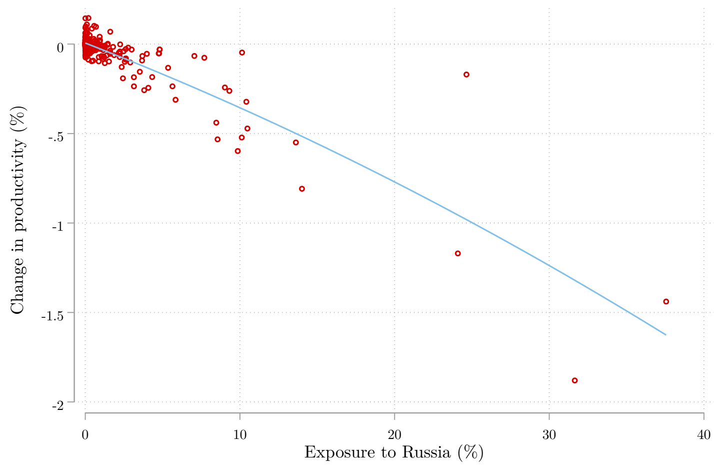
3.2 Effects on Productivity

In this section, I will turn to the effects of tariffs on productivity $\mathcal{A}_n^j$. Consider the case of a coalition country which imposes sanctions on Russia. The imposition of sanctions will make importing goods from Russia more expensive. Therefore, and keeping all other international prices constant, it follows that the share of home consumption of home produced goods π_{nn}^j must increase. This leads to a decrease in sectoral productivity or TFP. The decrease in TFP is the reason why countries imposing tariffs might suffer some losses. In Ricardian models of trade, free trade leads to welfare gains because firms are able to import cheaper inputs from abroad. As countries impose tariffs, and move away from free trade, these gains disappear and countries suffer welfare losses.

However, welfare losses are not identical across all coalition countries. Countries which are more exposed to Russia, i.e. import more from Russia before the imposition of tariffs, will see a larger drop in productivity because a larger amount of imports will be substituted by domestic production. In order to show this, I can compare the change in productivity $\hat{\mathcal{A}}_n^j$ for all country-sectors for coalition countries with the pair's exposure to Russia. I define exposure to Russia as the share of goods from that country-sector that were imported from Russia before the imposition of tariffs. I present the results of this comparison in Figure 3.

FIGURE 3. Productivity for coalition countries

This figure plots the change in productivity for all country-sector pairs for coalition countries against the pairs' exposure from Russia. I define exposure to Russia as the share of goods from that country-sector that were imported from Russia before the imposition of tariffs.

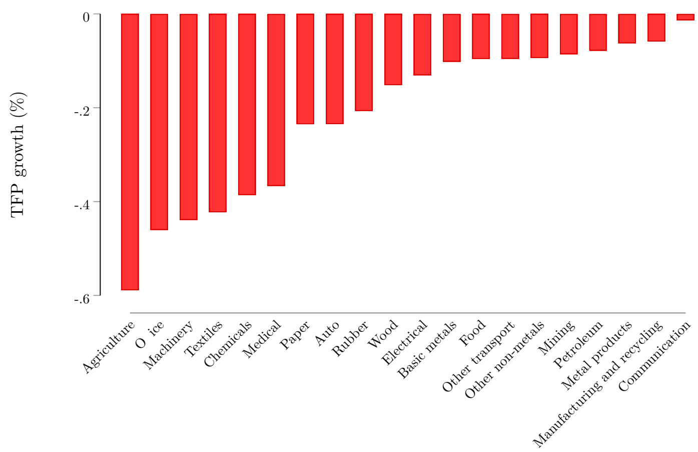


There are many sectors in many countries that have no exposure to Russia before the imposition of tariffs. These sectors will exhibit no change in TFP as a result of sanctions and explain the cluster of zeros in Figure 3. However, as exposure to Russia increases, so does the drop in productivity. In fact, exposure to Russia explains 89% of the variation in productivity in coalition countries.

I now turn to Russia and to changes in its productivity induced by the imposition of tariffs. I present the change in TFP for all tradable sectors in Russia in Figure 4.

FIGURE 4. Change in TFP for Russia

This figure plots the change in productivity for all tradable sectors in Russia.



There is a decrease in sectoral TFP for all tradable sectors in Russia. In order to understand the mechanism, recall that changes in productivity are driven by changes in the own share of firm consumption π_{nn}^{j}. As coalition countries impose tariffs on Russia, foreign demand for Russian goods decreases. This leads to a drop in production in Russia. However, this decrease in demand also leads to a decrease in factor prices and in nominal wages in Russia, which in turn lowers Russian marginal costs. As Russian marginal costs decrease, Russian demand for Russian goods increases and so does the share of own consumption. However, this implies that gains from trade, and therefore TFP, are smaller. There is also some heterogeneity across sectors: TFP in Agriculture decreases by almost 0.6% while TFP in Communication does not change at all. This heterogeneity is explained by how much these sectors exported to coalition countries, as well as the input-output structure of the Russian economy.

3.3 Effects on Welfare

So far, I have discussed the impact tariffs have on trade flows and on productivity. I will turn to an analysis of the effects of sanctions on coalition countries and on Russia. I consider three measures of welfare: aggregate TFP, the real wage and real household income. Aggregate TFP is the weighted average of the changes in sectoral productivity, and where the weights are given by the share of value added of that sector before the imposition of tariffs. In this model, welfare is given by real household income, which is a convex combination of the real wage and changes in tariff revenue. This measure can be decomposed in a terms of trade effect and in a volume of trade effect. I present these results in Table III.

TABLE III. Effects on welfare

This table presents the effect of the increase on tariffs imposed by coalition countries on welfare of coalition countries and Russia. I present three measures of welfare: aggregate TFP, the real wage and real household income. Aggregate TFP is the weighted average of the changes in sectoral productivity, and where the weights are given by the share of value added of that sector before the imposition of tariffs. In this model, welfare is given by real household income, which is a convex combination of the real wage and changes in tariff revenue. This measure can be decomposed in a terms of trade effect and in a volume of trade effect.

			Welfare (%)		
	Aggregate TFP (%)	Real wage (%)	Terms of trade	Volume of trade	Total
Australia	-0.006	-0.004	-0.003	-0.000	-0.003
Austria	-0.000	-0.001	0.010	-0.000	0.009
Canada	0.017	0.009	0.011	-0.001	0.009
Denmark	-0.021	-0.011	0.009	-0.002	0.006
Finland	-0.183	-0.132	.07347	-0.012	0.060
France	-0.014	-0.008	-0.002	-0.000	-0.003
Germany	-0.038	-0.023	-0.001	-0.001	-0.003
Greece	-0.100	-0.044	-0.003	-0.003	-0.007
Hungary	-0.170	-0.130	-0.007	-0.003	-0.011
Ireland	-0.011	-0.007	-0.003	-0.000	-0.004
Italy	-0.046	-0.022	0.005	-0.000	0.004
Japan	-0.001	-0.001	0.009	-0.002	0.006
Korea	-0.032	-0.030	0.000	-0.010	-0.010
Netherlands	-0.186	-0.087	0.015	-0.004	0.011
New Zealand	-0.004	-0.003	-0.002	-0.000	-0.002
Norway	0.024	0.012	0.032	-0.000	0.031
Portugal	-0.024	-0.017	0.004	-0.001	0.002
Spain	-0.017	-0.009	-0.002	-0.000	-0.003
Sweden	-0.033	-0.016	0.005	-0.001	0.003
Turkey	-0.063	-0.063	0.030	-0.018	0.012
U.K.	-0.015	-0.007	0.000	-0.000	0.000
U.S.	-0.007	-0.004	-0.001	-0.000	-0.001
Russia	-0.187	-0.226	-0.183	-0.121	-0.305

Starting with aggregate TFP, Russian productivity falls by 0.19% as a result of the imposition of tariffs. However, some coalition countries also exhibit similar drops in TFP like Hungary, Finland or the Netherlands.[12] These drops come from the fact that sectoral productivities in sectors with high value-added are sizable. The results for the real wage are similar but with some important differences. Russian real wage falls by 0.23%, which is similar to the drop in aggregate TFP. The same is not true of all countries. For example, Dutch TFP falls by 0.19% while its real wage falls by only 0.09%. This difference is explained by two facts. First, the weights used in the aggregation of sectoral productivity are not the same in both measures. Aggregate TFP uses the share of value-weighted while the real wage uses the input-output matrix together with each sector's share of value weighted. Second, the real wage includes the effects coming in from relative prices as shown in equation (14), while aggregate TFP does not.

I now turn to real household income, which is the utility of the representative household in this model. Russian welfare drops by 0.3%, which is larger than the drop of its real wage. This happens because, as Russian exports fall by 10% and I impose a balanced trade condition with no trade deficits, Russian imports must also fall. This decrease leads to a decrease in revenue from tariffs. In contrast, most coalition countries

[12] This impact on coalition countries can also explain why some E.U. countries may be reluctant to impose large sanctions on Russia. For example, Hungary experiences a drop in aggregate TFP that is basically identical to the drop experienced by Russia.

experience no relevant change in welfare. For example, Hungary, which experiences a 0.13% drop in the real wage, only exhibits a 0.01% drop in welfare because revenues from tariffs increase significantly.

