Sanctions and the Exchange Rate*

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July 23, 2025

Abstract

Trade wars and financial sanctions are again becoming an increasingly common part of the international economic landscape, and the dynamics of the exchange rate are often used in real time to evaluate the effectiveness of sanctions and policy responses. We show that sanctions limiting a country's exports or freezing its assets depreciate the exchange rate, while sanctions limiting imports appreciate it, even when both types of policies have exactly the same effect on real allocations, including household welfare and government fiscal revenues. Beyond the direct effect from sanctions, increased precautionary savings in foreign currency also depreciate the exchange rate when they are not offset by the sale of official reserves or financial repression of foreign-currency savings. We show that the dynamics of the ruble exchange rate following Russia's invasion of Ukraine in February 2022 are quantitatively consistent with the combined effects of these forces calibrated to the observed sanctions and government policies. We evaluate the associated welfare, fiscal and inflationary consequences for both Russia and the coalition of Western countries.

*We thank Pol Antràs, Costas Arkolakis, David Baqaee, Christoph Boehm, Laura Castillo-Martinez, Natalie Chen, Arnaud Costinot, Jonathan Eaton, Sebastián Fanelli, Javier Garciá-Cicco, Luis Garicano, Rohan Kekre, Arnaud Mehl, Ben Moll, Juan Pablo Nicolini, Romain Rancière, Elina Ribakova and Isabel Vansteenkiste for insightful discussions, numerous seminar and conference participants for very helpful suggestions, Ivan Belousov, Maria Besedovskaya, Timur Magzhanov and especially Anna Pilipentseva for outstanding research assistance. Dmitry Mukhin acknowledges the support from the Economic and Social Research Council (ESRC) [grant number ES/Y001540/1].

1 Introduction

Despite a period of liberalization following the end of the Cold War, tariffs, trade wars and financial sanctions have become frequent tools of international policymaking in the last ten years. This renewal has led to an increased interest in the welfare and allocative consequences, and, more generally, the overall effectiveness of different forms of international economic and financial warfare, as well as the ability of affected countries to neutralize its effects with various domestic policies. The real effects of trade restrictions and financial sanctions are often difficult to evaluate in real time, and this is why the exchange rate — a variable that responds observably and swiftly to news and reflects the expected near-term and long-term consequences of policies — has received particular attention as a telltale for the economic impact of trade restrictions and sanctions.

This paper is motivated, in particular, by the recent sequence of sanctions imposed by the coalition of Western countries on the Russian economy in response to Russia's invasion of Ukraine on February 24, 2022. In the immediate aftermath of the invasion and the imposition of sanctions, the Russian ruble quickly lost half of its value. However, the exchange rate recovered to its pre-war level a few weeks later, appreciated another 30% by June, and then gradually depreciated over the following year, stabilizing about 20% weaker relative to its pre-war level (see Figure 1). These dynamics pose a number of challenges for policy analysis. What explains these large swings in the exchange rate despite a monotonically increasing number of sanctions imposed on the Russian economy? Did a strong ruble in 2022 mean that initial sanctions were not working and had only minor effects on the Russian economy? Or, to the contrary, is the ruble exchange rate no longer relevant for economic allocations because of Russian-imposed capital controls and financial repression, as has been suggested by other commentators?[1] What are the fiscal implications, and can domestic policy curb the negative effects of international sanctions?

This paper offers a unifying framework to address these questions building on the model from Itskhoki and Mukhin (2021, 2025a) that has been shown to be consistent with the major properties of exchange rates in the data. In accordance with the decoupling of the Russian financial market from the global market, we assume a form of financial market segmentation in which only the government sector (including state banks and exporting companies) can intermediate capital flows across the border, subject to international restrictions.[2] This leaves exports and foreign exchange (FX) reserves as key sources of currency supply to the economy, and imports and domestic foreign-currency savings as key sources of currency demand. The equilibrium value of

[1] See e.g., P. Krugman "Wonking Out: The Curious Case of the Recovering Ruble" (NYT, April 1, 2022), S. Guriev "The Incredible Bouncing Ruble" (Project Syndicate, April 12, 2022), and L. Garicano "Sanctions against Russia" (March 8, 2022).

[2] This captures both the withdrawal of foreign investors from the Russian market and the segmentation of Russian households from the international financial market due to external sanctions and domestic capital controls.

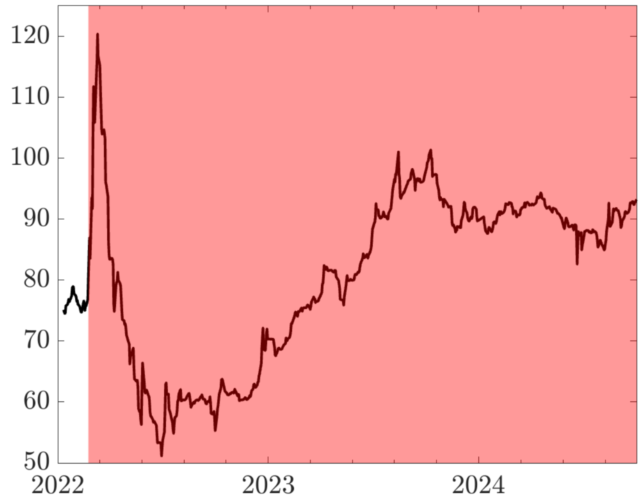

Figure 1: Daily ruble exchange rate (per one USD) since January 1, 2022

the exchange rate is determined by the balance of currency demand and supply in the domestic market, and depends crucially on shocks in both goods and asset markets. The model is tractable and attains a closed-form characterization, yet features a rich set of international sanctions and domestic policy responses which allows us to perform a detailed quantitative analysis of the effects of a spectrum of sanctions on the exchange rate, welfare, budget deficit and inflation.

Our first main result shows that sanctions limiting imports of a country tend to appreciate the country's exchange rate, while sanctions limiting exports (and seizing foreign assets) tend to depreciate it, even though both policies have the same effect on real allocations and the resulting welfare. Intuitively, both kinds of sanctions reduce the real income of the economy – either by limiting the inflow of dollars or increasing the dollar prices of foreign goods – resulting in lower consumption of foreign goods. We show that this equivalence is a manifestation of Lerner (1936) symmetry, which postulates that export and import restrictions yield the same economic outcomes, but are sustained by a differential movement in relative prices.[3] In our context, since export sanctions reduce the supply of foreign currency, they depreciate the country's exchange rate, and vice versa import sanctions reduce the demand for foreign currency and appreciate the country's exchange rate.

[3]By Lerner symmetry, export (import) restrictions result in a reduction (increase) in the country's relative wages — a form of a *real* depreciation (appreciation) — in order to achieve intertemporal trade balance. The *terms of trade*, however, move in the same way for both cases: in particular, they deteriorate under foreign-imposed restrictions. Nonetheless, measuring the effective terms of trade is challenging because many trade sanctions take the form of quantity restrictions. This is the reason why most commentators focus on the easily observable exchange rate. For the recent macroeconomic analysis of Lerner symmetry in other contexts, see Farhi, Gopinath, and Itskhoki (2014), Barbiero, Farhi, Gopinath, and Itskhoki (2019), Costinot and Werning (2019) and Lindé and Pescatori (2019). While trade applications of Lerner symmetry emphasize *uniform* tariffs across traded goods, *macroeconomic* symmetry emphasizes uniform shifts in aggregate terms of trade over time (see Itskhoki and Mukhin 2023a).

This observation clarifies several recently debated issues. First, it follows immediately that there is no one-to-one mapping between the exchange rate and welfare. Therefore, one cannot evaluate the effectiveness of sanctions based solely on the dynamics of the exchange rate. Second, while import and export restrictions have the same allocative effects, the effectiveness of each tool is limited if the sanctioned country can find alternative trade partners. In this case, it might be optimal to employ both types of sanctions as they have a cumulative effect.[4] Third, perhaps most surprisingly, the equivalence result for export and import sanctions extends to the fiscal balance, even when the government relies exclusively on exports for fiscal revenues. This is achieved by means of a general equilibrium adjustment in the exchange rate. That is, a depreciation partially ameliorates the impact of export sanctions by increasing the local-currency purchasing power of export revenues, while import sanctions result in an exchange rate appreciation which has the opposite effect. The net fiscal-balance effect of both kinds of sanctions ends up being the same.

When the sanctioned economy is large, e.g., like Russia in the global commodity market, we show that import prices and export revenues still constitute a sufficient statistic for the macroeconomic effects on the economy under sanctions. At the same time, the welfare implications for the rest of the world depend crucially on whether sanctions take the form of trade taxes or quantity restrictions. In particular, both a tax imposed on the country's imports and a tax imposed on its exports ultimately reduce the country's terms of trade and transfer wealth to the rest of the world. Similarly, a price cap on exported commodities can replicate the effect of a tax on exports achieving the desired wealth transfer. In contrast, imposing quantity restrictions on a large commodity exporter reduces global supply and drives up world energy prices. While this still hurts the sanctioned economy when it lowers its export revenues, such policy is also associated with substantial costs to sender.

Turning to financial sanctions, we show that their effects depend crucially on the policy response. In particular, an increase in the household precautionary demand for foreign currency due to a collapsing supply of alternative savings vehicles (e.g., local stock market, bank deposits) results in exchange rate depreciation in the absence of active government intervention. With financial restrictions on international borrowing and inelastic inflow of foreign currency from exports, a large jump-depreciation is required to restore the equilibrium by curbing the increased demand for foreign currency via lower expected returns and higher prices of imports. The effect of the financial shock is transitory and dies out as households accumulate enough foreign-currency savings. The optimal policy response to the financial shock aims to smooth out these dynamics by selling FX reserves to the households. This is a welfare enhancing intervention because it accommodates the increased household demand for foreign currency without an exchange rate

[4] Studying sanctions evasion and the substitution between trade partners is crucial for the optimal sanctions design, but goes beyond the scope of this paper (see Egorov, Korovkin, Makarin, and Nigmatulina 2024, Chupilkin, Javorcik, and Plekhanov 2024).

devaluation or a drop in import consumption (see Itskhoki and Mukhin 2023b). However, FX interventions rely on the availability of official reserves, and this policy may be altogether infeasible under international financial sanctions against the central bank.

When FX interventions are infeasible, the government can use financial repression to offset the effects of financial shocks on the exchange rate and import consumption, albeit with a distortion in the domestic financial market. Specifically, the central bank can reduce the household foreign-currency demand for savings by lowering the returns on foreign-currency deposits through fees on purchasing and withdrawing foreign currency.[5] While financial repression is suboptimal in a representative-agent economy, it may emerge as a second-best policy to smooth out redistributive effects of exchange rate fluctuations in heterogenous-agent economies or economies with balance-sheet effects. Importantly, the exchange rate remains allocative even under financial sanctions and financial repression.

Finally, we quantitatively evaluate the ruble exchange rate dynamics since the beginning of the war by combining financial and trade sanctions and policy responses in a calibrated model. We use the standard values of import and savings demand elasticities and adopt two alternative strategies to calibrate the paths of shocks. The first one reproduces our *ex-ante* calibration from the 2022 version of the paper (Itskhoki and Mukhin 2022) based on scant data that were available in the first months after the start of the war and without targeting any exchange rate moments. The calibration provides a remarkable out-of-sample fit, predicting accurately the dynamics of the exchange rate in the following two years. We then compare it with an *ex-post* calibration that infers structural shocks to perfectly match observed dynamics of Russian imports and exports, commodity prices, domestic output, official FX reserves, inflation and the exchange rate.

The two approaches largely agree on the decomposition of the exchange rate confirming the quantitative importance of theoretical mechanisms discussed above. In particular, we find that the sharp depreciation of the ruble in the first weeks of the war is mostly driven by increased precautionary demand for foreign currency. The large amount of FX reserves frozen by sanctions translates into modest losses of permanent income and generates only a 3% depreciation of the exchange rate. However, the asset freeze and sanctions on the Central Bank likely had a much larger indirect effect by limiting the capacity to accommodate the financial shock with FX interventions.

One month out, trade shocks begin to dominate the dynamics of the exchange rate. Restrictions on imports curb FX demand to purchase imported goods, while the spike in energy prices elevates Russian export revenues in the first months after the invasion, increasing the inflows of foreign currency. These forces combined neutralize capital outflows and the surge in financial

[5] Indeed, the Russian central bank introduced a temporary fee on buying foreign currency in March-April, which lowered the depreciatory pressure on the exchange rate.

FX demand, and explain the sharp appreciation of the ruble by summer 2022. Over time, import quantities recover as parallel imports and new trade linkages are established, and the inflow of foreign currency contracts as commodity export revenues decline. This brings the exchange rate back to the pre-war level about one year after the start of the war with a continued gradual depreciation thereafter.

We further use the calibrated model to evaluate the impact of sanctions on the household welfare and the government budget balance, as well as implications for the sanctioning coalition. The initial depreciation of the exchange rate boosts fiscal revenues by 12% and this is further amplified by greater export revenues starting in the second month. These effects are offset in the medium run as a result of the exchange rate appreciation due to trade sanctions with the net real income turning negative starting from April 2022. The international sanctions decrease the long-run real government revenues by about 4%, mostly due to a reduction in export revenues. The combined effect from 2.5 years of sanctions also corresponds to a permanent decline in consumption by 0.9% in Russia, vastly larger than the conventional estimates of the cost of a business cycle, and it is close to zero on net for the rest of the world. Consistent with our theoretical results, the freeze of FX reserves and import tariffs act as a positive transfer from Russia to the rest of the world, while quantity restrictions on exports result in higher energy prices, lower consumption, and global welfare losses.

This paper contributes to the growing literature on the economic effects of sanctions. Korhonen (2019), Itskhoki and Ribakova (2024) and Mohr and Trebesch (2025) provide surveys of the earlier and recent work with particular focus on the Russian economy.[6] The analysis of the effects of a Russian energy export ban on the European economy is the focus of Bachmann, Baqaee, Bayer, Kuhn, Löschel, Moll, Peichl, Pittel, and Schularick (2024). Bianchi and Sosa-Padilla (2022), Sturm (2022), de Souza, Hu, Li, and Mei (2022) and Alekseev and Lin (2024) study the design of optimal sanctions (see also the early work on the topic, e.g., Eaton and Engers 1992), while Clayton, Maggiori, and Schreger (2023) analyze strategic interactions between economies. Eichengreen, Ferrari Minesso, Mehl, Vansteenkiste, and Vicquéry (2023), Krahnke, Ferrari Minesso, Mehl, and Vansteenkiste (2024) provide historical evidence about the effects of trade sanctions which validate the main predictions of our model.

Our theoretical results on trade sanctions are closely related to the contemporaneous work of Lorenzoni and Werning (2022). We show how to cast the analysis of static trade sanctions within a macroeconomic model, extending the seminal Lerner (1936) symmetry result to a fully

[6]For broader surveys of the earlier work on international sanctions see Eaton and Sykes (1998) and Hufbauer, Schott, and Elliott (2009). A large parallel literature, summarized recently in Fajgelbaum and Khandelwal (2022), studies the economic effects of tariffs and trade wars. A related macroeconomic literature on sanctions, trade wars, currency wars and currency manipulations includes Svensson and Razin (1983), Auray, Devereux, and Eyquem (2021), Jeanne (2021), Hassan, Mertens, and Zhang (2022), Mamonov and Pestova (2022) and Ghironi, Kim, and Ozhan (2022).

dynamic environment. Furthermore, we go beyond Lerner symmetry to analytically and quantitatively study the implications of dynamic trade and financial sanctions for exchange rates, welfare, inflation and government revenues under alternative policy responses.

2 Small Economy under Sanctions

We start our analysis with the case of a small open endowment economy under trade and financial sanctions, where trade sanction are summarized by an exogenous deterioration of the country's terms of trade. In the following Section 3, we extend our analysis to an economy that is large in the world commodity market and consider various specific instruments of trade sanctions imposed by the rest of the world. We make one departure from a conventional international macro model in that the households are segmented from the international financial market and demand foreign currency to both purchase imports and as a store of value.[7]

2.1 The model economy

Households choose the path of consumption of domestic and imported goods C_{Ht} and C_{Ft} to maximize their intertemporal utility

$$U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u(C_{Ht}, C_{Ft}) + v\left(\frac{B^*_{t+1}}{P^*_{t+1}}; \Psi_t \right) \right], \tag{1}$$

subject to the household budget constraint

$$P_t C_{Ht} + \mathcal{E}_t P^*_t C_{Ft} + \frac{B_{t+1}}{R_t} + \frac{\mathcal{E}_t B^*_{t+1}}{R^*_{Ht}} \le B_t + \mathcal{E}_t B^*_t + W_t, \tag{2}$$

where P_t and P^*_t are consumer prices of domestic and imported goods in the local and foreign currency, respectively, and W_t is the nominal income of the households. Asterisk * denotes variables denominated in foreign currency and the nominal exchange rate $\mathcal{E}_t$ is applied to convert them to local currency: $\mathcal{E}_t$ is defined as units of local currency for one unit of foreign currency and an increase in $\mathcal{E}_t$ corresponds to the local currency devaluation.