I can further decompose the change in welfare as the change coming in from terms of trade and coming in from the volume of trade. For Russia, 40% of the drop in welfare comes from a decrease in volume of trade caused by the drop in imports. This is an important mechanism through which sanctions operate: forcing Russian exports to decrease will lead to a decrease in Russian imports which will have negative consequences for welfare.[13] The majority of the welfare losses for Russia come from a change in terms of trade. One of the consequences of tariffs is a decrease in Russian marginal costs. This implies a decrease in the price of Russian exports relative to the price of its imports. Therefore, the imposition of tariffs leads to a worsening of terms of trade for Russia, as stated by Sturm (2022). However, it does not necessarily lead to an improvement of terms of trade for coalition countries.

I can also decompose the change in welfare by sector. In particular, I can use equation (15) to compute the contribution of each tradable sector j to the change in welfare arising from either the terms of trade effect or the volume of trade effect. I present the results of this decomposition in Table IV.

TABLE IV. Decomposition of effects on welfare by sector

This table presents the effect of the increase on tariffs imposed by coalition countries on welfare of coalition countries and Russia. I consider three countries: Germany, coalition countries and Russia. For each country, I present the contribution in percentage of each sector to the terms of trade and volume of trade effect.

	Germany		Coalition		Russia	
Sector	Terms of trade	Volume of trade	Terms of trade	Volume of trade	Terms of trade	Volume of trade
Agriculture	10.59	3.43	8.79	12.44	9.85	4.42
Mining	-40.54	3.46	17.15	4.10	55.95	2.99
Food	20.04	27.74	1.01	39.24	2.89	7.12
Textiles	19.09	0.39	-4.02	3.57	0.32	5.69
Wood	0.92	4.63	0.79	2.37	1.73	0.94
Paper	16.00	0.00	1.18	0.15	0.60	3.10
Petroleum	3.35	-1.74	6.79	-1.34	0.25	27.24
Chemicals	-11.30	17.17	16.87	13.35	8.13	7.65
Rubber	4.75	3.43	1.27	0.90	0.69	2.37
Other non-metals	2.43	1.29	0.85	0.39	0.49	1.93
Basic metals	-51.85	23.11	34.09	18.51	14.07	3.89
Metal products	13.17	0.87	3.95	0.19	0.43	3.68
Machinery	0.39	2.01	8.68	0.84	1.57	6.38
Office	33.41	-0.13	-2.56	0.43	0.53	0.31
Electrical	23.08	2.14	2.96	0.01	0.39	4.20
Communication	2.85	0.14	-0.12	0.03	0.08	0.03
Medical	9.22	0.53	-2.39	0.18	0.05	0.86
Auto	31.31	8.85	1.36	2.16	0.95	9.72
Other transport	1.83	1.71	4.35	2.28	0.82	4.85
Manufacturing and recycling	11.26	0.98	-0.99	0.18	0.21	2.63

[13]This example is an extreme case where Russia must have no current account deficit. In the short run, it is possible that Russian could maintain its level of imports and finance it with debt. However, that will have two implications. First, Russia will have to run trade surpluses in the future which requires an ever larger adjustment in imports (or an expansion of exports). Second, the terms Russia will obtain in this new debt will not be favorable which will be another source of losses in welfare.

It is also important to note that I have not allowed coalition countries to impose restrictions on exports to Russia. In that case, there would be an additional negative effect on the volume of trade component. There would also be an additional loss in welfare for coalition countries.

Starting with Germany, the contribution of the Mining sector (which includes oil and gas) to terms of trade is negative. Since the terms of trade effect is negative for Germany, this means that terms of trade for the Mining sector improve. This happens because the price of Mining products without tariffs decreases as Russian marginal costs decrease. However, for most sector, terms of trade depreciate as the relative price of German exports falls. If I instead consider all coalition countries, terms of trade improve as a whole, which is why the contribution of the Mining sector is positive because, absent tariffs, the price of Russian Mining products actually falls as Russian marginal costs fall. Turning to Russia, the terms of trade effect is dominated once again by the Mining sector. As the Russian economy becomes depressed, factor prices fall. Therefore, marginal costs fall as well and none fall more than the Mining sector. Therefore, the price of Russian exports falls, which leads to a depreciation of terms of trade. In terms of volume of trade, all sectors display losses because Russian must decrease imports of all products in order to maintain balanced trade.

As a result of an increase of 10 percentage points on tariffs imposed on imports from Russia, trade flows change quite dramatically. In fact, trade flows are quite responsive with drops in exports of around 40%. The same is not true for welfare. Russian real household income, which is the measure of welfare in this model, decreases by 0.3% which is two orders of magnitude below the change in trade flows and one order of magnitude lower than the change in tariffs. This apparent disconnect between changes in trade flows is an ubiquitous feature of trade models, as shown in Arkolakis et al. (2012). The reason is simple: one of the chief determinants of welfare is the change in productivity, and this change is very small because marginal costs don't change as much as trade flows.

These results also show that it is possible to inflict hardship on the Russian economy with relatively minor impacts on coalition countries. The increase of tariffs in my baseline exercise is relatively small, particularly when compared to outright banning imports from Russia. Nevertheless, it still has sizable impacts on welfare, as well as very large effects on trade flows.

3.4 Oil & Gas

The results in the previous exercise suggest that the Mining sector, which contains oil and gas, is of paramount importance when it comes to sanctions. It represents a large share of coalition imports from Russia and is currently the main source of revenue for the Russian government. However, in the short-run, it is very difficult to change the source of oil and gas as these products are not homogeneous across source countries. Therefore, the E.U. has excluded oil and gas from sanctions although it has pledged to ban imports of these goods in the future. Therefore, it is important to consider the effects of sanctions on all products but Mining products. I present the results of this exercise in Table V.

TABLE V. Effects on welfare when sanctions do not include oil and gas

This table presents the effect of the increase on tariffs imposed by coalition countries on welfare of coalition countries and Russia. I present two measures of welfare: the real wage and real household income. In this model, welfare is given by real household income, which is a convex combination of the real wage and changes in tariff revenue. This measure can be decomposed in a terms of trade effect and in a volume of trade effect.

		Welfare (%)		
	Real wage (%)	Terms of trade	Volume of trade	Welfare
Russia	0.024	0.019	-0.073	-0.054
Coalition	-0.015	0.005	-0.003	0.002
Germany	-0.011	0.000	-0.001	-0.002
Netherlands	-0.030	0.015	-0.005	0.010
Hungary	-0.035	-0.002	-0.004	-0.006

In this case, the real wage in Russia increases by 0.02%. This happens because the productivity of the Mining sector increases and the real wage is a weighted average of sectoral productivities, where the weights depend on each sector's importance in the input-output structure of the economy. As all sectors need oil or gas, this sector will have a large weight. Productivity increases because marginal costs increase, and marginal costs increase because the nominal wage increases in Russia (as do factor prices). If tariffs do not include the Mining sector, global demand for Russian products does not fall much and so factor demand does not fall. As marginal costs increase for Russia's main export, Russian terms of trade improve, which increases Russian welfare. On the other hand, Russian exports fall slightly and so do Russian imports due to the balanced trade condition, which leads to a negative volume of trade effect and which decreases Russian welfare. Overall, Russian welfare falls by 0.05%, which is one sixth of the welfare losses Russia would have suffered under full sanctions. Therefore, it is crucial to include this sector in the sanction packages. It's also important to note that, if the volume of trade effect is small (which might happen in the short run as firms cannot freely adjust their inputs), Russian welfare might actually increase due to the terms of trade effect. As oil prices increase, Russia might exhibit small welfare gains.

3.5 Coalition vs. a single country

I have so far considered the case of a coalition of countries imposing sanctions on Russia. This case may not be realistic as some coalition countries may not be willing to impose this level of sanctions on Russia on a coordinated basis. For example, Hungary experiences some losses in terms of productivity which might make the Hungarian government less eager to embark on this path. In order to understand the differences between a large and small coalition, I will conduct a simple exercise in which I will assume that only one country, Germany, imposes sanctions on Russia. This will allow us to understand the differences between a coalition imposing sanctions and a single country imposing sanctions. I present the results of this exercise in Table (VI).

TABLE VI. Tariffs with a small coalition

This table presents the effect of the increase on tariffs imposed by Germany on Russia. I present results for Russia, Germany, Hungary and the E.U. as a whole. I present the change in imports from Russia, the change in the real wage and the change in real household income for each country. For the E.U., all results except the change in imports are the average of the measures of E.U. countries. In this model, welfare is given by real household income, which is a convex combination of the real wage and changes in tariff revenue. This measure can be decomposed in a terms of trade effect and in a volume of trade effect.