Households can save or borrow using local- and foreign-currency bonds, that is, bank deposits and loans. We denote with B_t and B^*_t the quantities of these bonds held by the households, and with R_t and R^*_{Ht} the respective gross interest rates. The return R^*_{Ht} on foreign-currency savings available to the households may differ from the international rate of return R^*_t due to household

[7] An alternative modeling approach features a frictional international intermediation sector as a source of inelastic foreign currency supply (as in Gabaix and Maggiori 2015, Itskhoki and Mukhin 2021). Our modeling choice is motivated by both simplicity and realism in the case of Russia under international sanctions.

segmentation from the international asset market. Households are assumed to have the real value of foreign-currency deposits in their utility function reflecting hedging (precautionary) demand for future purchases of foreign tradables, and Ψ_t captures a shock to the demand for foreign-currency balances.[8]

While our theoretical results require only weak assumptions on the utility function, we adopt the following functional forms that we use in particular in our quantitative analysis:

$$u(C_H, C_F) = C_H^{\frac{\theta-1}{\theta}} + \gamma^{1/\theta} C_F^{\frac{\theta-1}{\theta}} \quad \text{and} \quad v(b;\Psi) = -\frac{\kappa}{2}\cdot(b-\Psi)^2, \tag{3}$$

where $\theta > 1$ is the elasticity of substitution between domestic and imported goods, $\gamma > 0$ is the exposure to imported goods (openness), and $\kappa \geq 0$ is the bond demand parameter.[9] This convenient separable utility specification implies that θ is also the intertemporal elasticity of substitution, and hence $1/\theta$ is relative risk aversion. The utility from FX bond holdings is increasing for $B^*_{t+1}/P^*_{t+1} < \Psi_t$ and has a bliss point at $B^*_{t+1}/P^*_{t+1} = \Psi_t$ for a given value of the shock Ψ_t.

Government, output, and financing We combine the government, production and financial sectors into one entity. While being a useful abstraction, this approach is representative of the structure of the Russian economy, where the public sector accounts — directly and indirectly — for a major fraction of employment in both tradables and non-tradables (natural resources, transportation, healthcare and education), as well as in finance and banking. The budget constraint of the government sector is:

$$\mathcal{E}_t\left(\frac{F^*_{t+1}}{R^*_t} - F^*_t\right) - \mathcal{E}_t\left(\frac{B^*_{t+1}}{R^*_{Ht}} - B^*_t\right) - \left(\frac{B_{t+1}}{R_t} - B_t\right) = \mathcal{E}_t Q^*_t X_t + P_t Y_t - W_t, \tag{4}$$

where X_t is the endowment of commodities sold to the rest of the world at foreign-currency price Q^*_t, and Y_t is the endowment of non-tradable domestic goods.

We denote with $TR_t \equiv \mathcal{E}_t Q^*_t X_t + P_t Y_t$ the aggregate national income in local currency and with W_t the wage income commitment to the households set in local nominal terms. While we abstract from price rigidities given the large size of the shock and quick inflation response

[8]We use this simple setup with bonds in the utility to generate fundamental foreign currency demand shocks, as opposed to an alternative setup with noise currency traders (as in Jeanne and Rose 2002, Itskhoki and Mukhin 2021). This makes our model directly amenable to the welfare and normative analysis of such policies as financial repression. The precautionary demand for safe assets also arises in a large class of models with incomplete markets (Aiyagari 1994) and overlapping generations (Diamond 1965, Blanchard 1985, Caballero, Farhi, and Gourinchas 2008); see also the growing empirical literature on convenience yields (Jiang, Krishnamurthy, and Lustig 2018, Bianchi, Bigio, and Engel 2021). All our results still hold if real bond holdings are computed using the consumer price index $\mathcal{P}_t$, replacing B^*_t/P^*_t with $\mathcal{E}_t B^*_t/\mathcal{P}_t$ in the utility.

[9]See the working paper version Itskhoki and Mukhin (2022) for the analysis under more general functional forms.

in the economy, the nominal wage commitment W_t is in some ways similar to the downward wage rigidity as it can be relaxed with price inflation, and the government infrequently resets the wage commitment to satisfy the government budget constraint. The budget constraint (4) can be generalized to include other government expenditures G_t which do not contribute to the household consumer surplus (e.g., military expenditure) with the effects of G_t on allocations equivalent to that of a reduction in the disposable output Y_t.

Finally, F_t^* are the (net) foreign assets and R_t^* is the world interest rate in foreign currency. The liabilities of the government sector are the local- and foreign-currency bonds, B_t and B_t^*, held by the households. Therefore, $A_t^* \equiv F_t^* - B_t^*$ are the net foreign assets, or FX reserves, held by the government sector. The set of government policies includes a standard fiscal choice between borrowing from households B_{t+1} and adjusting expenditure commitment W_t, a conventional monetary policy tool R_t that pins down the path of domestic prices P_t, as well as accumulation (or decumulation) of FX reserves A_{t+1}^*. In addition, the government can use financial repression or capital controls that depress household rate of return on foreign-currency savings R_{Ht}^* below the international rate of return R_t^*.

International sanctions and shocks The rest of the world is large. It exports to Russia the international tradable good C_{Ft} and imports from Russia commodities X_t at the relative price Q_t^*/P_t^*. The rest of the world imposes trade sanctions on the Russian economy. In this section, we capture them in a stylized way as shocks to trade prices Q_t^* and P_t^*, and thus the rest of the world can exogenously impose a deterioration of the Russian terms of trade Q_t^*/P_t^*. We relax this assumption in Section 3 by providing the full description of the international economy where we model Russia as a large exporter of commodities, as well as spell out the specific policy instruments used to impose sanctions.

In our baseline analysis, we also consider the effect of foreign asset freezes, which we capture as a reduction in the net foreign asset position F_0^*, as featured in (4). Financial sanctions are also associated with an increase in the household precautionary demand for foreign currency Ψ_t due to a collapsing supply of alternative vehicles of savings, and in particular safe assets.[10] Therefore, we consider the financial shock Ψ_t along with financial sanctions. We also allow for a general path of other exogenous shocks to endowment of domestic goods Y_t and the international interest rate R_t^*. The latter shock can proxy for additional financial sanctions that exclude the country from the financial market, while the domestic disposable output may decline as a result of the war and spillover effect from financial and trade sanctions on the domestic economy.

[10] In the Russian context, the local stock market collapsed, home currency deposits were subject to inflation and bank-run risks, and access to foreign assets was constrained.

Equilibrium The goods market clearing condition in the non-tradable sector is $C_{Ht} = Y_t$. The local-currency nominal interest rate R_t allows the government to control non-tradable price inflation P_{t+1}/P_t by choosing the slope of the household Euler equation, $\beta R_t \mathbb{E}_t\big\{\big(\frac{C_{Ht}}{C_{Ht+1}}\big)^{1/\theta}\frac{P_t}{P_{t+1}}\big\} = 1$. This acts as a side equation that allows us to treat the path of prices P_t as chosen directly by monetary policy.

Households make their consumption and savings decisions taking as given the path of income W_t, prices P_t and $\mathcal{E}_t P_t^*$, and interest rates R_t and R_{Ht}^*. This leads to the import demand schedule:

$$C_{Ft} = \left(\frac{\mathcal{E}_t P_t^*}{P_t}\right)^{-\theta} \gamma Y_t, \tag{5}$$

where we used the domestic good market clearing condition $C_{Ht} = Y_t$. In turn, the household demand for foreign-currency bonds B_{t+1}^* satisfies the following Euler equation:

$$\beta R_{Ht}^* \mathbb{E}_t\left\{\frac{P_t^*}{P_{t+1}^*}\left[\left(\frac{C_{Ft}}{C_{F,t+1}}\right)^{1/\theta} + \tilde{\kappa} C_{Ft}^{1/\theta}\left(\Psi_t - \frac{B_{t+1}^*}{P_{t+1}^*}\right)\right]\right\} = 1, \tag{6}$$

where $\tilde{\kappa} \equiv \frac{\theta}{\theta-1}\frac{\kappa}{\beta\gamma^{1/\theta}} \geq 0$. In addition to the conventional import consumption smoothing motive for savings, household currency demand (6) features the Ψ_t shock which reflects additional precautionary savings motive, or demand for safe assets. In particular, an increase in Ψ_t above the real value of household FX savings B_t^*/P_t^* results in a force to accumulate foreign-currency savings despite their, possibly, low expected return for households R_{Ht}^*.

Lastly, the path of import consumption must satisfy the intertemporal budget constraint of the country which combines the household and the government budget constraints (2) and (4). Expressing it in foreign-currency terms and using the non-tradable market clearing condition, we arrive at:

$$\frac{F_{t+1}^*}{R_t^*} - F_t^* = Q_t^* X_t - P_t^* C_{Ft}, \tag{7}$$

where the right-hand side is the country's net exports expressed in foreign-currency terms, $NX_t^* = Q_t^* X_t - P_t^* C_{Ft}$. Note that NX_t^* is also the inflow of new foreign currency (outflow if negative), while F_t^* is the stock of foreign currency held jointly by the households B_t^* and the government $A_t^* = F_t^* - B_t^*$. The country budget constraint features the world interest rate R_t^* in contrast with the household currency demand (6) which depends on R_{Ht}^*.[11]

Taking the paths of endowments (X_t, Y_t), export and import prices (Q_t^*, P_t^*), the world interest rate R_t^*, and the financial shock Ψ_t as given, the equilibrium vector $(C_{Ft}, \mathcal{E}_t, B_{t+1}^*)$ satisfies import demand (5), the country budget constraint (7), and the household demand for for-

[11] The gap between the world and the local interest rates R_t^* and R_{Ht}^* does not affect the aggregate country budget constraint because it only results in a transfer between the households and the government budget constraint (4).

eign currency (6), given non-tradable goods market clearing $C_{Ht} = Y_t$, initial net foreign assets $F_0^* = A_0^* + B_0^*$, and government policies. The latter consist of reserve accumulation A_t^*, the path of nominal non-tradable prices P_t implemented by monetary policy R_t, and the extent of financial repression $R_{Ht}^* \leq R_t^*$ of foreign currency deposits. Note from the equilibrium system that $\mathcal{E}_t/P_t$ — a measure of the real exchange rate — is determined independently of monetary policy (inflation), and changes in home good inflation shift the path of the nominal exchange rate $\mathcal{E}_t$ one-for-one with P_t. Also note that, with $\tilde{\kappa} > 0$ in (6), Ricardian equivalence does not apply for savings in foreign currency because households cannot costlessly adjust B_t^* to offset the government asset position. Hence, the choice of government reserves A_t^* affects the equilibrium allocation.

To provide intuition for the results that follow, we focus on equilibrium dynamics shaped by the interplay between the country budget constraint (7) and the household Euler equation (6), characterizing the net supply of foreign currency to the economy and the household demand for foreign currency, respectively. Trade and financial sanctions affect the equilibrium dynamics via these two conditions, while the import demand schedule (5) acts as a side equations that pins down the exchange rate that supports this equilibrium allocation.

2.2 Trade sanctions

We begin with the analysis of permanent trade sanctions in a fully dynamic equilibrium environment. We prove an allocative equivalence result between import and export sanctions, with the equivalence supported by a differential equilibrium exchange rate adjustment. This result extends the logic of seminal Lerner (1936) symmetry between a uniform import tariff and a uniform export tax to a dynamic international macro environment. We then discuss instances where the equivalence between import and export sanctions fails.

For any equilibrium path characterized by exogenous shocks $\{X_t, Y_t, Q_t^*, P_t^*, R_t^*\}$, government policies $\{P_t, R_{Ht}^*, A_{t+1}^*\}$, and endogenous equilibrium outcomes $\{C_{Ft}, \mathcal{E}_t, B_{t+1}^*, F_{t+1}^*\}$, given the initial asset positions (A_0^*, B_0^*), we consider two alternative trade sanctions policies operating via import and exports prices, respectively. Specifically, we consider a deterioration in the country's terms of trade Q_t^*/P_t^* brought about either by a reduction in export prices Q_t^* or an increase in import prices P_t^*. We denote with $\hat{Q}_t^* \equiv \log(Q_t^{*\prime}/Q_t^*)$ the proportional (log) change in the export price in the new equilibrium relative to the original equilibrium, and similarly for other variables. Our baseline result focuses on a one-time unanticipated and permanent sanctions policies at $t_0 \geq 0$ such that for all $t \geq t_0$ and some $\tau > 0$:

$$\hat{Q}_t^* = -\tau < 0 \qquad \text{or} \qquad \hat{P}_t^* = \tau > 0. \tag{8}$$

Additionally, we allow for a one-time permanent freeze of net foreign assets $\hat{F}_t^* = -\tau$ at $t = t_0$.

For concreteness, we assume — as was relevant in the case of Russia — that $F_0^*, A_0^* > 0$, and that the foreign asset freeze extends proportionally to both publicly and privately held assets, $\hat{A}_t^* = \hat{B}_t^* = -\tau$. Virtually none of our results hinge on these added assumptions.

Note that the two policies in (8) have the same effect of deteriorating the country's terms of trade by τ percent ($\tau \cdot 100$ log points, to be precise), while the asset freeze reduces the purchasing power of accumulated net foreign assets by the same factor. Without loss of generality, we focus on the case where $t_0 = 0$, and we discuss the case of anticipated and non-permanent sanctions below.

Proposition 1 *Permanent sanctions on imports, $\hat{P}_t^* = \tau > 0$ for all $t \geq 0$, are equivalent to a combination of permanent sanctions on exports, $\hat{Q}_t^* = -\tau < 0$, and a partial seizure of foreign assets $\hat{F}_0^* = -\tau$: both sets of sanctions result in the same path of reduced import quantities, $\hat{C}_{Ft} < 0$, and welfare. However, sanctions on exports (cum foreign assets) are associated with an additional depreciation of the exchange rate by τ percent relative to sanctions on imports.*

To prove Proposition 1, rewrite the country budget constraint (7) in real units of imports C_{Ft}:

$$\frac{P_{t+1}^*/P_t^*}{R_t^*} \cdot \frac{F_{t+1}^*}{P_{t+1}^*} - \frac{F_t^*}{P_t^*} = \frac{Q_t^*}{P_t^*} \cdot X_t - C_{Ft}. \tag{9}$$

There are three distinct effects from trade sanctions. The first is the effect on the terms of trade Q_t^*/P_t^* common under both kinds of sanctions to diminish the feasible import consumption set. While export sanctions curb international revenues directly, import sanctions reduce the purchasing power of export revenues. Import sanctions have two additional effects: they reduce the purchasing power of already accumulated foreign assets, F_0^*/P_0^*, and, in general, affect the real rate of return on international savings, $R_t^* \frac{P_t^*}{P_{t+1}^*}$. The latter effect is absent under permanent sanctions, as P_t^* increases proportionally for all t. The former effect, however, is always present when $F_0^* \neq 0$. Therefore, the equivalence between the two types of sanctions requires that export sanctions are combined with a partial seizure of accumulated net foreign assets to induce a proportional reduction in the real value of F_0^*/P_0^* (*cf.* Farhi, Gopinath, and Itskhoki 2014, in the context of fiscal devaluations). Finally, we note that the Euler equation (6) is equivalently satisfied under both policies for the same lower path of C_{Ft} and the same real value of foreign currency holding by the households B_{t+1}^*/P_{t+1}^* with the unchanged path of the interest rate R_{Ht}^*.[12] This completes the proof that the same path of imports C_{Ft} and the same evolution of real net foreign assets F_t^*/P_t^* occurs under both sanctions regimes, resulting in the same lower welfare.

[12]When the economy is non-Ricardian, i.e., $\kappa > 0$, the equivalence requires that real official FX reserves, $A_t^*/P_t^* = (F_t^* - B_t^*)/P_t^*$, follow the same path under the two sanctions regimes, adjusting downwards because of either higher import prices P_t^* or a partial seizure of central bank's assets. This condition can hold irrespective of whether the government actively uses FX interventions or not in response to the sanctions shock. It is trivially satisfied in the special cases with no official reserves $A_t^* = 0$ or no household FX holdings $B_t^* = 0$.

To establish the consequences for the exchange rate, we study the import demand schedule (5), which we rewrite as:

$$\frac{\mathcal{E}_t}{P_t} = \frac{1}{P_t^*} \left(\frac{C_{Ft}}{\gamma Y_t} \right)^{-1/\theta}. \tag{10}$$

Since the path of import consumption C_{Ft} changes identically, the path of the exchange rate is different under the two sanction policies. While lower imports $\hat{C}_{Ft} < 0$ are supported by an exchange rate depreciation $\hat{\mathcal{E}}_t > 0$, import sanctions with $\hat{P}_t^* > 0$ have an additional effect to appreciate the exchange rate.[13]

At an intuitive level, the exchange rate movements ensure in both cases that the allocation afforded by the country budget constraint is also consistent with consumer optimization over expenditure on imports and domestic goods. While the country budget constraint shrinks equivalently in real terms in both cases, the mechanism is different — operating either via a reduction of export income or, alternatively, an increase in the cost of imports. Therefore, in the former case, the exchange rate must depreciate to discourage import consumption and bring it in line with the new budget constraint. In the latter case, the exchange rate must appreciate to offset expenditure switching from higher import prices that would otherwise result in excess demand for non-tradables leaving export revenues partially unused. This is a macroeconomic version of the Lerner (1936) symmetry logic by which an import tariff is equivalent to an export tax as they result in the same allocation with depressed international trade flows yet sustained with a differential movement in prices.[14]

Before delving deeper into the intuition for the exchange rate result, we provide a further equilibrium characterization of the dynamic response to permanent trade sanctions in two instructive special cases which correspond to the economy starting in a stationary equilibrium prior to the sanctions shock:

Proposition 2 (a) *If either $\kappa = 0$ or $B_0^* = \Psi_t \equiv 0$, then the two permanent trade sanctions policies result in $\hat{C}_{Ft} = -\tau < 0$ for all $t \geq 0$ with a permanent exchange rate appreciation $\hat{\mathcal{E}}_t = -\frac{\theta-1}{\theta}\tau < 0$ under import sanctions and depreciation $\hat{\mathcal{E}}_t = \frac{1}{\theta}\tau > 0$ under export (cum foreign asset) sanctions.* (b) *Alternatively, with $\kappa > 0$ and $\Psi_t \equiv \frac{B_0^*}{P_0^*} > 0$, there is an additional transitory depreciation of the exchange rate in both cases relative to its respective long-run levels.*

The former case corresponds to the immediate adjustment to a permanent real income shock, which happens even in a generally non-stationary stochastic environment. In this case, perma-

[13] The real exchange rate, $\mathcal{E}_t/P_t$, tracks the nominal exchange rate $\mathcal{E}_t$ when monetary policy stabilizes domestic prices P_t. Indeed, the appreciation and depreciation forces from trade sanctions are *real*, and characterize the adjustment in the real exchange rate $\mathcal{E}_t/P_t$.

[14] According to Lerner symmetry, an import tariff results in a trade surplus on impact, which must be eliminated in equilibrium by means of an increase in the relative wage at home (an appreciation); an export tax does the reverse on impact, and requires a reduction in the home relative wage (a depreciation). Nonetheless, the real wage in terms of the home consumption basket declines in the same way in both cases, while the real exchange rate moves differentially.

nent sanctions of both kinds result in a permanent reduction of import consumption, $\hat{C}_{Ft} = -\tau$, which simultaneously satisfies the country budget constraint (9) and the household Euler equation for foreign-currency savings (6).[15] This common permanent adjustment is supported with a differential exchange rate movement in (10) to equilibrate the currency market: namely, a permanent depreciation under export sanctions and a permanent appreciation under import sanctions:

$$\hat{\mathcal{E}}_t = -\frac{1}{\theta}\hat{Q}_t^* = \frac{1}{\theta}\tau > 0 \qquad \text{versus} \qquad \hat{\mathcal{E}}_t = -\frac{\theta-1}{\theta}\hat{P}_t^* = -\frac{\theta-1}{\theta}\tau < 0. \tag{11}$$

In the second case with $\kappa > 0$ and $\Psi_t > 0$, the non-Ricardian term in the household Euler equation (6) requires an additional dynamic adjustment to the permanent sanctions shock. Indeed, the sanctions-induced decline in the available foreign assets or their international purchasing power, B_t^*/P_t^*, motivates the households to delay import consumption and accumulate foreign-currency savings until the bliss point is reached again. This increased FX demand results in an additional depreciation of the exchange rate in the short run, over and above the respective long-run adjustment emphasized in the first case of the proposition. Thus, permanent trade sanctions in this case additionally trigger an effective financial shock and ensuing depreciation of the kind we analyze below in Section 2.3. In Section 4, we further show that non-Ricardian dynamics are important *quantitatively* in response to temporary trade sanctions.

Stationary equilibrium To further spell out the forces behind the equilibrium exchange rate adjustment, we consider the special case of a stationary equilibrium with $R_{Ht}^* = R_t^* = 1/\beta$ and in the absence of foreign-currency demand shocks, $\Psi_t = 0$. Starting with $B_0^* = 0$, this equilibrium features $B_t^* = 0$ for all t, irrespective of the value of the country's net foreign assets F_0^*, eliminating the need to further utilize the Euler equation. Then, any permanent sanctions shock results in no transition dynamics and a jump to a new stationary equilibrium with

$$C_{Ft} = \frac{Q_t^* X_t + (1-\beta)F_0^*}{P_t^*}, \tag{12}$$

and the new value of the exchange rate given by (10). This provides a complete closed-form characterization of the equilibrium allocation.

Condition (12) characterizes the budget-feasible level of consumption. It illustrates the equivalence of all trade sanctions — whether on imports P_t^*, exports Q_t^*, or foreign assets F_0^* — in their impact on import consumption and welfare. Then, condition (10) determines the value of the exchange rate that supports this quantity of imports. While both import and export sanc-

[15] Note that when either $\kappa = 0$ or $B_t^* = \Psi_t = 0$ for all $t \geq 0$, the Euler equation (6) effectively becomes $\beta R_{Ht}^* \mathbb{E}_t\big\{\big(\frac{C_{Ft}}{C_{F,t+1}}\big)^{1/\theta}\frac{P_t^*}{P_{t+1}^*}\big\} = 1$, so that proportional shifts in P_t^* and C_{Ft}^* for all t leave it unchanged, and hence $B_t^* = 0$ for all $t \geq 0$ remains a part of the equilibrium path starting from $B_0^* = 0$, as stated in the proposition.

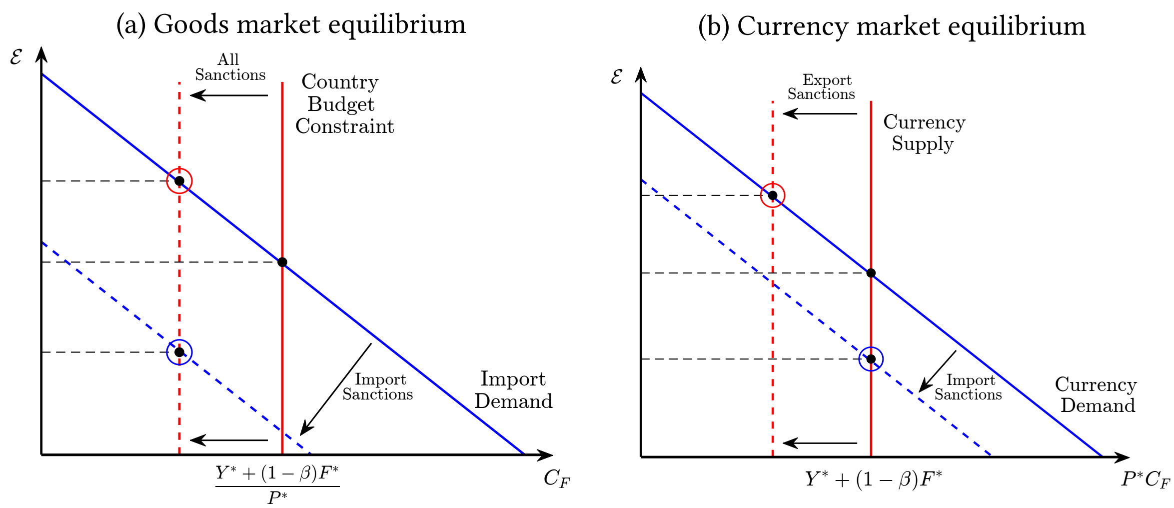

Figure 2: Trade sanctions and the exchange rate

Note: The left panel describes the equilibrium in the goods market, while the right panel describes the equilibrium in the currency market. In both cases, figures plot the stationary equilibrium conditions (10) and (12), with the exchange rate $\mathcal{E}$ against real imports C_F in the left panel and against import expenditure P^*C_F in the right panel. Export sanctions shift (12) leftward in both panels, while import sanctions do the same only in the left panel. Import sanctions additionally shift inward (10) in both panels.

tions tighten the budget constraint by reducing the real purchasing power of export revenues, they have a differential effect on the currency market and the exchange rate — depending on whether they curb export revenues or increase the cost of imports.

There are two equivalent ways to see this result, as we illustrate in the two panels of Figure 2. From the perspective of the currency market, in the right panel (b) of the figure, export and foreign asset sanctions reduce the supply of foreign currency to the economy, while import sanctions limit the demand for foreign currency to purchase imports.[16] To clear the currency market, the country's exchange rate depreciates when FX becomes scarce under export sanctions and appreciates when FX becomes relatively abundant under import sanctions.

The equilibrium in the goods market is a direct reflection of the equilibrium in the currency market, as we illustrate in the left panel (a) of Figure 2 which restates the equilibrium conditions in terms of goods flows. Import sanctions shift inward the import demand schedule (10), and, absent an exchange rate appreciation, the economy will not be willing to use all of its unsanctioned export proceeds on now more expensive imports. As a result, an exchange rate appreciation

[16]The last statement is true when the elasticity of substitution between imported and domestic goods is greater than one, $\theta > 1$ as we assume, and hence an increase in import prices reduces the expenditure share on imports, making foreign currency less demanded. When $\theta < 1$, the rest of the world has an unlimited economic power over the economy with minimal sanctions, and this case is unrealistic in the real world with much of substitution operating effectively via non-aligned foreign countries. See the working paper version Itskhoki and Mukhin (2022) for the analysis in an interesting limiting case with $\theta = 1$, i.e., the Cobb-Douglas case.

must happen in equilibrium to ensure that aggregate imports still exhaust the country budget constraint (see Lorenzoni and Werning 2022). Our approach of focusing on the currency market is less conventional in real international macro models, but provides a clearer intuition in this case and proves particularly useful later when we consider financial FX savings as an additional source of foreign currency demand.

Fiscal revenues and the real cost of living The allocational equivalence of import and export sanctions in Proposition 1 further extends to the government fiscal balance, consumer price inflation, and the real cost of living. Recall that fiscal revenues in the government budget constraint (4) equal the nominal national income, $TR_t = \mathcal{E}_t Q_t^* X_t + P_t Y_t$, yet our results generalize to the case where fiscal revenues are collected differentially on exported and domestic value added.

Proposition 3 *Permanent import and export (cum foreign asset) sanctions have identical effects on the fiscal revenues of the government sector, as well as on the consumer price inflation and the real cost of living $\mathcal{P}_t$, for a given monetary policy response P_t.*

We can directly evaluate fiscal revenues TR_t in (4) and the ideal consumer price index $\mathcal{P}_t$ using the equilibrium expression for the exchange rate (10). We have:

$$\begin{aligned} TR_t &\equiv \mathcal{E}_t Q_t^* X_t + P_t Y_t = P_t \left[Y_t + \frac{Q_t^*}{P_t^*} \left(\frac{\gamma Y_t}{C_{Ft}} \right)^{\frac{1}{\theta}} \right], \\ \mathcal{P}_t &\equiv \left[P_t^{1-\theta} + \gamma (\mathcal{E}_t P_t^*)^{1-\theta} \right]^{\frac{1}{1-\theta}} = P_t \left[1 + \gamma \left(\frac{\gamma Y_t}{C_{Ft}} \right)^{\frac{1-\theta}{\theta}} \right]^{\frac{1}{1-\theta}}. \end{aligned} \tag{13}$$

From Proposition 1, C_{Ft} follows the same reduced path under both sets of sanctions, which in both cases involve a deterioration in the terms of trade Q_t^*/P_t^* by τ log points. In particular, in the special case of Proposition 2a with a permanent import quantity adjustment, $\hat{C}_{Ft} = -\tau$, we can evaluate the proportional loss in fiscal revenues and the additional consumer price inflation relative to the equilibrium path without sanctions as follows:

$$\widehat{TR}_t = -\chi_t \cdot \frac{\theta - 1}{\theta} \cdot \tau < 0 \qquad \text{and} \qquad \widehat{\mathcal{P}}_t = \mu_t \cdot \frac{1}{\theta} \cdot \tau > 0, \tag{14}$$

where $\chi_t \equiv \frac{\mathcal{E}_t Q_t^* X_t}{\mathcal{E}_t Q_t^* X_t + P_t Y_t}$ is the revenue share of exports and $\mu_t \equiv \frac{\mathcal{E}_t P_t^* C_{Ft}}{\mathcal{E}_t P_t^* C_{Ft} + P_t C_{Ht}}$ is the expenditure share on imports.[17] As before, τ is the size of terms of trade deterioration induced by either kind of sanctions policy and θ is the elasticity of import demand which determines the magnitude of the equilibrium exchange rate adjustment (recall (11)).

[17] These linear formulas are exact for small τ, and the non-linear formulas are provided in Appendix A using the exact hat algebra approach around the general pre-sanctions equilibrium path characterize by $\{\chi_t, \mu_t\}$.

As could be expected, the effect of import sanctions on the costs of living is proportional to the share of imports in expenditure μ_t, while the effect of export sanctions on fiscal revenues is proportional to the share of government revenues from exports χ_t, and this generalizes to the case when revenues need to be raised with taxes. What is remarkable, however, is the general equivalence between export and import sanctions in their effects on fiscal revenues and inflation. For example, import sanctions have exactly the same impact on fiscal revenues even when no taxes are levied on imports and all tax revenues come from exports, and export sanctions with no direct impact on import prices have the same equilibrium effect on consumer prices. This is the case because of the equilibrium adjustment in the exchange rate $\mathcal{E}_t$: the appreciation under import sanctions lowers local-currency fiscal revenues from exports, while the depreciation under export sanctions increases consumer prices.[18]

The results from Proposition 3 are more general than it might seem at first. First, it is not just the nominal home-currency fiscal revenues that decrease identically, but also the purchasing power of fiscal revenues in terms of aggregate consumption $\frac{TR_t}{\mathcal{P}_t}$ and in terms of imports $\frac{TR_t}{\mathcal{E}_t P_t^*}$ (see also Barbiero, Farhi, Gopinath, and Itskhoki 2019). Second, as import and export sanctions reduce fiscal revenues and tighten the government budget constraint (4), they might put a pressure on the government to cut nominal wages W_t, inflate them away via higher domestic prices P_t, or raise taxes with potentially distortionary effects on home output (captured with an exogenous reduction in Y_t in our simple endowment model).[19] The government may also want to respond to a rising cost of living $\mathcal{P}_t$ with a tight or accommodative monetary and fiscal policy changing the paths of P_t, W_t, and/or Y_t. None of these endogenous policy responses invalidate the equivalence in Proposition 3: since the direct effect of the two types of sanctions on TR_t, $\mathcal{P}_t$, and other allocation-relevant quantities is the same, any policy that depends only on such variables — and not on the exchange rate — responds in the same way to import and export sanctions.

Policy implications Theoretical results above clarify several key issues that were at the heart of the policy debate about the effects of sanctions on the Russian economy in 2022. In particular, the fact that export and import sanctions have the same allocative, fiscal and welfare implications but the opposite effects on the exchange rate implies that, without further information, one cannot infer the effectiveness of sanctions from the dynamics of the exchange rate. For example, the

[18]In addition to their direct effect on government revenues, sanctions that induce a decline in disposable home output, $C_{Ht} = Y_t$, also increase fiscal deficit and consumer prices via the exchange rate appreciation in (10) as a result of a negative income effect on import demand.

[19]Consider, for simplicity, a stationary version of the government budget constraint (4) with $R_t = R_t^* = R_{Ht}^* = \frac{1}{\beta}$ and $B_t = 0$:

$$\frac{W_t}{P_t} = Y_t + \frac{\mathcal{E}_t P_t^*}{P_t} \cdot \left[\frac{Q_t^*}{P_t^*} \cdot X_t + (1-\beta)\frac{F_t^* - B_t^*}{P_t^*}\right].$$

Both kinds of sanctions reduce the square brackets by τ percent, while the exchange rate term in front partially relaxes it by τ/θ percent according to (10). All in all, the government needs to either reduce W_t or increase P_t.

appreciation of the ruble in summer 2022 is in line with the fact that the Western coalition prioritized import sanctions and should not be interpreted to mean the impotence of such restrictions.