			Welfare (%)		
	Imports from Russia (%)	Real wage (%)	Terms of trade	Volume of trade	Total
Russia	-	0.079	0.063	-0.054	0.008
Germany	-58.6	-0.022	-0.001	-0.002	-0.003
Hungary	-2.17	-0.012	-0.011	0.000	-0.012
E.U.	-15.3	-0.004	-0.003	0.000	-0.003

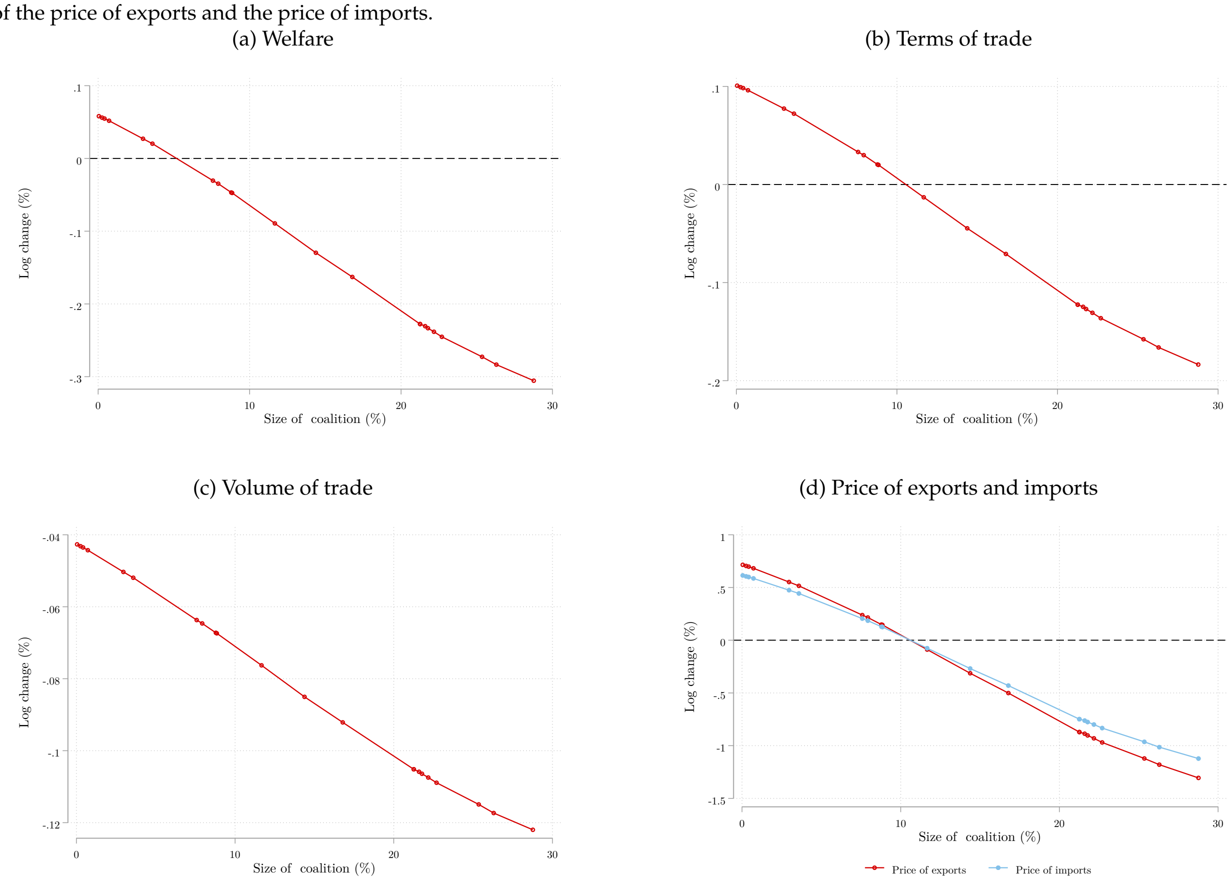
The first conclusion is that with a small coalition (only Germany in this case), Russia is not harmed by tariffs at all. In fact, both the real wage and real household income increase as a consequence of tariffs. Why is this the case? The answer is simple - if only one country imposes tariffs (or a small set of countries), Russia does not need to reduce its exports by a large amount. As a consequence, Russian wages and marginal costs do not decrease by much and neither does productivity in Russia. In fact, the opposite happens as marginal costs rise relative to sector prices. This is only possible if Russia can easily substitute away its exports to Germany to other countries, which is the case when there is a small coalition. With a small coalition, Russia will not experience losses arising from a worsening of terms of trade; in fact, Russian terms of trade improve. However, it will still experience losses arising from a decrease in the volume of trade as Russian imports decrease in response to a decrease in exports.

It's also important to note that German losses are identical in this case and in the case of a coalition of countries. The same is true for Hungary, which is one of the countries in the European Union which is more reluctant to increase sanctions on Russia. Therefore, if the goal of the coalition is to impose the largest possible amount of economic hardship on Russia conditional on an acceptable level of losses at home, it is better to have a large coalition than a smaller one. Moreover, this is also true for countries outside of the small coalition, like Hungary, who will still experience some losses due to the interconnectedness of the European Union.

In order to understand the role of the size of the coalition, I will conduct a simple exercise in which I start with a coalition of one country and add a new country every time until I reach the full size of the coalition. The goal is to understand how changes in Russian welfare move with coalition size. I define the size of the coalition as the share of Russian imports that go to coalition countries. In Figure 5, I present the results of this exercise, focusing on the change in Russian welfare. I also present the decomposition into the terms-of-trade and volume-of-trade effects, as well as a decomposition of the terms-of-trade effect into its two components - price of exports and price of imports.

FIGURE 5. Russian welfare with a varying coalition size

This figure presents the effect of an increase in tariffs imposed by a coalition of countries on Russia. The horizontal axis is the size of the coalition, which I define as the share of total Russian imports that are directed at coalition countries. In panel (a), I present the logarithm of the change in real household income. In panel (b), I present the logarithm of the change in the terms-of-trade effect as in equation (15). In panel (c), I present the logarithm of the change in the volume-of-trade effect. In panel (d), I present the contribution of the price of exports and the price of imports.



If the coalition size is small, Russian welfare actually improves. Why is this the case? First, the volume-of-trade effect is always negative, regardless of coalition size. The reason is simple: even if a single country imposes tariffs on Russia, Russian exports fall and so, from the balanced trade condition, Russian imports must fall as well. As Russian imports fall, productivity falls as Russia must rely on domestically produced goods and tariff revenue falls because imports decrease. However, this effect is much smaller than the terms-of-trade effect (around half) and so I will focus on the latter to understand the variation in welfare. If the coalition is small, the terms-of-trade effect is positive, i.e., Russian terms-of-trade appreciate as the price of imports falls relative to the price of exports. The price of exports increases because marginal costs in Russia increase due to the increased reliance on domestically produced goods. The price of imports increases because coalition countries also face higher marginal costs as they too must rely more on domestically produced goods. As the coalition size increases, the terms-of-trade effect turns negative, generating a welfare loss for Russia. This happens because the price of Russian exports falls more than the price of Russian imports. Therefore, as the coalition size increases, coalition countries are able to generate a recession in Russia where factor prices fall, which generates a decrease in the price of Russian exports. The cost of this recession is a small recession at home, as marginal costs of coalition countries also fall. However, this decrease is smaller and part of it is compensated by an increase in tariff revenue.

The conclusion from this exercise is simple: the goal of a coalition is to affect Russian terms of trade, which is also the insight in Sturm (2022). However, here I provide evidence that the depreciation of Russian terms of trade comes from a decrease in the price of Russian exports. This decrease is in turn driven by a decrease in nominal wages and factor prices in Russia, and this decrease becomes more pronounced as coalition size increases.

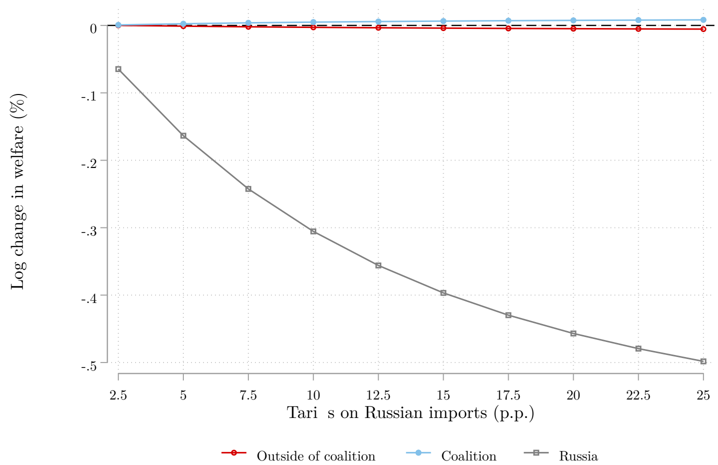
3.6 Varying the size of the tariff change

I have so far focused on the consequences of sanctions on Russia for a given level of tariffs. I will now turn my attention to the case of optimal tariffs. I have already shown evidence to suggest that, conditional on an increase in tariffs, it is better for countries to form a large coalition to impose those tariffs. Therefore, the larger the coalition, the better in terms of maximizing damage to Russia conditional on an acceptable level of domestic hardship. However, the question of the optimal level of tariffs remains. In order to address this question, I will make two simplifying assumptions: (1) tariffs imposed by the coalition are identical for all participating countries and (2) tariffs are identical for all sectors. The first assumption ensures that the coalition has uniform tariffs, which is a good starting point for the analysis. The second assumption greatly simplifies the numerical exercise but it also implies that coalition countries are not maximizing damage to Russia. To understand why, recall that the change in sectoral productivity is decreasing in the change of own consumption and increasing in the inverse trade elasticity. Therefore, an optimal tariff would seek to leverage this relation by designing tariffs that induce a negative correlation between the change in own consumption and trade elasticities. Nevertheless, this limitation only implies that the drop in Russian welfare could be larger and so my results can be viewed as a lower bound.

I will therefore solve the equilibrium in changes for different levels of uniform tariffs. I will then consider three groups of countries: (1) countries outside of the coalition, (2) countries inside the coalition, and (3) Russia. I present the change in real household income for these three groups for different levels of tariffs in Figure 6.

FIGURE 6. Welfare losses for different tariffs

This figure plots the change in real household income for different tariff levels. for three groups of countries: (1) countries outside of the coalition, (2) countries inside the coalition, and (3) Russia. For each group, I compute the change in group real household income as the average of the change in individual real household income.



I will start by looking at coalition countries. As the level of sanctions increase, coalition welfare does not change much. In fact, it increases very slightly as tariff revenues increase. Therefore, concerns that high sanctions will have large negative consequences for coalition countries are not true in the long run. As sanctions increase, so does the drop in real household income in Russia. For example, with a tariff increase of 25 percentage points, Russian real household income drops by 0.5%. This decrease is also concave: incremental increases in tariffs will have a smaller effect on Russian welfare. This happens because, as tariffs increase, Russian exports to coalition countries fall quite sharply. Therefore, if coalition countries consider increasing tariffs from an already large level, the scope for effect is small. In order to understand this, I can decompose the change in Russian welfare into two effects: (1) terms of trade and (2) volume of trade. I show the results of this decomposition in Figure 7.

FIGURE 7. Decomposition of Russian welfare losses for different tariffs

This figure plots the decomposition of the change in Russian real household income for different tariff levels. This measure can be decomposed in a terms of trade effect and in a volume of trade effect.

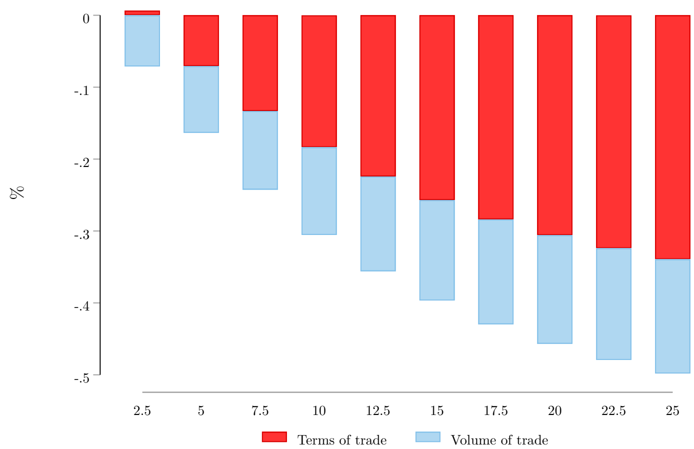


Figure 7 is crucial to understand the mechanics of tariffs. Consider first a small tariff increase. In this case, Russian exports to coalition countries decrease and this decrease is not offset by an increase in exports to non-coalition countries. As I impose that Russia must not run trade deficits (or surpluses), Russian imports must also decrease. This decrease in volume of trade leads to a decrease in welfare because Russian firms must rely on more expensive domestic inputs. However, as the increase in tariffs is small, foreign demand for Russian goods does not fall very sharply and so Russian factor prices do not change much. As a consequence, Russian marginal costs do not change by much. This implies that terms of trade remain relatively constant.Now, consider the case of a large tariff increase. The volume of trade effect is slightly larger but not by much. The main determinant of the larger welfare losses is the change in terms of trade. With a large tariff, Russian marginal costs must fall and so Russian export prices fall relative to their import prices. Therefore, with small tariffs, the key consequence of tariffs is a decrease in volume of trade and, with large tariffs, the key consequence lies with a change in terms of trade.

3.7 Short vs. long run effects

All the results I have presented relate to the long-run consequences of tariffs. This long run assumes that firms can perfectly adjust their supplies and consumers. It also assumes, for example, that there are no nominal rigidities such as price stickiness, or real rigidities like market power. These phenomena are excluded in order to make the model more tractable. However, understanding the difference between the long run and the short run is important to understand the political economy of sanctions. I have shown that, in general, coalition countries do not experience losses in the long run. This is not necessarily the case for the short-run.

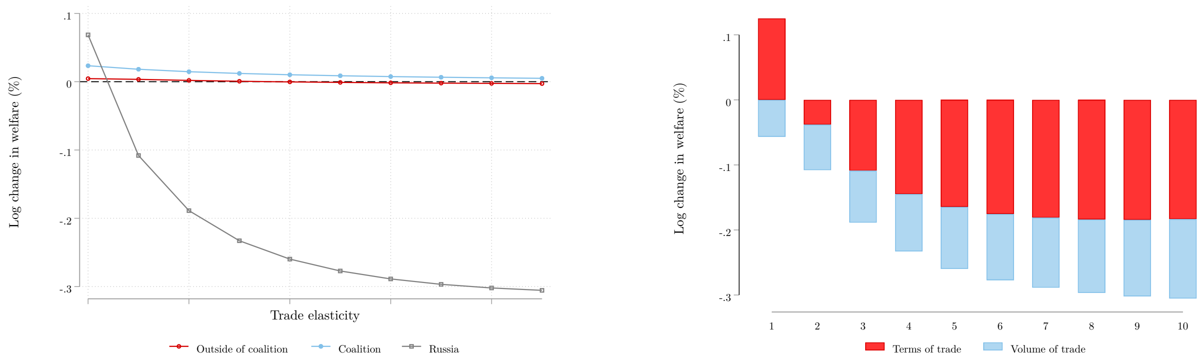
In order to conduct this exercise, I will define the short run as an economy where adjusting the suppliers and consumers is difficult, which makes changing π_{in}^{j} difficult. Consider the gravity equation (4). The effect of a change in trade costs on trade flows increases with the trade elasticity. Therefore, in order to mimic the short-run, I will consider an economy where trade elasticities are lower. The intuition for this choice comes from the Le Chatelier principle: short run elasticities tend to be smaller than long run elasticities. However, there is also empirical evidence that this holds in the context of international trade as Boehm et al. (2020) find that trade elasticities increase with the time horizon.

The exercise is as follows. I will multiply the entire vector of trade elasticities by a constant $\varphi \in (0, 1]$. A small φ stands for the short run while $\varphi = 1$ is the long run. I will solve the equilibrium in changes for a fixed level of tariffs while allowing trade elasticities to increase. In Figure 8, I present the changes in real household income for coalition countries, countries outside of the coalition and Russia for increasing values of the trade elasticities. The largest value for trade elasticities I consider is the long run, which is the vector I have used in my previous analysis.

FIGURE 8. Welfare effects in the short and long run

This figure plots the evolution of welfare as trade elasticities increase. I consider three groups of countries: coalition countries, countries outside of the coalition and Russia. In panel (a), I present the evolution of changes in real household income as trade elasticities approach their long-run value for these three groups. In panel (b), I decompose the change in real household income for Russia into a terms of trade effect and in a volume of trade effect.

(a) Real household income | (b) Decomposition of Russian welfare



Looking at panel (a), welfare losses in Russia increase as the economy approaches the long-run. As elasticities increase, and conditional on the size of the shock, firms in coalition countries stop importing Russian goods and therefore the Russian economy suffers the full effects of sanctions. It is interesting to note that, when elasticities are very low (in the immediate short-run), the Russian economy may experience a temporary gain in welfare. Why is this the case? In order to understand the reason, I need to turn to panel (b), where I decompose the change in Russian welfare into a terms of trade effect and a volume of trade effect. When elasticities are low, the volume of trade effect is negative as expected but the terms of trade effect is positive. Therefore, when elasticities are low, the relative price of Russian exports actually increases relative to the price of imports. It must be that coalition countries are experiencing a drop in factor prices which decreases their marginal costs and therefore decreases the price of their exports. As a consequence, the price of Russian imports decreases in the short-run which generates this effect. However, as elasticities increase, the terms of trade effect turns negative and then increases in absolute value. As with the exercise in which we varied the size of the shock, the bulk of the increase in welfare losses is due to an increase in the terms of trade effect.

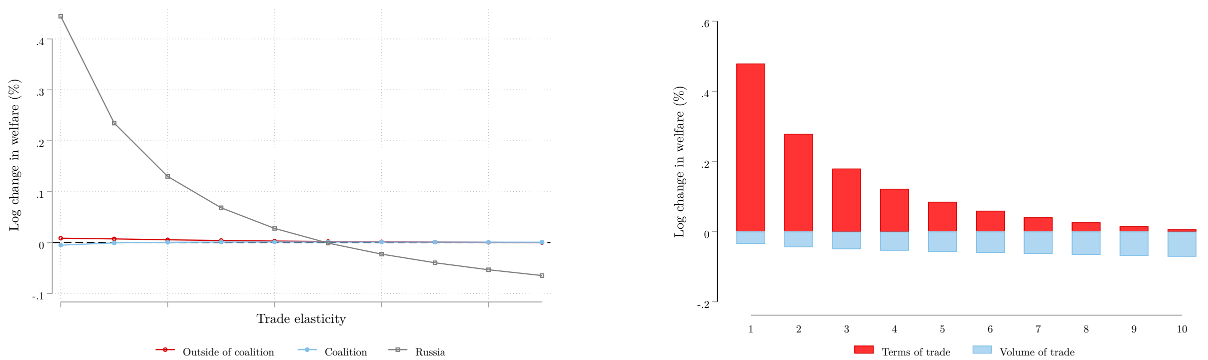
Changing elasticities, changing the size of the shock and changing the size of the coalition all seem to have similar effects on welfare. A small shock or a small trade elasticity both may yield welfare improvements for Russia, as is the case with a small coalition. Therefore, it's important to look at a case in which sanctions are mild. For example, there may be discord within the coalition which leads countries to compromise. Or, for example, some coalition countries may be concerned with the adverse effects of sanctions in their own economy. In order to answer this question, I will repeat this exercise with a much smaller increase in sanctions (2.5 percentage points). I present the results in Figure 9.