Propositions 1 also sheds light on the discussion whether the two types of trade sanctions should be treated as substitutes or complements in terms of inflicting damage on the economy. While the same economic impact can be achieved by means of either export or import sanctions, their combined effect is cumulative and both kinds of sanctions matter on the margin, provided that international trade is not fully shut down. The latter condition is all but certain to hold in practice given the rerouting of trade and the substitution of imports and exports away from sanctioning coalition towards third countries.

Limits of equivalence Propositions 1 to 3 emphasize a general equivalence result for import and export sanctions in terms of their allocative effects despite the differential exchange rate adjustment. Importantly, this is not a knife-edge result in the sense that it offers a reliable benchmark for qualitative and quantitative analysis of sanctions even when the exact conditions of equivalence do not hold, as we further explore in the quantitative Section 4. Nonetheless, a few important caveats are in order.

First, the original Lerner (1936) symmetry emphasizes the requirement of a *uniform* import tariff and export subsidy, i.e., that they apply equally to every traded good in the context of a static international trade model. In a dynamic macroeconomic environment, the uniformity across goods is not central. We do not need to specify what subsets of countries are engaged in sanctions and which subsets of goods are excluded from trade as long as we condition on the overall decline in the country's price of exports Q_t^* and the increase in the cost of imports P_t^*, where these objects are the ideal price indexes that incorporate the implied substitution responses (see Section 3). Instead, it is the uniformity across periods that is crucial for the equivalence in a dynamic setting. This includes taxing all past as well as future trade flows. As it turns out, total net foreign-currency assets F_t^* provide a sufficient statistic for past trade imbalances, and this is the reason why dynamic Lerner symmetry requires export sanctions to be combined with an additional asset freeze on these accumulated net exports.

Second, the uniformity condition fails and Lerner symmetry does not apply when trade sanctions are anticipated before they are imposed or are expected to be lifted in the future.[20] In particular, while both types of trade sanctions worsen the terms of trade Q_t^*/P_t^*, temporary import sanctions also result in a positive interest rate shock $R_t^* \frac{P_t^*}{P_{t+1}^*}$, which reduces welfare for borrowers and improves welfare for lenders. As a result, export sanctions have larger effect on countries running a current account surplus and import sanctions affect more economies with a current

[20] A more general equivalence for dynamic, partially anticipated sanctions shocks requires the use of additional capital controls instruments to offset the tilt in the FX demand in (6) and the budget constraint (9) induced by anticipated changes in import prices P_t^* (see Farhi, Gopinath, and Itskhoki 2014).

account deficit. We formally study this and other related effects of anticipated and temporary sanctions in Itskhoki and Mukhin (2023a).

Third, it is natural to ask about the interactions between trade and financial sanctions given that the two policies are often imposed together in practice. Interestingly, even though borrowing constraints affect the equilibrium allocation when countries run a current account deficit, they do not compromise Lerner symmetry between permanent import and export sanctions.[21] In contrast, financial restrictions may amplify the differences between temporary trade sanctions. Front-loading export sanctions results in a larger drop in imports and a larger exchange rate depreciation if the country is unable to borrow internationally and cannot smooth out the negative shock over time. Instead, temporary import sanctions provide incentives to delay consumption of foreign goods until sanctions wane, which relaxes the borrowing constraint.[22]

Finally, deviations from Lerner symmetry may arise when financial constraints on the economy are amplified by the exchange rate depreciation. Despite the same terms-of-trade effect, import and export sanctions have asymmetric implications for the exchange rate and may result in a differential tightening of the borrowing limits (see e.g., Bianchi 2011) or the debt overhang constraint in the domestic economy (see e.g., Eggertsson and Krugman 2012). For example, a depreciation of the exchange rate increases the real burden of debt issued in foreign currencies and can result in a bank run, financial crisis and an economic recession. It follows from Proposition 1 that — if not offset by government bailouts, bank holidays, or partial defaults — export sanctions may have more negative effects via the exchange rate channel than import restrictions, especially in highly dollarized economies.[23]

2.3 Financial sanctions and financial repression

We now study the effects of financial sanctions in the context of the same equilibrium system (5)–(7) by considering a response to a foreign-currency demand shock Ψ_t in (6). Such shock is likely to arise for two reasons. First, an increased demand for foreign-currency savings by households may arise due to elevated uncertainty and the collapse of alternative home-currency vehicles for savings as a result of the war and sanctions. Second, the risk of being hit by further rounds of sanctions and retaliation policies makes foreign investors unwind their financial positions in the economy under sanctions. This leads to sudden-stop dynamics with foreigners selling

[21] Furthermore, if the country completely loses access to global financial markets and its trade must be balanced state-by-state, import and export sanctions become equivalent irrespective of their dynamic time path.

[22] That said, import sanctions that result in additional foreign asset accumulation expose the country to the risk of future rounds of financial sanctions and asset freezes.

[23] We omit such balance sheet effects from our analysis as they are likely quantitatively unimportant in the case of 2022 Russian sanctions. As a result of 2014 financial sanctions and government policy response, Russia had no *net* foreign-currency debt and only limited dollarization of contracts within the economy by 2022. A record-breaking current account surplus in the first year of the war more than undid the effects of the new financial sanctions.

local assets in exchange for foreign currency, as we quantify in the data in Section 4. In the model, this is also captured in a reduced-form as an increase in Ψ_t which acts as a summary statistic for the aggregate financial shock induced by the war and sanctions. The government may respond to this shock with FX interventions, A_t^*, and financial repression, $R_{Ht}^* < R_t^*$.[24]

For simplicity, we focus on the case where the original dynamic equilibrium path features $\Psi_t = B_t^*/P_t^* \equiv \bar{\Psi} > 0$ and $R_t^* \equiv \frac{1}{\beta}$ for all t, and consider a permanent unanticipated shock to FX demand $\hat{\Psi}_t = \psi > 0$ for all $t \geq 0$.[25] Using the equilibrium system (5)–(7), we prove in Appendix C:

Proposition 4 *Consider a permanent increase in foreign currency demand $\hat{\Psi}_t = \psi$ for all $t \geq 0$.*

(a) *If the government accommodates the shock by selling FX reserves $\hat{A}_t^* < 0$ such that $\hat{B}_t^* = \psi$, then import quantities, the exchange rate and total net foreign assets do not respond to the shock, $\hat{C}_{Ft} = \hat{\mathcal{E}}_t = \hat{F}_t^* = 0$, and follow the original equilibrium path. This is a welfare-maximizing policy response.*

(b) *If the government is passive, $\hat{A}_t^* = 0$ and $R_{Ht}^* = R_t^*$, then import quantities decline $\hat{C}_{Ft} < 0$ and the exchange rate depreciates $\hat{\mathcal{E}}_t > 0$ for $t \in [0, T]$ and some $T > 0$, while FX savings B_t^* and net foreign assets F_t^* are accumulated until the new long-run equilibrium is reached.*

(c) *Without FX interventions, $\hat{A}_t^* = 0$, there exists a tax on foreign currency purchases by the households which results in $R_{Ht}^* < R_t^*$ such that import quantities, the exchange rate and foreign-currency assets remain unchanged, $\hat{C}_{Ft} = \hat{\mathcal{E}}_t = \hat{B}_t^* = \hat{F}_t^* = 0$ for all t. This involves a household welfare loss from the unaccommodated currency demand shock $\hat{\Psi}_t = \psi$.*

The logic of the proof relies on the fact that — from the perspective of equilibrium dynamics — there is a symmetry in the way the financial shock Ψ_t, the local-market FX interest rate R_{Ht}^*, and FX interventions $\hat{A}_t^*$ enter the equilibrium system. Indeed, all these variables affect only the household Euler equation (6), but not the country budget constraint (7) or the import demand schedule (5). As a result, the effect of the Ψ_t shock can be fully offset by either FX interventions or financial repression. Without either intervention, the increased currency demand of the household constrains the joint evolution of imports C_{Ft} and FX savings B_t^*. In all case, the exchange rate $\mathcal{E}_t$ adjusts to sustain the equilibrium dynamics consistent with the country budget constraint.

[24]Our analysis, in general, nests as a special case the situation of financial autarky defined as an inability to access international borrowing, $F_t^* \geq 0$, or collect return on FX savings, $R_t^* \leq 1$. These additional constraints were of limited effect on Russia in 2022, which was already significantly cut off from international borrowing after 2014, and ran a combination of current account and fiscal surpluses with $F_t^* > 0$ prior to the start of the war. We leave the analysis of "payment system sanctions" to future work. For further discussion, see Itskhoki and Ribakova (2024).

[25]The focus on a one-time permanent shock is for convenience only, and the results can be generalized to an arbitrary dynamic shock process (see Itskhoki and Mukhin 2021). Our quantitative analysis in Section 4 relaxes these assumptions.

We now zoom in on specific mechanisms operating in each case. In general, an increase in Ψ_0 leads to $B_0^*/P_0^* < \Psi_0$ on impact, resulting in an increased foreign currency demand by households. Proposition 4 emphasizes the three different ways in which this excess demand can be accommodated. First, increased household demand for foreign currency can be accommodated with the official FX interventions, whereby FX reserves A_0^* are sold to the households without changing the overall net foreign assets of the country, $F_0^* = A_0^* + B_0^*$. Assuming FX reserves are sufficient, this allows to fully eliminate the fluctuations in import consumption and the exchange rate. This ensures that both (6) and (7) are satisfied for the original path of C_{Ft}, $\mathcal{E}_t$ and F_t^* despite the shock $\hat{\Psi}_t$. From the normative perspective, such policy is optimal, akin to a Friedman rule, as it accommodates the currency demand of the households without distorting their consumption and savings decisions.[26]

Second, when FX interventions are infeasible due to insufficient FX reserves or sanctions on the central bank, the laissez-faire equilibrium response to the currency demand shock is an exchange rate depreciation which forces the households to cut down on their import consumption C_{Ft} and accumulate foreign currency arising from the resulting trade surplus. The country accumulates net foreign assets F_t^* along with B_t^*, and over time B_t^*/P_t^* increases towards the new value of Ψ_t. Foreign asset accumulation happens at the cost of reduced imports along the transition path. Over time, imports C_{Ft} gradually recover and slightly overshoot in the long run (if $R_t^* > 1$), reflecting the increased net foreign asset position of the country. In parallel, the exchange rate $\mathcal{E}_t$ that depreciated on impact then gradually appreciates, reflecting the accumulation of the local FX supply. Figure 3 provides an illustration: steeper foreign currency savings demand κ implies faster accumulation of foreign currency, which in turn requires a larger initial drop in imports and depreciation of the exchange rate.

Finally, an alternative to FX interventions is a policy of financial repression of foreign-currency deposits by means of direct or indirect taxation (e.g., caps on withdrawal or conversion). We capture this policy with a resulting wedge in the local-market interest rate on FX savings, $R_{Ht}^* < R_t^*$, which discourages foreign currency savings B_t^* in (6), even when Ψ_t is high. This curbs the exchange rate depreciation and the associated reduction in imports. In other words, financial repression ensures that scarce foreign currency is used to buy imports C_{Ft} rather than hoard foreign cash B_t^*. While smoothing the path of imports and the exchange rate, just like under the optimal FX interventions, such policy results in household welfare losses from distorted foreign currency savings, as captured by $v(B_{t+1}^*/P_{t+1}^*; \Psi_t)$ in the utility (1).[27]

Our discussion emphasizes the competing uses of foreign currency for import purchases and

[26] See Itskhoki and Mukhin (2023b) for the analysis of the optimal FX interventions in a more general environment.

[27] The result that imports are undistorted relies on the assumption that the tax is paid only by agents that purchase foreign currency as a store of value, while importers are exempt from it and can freely exchange currencies to pay for foreign goods.

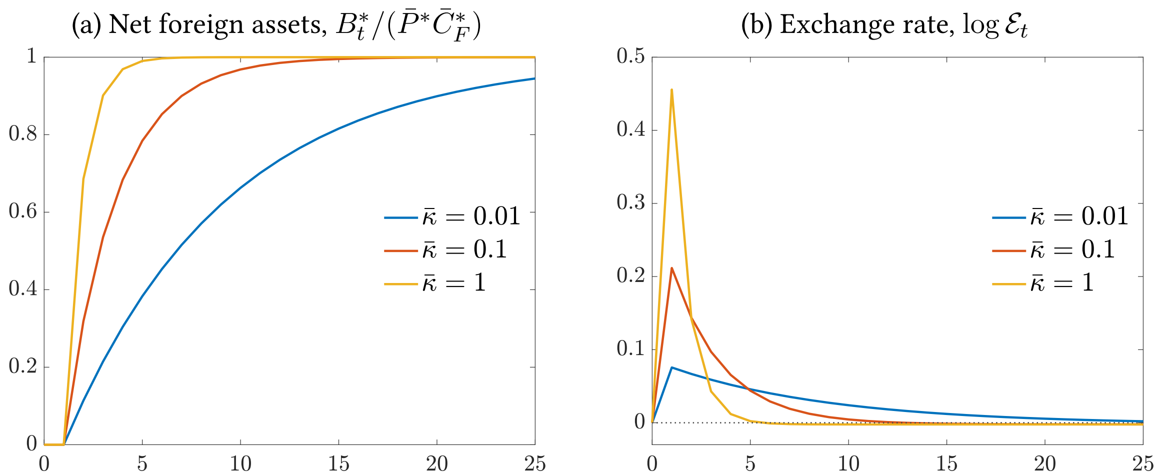

Figure 3: Laissez-faire response to the foreign currency demand shock Ψ_t

Note: The figure plots impulse responses — of the household's holdings of foreign currency (as a share of pre-shock imports) in the left panel and of the exchange rate in the right panel — to a permanent increase in foreign currency savings demand Ψ_t equal to the country's monthly imports and corresponding to the long-run increase in B_t^* in the left panel. One period corresponds to one month, $\beta = 0.96^{1/12}$, $\beta R_t^* = 1$; we use $\theta = 1.5$ and three different values of the currency demand parameter $\bar{\kappa} \equiv \frac{\theta\kappa/\beta}{\theta-1}(\bar{C}_F/\gamma)^{1/\theta}$.

saving when the supply of FX to the economy is constrained. Proposition 4 also suggests a welfare ranking of policies. FX interventions that accommodate the currency demand shock dominate laissez faire. In turn, in a representative agent environment, the laissez-faire equilibrium dominates the equilibrium with financial repression that suppresses the currency demand shock, as we formally show in Appendix C.2. All mechanisms identified in Proposition 4 were partly at play in Russia in the aftermath of the invasion and sanctions.[28]

The welfare ranking of policies raises two questions. First, why not always resort to FXI in response to increased private currency demand? Scarcity of official FX reserves limit their possible use, and financial sanctions such as asset freezes can dramatically reduce this capacity as well. The government can attempt to create synthetic foreign currency deposits for savers not backed by foreign assets (i.e., $A_t^* = -B_t^* < 0$ with $F_t^* = 0$) and financed with future consolidated revenues. This creates a currency mismatch on the government balance sheet making it vulnerable to further exchange rate depreciation shocks and bank runs (*cf.* Krugman 1979, Obstfeld 1996). Furthermore, a government running a budget deficit might want to *increase* FX reserves and *depreciate* national currency further to boost local-currency revenues TR_t. As we discuss in Appendix C.3, even though such policy has no effect on the country's real income, it does provide a temporary fiscal relief by shifting household consumption over time.

[28]In the working paper version (Itskhoki and Mukhin 2022), we provide direct evidence of financial repression in Russia in March-April 2022 applied differentially across foreign currencies, and as a result distorting the domestic-market bilateral exchange rates between currencies relative to their international exchange rates, a rather peculiar outcome. In quantitative Section 4, we calibrate both the path of FX interventions and the net effect of financial shocks and financial repression which are jointly consistent with the observed dynamics of the exchange rate.

Second, if financial repression is necessarily welfare-reducing, why do we observe it used often in practice? One possible explanation is that a depreciation of the exchange rate in response to currency demand shocks can destabilize financial markets and lead to output losses in the presence of balance sheet constraints discussed above. However, as we show in Appendix C.2, financial repression may also be an effective tool of redistribution — between consumers and savers — in heterogenous agent economies (*cf.* De Ferra, Mitman, and Romei 2020, Fanelli and Straub 2021). In such economies, the exchange rate still plays an important allocative role even under financial autarky and financial repression. An exchange rate depreciation discourages imports by consumers, while financial repression of FX savings curbs such depreciations and hence supports import consumption. As a result, if many agents are hand-to-mouth consumers relative to few FX savers, financial repression may increase the utilitarian welfare objective.