FIGURE 9. Welfare effects in the short and long run with a small increase in tariffs

This figure plots the evolution of welfare as trade elasticities increase, with a 2.5 percentage point increase in tariffs. I consider three groups of countries: coalition countries, countries outside of the coalition and Russia. In panel (a), I present the evolution of changes in real household income as trade elasticities approach their long-run value for these three groups. In panel (b), I decompose the change in real household income for Russia into a terms of trade effect and in a volume of trade effect.

(a) Real household income

(b) Decomposition of Russian welfare



As I suggested, with a small shock, Russia may experience significant welfare improvements in the short run. Therefore, if the coalition decides to impose very mild sanctions, they will in fact see the Russian economy improve in the short run. Moreover, if the argument for mild sanctions is that they will not harm the Russian economy and the short run is more important than the long run for policymakers in coalition countries, the argument is certainly vindicated by these results. The Russian sees an improvement in real household income in the short run because the price of its imports decreases and so its terms of trade improve, as shown in panel (b).

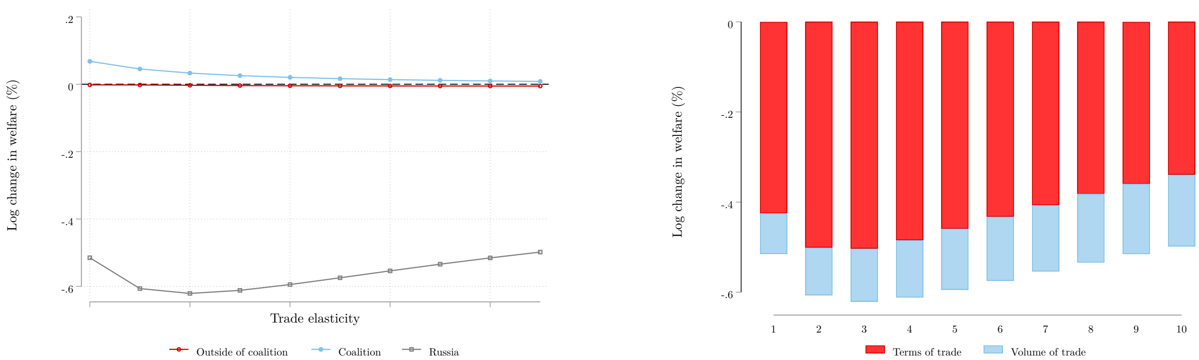
However, it is important to note that the short run effects are positive for Russia precisely because sanctions are mild, and not because of the imposition of sanctions. With large sanctions, this would not take place. In order to see this, I can again conduct this exercise with a large increase in sanctions (25 percentage points).

FIGURE 10. Welfare effects in the short and long run with a large increase in tariffs

This figure plots the evolution of welfare as trade elasticities increase, with a 25 percentage point increase in tariffs. I consider three groups of countries: coalition countries, countries outside of the coalition and Russia. In panel (a), I present the evolution of changes in real household income as trade elasticities approach their long-run value for these three groups. In panel (b), I decompose the change in real household income for Russia into a terms of trade effect and in a volume of trade effect.

(a) Real household income

(b) Decomposition of Russian welfare



In Figure 10, which shows the results for a large increase in sanctions, it is easy to conclude that even in the short run the Russian economy experiences a large drop in welfare. This drop takes place precisely because terms of trade worse in the short run as factor prices in Russia fall sharply, thus decreasing the price of its exports.

4 Sanctions on Exports to Russia

So far, I have focused on the case of tariffs imposed by coalition countries on imports coming from Russia. This type of sanction is both common and easy to implement. However, countries have imposed different sanctions. For example, the U.S. has imposed numerous sectoral sanctions that restrict or prohibit the export of goods to Russian firms. The sanctions have the goal of increasing the cost of Russian imports (or, in the case of some goods, preventing Russian firms from importing certain goods). In this section, I will consider the imposition of these types of sanctions on Russian firms and its impact on both Russia and coalition countries.

To model sanctions on exports to Russia, I will consider an increase in iceberg costs on goods produced in coalition countries and sold in Russia. I will consider an extension of the model I presented in Section 2 where iceberg costs may change but tariffs may not. This is a simplifying assumption that allows me to obtain simple expressions for the change in welfare. The following Proposition presents the effects of a change in iceberg costs on welfare.

Proposition 5. *The changes in welfare in country n can be decomposed as*

$$d\log W_n = \frac{1}{I_n}\sum_{j=1}^{J}\sum_{i=1}^{N}\left(E^j_{ni} d\log c^j_n - M^j_{in} d\log c^j_i\right) + \frac{1}{I_n}\sum_{j=1}^{J}\sum_{i=1}^{N}\tau^j_{in}M^j_{in}\left(d\log M^j_{in} - d\log c^j_i\right)$$
$$- \frac{1}{I_n}\sum_{j=1}^{J}\sum_{i=1}^{N}\left(1+\tau^j_{in}\right)M^j_{in} dd^j_{in} \tag{16}$$

where $E^j_{ni} = X^j_i \frac{\pi^j_{ni}}{1+\tau^j_{ni}}$ *are country n's exports of sector j goods to country i and* $M^j_{in} = X^j_n \frac{\pi^j_{in}}{1+\tau^j_{in}}$ *are country n's imports of country i's sector j products.*

Proof. In Appendix A. □

The terms in equation (16) look very similar to those in equation (15). The first two terms are the classical terms-of-trade and volume-of-trade effects. The third term, which I call the cost-of-trade effect, represents the welfare losses arising from an increase of iceberg costs. As iceberg costs for exports coming from country i to country n increase, welfare in country n decreases because the price firms in country n pay for imports increases. This effect is not absorbed in the other two terms because, unlike with tariffs, this increased cost represents a pure efficiency loss. With tariffs, the extra cost of imports is captured by the government and distributed as transfers. With changes in iceberg costs, the government's revenue does not change to reflect the added cost of imports. Therefore, I will think of the third term in equation (16) as the direct effect of the increase in interest rates, while keeping all trade flows and prices constant.[14]

Consider the case of Russia. If coalition countries impose sanctions on exports (and iceberg costs increase), there are three different effects on Russian welfare. First, if trade flows and prices do not change, Russian imports become more expensive, which leads to an increase in marginal costs for Russian firms. As marginal costs increase, the marginal productivity of all factors of production decreases, which leads to a decrease in wages, which in turn depresses real household income and welfare. Second, there is a negative volume-of-trade effect – as imports become more expensive, Russia imports less which leads a higher reliance on more expensive domestic goods, which depresses welfare. Third, there is an ambiguous effect on terms-of-trade. On one hand, Russian marginal costs will increase due to the iceberg costs, which increases the price of Russian exports and, keeping trade flows constant, improves welfare. On the other hand, the price of Russian imports may increase as well. The sign of the overall effect is unclear.

4.1 Effect on trade flows and welfare

I will consider an increase of 10 percentage points in iceberg costs for goods produced in coalition countries and sold in Russia.[15] I present the effects of this change in trade flows in Table VII.

[14]This intuition is very similar to the one in Monteiro and Moreira (2023), who look at the effects of a change in interest rates on trade flows. In their model, interest rates behave in the same way as iceberg costs.

[15]This is the same size of the shock I consider in tariffs. However, because I do not have data on the initial value of iceberg costs, I cannot compare the percentage change in tariffs with the percentage change in iceberg costs.

TABLE VII. Effects on trade flows

This table presents the change in exports (in percentage) for all countries. I present the change in total exports, in exports to Russia, and in exports to all other countries.

Country	Total exports	Exports to Russia	Exports to other countries
Coalition countries			
Australia	0.08	-28.90	0.15
Austria	-0.20	-33.24	0.32
Canada	-0.30	-33.66	-0.26
Denmark	-0.31	-37.78	0.35
Finland	-1.01	-39.94	1.22
France	-0.19	-37.20	0.33
Germany	-0.31	-32.59	0.40
Greece	0.23	-42.33	0.62
Hungary	-0.24	-40.01	0.56
Ireland	-0.07	-26.61	0.11
Italy	-0.31	-32.53	0.27
Japan	-0.90	-53.34	-0.03
Korea	-0.31	-37.86	0.33
Netherlands	-0.20	-39.54	0.21
New Zealand	0.04	-31.88	0.12
Norway	-0.05	-38.31	0.11
Portugal	-0.13	-46.18	0.22
Spain	-0.13	-34.99	0.23
Sweden	-0.19	-34.39	0.34
Turkey	-0.65	-45.22	0.62
U.K.	-0.50	-74.09	0.95
U.S.	-0.09	-46.58	0.20
Non-coalition countries			
Argentina	-0.08	3.87	-0.12
Brazil	-0.37	9.64	-0.44
Chile	0.00	2.99	-0.03
China	0.03	14.75	-0.31
India	0.16	19.82	-0.08
Indonesia	-0.13	4.21	-0.16
Mexico	-0.41	18.40	-0.45
South Africa	0.12	9.37	0.04
Russia	-9.59		-9.59

Exports of coalition countries to Russia decline quite substantially. [16] For example, German exports to Russia decline by almost 33 percent. Moreover, there is little change in exports from coalition countries to other countries (with the exception of Finland and the U.K.). This lack of export substitution is explained by the fact that marginal costs in coalition countries don't change by much in response to the imposition of sanctions on exports. Overall exports by coalition countries also decline, but very little, as Russia is not a key destination for coalition exports. Exports from non-coalition countries to Russia increase because the goods produced by these countries become relatively cheaper for Russian importers. However, this increase in exports from non-coalition countries to Russia is not enough to prevent Russian imports from

[16] This decline is also in the same order of magnitude as the change in imports I observe for coalition countries in the case of change in tariffs. As both tariffs and iceberg costs are multiplied by the trade elasticity in the quantity equation, this suggests that the fact that the two shocks have comparable effects implies that the magnitudes are also comparable.

declining almost 10 percent.[17]

In Table VIII, I present the change in welfare (measured as the change in real household income) for all countries, and its decomposition into the terms-of-trade effect, the volume-of-trade effect and the cost-of-trade effect.

TABLE VIII. Effects on welfare

This table presents the change in real household income (in percentage) for all countries. I present the total change in welfare and its decomposition into: (1) the terms-of-trade effect, (2) the volume-of-trade effect, and (3) the cost-of-trade effect.

Country	Terms of Trade	Volume of Trade	Cost of trade	Welfare
Coalition countries				
Australia	0.008	0.000	0.000	0.008
Austria	-0.018	-0.002	0.000	-0.020
Canada	0.014	-0.002	0.000	0.012
Denmark	-0.020	-0.003	0.000	-0.023
Finland	-0.075	-0.006	0.000	-0.081
France	-0.012	-0.001	0.000	-0.013
Germany	-0.029	-0.002	0.000	-0.031
Greece	0.001	0.000	0.000	0.001
Hungary	-0.078	-0.004	0.000	-0.082
Ireland	-0.003	-0.001	0.000	-0.003
Italy	-0.019	-0.001	0.000	-0.021
Japan	-0.005	-0.004	0.000	-0.008
Korea	-0.023	-0.007	0.000	-0.029
Netherlands	-0.006	-0.004	0.000	-0.010
New Zealand	0.004	0.000	0.000	0.005
Norway	0.002	0.000	0.000	0.002
Portugal	-0.015	-0.001	0.000	-0.016
Spain	-0.009	-0.001	0.000	-0.011
Sweden	-0.014	-0.001	0.000	-0.015
Turkey	-0.033	-0.010	0.000	-0.043
U.K.	-0.018	-0.001	0.000	-0.019
U.S.	-0.002	0.000	0.000	-0.002
Non-coalition countries				
Argentina	-0.004	0.001	0.000	-0.003
Brazil	0.023	-0.009	0.000	0.014
Chile	0.002	0.000	0.000	0.002
China	-0.002	0.000	0.000	-0.001
India	0.005	0.002	0.000	0.007
Indonesia	0.018	-0.002	0.000	0.015
Mexico	0.019	-0.003	0.000	0.016
South Africa	0.014	-0.001	0.000	0.012
Russia	0.332	-0.166	-1.208	-1.042

The first conclusion fro Table VIII is that Russian welfare losses are much larger with sanctions on exports than they are with tariffs on imports. Under a 10 percentage point increase in tariffs, Russian welfare declines by 0.3%. Under a 10 percentage point increase in iceberg costs, Russian welfare declines by 1%. The difference in size is explained by the transmission of the shock. With tariffs on imports, most

[17]To see this, note that Russian exports decline by 9.59% and that, from the balanced trade equation, imports must also decline by the same amount.

of the welfare loss comes from a depreciation of terms of trade. Russian terms of trade depreciate because Russian marginal costs decrease as the wage decline. The decrease in the wage is driven by a lower demand for inputs as demand for Russian goods decreases. Therefore, the impact of tariffs on Russian welfare depends on the trade elasticity and on the elasticity of the wage to demand. In contrast, the effect of an increase in iceberg costs if far more direct – Russian marginal costs increase depending on the share of imported inputs and the share of inputs in production. This effect does not depend on general equilibrium forces (and is in fact partially undone by a decrease in demand for domestic factors) and is therefore larger. The welfare losses of coalition countries are also larger. For example, Hungary observes a decline in real household income of 0.08 percent, compared with a decline of 0.01 percent under tariffs on imports.

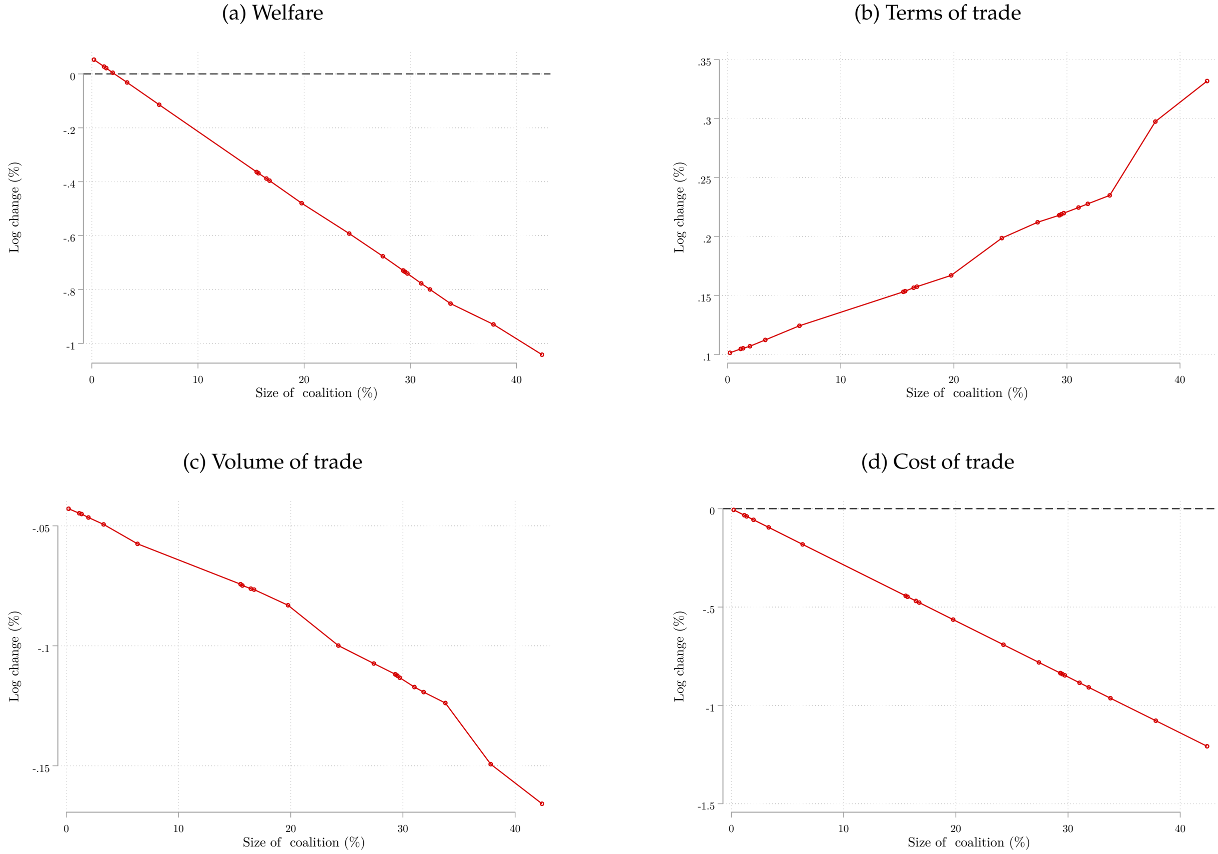
The difference in welfare losses suggests that, from the perspective of coalition countries, there is trade-off not just in the size of the sanctions but in the type of sanctions. If coalition countries wish to impose the largest possible welfare losses on Russia, then they should choose to impose sanctions on exports. If, on the other hand, coalition countries wish to minimize welfare losses in their own economies, they might prefer to use tariffs on imports as a tool for sanctions.

4.2 Importance of the size of the coalition

The size of the coalition is also going to be an important determinant of the effectiveness of sanctions. In this case, the size of the coalition is the share of Russian imports that are produced in coalition countries. In Figure, 11 I report the change in welfare, terms-of-trade, volume-of-trade, and cost-of-trade for Russia as the size of the coalition increases.

FIGURE 11. Russian welfare with a varying coalition size

This figure presents the effect of an increase in iceberg costs imposed by a coalition of countries on Russia. The horizontal axis is the size of the coalition, which I define as the share of total Russian exports that are produced in coalition countries. In panel (a), I present the logarithm of the change in real household income. In panel (b), I present the logarithm of the change in the terms-of-trade effect as in equation (16). In panel (c), I present the logarithm of the change in the volume-of-trade effect. In panel (d), I present the contribution of cost-of-trade effect.



Welfare losses in Russian increase almost linearly with the size of the coalition, as seen in panel (a). This is because the most important component, which is the cost-of-trade effect, increases linearly with coalition size as seen in equation (16). As I had argued, the volume-of-trade effect is always negative because Russian imports decline and the terms-of-trade effect is positive and increasing in coalition size. This happens because a larger coalition is able to impose larger increases in Russian marginal costs, which leads to larger increases in the price of Russian exports.