3 Sanctions on a Large Commodity Exporter

We now extend our analysis to accommodate the case in which the economy under sanctions is large in the commodity market and, thus, sanctions affect world commodity prices and foreign welfare. To this end, we lay out a fully specified model of the rest of the world. We also formalize various specific trade sanction policies that can be adopted by the rest of the world and study when they remain equivalent to the baseline import and export tariffs.

3.1 The rest of the world

We model the rest of the world to capture the fact that it is large relative to the economy under sanctions in all markets, but commodities, where by large or small we mean whether the country has the ability to affect world prices. Towards this goal, we assume that international households have a quasi-linear utility function in the internationally tradable good C^*_{Ft} and concave in the consumption of commodities $\mathcal{C}^*_t$:

$$u^*_t = C^*_{Ft} + \frac{\eta}{\eta - 1}\gamma^{*\frac{1}{\eta}}\mathcal{C}^{*\frac{\eta-1}{\eta}}_t, \tag{15}$$

where $\eta > 0$ is the elasticity of demand for commodities and $\gamma^* > 0$ parametrizes the commodity-intensity of the world consumption basket. Households maximize the expected intertemporal utility with a discount factor β.

The international economy enjoys endowments Y^*_t of the tradable good and X^*_t of commodities with international prices P^w_t and Q^w_t, respectively. It procures an additional quantity X_t of commodities from the economy under sanctions and sells in return a quantity C_{Ft} of the international good at prices Q^*_t and P^*_t, respectively. We denote with τ^Q_t and τ^P_t the corresponding wedges relative to the world prices Q_t^w and P_t^w such that:

$$Q_t^w = (1+\tau_t^Q)Q_t^* \qquad \text{and} \qquad P_t^* = (1+\tau_t^P)P_t^w. \tag{16}$$

Therefore, $\mathcal{T}_t^* = \frac{\tau_t^Q}{1+\tau_t^Q} Q_t^w X_t + \tau_t^P P_t^w C_{Ft} + \tau_t^F F_t^*$ are the rents resulting form sanctions, where the last term captures a seizure of fraction τ_t^F of the country's net foreign assets.

The market clearing conditions for the two goods are:

$$\mathcal{C}_t^* = X_t^* + X_t \qquad \text{and} \qquad C_{Ft}^* + C_{Ft} = Y_t^*. \tag{17}$$

We denote with $s_t = \frac{X_t}{X_t^*+X_t} \in (0,1)$ the share of the world commodity output provided by the sanctioned economy. International households choose consumption given the world consumer prices, resulting in the following demand schedule for commodities:

$$\mathcal{C}_t^* = \gamma^* \left(\frac{Q_t^w}{P_t^w}\right)^{-\eta}, \tag{18}$$

which depends on the relative price of commodities with elasticity η. Note that the elasticity of the world relative price of commodities with respect to commodity supply from the sanctioned economy is given by $\partial \log(Q_t^w/P_t^w)/\partial \log X_t = -s_t/\eta < 0$.

To complete the model description, note that the Euler equation for savings is given by $\beta R_t^* \mathbb{E}_t\{P_t^w/P_{t+1}^w\} = 1$, and the world monetary authority chooses R_t^* to implement a desirable path of the world prices P_t^w. In particular, if the goal is to implement stable prices, $P_t^w = 1$, then the equilibrium interest rate equals $R_t^* = 1/\beta$.

3.2 Alternative sanctions policies

We first show how the small-economy results in Proposition 1 generalize to the environment with the rest of the world which imposes sanctions in the form of import and export tariffs, τ_t^P and τ_t^Q in (16), resulting in the transfer $\mathcal{T}_t^*$ equal to tariff revenues along with the value of sanctioned foreign assets. We show that the symmetry between import and export tariffs applies not just for the economy under sanctions, but also for the rest of the world, which generally benefits from such tariffs at the expense of the sanctioned economy. We then consider alternative sanctions policies other than tariffs and the resulting welfare consequences for the sanctioning coalition.

While the economy under sanctions is now large in the sense that the quantity of its exports X_t affect the world price Q_t^w, we still assume that the country is a price-taker in the world commodity markets. Since we model commodities as endowment, this is equivalent to assuming that all endowment is used. This convenient assumption is also empirically realistic in the context of sanctions against Russian commodity exports, as we discuss below. Furthermore, the general equivalence emphasized in our results does not rely on this assumption.

Proposition 5 *Permanent tariff on imports, $\tau_t^P = \tau$ for all $t \geq 0$, is equivalent to a permanent tax on exports, $\tau_t^Q = \tau$, combined with a partial seizure of foreign assets, $\tau_0^F = \frac{\tau}{1+\tau}$: both policies result in a permanent deterioration in the terms of trade for the economy under sanctions, $\frac{Q_t^*}{P_t^*} = \frac{1}{1+\tau}\frac{Q_t^w}{P_t^w}$, a decline in its imports C_{Ft}, and a welfare gain in the rest of the world equal to the transfer of wealth:*

$$\frac{1}{P_0^w}\sum_{t=0}^{\infty}\beta^t \mathcal{T}_t^* = \frac{\tau}{1+\tau}\left[\frac{F_0^*}{P_0^w} + \sum_{t=0}^{\infty}\beta^t \frac{P_t^w}{P_0^w}\frac{Q_t^w}{P_t^w}X_t\right], \tag{19}$$

while the paths of world prices Q_t^w and P_t^w, and export quantities X_t remain unchanged.

We, therefore, see that the equivalence of Proposition 1 extends to the impact on the rest of the world (see the prove in Appendix B).[29] With endowment of commodities, both import and export sanctions affect the terms of trade and the allocation of the imported good C_{Ft}, but not commodity exports X_t or world prices Q_t^w/P_t^w. Lerner symmetry holds for the rest of the world, as well as for the economy under sanctions. In particular, the rest of the world receives a transfer of rents resulting from tariffs. This transfer results directly in welfare gains without inflationary effects or loss of commodity consumption, and there is no need to accommodate such sanctions with monetary policy. The same is generally true when foreign assets are taxed, as this is by definition a pure transfer with no *costs to sender*, and these were indeed the first sanctions imposed on Russia following the invasion in 2022.

The assumption of endowment of commodities implies inelastic supply of exports from the economy under sanctions. As a result, the rest of the world can effectively extract the full surplus with the optimal tariff, manipulating the terms of trade to the limit. In Appendix B, we generalize this optimal tariff result to the case where the supply of commodities is elastic. In this case, the optimal tariff $\tau = 1/\varepsilon$ is finite and is inversely related to the export supply elasticity ε, irrespective of other elasticities (Johnson 1953, Helpman and Krugman 1989).[30] The equivalence between export and import tariffs still holds in this case by Lerner symmetry, yet now both tariffs distort the commodity supply X_t and the world commodity prices Q_t^w/P_t^w, resulting in a dead-weight loss and global inefficiency. Nonetheless, the rents from the tariff more than compensate the losses from commodity consumption in the rest of the world. The economy under sanctions necessarily loses and the rest of the world necessarily gains from such tariffs.

[29] The mapping of taxes τ^Q, τ^P and τ^F into log-deviation in Proposition 1 is as follows: $\hat{Q}_t^* = -\log(1+\tau^Q)$, $\hat{P}_t^* = \log(1+\tau^P)$ and $\hat{F}_0^* = \log(1-\tau^F)$, which is the reason why $\tau^F = \tau/(1+\tau)$ in Proposition 5.

[30] The reason why other elasticities do not matter is that the country under the optimal tariff buys imports according to its budget constraint irrespective of the elasticity of import demand, and the exchange rate adjustment supports this equilibrium outcome. Thus, the entire objective of the optimal tariff is to extract maximum surplus from the supply of exports, a monopsony outcome. For further discussion see Itskhoki and Mukhin (2025b).

Alternative export sanctions We now zoom in on export restrictions and consider the effects of alternative policies. There are two dimensions of export sanctions that ensure their equivalence to the baseline tariff policy in Proposition 5. First, the sanctions policy must implement the same physical allocation of export quantities with the path of X_t that remains unchanged under the endowment assumption. Second, the sanctions policy must result in the same real rent transfer $\mathcal{T}_t^*$ from the sanctioned economy to the rest of the world. If these two conditions are satisfied, the policy implements the same sanctioned path of import consumption C_{Ft} with the path of the exchange rate supporting it that is still given by (10).

With this general insight, we now consider two alternative policies: a price cap and a quantity restriction (or partial embargo). First, we note that the price cap achieves the same outcome as the tariff τ if the cap is set as fraction $1/(1+\tau)$ of the world commodity price Q_t^w. This results in the export price $Q_t^* = Q_t^w/(1+\tau)$ to the sanctioned country and the gap between Q_t^w and Q_t^* becomes rents that must be split in the rest of the world. If the distribution of these rents is of no concern — that is, whether they accrue to individual countries or to commodity intermediaries rather than the government — then the equivalence with the tariff applies, irrespective of whether the export supply of commodities were elastic or not.[31]

Matters are significantly different with a quantity restrictions on exports captured with a binding constraint $X_t \leq \check{X}_t$. We can see immediately that, as long as the export supply of commodities is inelastic, quantity restrictions distort the allocation and result in a dead-weight loss relative to a tariff or a price cap. However, this is specific to the inelastic case and does not generalize when the export supply of commodities is elastic. With a positive elasticity $\varepsilon > 0$, for any tariff τ, there exists a binding quantity restriction $\check{X}_t$ that mechanically implements the same path of export quantity allocations. Nevertheless, what is general for both inelastic and elastic cases is the difficulty to extract rents. This is particularly apparent in the inelastic case, where a quantity restriction results in a movement up the commodity demand schedule (18) and an elevated consumer price Q_t^w/P_t^w with rents up for grabs by whoever controls the distribution of commodities to consumer. Intuitively, the goal of the policy is to move down along the export supply curve, which is vertical in the inelastic case, rather than up the commodity demand curve (see Figure O1 in Appendix B). With elastic supply, it is always possible to implement the right quantity sliding up the demand curve, but equivalence additionally requires a second policy tool to collect the rents.

If rents cannot be captured, are quantity restrictions purely wasteful from the perspective of the rest of the world? On the one hand, the rest of world necessarily experiences a welfare loss.

[31] In practice, total Russian oil export quantities remained remarkably stable throughout both 2022 and 2023 while it was facing significant export price discounts largely due to the relocation of its exports away from Europe and towards new customers in China, India and Turkey (Hilgenstock, Ribakova, Shapoval, Babina, Itskhoki, and Mironov 2023). See Johnson, Rachel, and Wolfram (2023) for the analysis of the price cap under monopolistic distortion.

On the other hand, the economy under sanctions also loses export revenues on net, but only if the elasticity of commodity demand with respect to X_t is less than one, that is, $s_t/\eta < 1$. In this case, the loss from lower quantities X_t dominates the gain from improved terms of trade. In other words, the dead-weight loss from the policy is so large as to eliminate gains for either of the parties despite rents being captured by the sanctioned economy. Therefore, if the goal of the policy is to reduce export revenues despite own welfare costs, then quantity restrictions may achieve this goal, yet they are inferior to a tariff or a price cap (*cf.* Sturm 2022).

Alternative imports sanctions Relative to various export sanctions, the equivalence applies more broadly across a variety of import sanctions policies. First, we address the case where the aggregate imported good C_F consists of a continuum of imperfectly substitutable varieties. With all varieties being symmetric, we nest the case of a single imported good studied so far. More generally, the varieties of the imported good may correspond to various source countries or to various types of product. Consider now the situation where only a subset of imported varieties are subject to a tariff τ. We show in Appendix B that, from the perspective of the macroeconomic allocation, this is equivalent to a uniform import tariff studied earlier and given by:

$$1 + \tau_t^P = \left[1 - \delta_t + \delta_t(1+\tau)^{1-\rho}\right]^{\frac{1}{1-\rho}}, \tag{20}$$

where $\rho > 0$ is the constant elasticity of substitution between varieties of import products and δ_t is the share of products under a tariff. This share may correspond to a subset of products or a subset of countries imposing sanctions.

The macroeconomic effect on the country under sanctions is still summarized by the aggregate path of τ_t^P in (20), which takes into account the substitutability of various import varieties. Naturally, a full sanctioning coalition can aim to ensure $\delta_t = 1$ and $\tau_t^P = \tau$. With incomplete coverage of sanctions, $\delta_t < 1$, it is necessarily the case that $\tau_t^P < \tau$, and this gap is increasing in ρ. In other words, the same aggregate effect requires increasingly larger individual sanctions τ the smaller is the sanctioning coalition and the more substitutable are the imported varieties.[32]

We also note that exact equivalence between τ_t^P and (τ_t, δ_t) in (20) fails for the rest of the world, as for a given τ_t^P, the case with $\delta_t \in (0,1)$ creates misallocation of produced varieties with the associated cost borne by the foreign economy. This is generally a second-order effect (in τ_t) and it is quantitatively very small when the economy under sanctions is small in terms of its import share of global output, C_F/Y^*. However, this can be important in cases where the burden of implementing and enforcing sanctions is not evenly split within the rest of the world.

[32]When $\rho > 1$, we can think of $\tau \to \infty$ as a ban on a subset of imported varieties. The result in (20) continues to hold in this limit, and we have $\tau_t^P = (1-\delta_t)^{1/(1-\rho)}$ under a ban on fraction δ_t of import varieties (formally, δ_t is the ex-ante expenditure share on the sanctioned varieties before the ban was in place). Our working paper Itskhoki and Mukhin (2022) explores the case of a ban when $\rho = 1$ and, thus, the limit of $\tau \to \infty$ cannot be simply taken.

Finally, we discuss the case of a homogenous good C_F (that is, when $\rho \to \infty$) with a quantity constraint on imports, $C_{Ft} \leq \check{C}_{Ft}$. First, note that in this case the full sanctioning coalition is essential. Indeed, according to (20), $\tau_t^P \to 0$ when $\rho \to \infty$ for any $\tau > 0$, as long as $\delta_t < 1$. Intuitively, with perfect substitutability, it is sufficient to find one supplier that is willing to deviate from the policy of sanctions. However, with a full coalition, it is possible to implement an effective quantity limit. This quantity limit results in rents from selling the imported good to the country under sanctions. If and only if these rents are captured by the rest of the world, the quantity restrictions are equivalent to a tariff, echoing our results on exports sanctions.[33]

To summarize, from the perspective of the economy under sanctions, a sufficient statistic for the impact of permanent trade sanctions is the change in the flow of export revenues adjusted for their purchasing power of imported goods — namely, the proportional change in $Q_t^* X_t / P_t^*$ irrespective of the composition of this change. In other words, the same impact can be achieved by means of reduces exports prices Q_t^*, reduced export quantities X_t, or increased import prices P_t^*. Matters are very different from the perspective of the sanctioning coalition, which aims to inflict a maximum deterioration in the terms of trade Q_t^*/P_t^* with a minimal impact on export quantities X_t and, by consequence, its own consumer prices Q_t^w/P_t^w. With a decrease in X_t, the rest of the world experiences loss of consumer surplus and inflationary pressures from increasing commodity prices, which may result in an overall welfare loss.

4 Quantitative Evaluation

This section provides a quantitative evaluation of the ruble exchange rate dynamics combining together various financial and trade shocks discussed in the previous sections. We further discuss the implications of sanctions shocks for other variables of interest, including fiscal revenues, inflation and welfare — both in the economy under sanctions and in the rest of the world.

We calibrate the model parameters and shocks with the aim of matching salient features of the Russian economy which is large in the global commodity market. We adopt two alternative strategies to calibrate the paths of the shocks that drive our quantitative results. First, we reproduce our *ex-ante* calibration from the 2022 version of the paper (Itskhoki and Mukhin 2022) based on the scarce data that were available in the first months after the start of the war and without targeting exchange rate moments. We show that this calibration provides a remarkable out-of-sample fit, predicting accurately the dynamics of the exchange rate in the following two years. Second, we develop an *ex-post* calibration that infers structural shocks from the observed macroeconomic dynamics up to September 2024 and, by construction, reproduces the path of the

[33] Formally, binding quantity restriction $\check{C}_{Ft}$ translates into a unique change in $P_t^* \mathcal{E}_t / P_t$ according to (10) and a unique path of $P_t^* > P_t^w$ consistent with the country budget constraint (9). Together, these conditions characterize the equilibrium real exchange rate which follows the same path as under an import tariff, $1 + \tau_t^P = P_t^*/P_t^w$.

exchange rate within our sample. We show that the two approaches largely agree on the decomposition of the exchange rate into the contributions of different sanctions shocks and policy responses, confirming the quantitative importance of theoretical mechanisms discussed above.

Calibration We solve the model using a first-order perturbation around a non-stochastic steady state, and we denote with small letters the log deviations of corresponding variables from their steady-state values.[34] The model is monthly and we focus on the period from February 2022 to September 2024, the last quarter with available data. The war started on February 24, 2022, and we label this month as $t = 0$, assuming the first shocks arrive by the end of this initial period.