5 Conclusion

I consider a Ricardian trade model with many countries and many sectors. Each country has a representative household that consumes only domestically produced goods and supplies labor inelastically. In each sector, there is a continuum of firms producing intermediate goods and a representative producer of a composite good. Producers of intermediate goods use labor and domestically produced composite goods from all sectors in their production. Therefore, the model features a network structure which will generate amplification of the effects of trade shocks. Producers of composite goods use intermediate goods from the same sector. However, they may import intermediate goods from abroad. However, trade is costly in this model. There are two costs of trade: tariffs on imports, which are rebated to households as a lump-sum transfer, and classic iceberg "melting" costs which are pure deadweight losses. I then use this model to evaluate the impact of an increase in tariffs on Russian imports.

The increase in tariffs has very significant effects on the volume of trade. Total Russian exports decrease by around 10% in response to these sanctions and the decrease is, of course, much larger for coalition countries. Russian exports to non-coalition countries increase. However, this increase is not enough to fully offset the impact of tariffs. Therefore, it is not true that, even in the long-run, Russia can simply shift its exports to other countries. The ability of Russia to increase exports to non-coalition countries comes from the fact that the prices of its exports drop. This drop is driven by a decrease in factor prices and nominal wages in Russia. As tariffs on Russian goods increase and global demand for Russian goods fall, Russian firms decrease their production which leads to a decrease in factor prices. This decrease then leads to a decrease in marginal costs and in export prices.

Russia suffers significant welfare losses as a result of tariffs. With a 10 percentage increase in tariffs on Russian imports, Russia displays a welfare loss of 0.31%. Most of the drop in welfare (around 60%) is driven by a decrease in terms of trade as the price of Russian exports falls due to the fall in the Russian nominal wage and factor prices. The remaining effect is driven by the drop in imports.

I also find that a large coalition is always better than a single country in imposing tariffs on Russian imports. With a large coalition, a larger increase in tariffs will yield a larger drop in Russian welfare with no discernible effect on coalition welfare. Therefore, if the goal of the coalition is to maximize economic hardship for the Russian economy conditional on an acceptable welfare loss for coalition countries, the optimal level of tariffs is possibly unboundedly large. As tariffs increase, Russian welfare decreases at a decreasing rate whereas coalition welfare is flat.

In order to simulate a short-run version of this economy, I will consider an equilibrium in which trade elasticities are low. In the short run, it is possible that Russia may display welfare gains in response to tariffs as its terms-of-trade improve. This effect is larger the smaller are the tariffs. Therefore, if policymakers are concerned that in the short run tariffs might be relatively more harmful for coalition countries than they are for Russia, it is better to impose larger sanctions. With large sanctions, the terms of trade effect is always negative, even in the very short run, and so the Russian economy always displays large welfare losses.

I also consider an alternative type of sanction, in which coalition countries make their exports to Russia more expensive. I model this increase as an increase in iceberg costs. Under these sanctions, coalition exports to Russia decline and, despite the fact that exports from non-coalition countries to Russia increase, Russian imports decline. For a 10 percentage point increase in iceberg costs, Russian imports decline by almost 10 percent. I find that Russian real household income declines by over 1 percent for a 10 percentage point increase in iceberg costs. However, this higher effectiveness of sanctions comes with a cost as welfare losses for coalition countries are also larger. This finding suggest that coalition countries face an important trade-off: if their goal is to maximize the damage to the Russian economy, they should choose to impose sanctions on exports. If they wish to minimize welfare losses in their own economies, they should choose tariffs on imports.

References

Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare, "New trade models, same old gains?," *American Economic Review*, 2012, *102* (1), 94–130.

Bachmann, Ruediger, David Baqaee, Christian Bayer, Moritz Kuhn, Andreas Löschel, Benjamin Moll, Andreas Peichl, Karen Pittel, Moritz Schularick et al., "What if? The economic effects for Germany of a stop of energy imports from Russia," Working Paper 2022.

Baqaee, David, Benjamin Moll, Camille Landais, and Philippe Martin, "The Economic Consequences of a Stop of Energy Imports from Russia," Working Paper 2022.

Boehm, Christoph E, Andrei A Levchenko, and Nitya Pandalai-Nayar, "The long and short (run) of trade elasticities," Technical Report, National Bureau of Economic Research 2020.

Caliendo, Lorenzo and Fernando Parro, "Estimates of the Trade and Welfare Effects of NAFTA," *The Review of Economic Studies*, 2015, *82* (1), 1–44.

Dekle, Robert, Jonathan Eaton, and Samuel Kortum, "Global rebalancing with gravity: Measuring the burden of adjustment," *IMF Staff Papers*, 2008, *55* (3), 511–540.

Eaton, Jonathan and Samuel Kortum, "Technology, geography, and trade," *Econometrica*, 2002, *70* (5), 1741–1779.

Krugman, Paul R, "Increasing returns, monopolistic competition, and international trade," *Journal of international Economics*, 1979, *9* (4), 469–479.

Melitz, Marc J, "The impact of trade on intra-industry reallocations and aggregate industry productivity," *Econometrica*, 2003, *71* (6), 1695–1725.

Monteiro, Joao and Pedro Moreira, "The Impact of a Higher Cost of Credit on Exporters: Evidence from a Change in Banking Regulation," Working Paper 2023.

Sturm, John, "A Theory of Economic Sanctions as Terms-of-Trade Manipulation," Working Paper 2022.

_ , Kai Menzel, and Jan Schmitz, "The Simple Economics of Optimal Sanctions: The Case of EU-Russia Energy Trade," Working Paper 2022.

A Model

A.1 Data

This appendix describes the data sources I use in solving the model. We consider 32 countries: Argentina, Australia, Austria, Brazil, Canada, Chile, China, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, Russia, South Africa, Spain, Sweden, Turkey, U.K., U.S., and a constructed rest of the world. We consider 40 sectors, which I report in Table A1.

TABLE A1. Tradable and non-tradable sectors

Number	Industry	ISIC Rev. 4
1	Agriculture	1-3
2	Mining	5-9
3	Food	10-12
4	Textile	13-15
5	Wood	16
6	Paper	17-18
7	Petroleum	19
8	Chemicals	20-21
9	Plastic	22
10	Minerals	23
11	Basic metals	24
12	Metal products	25
13	Machinery n.e.c.	28
14	Office	26
15	Electrical	27
16	Communication	58-60
17	Medical	325,266
18	Auto	29
19	Other transport	30
20	Other	31-33
21	Electricity	35-39
22	Construction	41-43
23	Retail	45-47
24	Hotels	55-56
25	Land transport	49
26	Water transport	50
27	Air transport	51
28	Auxiliary transport	52, 79
29	Post and telecom	53, 61
30	Finance	64-66
31	Real estate	68
32	Renting	77
33	Computer	62, 63, 95
34	R&D	72
35	Other business	69-71, 73-74, 80-82
36	Public admin	84
37	Education	85
38	Health	75, 86-88
39	Other services	78, 90-96
40	Private households	97-98

In Figure A1 I present the coverage of our model, which is the share of world trade which is attributable to the countries in the quantitative model.

FIGURE A1. Model coverage

This Figure presents the share of world trtade attributable to the countries in our quantitative model. In panel (a), we present the share of world exports that is attributable to the countries in our quantitative model. In panel (b) we present the share of world exports that is attributable to the countries in our quantitative model.. In panel (c), we present the share of world exports to Russia that is attributable to the countries in our quantitative model.. In panel (d), we present the same share for imports from Russia.

A.1.1 Bilateral trade shares

I use bilateral trade flows for 2018 for our sample of countries and the first 20 sectors (which are the tradable sectors) in Table A1. Bilateral trade data come from CEPII, which collects bilateral trade from the United Nations Statistical Division Commodity Trade database. Values are in thousands of dollars at current prices and exclude cost, insurance and freight (CIF). We define commodities using the Harmonized Commodity Description and Coding System (HS) 12. I match each commodity to a 2-digit ISIC Rev. 4 industry code using the OECD's concordance table. To compute imports from the rest of the world I, for each country in our sample, subtract total imports from all other countries in the sample from total imports of that country. To compute exports to the rest of the world I, for each country in our sample, subtract export to all other countries in the sample from total exports of that country.

A.1.2 Tariffs

I obtain bilateral trade tariffs at the sectoral level for the year 2018 from World Integrated Trade Solutions (WITS). I extract the effectively applied tariffs for all reporting countries and partner countries and for all

3 digit ISIC Rev. 3 sectors. I then map the 3 digit ISIC Rev. 3 sectors to ISIC Rev. 4 sectors and then to our sectoral classification. I also use data from years 2011, 2012, 2014 and 2015 to fill some missing values for tariff data. At the end of this process, close to 20% of the observations still contain missing data. In order to address this I will use two sequential algorithms. First, I replace the missing value with the median tariff applied by the same country to the same source country (across all sectors). Second, I replace the missing values that are not replace by the first manual input with the median tariff applied by the same country to the same sector products (across all source countries). This allows me to fill all of the missing values.

A.1.3 Value added and gross production

Following Caliendo and Parro (2015), I obtain data on gross output and value added at the sectoral level for the year 2018 from three different datasets. I list these datasets in order of preference. For example, if I have data for the same variable for the same sector-country pair from dataset 1 and from dataset 2, I will use the value from dataset 1.

OECD STAN: the first dataset is the OECD STAN database for industrial analysis. This dataset contains information on gross output and value added for OECD countries at the sectoral level using the ISIC Rev. 4 classification at current prices and in national currency. I convert these values to U.S. dollars using the exchange rates available at the OECD STAN database. This database allows me to fill around 75% of the information on value added per sector.

INDSTAT: the second dataset is the Industrial Statistics Database INDSTAT2. This dataset contains information at current prices in U.S. dollars for 71 3-digit manufacturing sectors. I aggregate these sectors at the 2-digit level and then use the allocation in Table A1 to compute value added and gross output for each sector-country. Using these two datasets allows me to fill most of the data for all countries in our sample.

OECD I-O and UNSTATS: I now need to compute the value added and gross production for the remaining sectors and countries. First, I use information from the OECD's Input-Output Tables to compute the value added and gross production for any sector and OECD country with missing data.Second, I use this dataset to compute value added for the following large sectors: Agricultural, Hunting, Forestry and Fishing (sector 1), Mining and Utilities (sectors 2-12 and 21), Manufacturing (sectors 13-15 and 17-20), Construction (sector 22), Wholesale, retail trade, restaurants and hotels (sectors 23-24), Transport, storage and communication (sectors 16 and 25-29) and other activities (sectors 30-40). I add up value added across all countries. For each of these big sectors, I compute total value added and the share of each sector in value added of the big sector. I then obtain data on these big sectors from the United Nations National Accounts Database, which contains value added data for 200 countries. I decompose the value added of these big sectors into our sectoral classification using the shares we computed in the OECD I-O database. I then use the median sectoral share of value added in the OECD I-O database to compute gross production.

Rest of the world: I need to compute sectoral value added and gross output for the rest of the world. I begin by computing the world's value added for the big sectors using the United Nations Database, after excluding the countries in our sample. I then apply the sectoral shares of value added we obtained from the I-O database to split the value added in our 40 sectors and use the shares of value added in the OECD I-O database to compute gross production.

Filters: I also impose some filters in all stages of this process. I exclude observations where gross production or value added are negative. I also interpret observations where value added is larger than gross production as an error and therefore exclude them accordingly.

A.1.4 Input-Output tables and intermediate consumption

For each sector, I need information on the share of intermediate inputs per sector of origin. I obtain these data from the WIOD database, which contains I-O tables for 43 countries. I use information from 2014 and combine information on use of domestic intermediate inputs and imported intermediate inputs. This database allows me to compute the shares for most of the sector-countries in our sample. I fill missing values by taking the median share for that sector across countries.

A.1.5 Dispersion of productivity

I use the estimates for the dispersion of productivity from Caliendo and Parro (2015).

A.2 Proofs

A.2.1 Proof Proposition 5

The change in welfare is given by

$$d\log W_n = \frac{w_n L_n}{I_n} d\log w_n + \frac{R_n}{I_n} d\log R_n - d\log P_n.$$

From equation (1), the change in marginal costs for a given sector j in country n is given by

$$d\log c_n^j = \gamma_n^j d\log w_n + \sum_{k=1}^{J} \gamma_n^{kj} d\log P_n^k$$

and so the change in the wage is given by

$$d\log w_n = \frac{1}{\gamma_n^j} d\log c_n^j - \sum_{k=1}^{J} \frac{\gamma_n^{kj}}{\gamma_n^j} d\log P_n^k.$$

Using the market clearing condition for labor, it also follows that

$$\begin{aligned}
\frac{w_n L_n}{I_n} d\log w_n &= \frac{1}{I_n} \sum_{j=1}^{N} \gamma_n^j \sum_{i=1}^{N} E_{ni}^j d\log w_n \\
&= \frac{1}{I_n} \sum_{j=1}^{N} \gamma_n^j \sum_{i=1}^{N} E_{ni}^j \left\{ \frac{1}{\gamma_n^j} d\log c_n^j - \sum_{k=1}^{J} \frac{\gamma_n^{kj}}{\gamma_n^j} d\log P_n^k \right\} \\
&= \frac{1}{I_n} \sum_{j=1}^{N} \sum_{i=1}^{N} E_{ni}^j d\log c_n^j - \frac{1}{I_n} \sum_{j=1}^{N} \sum_{i=1}^{N} E_{ni}^j \sum_{k=1}^{J} \gamma_n^{kj} d\log P_n^k \\
&= \underbrace{\frac{1}{I_n} \sum_{j=1}^{N} \sum_{i=1}^{N} E_{ni}^j d\log c_n^j}_{A_1} - \underbrace{\frac{1}{I_n} \sum_{j=1}^{N} \sum_{k=1}^{J} \gamma_n^{kj} d\log P_n^k \sum_{i=1}^{N} E_{ni}^j}_{A_2}
\end{aligned}$$

where $E^j_{ni} \equiv X^j_i \pi^j_{ni} / \left(1+\tau^j_{ni}\right)$ are the exports of sector j goods from country n to country i.

The change in tariff revenue is given by

$$\begin{aligned} d\log R_n &= \frac{\sum_{j=1}^J \sum_{i=1}^N \tau^j_{in} M^j_{in} \left(d\log X^j_n + d\log \pi^j_{in}\right)}{R_n} \\ &= \frac{\sum_{j=1}^J \sum_{i=1}^N \tau^j_{in} M^j_{in} d\log M^j_{in}}{R_n} \end{aligned}$$

where $M^j_{in} \equiv X^j_n \pi^j_{in} / \left(1+\tau^j_{in}\right)$ are country n's imports of sector j goods from country i. Therefore, it follows that

$$\frac{R_n}{I_n} d\log R_n = \underbrace{\frac{1}{I_n}\sum_{j=1}^J \sum_{i=1}^N \tau^j_{in} M^j_{in} d\log M^j_{in}}_{A_3}.$$

From equation (2), I can write the change in the domestic CPI as

$$d\log P_n = \sum_{j=1}^J \alpha^j_n \sum_{i=1}^N \pi^j_{in} \left(d\log c^j_i + d\log \kappa^j_{in}\right)$$

and then, using the market clearing condition for sector j, I can write

$$\alpha^j_n = \frac{X^j_n}{I_n} - \frac{1}{I_n}\sum_{k=1}^J \gamma^{jk}_n \sum_{i=1}^N E^k_{ni}$$

and so the change in the domestic CPI is given by

$$\begin{aligned} d\log P_n &= \sum_{j=1}^J \left\{ \frac{X^j_n}{I_n} - \frac{1}{I_n}\sum_{k=1}^J \gamma^{jk}_n \sum_{i=1}^N E^k_{ni} \right\} \sum_{i=1}^N \pi^j_{in} \left(d\log c^j_i + d\log \kappa^j_{in}\right) \\ &= \underbrace{\sum_{j=1}^J \frac{X^j_n}{I_n} \sum_{i=1}^N \pi^j_{in} \left(d\log c^j_i + d\log \kappa^j_{in}\right)}_{B_1} - \underbrace{\frac{1}{I_n}\sum_{j=1}^J \sum_{k=1}^J \gamma^{jk}_n \sum_{i=1}^N E^k_{ni} \sum_{i=1}^N \pi^j_{in} \left(d\log c^j_i + d\log \kappa^j_{in}\right)}_{A_4} \end{aligned}$$

and I can write the first term as

$$\begin{aligned} B_1 &= \frac{1}{I_n}\sum_{j=1}^J \sum_{i=1}^N \pi^j_{in} X^j_n \left(d\log c^j_i + d\log \kappa^j_{in}\right) \\ &= \frac{1}{I_n}\sum_{j=1}^J \sum_{i=1}^N \left(1+\tau^j_{in}\right) M^j_{in} \left(d\log c^j_i + d\log \kappa^j_{in}\right) \\ &= A_5 + A_6 + A_7 \end{aligned}$$

where

$$A_5 = \frac{1}{I_n}\sum_{j=1}^J \sum_{i=1}^N M^j_{in} d\log c^j_i,$$

$$A_6 = \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \left(1 + \tau_{in}^{j}\right) M_{in}^{j} d \log \kappa_{in}^{j},$$

$$A_7 = \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{in}^{j} M_{in}^{j} d \log c_{i}^{j}.$$

Therefore, the change in the real wage can be written as

$$d \log W_n = A_1 - A_2 + A_3 + A_4 - A_5 - A_6 - A_7.$$

Gathering terms, note that

$$A_1 - A_5 = \frac{1}{I_n} \sum_{j=1}^{N} \sum_{i=1}^{N} \left(E_{ni}^{j} d \log c_{n}^{j} - M_{in}^{j} d \log c_{i}^{j}\right)$$

$$A_3 - A_7 = \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{in}^{j} M_{in}^{j} \left(d \log M_{in}^{j} - d \log c_{i}^{j}\right)$$

$$A_4 - A_2 = 0$$

$$-A_6 = -\frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \left(1 + \tau_{in}^{j}\right) M_{in}^{j} d \log \kappa_{in}^{j}$$

and so the change in welfare is given by

$$\begin{aligned} d \log W_n = {} & \frac{1}{I_n} \sum_{j=1}^{N} \sum_{i=1}^{N} \left(E_{ni}^{j} d \log c_{n}^{j} - M_{in}^{j} d \log c_{i}^{j}\right) + \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{in}^{j} M_{in}^{j} \left(d \log M_{in}^{j} - d \log c_{i}^{j}\right) \\ & - \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \left(1 + \tau_{in}^{j}\right) M_{in}^{j} d \log \kappa_{in}^{j} \end{aligned}$$

as I wanted to show.