Whenever possible, we rely on conventional values of parameters from the earlier literature. We set the monthly discount factor $\beta = 0.96^{\frac{1}{12}}$. We use $\theta = 1.5$ consistent with conventional values of the macro elasticity of substitution between home and foreign goods (Chari, Kehoe, and McGrattan 2002, Feenstra, Luck, Obstfeld, and Russ 2014). With scarce empirical guidance, we set the bonds-in-the-utility parameter $\bar{\kappa} = 0.33$, which implies that the demand elasticity for dollar deposits with respect to dollar interest rate is equal to 3. This is a bit higher than the estimates for the U.S. money demand elasticity of 1–2 (Lucas 2000, Ireland 2009), but in line with the estimates of the foreign-currency demand elasticity in developing countries (Agénor and Khan 1996).

We choose the expenditure share parameters $\gamma = 0.25$ and $\gamma^* = 0.04$ in (3) and (15), respectively, as well as the countries' steady-state endowments to match the share of imports in total spendings in Russia of 20%, the contribution of Russia to the world GDP of 2%, and its share in the global oil market of 12.5%. We set the value of the commodity demand elasticity $\eta = 0.05$ closer to the lower estimates in the literature capturing the short-run response at the global level (Bachmann, Baqaee, Bayer, Kuhn, Löschel, Moll, Peichl, Pittel, and Schularick 2024).

We hold constant the parameter values across the two calibrations of shocks. In the ex-ante calibration, we choose the path of shocks as simple autoregressive processes that resemble the early information on sanctions, as summarized in Appendix Table A1. About half (or $300 billion) of Russian foreign assets were frozen in the first week of the war which corresponds to a permanent decrease in f_0^* by 12 months worth of imports. The beginning of the war was associated with a sharp increase in uncertainty, in demand for FX safe assets, and in capital outflows. We capture this shock with an increase in foreign currency demand, $\psi_0 = 1.5$, corresponding to 1.5 months of imports, with a half-life of one year.[35] As financial repression and FX interventions

[34] We focus on a steady state in which all prices are normalized to one, $F^* = B^* = \Psi = 0$, and $R^* = R_H^* = 1/\beta$.

[35] While it is difficult to obtain data on the demand for foreign currency, our calibration is broadly consistent with the combined $20 billion increase in household FX cash holdings (reported by the Central Bank of Russia) and $100 billion withdrawal from the Russian bond and equity funds by foreigners in February–March 2022 (reported by EPFR/Haver Analytics). We provide a further validation for the quantitative magnitude of this shock below.

can partially offset the financial shock, we do not consider them separately and interpret ψ_t as the net effect of financial distress partially offset with government policies.

All other shocks arrive with a one month lag to capture the delayed effects of non-financial sanctions. Following early estimates, a fall in domestic output is calibrated to 5% with a half-life of 3 years. As Russian imports were down from a monthly level of $30 billion before the war to $17 billion in April and rebounded to $24 billion in mid-summer, the import sanctions shock is calibrated to feature a 50% increase in the import price index on impact with a half-life of 4 months. To capture both a spike in energy prices in the first months of the invasion and an expected fall in export revenues as European countries switch to alternative sources of energy imports, we introduce shocks to both Russian and the rest-of-the-world supply of commodities, x_t and x_t^*, that result in a temporary increase of export revenues of 50% with a half-life of 8 months and a permanent decline of 30%.[36] Finally, we abstract from monetary shocks that are hard to disentangle ex ante from inflation driven by import prices, and we omit shocks to foreign output y_t^* that are irrelevant for the economy under sanctions.

In the ex-post calibration, some shocks can be directly observed while other need to be backed out to match the observable data. In particular, FX reserves a_t^* are reported by the Central Bank of Russia, monetary shocks p_t and p_t^w correspond to consumer price indexes in Russia and the U.S., and domestic output y_t and y_t^* is proxied with real GDP in the two countries. The Russian commodity output is the difference between observable export revenues and commodity prices, $x_t = ex_t - q_t^*$, while the foreign commodity output x_t^* is calibrated to match the path of world commodity prices q_t^*.[37] Given other variables, Russian import prices p_t^* are inferred using the import demand schedule (5) to match the path of import expenditure. This provides the description of trade shocks.

The asset freeze f_0^* is calibrated as before. By contrast, we now recover the financial shock ψ_t as a residual, upon including all other shocks, that allows to perfectly fit the observed path of the exchange rate. This requires making an assumption about agents' expectations about the shock process, and our baseline is perfect foresight. We interpret the resulting ψ_t series as the net FX demand shocks partially offset by financial repression which we do not identify separately. We provide below a validation of the recovered ψ_t series using data on interest rate spreads and capital outflows (see Appendix E).

[36] In the data, Russian monthly export revenues increased from $35 billion pre-war to $50 billion for the period of February to June and then began to decline as energy prices came down and Western countries substituted away from Russian oil and gas (Babina, Hilgenstock, Itskhoki, Mironov, and Ribakova 2023).

[37] Recall from our discussion in Section 3.2 that the outcomes for the sanctioned economy depend only on the path of the overall export revenues, while the decomposition of their dynamics into export quantities and commodity prices is central for the outcomes in the rest of the world. In matching the observed dynamics of export revenues and commodity prices, we do not need to take a stance on whether the commodity supply from Russia is elastic or inelastic, an assumption that would be essential for counterfactual analysis.

Figure O2 in Appendix D shows the time series used to calibrate the model and the inferred paths of the shocks that we feed into the model. We solve the model under a perfect foresight assumption, where as before the asset freeze and the financial shocks are revealed at $t = 0$, while the paths of other shocks become known with a one period lag, at $t = 1$. The results are largely unchanged under an alternative specification with shocks following a random walk with each period's innovation being unexpected. See Appendix D for further details about the data, the alternative calibrations, and the numerical algorithm used to solve the model.

4.1 Exchange rate dynamics

We now explore the dynamics of the exchange rate through the prism of our quantitative model. Figure 4 plots the realized path of the ruble exchange rate in the data, from February 2022 to September 2024, as well as the equilibrium path of the exchange rate in the ex-ante calibrated model. Even though the exchange rate is not directly targeted in this calibration, the simulated path closely resembles the dynamics of the ruble in the data — the exchange rate depreciates on impact by 50%, returns to the initial level about a month after the impact, and then keeps appreciating to a peak of 20% above the pre-war level at the four-month horizon. Calibrated originally in September 2022, when the ruble was still significantly appreciated, the model predicts a return of the exchange rate to pre-war level around February 2023 — remarkably in line with the future realization of the data. The model misses large swings in the exchange rate during political turmoil — the armed mutiny in the summer 2023 (Wagner Group rebellion) — but captures well the long-run depreciation of the ruble by 20% towards the end of our sample.[38]

One advantage of a structural model is that it allows us to decompose the dynamics of the exchange rate into various sanctions shocks. Figure 5 presents the results for the ex-ante and the ex-post calibrations, where the black lines correspond to the simulated paths of the exchange rate and the colored bars show the counterfactual dynamics of the exchange rate when only one shock is present. Recall that the ex-post calibration matches the overall monthly path of the exchange rate exactly by construction. Despite different methodologies, the two calibrations largely agree on the underlying drivers of the exchange rate during this period. The main discrepancy comes from the fact that, in the ex-post calibration, import sanctions and financial shocks are larger and more persistent, while the domestic recession is shorter-lived, which explains the finer differences in magnitudes in the two panels.

Both panels of Figure 5 reveal that the role of different shocks changes significantly over time. In particular, we find that capital outflows driven by the financial shock ψ_t were the key driver behind the sharp depreciation of the ruble in the first weeks. Furthermore, the ex-post calibration

[38]While we do not extend the sample further, the ruble exchange rate has stabilized around 95 rubles per dollar, close to the long-run prediction of our ex-ante model equal to 92 against the pre-war level of 75.

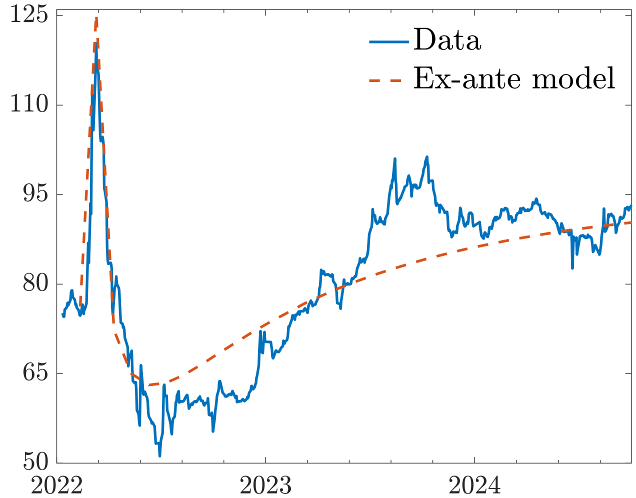

Figure 4: Exchange rate dynamics

Note: The figure plots the dynamics of the ruble-dollar exchange rate (in units of rubles per one dollar) in the data and in the model under the ex-ante calibration (with shocks as described in Appendix Table A1).

in panel (b) reveals that the depreciation of the exchange rate would have been 10% larger if the central bank did not sell foreign reserves to satisfy the increased demand for foreign currency. In contrast, despite the large amount of FX reserves frozen by sanctions, the impact of this freeze on the value of the exchange rate is small (albeit very persistent) and generates a permanent 3% depreciation of the exchange rate (see panel a). Indeed, a permanent income loss from an asset freeze worth 100% of annual exports corresponds to a permanent reduction of export flows of about 4%, i.e., the annual rate of interest. Nonetheless, the FX freeze and sanctions on the Central Bank likely constrained its ability to fully accommodate the financial shock with unrestricted FX interventions (*cf.* Proposition 4 and Figure O2e in Appendix D).

One month out, trade shocks begin to dominate the dynamics of the exchange rate. First, trade restrictions that result in higher effective import prices and a decline in import quantities curb demand for foreign currency and act as a major ruble appreciation force in summer 2022. Second, the increase in energy prices and Russian export revenues in the first months after the invasion increase supply of foreign currency and also contribute to the appreciation of the currency. Finally, a contraction in domestic consumption also reduces import demand and contributes to the strengthening of the ruble, although this effect is quantitatively small. All in all, the combined effect neutralizes the surge in financial demand for foreign currency and, consistent with Propositions 1 and 2, explains the appreciation of the ruble from the third month onward.

Over time, import prices mean revert and import quantities recover as parallel imports and new trade linkages are established, resulting in a rebound in foreign-currency demand and an exchange rate depreciation. At the same time, the inflow of foreign currency contracts as commodity export revenues decline. Combined together, these forces bring the exchange rate back to

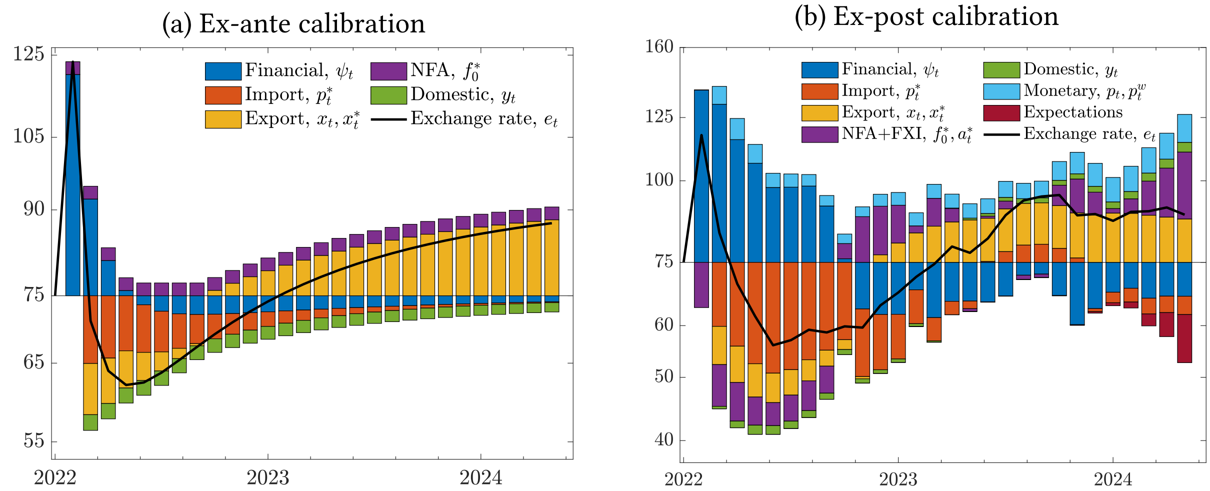

Figure 5: Exchange rate decomposition

Note: The figures shows with solid black lines the simulated path of the exchange rate (in levels) and with colored bars the contribution of each shock according to the model with ex-ante calibration (panel a) and ex-post calibration that by construction reproduces dynamics of the exchange rate and macro variables (panel b; "Expectations" summarize the contribution of all future shocks after the last period in the sample).

the pre-war level about one year after the start of the war with a continued gradual depreciation thereafter. This trend is exacerbated by the government policy to rebuild the FX reserves starting in the end of 2022. The eventual decline in export revenues dominates in the long run, both in the ex-ante and ex-post calibrations, and the ruble ultimately depreciates by around 20% relative to its pre-war level. Finally, note the contribution of monetary accommodation (inflation) which results in additional nominal depreciation, albeit small (see panel b; not featured in the ex-ante calibration).

In sum, we find that the dynamics of the exchange rate is primarily shaped by the balance of financial shocks and trade restrictions, with the financial shock having a sharper effect in the very short run, and import and export sanctions dominating in the medium and long run. Speculatively, the particular mix of sanctions — that were concentrated on curbing Russian imports without curbing Russian export revenues boosted by high energy prices — allowed the government to avoid a full-scale currency and banking crises.

Robustness Appendix Figure A1 displays two alternative calibrations. In the left panel, we show that replacing the assumption of perfect foresight with the assumption of martingale shocks, that is, with agents being surprised each period with the additional innovation to shocks, does not qualitatively change the prediction of the model about the contributions of shocks to the exchange rate dynamics. The reason is the combination of the persistence of calibrated shocks and the endogenous propagation of the responses to shocks in our model. Indeed, in a Ricardian model with $\kappa = 0$ in (3), financial shocks have no effect on allocation or the exchange rate, while trade sanctions result in an immediate permanent-income adjustment with no further dynamics, as we show in the right panel of Appendix Figure A1. In contrast, under the calibrated value of $\bar{\kappa} > 0$, the equilibrium consumption and the exchange rate respond more to contemporaneous shocks than to expected future shocks, a property our model shares with a large class of non-Ricardian models (*cf.* Auclert, Rognlie, and Straub 2024, Angeletos, Lian, and Wolf 2024).

Validation of financial shocks In the ex-post calibration of the model, the financial currency demand shock ψ_t is backed out as a residual to match the empirical path of the exchange rate. In Appendix E, we introduce two additional data series that allow us to validate the recovered financial shock process. The first series is the foreign-currency (euro) interest rate spread in Russia which we interpret as the premium to compel households to hold their savings domestically rather than taking them abroad as a result of the FX demand shock. This spread spikes after the start of the war and stays elevated for the next several months before coming down after mid-2022 and staying suppressed thereafter, in line with the dynamics of the component of the exchange rate induced by the calibrated ψ_t shock, as we show in Figure O3 in Appendix E.

Perhaps more importantly, we show that the calibrated ψ_t shock allows the model to track the sudden stop in capital flows to Russia captured by the collapse in external liabilities. In particular, we show that there is a spike in capital outflows after the start of the war which slowly reverts over the next year. When we interpret ψ_t as the decline in foreigners' demand for financial investments in Russia, the model reproduces accurately the additional data on gross capital flows, in addition to net capital flows that are matched by virtue of fitting the trade balance. Conversely, when we back out the path of ψ_t shock by matching exactly the dynamics of gross external liabilities without targeting the exchange rate, the model still captures well the empirical path of the exchange rate. We report these results in the two panels of Figure O4 in Appendix E.

4.2 Fiscal revenues, inflation and welfare

What was the ultimate effect of sanctions on the Russian economy and on the rest of the world? To answer this question, this subsection goes beyond the exchange rate and discusses the dynamics of other macroeconomic variables, using the ex-post calibration of the model.

Consider first fiscal revenues that, in our model, are proportional to nominal GDP.[39] The left panel of Figure 6 shows the aggregate revenues (black line) and its decomposition into different shocks. The initial depreciation of the exchange rate *boosts* local-currency revenues by 12% and this is further amplified by greater export revenues starting in the second month. These effects

[39] As in the theory sections, we focus on the revenues of the consolidated budget abstracting from a disproportionately large contribution of energy exports to Russian federal budget (40% against 25% share in GDP) and a significant rise in government expenditures driving the fiscal deficit.

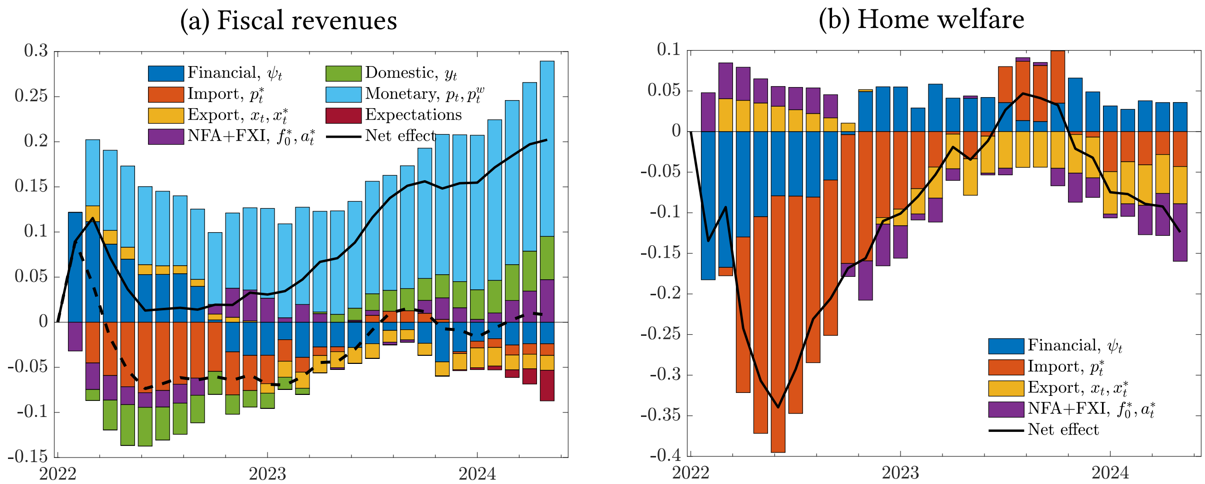

Figure 6: Fiscal and welfare implications

Note: The figure shows a simulated response of government revenues (or equivalently nominal GDP, panel a) and home welfare (or equivalently real consumption, panel b) in log-percentage changes relative to the pre-war level (the black line) and their components driven by different shocks (colored bars). The dashed black line in the left panel shows the real effect (equal to the solid line net of monetary component). "Expectations" summarize the contribution of all shocks after the last period in the sample; panel b only shows welfare effects of trade and financial sanctions.

are offset in the medium run as a result of the exchange rate appreciation due to trade sanctions, and also by lower tax revenues because of the recession in the domestic economy. Nominal fiscal revenues, nonetheless, stay positive and even increase over time because of monetary inflation that builds up to 20% over the period. Once this component is excluded, the net *real* income (relative to the pre-war level) turns negative starting from April 2022 and remains mostly below zero after that (the dashed black line in the figure). The long-run real losses are close to zero because the exchange rate depreciation and the recovery of home production offset losses due to the reduction in foreign-currency exports. Excluding the contribution of domestic output, which arguably mirrors government war expenditure, we establish that international sanctions decrease the long-run real government revenues and national income by about 4%.

Zooming in on the welfare implications of sanctions, the right panel of Figure 6 shows the effects of trade and financial shocks on aggregate consumption.[40] In line with Proposition 4, the capital outflows shock ψ_t that is not fully offset by FX interventions in the first months results in a ruble depreciation and makes domestic households cut their consumption of foreign goods. Because financial shocks generate intertemporal substitution without changing the country's resource constraint, their negative short-run effects are largely transitory and offset in the medium and long run. In contrast, the decline in real imports driven by trade restrictions is the main source of welfare losses with import sanctions dominating in the medium run and export sanctions explaining most of the long-run dynamics. The corresponding welfare losses in terms of a

[40] We exclude from the analysis changes in domestic production that are largely unrelated to foreign sanctions.

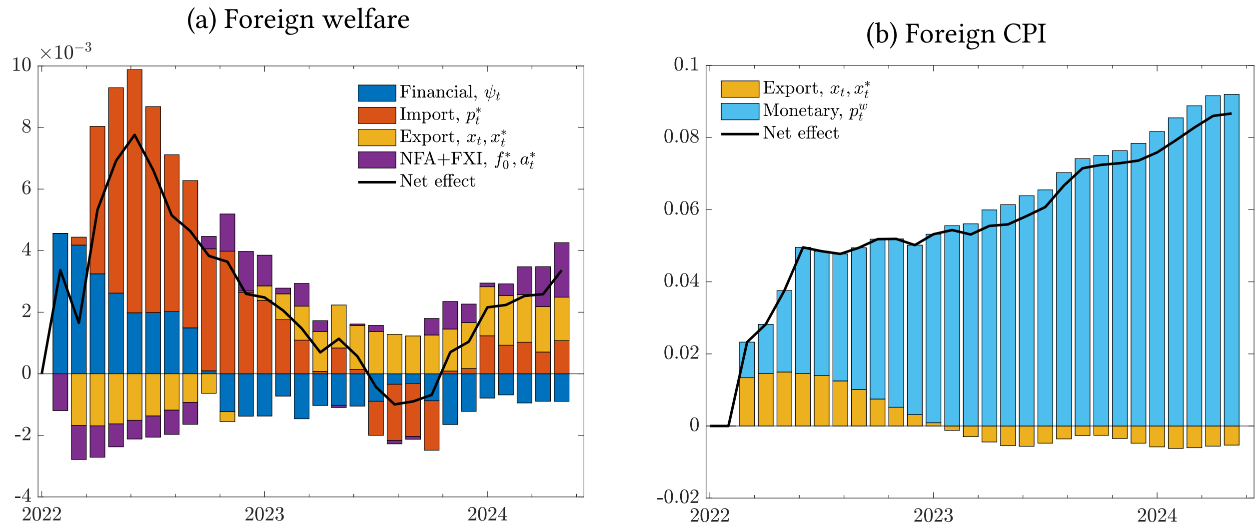

Figure 7: Effects of sanctions on the rest of the world

Note: The figure shows simulated welfare (or, equivalently, real consumption, in panel a) and consumer price index (in panel b) in the rest of the world in log-percentage changes relative to the pre-war level (black lines) and their components driven by different shocks (colored bars).

decline in real consumption during the sample period are equal to 7% and 1.8% for import and export sanctions, and 0.6% for the net foreign asset freeze combined with changes in FX reserves.[41] The combined effect from 2.5 years of sanctions also corresponds to a *permanent* decline in consumption by 0.9%, vastly larger than the conventional estimates of the cost of a business cycle. While the effect is largely front-loaded in the figure, the decline in consumption and welfare is likely to be more gradual and muted in practice because of the pre-war stockpile of durables and inventories of imported goods.

The welfare dynamics is also closely related to CPI inflation. Indeed, equation (13) shows that consumer prices are inversely proportional to import quantities c_{Ft} and depend also on local production y_t and monetary inflation p_t. This explains why the dynamics of the consumer price index, shown in Appendix Figure A2, tracks to a large extent the dynamics of welfare in Figure 6, but with the opposite sign and augmented by monetary shocks. As with import quantities, the model likely overstates the short-run pass-through of border prices into consumer prices, both due to sticky retail prices and the stockpile of imported inventories.

Rest of the world Our analysis sheds light on the welfare implications for the sanctioning coalition. Consistent with our findings in Section 3.2, the freeze of foreign assets, import tariffs, and financial shocks act as a positive transfer from the home economy to the rest of the world.

[41] Note that our definition of export sanctions incorporates the positive short-run effect from increased commodity prices, as can be seen in Figure 6b.

As a result, the welfare effects of these shocks on foreign welfare is the same as on home welfare, but with the opposite sign and smaller in magnitude. The net effect is positive throughout most of the period and equivalent to 0.2% increase in annual consumption during this period, as we show in the left panel (a) of Figure 7.

In contrast, export sanctions that are imposed in the form of quantity restrictions rather than tariffs also change the supply of commodities to the rest of the world resulting in higher energy prices, lower energy consumption, and welfare losses. Recall that our calibration infers the path of export quantities from the path of Russian export revenues and the world commodity prices. The implied decline in these quantities results in the welfare losses in the rest of the world during 2022, which are eliminated starting in 2023 due to higher energy supply within the rest of the world. We find that the net effect on the rest of the world from all economic sanctions combined is close to zero. This calculation does not factor in the direct military and economic costs of the war.

These estimates also do not take into account the indirect effect of sanctions-induced inflation that can lead to monetary tightening and additional output losses under sticky prices.[42] While such analysis goes beyond the scope of this paper, the right panel (b) of Figure 7 shows that a rise in energy prices due to export sanctions increases foreign consumer prices by about 1% in the first months, explaining half of the overall inflation in that period. Just like with welfare, the inflationary effects of sanctions dissipate starting in 2023, in line with the evidence of fast substitution in the world energy market (see e.g. Moll, Schularick, and Zachmann 2023).

5 Conclusion

A record number of economic sanctions have been imposed on the Russian economy since the invasion of Ukraine in February 2022. Given that it might take months or even years for these restrictions to take the toll on the economy, many commentators and policymakers attempted to infer the effects of sanctions from the contemporaneous dynamics of the ruble exchange rate. Building on recent models of equilibrium exchange rate determination, this paper clarifies the relationship between sanctions, exchange rates, government revenues and welfare.

We show theoretically that all forms of trade sanctions tend to reduce economic welfare by means of tightening the country budget constraint — whether by reducing the sources of income or by increasing the costs of imports — and this equivalnce also extends to governement fiscal revenues. However, the implications for the equilibrium exchange rate are polar opposite. While import sanctions trigger a trade and currency surplus and require an exchange rate appreciation

[42] While the optimal monetary policy targets only prices that are sticky in local currency, it does respond to higher prices of imported commodities whenever the latter are used as inputs in production (Egorov and Mukhin 2023). We quantify inflation in the rest of the world as $\Delta \log \mathcal{P}^*_t = (1-\gamma^*)\Delta \log P^w_t + \gamma^* \Delta \log Q^w_t$, where γ^* is the steady-state share of commodities in total expenditure.

to rebalance the goods and currency markets, export and foreign asset sanctions reduce the inflow of foreign currency and lead to a depreciation. Thus, even though the exchange rate is allocative and responds to sanctions, it is not a sufficient statistic to judge the economic impact. We also show that financial sanctions that increase private FX demand — either for domestic savings or as a result of capital outflows — can be fully offset with FX interventions which eliminate the impact on the exchange rate and imports. Otherwise, the central bank faces an unpleasant trade-off between depreciating the currency and distorting imports or using financial repression to suppress household demand for FX savings.

A simple quantitative model provides a surprisingly good out-of-sample fit and reconciles the seemingly puzzling swings in the exchange rate with the collection of sanctions imposed on Russia and their dynamics over time. Among intriguing questions left for future research is the missing financial crisis in Russia in spring 2022, despite unprecedented financial sanctions and a sharp exchange rate devaluation in the first weeks of the war. The combination of a large trade surplus, a fiscal surplus, and no domestic contract dollarization was likely the reason why the Bank of Russia managed to fend off a full-scale financial crisis with a steep increase in the ruble policy rate and a battery of financial repressions, including a ban on withdrawal of foreign currency deposits. However, the relative contribution of these factors is less clear. In particular, it is unclear whether the economy was in the region of multiple equilibria and managed to navigate away from a crisis equilibrium or whether an alternative sanctions policy — e.g., focused on curbing export revenues rather than restricting imports — could have eliminated the existence of the no-crisis equilibrium.

Appendix: Additional Displays

Table A1: Ex-ante calibration of shocks

	Financial		Import	Export		Domestic
	f_0^*, a_0^*	ψ_t	p_t^*	Temp., x_t	Perm., x_t^*	output, y_t
Initial shock, ε_{t_0}	−12	1.5	0.5	0.5	−0.3	−0.05
— arrives in period, t_0	0	0	1	1	1	1
Persistence, ρ	1	0.94	0.84	0.92	1	0.98
— half life (months)	∞	12	4	8	∞	36

Note: For each shock, the table shows calibrated values of the initial innovation ε_{t_0}, the period when the shock arrives t_0, as well as persistence (autocorrelation) and corresponding half lives. All shocks follow AR(1) processes. Export revenues, $ex_t = q_t^* + x_t = -\frac{\bar{s}-\eta}{\eta} x_t - \frac{1-\bar{s}}{\eta} x_t^*$, combine a permanent shock $x_{t_0}^* = 0.3\frac{\eta}{1-\bar{s}}$ and a temporary shock $x_{t_0} = -0.5\frac{\eta}{\bar{s}-\eta}$. The values of financial shocks are expressed in terms of steady-state monthly imports, while all other shocks are expressed in proportional changes (log point deviations from the initial steady state values).

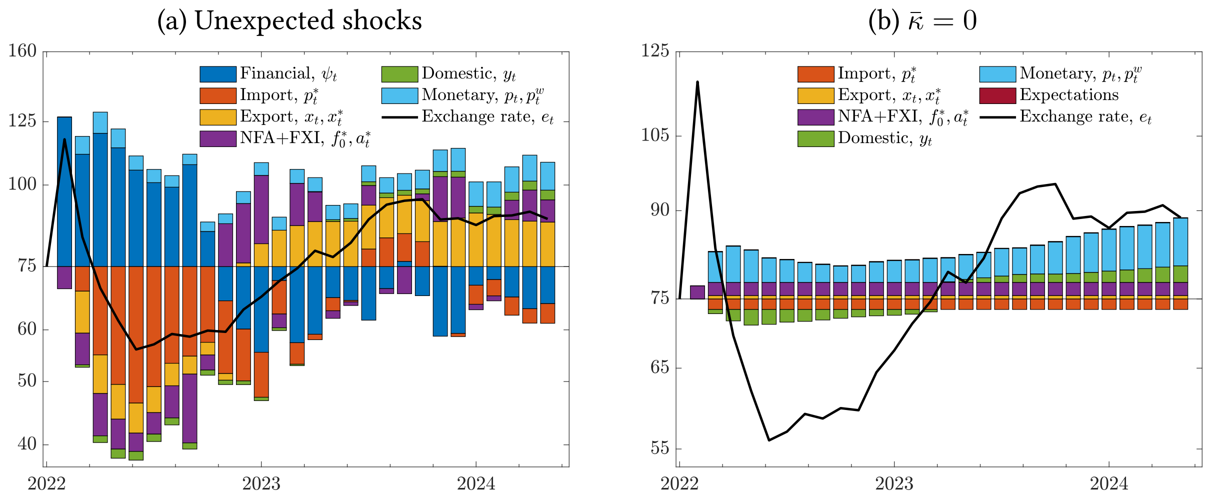

Figure A1: Alternative ex-post calibrations

Note: The figure shows the simulated path of the exchange rate (solid black lines) and the contribution of each shock (colored bars) according to the model with ex-post calibration similar to the one shown in Figure 5b. Panel a replaces a perfect foresight assumption with shocks following a random walk (each period featuring a surprise change; see Appendix D) and panel b considers an alternative calibration with $\bar{\kappa} = 0$ (a Ricardian model with a permanent-income response to all shocks). Note that with $\bar{\kappa} = 0$, financial shocks play no role and trade shocks result in a random-walk-like impulse responses, hence the model cannot match the dynamics of the exchange rate.

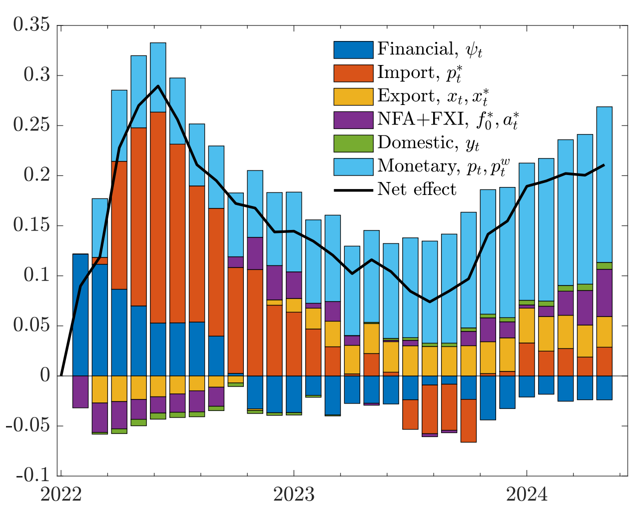

Figure A2: Inflation

Note: The figure shows a simulated response of consumer price index in log-percentage changes relative to the pre-war level (the black line) and its components driven by different shocks (colored bars). "Expectations" summarize the contribution of all shocks after the last period in the sample.

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ONLINE APPENDIX

A Fiscal Revenues and Price Index

This appendix generalizes and proves the result in Proposition 3. We consider here the generalized case where total fiscal revenues $TR_t = \xi_t^* \mathcal{E}_t Y_t^* + \xi_t P_t Y_t$ and $(\xi_t^*, \xi_t) \in [0,1]^2$ are arbitrary tax rates on exports and domestic revenues. We defined

$$\chi_t = \frac{\xi_t^* \mathcal{E}_t Y_t^*}{\xi_t^* \mathcal{E}_t Y_t^* + \xi_t P_t Y_t}$$

to be the equilibrium share of taxes on exports in total tax revenues of the government. We take the path of domestic prices and output (P_t, Y_t) as given, and evaluate the marginal effect of export and import sanctions on TR_t and consumer price index $\mathcal{P}_t$ defined in the text (see (13)). We rewrite these variables as:

$$TR_t \equiv \xi_t^* \mathcal{E}_t Q_t^* X_t + \xi_t P_t Y_t = \xi_t P_t Y_t \left[1 + \frac{\xi_t^*}{\xi_t Y_t} \frac{Q_t^*}{P_t^*} \left(\frac{\gamma Y_t}{C_{Ft}}\right)^{\frac{1}{\theta}}\right],$$

$$\mathcal{P}_t \equiv \left[P_t^{1-\theta} + \gamma (\mathcal{E}_t P_t^*)^{1-\theta}\right]^{\frac{1}{1-\theta}} = P_t \left[1 + \gamma \left(\frac{\gamma Y_t}{C_{Ft}}\right)^{\frac{1-\theta}{\theta}}\right]^{\frac{1}{1-\theta}},$$

where we have used (10) to solve out the exchange rate $\mathcal{E}_t$.

The exact hat algebra allows us to write the change in the paths of these two outcomes from the original to the new equilibrium under sanctions (denoted with $'$) as follows:

$$\frac{TR_t'}{TR_t} - 1 = \frac{\frac{\xi_t^*}{\xi_t Y_t} \frac{Q_t^*}{P_t^*} \left(\frac{\gamma Y_t}{C_{Ft}}\right)^{\frac{1}{\theta}} \left[e^{\hat{Q}_t^* - \hat{P}_t^* - \frac{1}{\theta}\hat{C}_{Ft}} - 1\right]}{1 + \frac{\xi_t^*}{\xi_t Y_t} \frac{Q_t^*}{P_t^*} \left(\frac{\gamma Y_t}{C_{Ft}}\right)^{\frac{1}{\theta}}} = \chi_t \left[e^{\hat{Q}_t^* - \hat{P}_t^* - \frac{1}{\theta}\hat{C}_{Ft}} - 1\right],$$

$$\frac{\mathcal{P}_t'}{\mathcal{P}_t} = \left[1 + \frac{\gamma \left(\frac{\gamma Y_t}{C_{Ft}}\right)^{\frac{1-\theta}{\theta}} \left[e^{\frac{\theta-1}{\theta}\hat{C}_{Ft}} - 1\right]}{1 + \gamma \left(\frac{\gamma Y_t}{C_{Ft}}\right)^{\frac{1-\theta}{\theta}}}\right]^{\frac{1}{1-\theta}} = \left(1 + \mu_t \left[e^{\frac{\theta-1}{\theta}\hat{C}_{Ft}} - 1\right]\right)^{\frac{1}{1-\theta}},$$

We collected terms using (10) again to form export and import shares, χ_t and μ_t, and we define the equilibrium share of imports in domestic production as:

$$\mu_t = \gamma \left(\frac{P_t^* \mathcal{E}_t}{P_t}\right)^{1-\theta} = \frac{\mathcal{E}_t P_t^* C_{Ft}}{\mathcal{E}_t P_t^* C_{Ft} + P_t C_{Ht}},$$

where $C_{Ht} = Y_t$ by domestic good market clearing. Recall that $\hat{C}_{Ft} \equiv \log(C_{Ft}'/C_{Ft})$ and similarly for Q_t^* and P_t^*.

The formulas above provide the exact expressions for changes in TR_t and $\mathcal{P}_t$. In particular, in the case (a) of Proposition 2, we have $\hat{Q}_t^* - \hat{P}_t^* = \hat{C}_{Ft} = -\tau$ under both kinds of sanctions regimes, but naturally the equivalence applies more generally as long as the general equivalence Proposition 1 is satisfied. We now derive the approximate formulas for small τ for the case of Proposition 2(a) with $\hat{Q}_t^* - \hat{P}_t^* = \hat{C}_{Ft} = -\tau$. Completing the derivation of (14), we have:

$$\widehat{TR}_t = \log(TR_t'/TR_t) = \chi_t \cdot \left(-1 + \frac{1}{\theta}\right)\tau < 0 \qquad \text{and} \qquad \widehat{\mathcal{P}}_t = \log(\mathcal{P}_t'/\mathcal{P}_t) \ = \mu_t \cdot \frac{1}{\theta}\tau > 0. \qquad \blacksquare$$

B Alternative Export and Import Sanctions

This appendix formalizes the results on alternative export and import sanctions discussed in Section 3.2.

Proof of Proposition 5 Given the inelastic supply of commodities by the sanctioned economy, the tariffs do not distort X_t, and the world (consumer) commodity price Q_t^w/P_t^w is determined exogenously from the demand schedule (18) given X_t and X_t^* such that:

$$X_t + X_t^* = \gamma^*(Q_t^w/P_t^w)^{-\eta}.$$

Given either the import, or the export tariff according to (16), we have:

$$\frac{Q_t^*}{P_t^*} = \frac{1}{1+\tau}\frac{Q_t^w}{P_t^w}.$$

Therefore, the country's terms of trade deteriorate by τ — or, more precisely, by $\log(1+\tau)$ in log deviations terms used in Proposition 1 — and, hence, the conditions of Proposition 1 are satisfied and the result follows. Note that the asset tax $(1-\tau^F)F_0^*$ translates into $\hat{F}_0^* = -\log(1+\tau)$ as well.

Finally, consider the rent $\mathcal{T}_t^*$ received by the rest of the world (RoW). In the case of export sanctions, the period t rent is given by $(Q_t^w - Q_t^*)X_t = \frac{\tau^Q}{1+\tau^Q}Q_t^w X_t$, using (16). In case of import sanctions, it is given by $(P_t^* - P_t^w)C_{Ft} = \tau^P P_t^w C_{Ft}$. Aggregating the sanctioned country's budget constraint (7) for $t \geq 0$, we have:

$$0 = (1-\tau^F)F_0 + \sum_{t=0}^{\infty}\beta^t(Q_t^* X_t - P_t^* C_{Ft}) = (1-\tau^F)F_0 + \sum_{t=0}^{\infty}\beta^t\left(\frac{1}{1+\tau^Q}Q_t^w X_t - (1+\tau^P)P_t^w C_{Ft}\right),$$

where we used (16) and the fact that $\beta R_t^* = 1$ in equilibrium. Note that either $\tau^Q = \tau$, $\tau^F = \frac{\tau}{1+\tau}$ and $\tau^P = 0$ under export sanctions, or $\tau^Q = \tau^F = 0$ and $\tau^P = \tau$ under import sanctions. We therefore can rewrite:

$$\begin{aligned}\sum_{t=0}^{\infty}\beta^t P_t^w C_{Ft} &= \frac{(1-\tau^F)}{(1+\tau^P)}F_0 + \frac{1}{(1+\tau^P)(1+\tau^Q)}\sum_{t=0}^{\infty}\beta^t Q_t^w X_t \\ &= \frac{1}{1+\tau}F_0 + \frac{1}{1+\tau}\sum_{t=0}^{\infty}\beta^t Q_t^w X_t\end{aligned}$$

irrespective of which of the two sanctions policies is used, implying the same decreased path in C_{Ft}. Furthermore, we can write the total rents in both cases as:

$$\tau\sum_{t=0}^{\infty}\beta^t P_t^w C_{Ft} = \frac{\tau}{1+\tau}F_0 + \frac{\tau}{1+\tau}\sum_{t=0}^{\infty}\beta^t Q_t^w X_t.$$

Diving through by P_0^w and rearranging terms completes the proof. ■

Elastic export supply and export sanctions Denote with $q \equiv Q^*/P^*$ and rewrite the RoW demand for commodities (18) as:

$$X + X^* = \gamma^* q^{-\eta}$$

Consider a supply schedule of X such that

$$X = X_0 (q/q_0)^{\varepsilon}, \tag{A1}$$

where constants (X_0, q_0) are such that $X_0 + X^* = \gamma^* q_0^{-\eta}$. The baseline inelastic case corresponds to the limit $\varepsilon = 0$ such that $X = X_0$ whenever $q \geq q_0$ for some $q_0 \geq 0$. Denote with $s_0 = X_0/(X_0 + X^*)$ the share of the country in global commodity supply in the original equilibrium. We can think of supply curve as defining the marginal cost of supplying X, $q(X) = q_0 (X/X_0)^{1/\varepsilon}$, such that the total cost is given by:

$$TC(X) = \int_0^X q(x)\mathrm{d}x = \int_0^X q_0 (x/X_0)^{1/\varepsilon}\mathrm{d}x = \frac{\varepsilon}{1+\varepsilon} q(X)X,$$

all in terms of the international tradable good C_F. We can then think of the economy under sanctions maximizing

$$\max C_F - TC(X)$$

subject to $NX = qX - C_F = 0$, which results in $C_F - TC(X) = qX - TC(X) = \frac{1}{1+\varepsilon} q(X)X$ irrespective of the utility over C_F and C_H, and hence of θ. This assumes marginal cost pricing $q = q(X)$ from the perspective of the economy under sanctions.

The RoW imposes a tariff to maximize

$$\max_{q,X} \frac{\eta}{\eta - 1} \gamma^{*\frac{1}{\eta}} (X + X^*)^{\frac{\eta-1}{\eta}} - qX$$

subject to (A1). The solution to this problem is:

$$\gamma^{*\frac{1}{\eta}} (X + X^*)^{-\frac{1}{\eta}} = q \left(1 + \frac{1}{\varepsilon} \frac{X}{X_0} (q_0/q)^{\varepsilon}\right) = \frac{1+\varepsilon}{\varepsilon} q$$

Therefore, the consumer price is $q_C = (1 + \tau)q$ with $\tau = \frac{1}{\varepsilon}$. Thus, the optimal tariff just depends on the supply elasticity ε, and not on either η or θ. Furthermore, we cannot distinguish whether this is import tariff or export tax, they are equivalent and only their combined effect on the terms of trade q is what matters.

We further show that the optimal tariff results in the equilibrium ToT q relative to laissez-faire q_0 such that:

$$s_0 \left[\left(\frac{q}{q_0}\right)^{\varepsilon} - 1 \right] = \left[\left(\frac{1+\varepsilon}{\varepsilon} \frac{q}{q_0}\right)^{-\eta} - 1 \right] \qquad \Rightarrow \qquad \frac{q}{q_0} \approx \left(\frac{\varepsilon}{1+\varepsilon}\right)^{\alpha}, \quad \alpha \equiv \frac{\eta/s_0}{\varepsilon + \eta/s_0}.$$

Both elasticities of demand η/s_0 and supply ε play a role in determining the split of consumer and producer surplus loss (both partially going towards tariff revenues), as we illustrate in Figure O1.

Note the equivalence between tariffs and quantity restrictions as long as this results in movement along supply curve and all rents are going to RoW. When either rents go (partially) to home as a result of quantity restriction on demand, or when it is impossible to move along supply curve as in the limit of $\varepsilon = 0$, there is no equivalence, and quantity restrictions are strictly worse. Furthermore, with $\varepsilon = 0$, quantity restrictions on demand are welfare reducing for RoW and may be welfare enhancing for the sanctioned economy when $\eta/s_0 < 1$. Otherwise they are welfare reducing for both due to the large dead-weight loss and even despite the rents going to home. See the right panel of Figure O1.

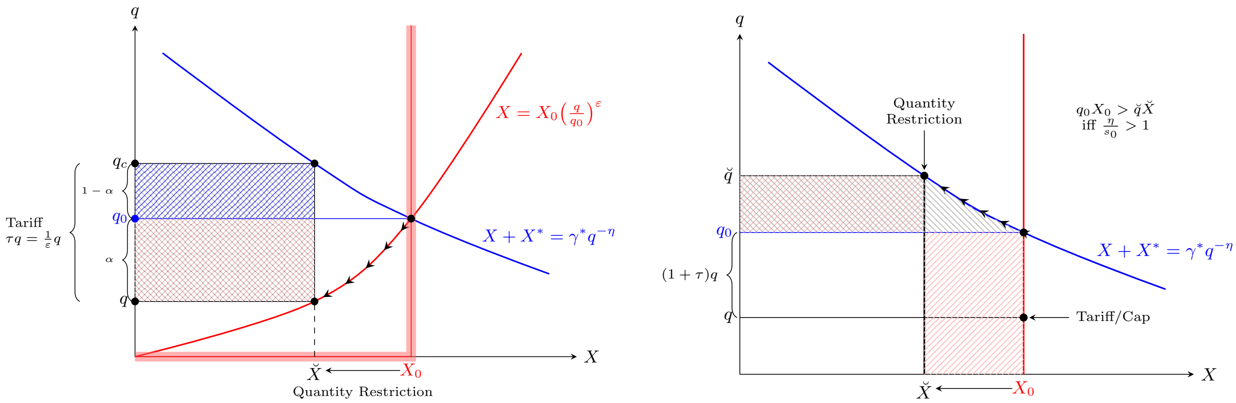


Figure O1: Tariff and quantity restrictions: elastic and inelastic export supply

Note: The left panel presents the case with a general elastic supply with $\varepsilon > 0$ (thin red smooth curve), where the limit $\varepsilon \to 0$ is captured with a thick red step curve; the share of the optimal tariff $\tau = 1/\varepsilon$ paid by the supplier is $\alpha \equiv \frac{\eta/s_0}{\varepsilon+\eta/s_0}$, while share $1-\alpha$ is paid by the consumer. In the right panel, we focus on the inelastic case, $\varepsilon = 0$, and show the difference between a tariff (cap), which keeps the quantity exported $X = X_0$, and a quantity restriction, $X \leq \check{X} < X_0$, with a movement up the demand curve. See the text for further details.

Import sanctions Consider a CES import consumption aggregator over a continuum of imported varieties:

$$C_{Ft} = \left[\int_0^1 C_{Ft}(i)^{\frac{\rho-1}{\rho}} \mathrm{d}i\right]^{\frac{\rho}{\rho-1}}$$

with an associated ideal import price index given by:

$$P_t^* = \left[\int_0^1 P_t^*(i)^{1-\rho} \mathrm{d}i\right]^{\frac{1}{1-\rho}}.$$

The individual import variety demand schedules are then given by:

$$C_{Ft}(i) = \left(\frac{P_t^*(i)}{P_t^*}\right)^{-\rho} C_{Ft}.$$

First, we note immediately that with symmetric varieties, $P_t^*(i) = P_t^*$ for all $i \in [0,1]$, we have that $C_{Ft}(i) = C_{Ft}$ for all $i \in [0,1]$ and irrespective of the value of ρ, thus nesting our baseline case studied in Section 2.

Second, we consider a deviation from symmetry where a subset of goods of measure δ_t feature a tariff τ, $P_t^*(i) = (1+\tau)P_t^*$ for all $i \in [0, \delta_t]$, while the other goods $i \in (\delta_t, 1]$ have no restrictions with $P_t^*(i) = P_t^*$ as before. In this case, the deviation of the ideal import price index due to sanctions is given by:

$$\frac{P_t^{*\prime}}{P_t^*} = \left[\int_0^{\delta_t} (1+\tau)^{1-\rho} \mathrm{d}i + \int_{\delta_t}^1 \mathrm{d}i\right]^{\frac{1}{1-\rho}} = \left[\delta_t(1+\tau)^{1-\rho} + (1-\delta_t)\right]^{\frac{1}{1-\rho}},$$

in line with (20) in the text. For $\rho > 1$, we can consider various special and limiting case using this formula directly, in particular the case of $\tau \to \infty$ yields $P_t^{*\prime}/P_t^* = (1-\delta_t)^{\frac{1}{1-\rho}}$.

C FXI and Financial Repression

C.1 Proof of Proposition 4

The equilibrium dynamics of $(C_{Ft}, \mathcal{E}_t, B^*_{t+1}, F^*_{t+1})$ is governed by the Euler equation (6), the country's budget constraint (7), and import demand (5). If the government accommodates the shock by selling FX reserves, $\hat{A}^*_{t+1} < 0$, such that $\hat{B}^*_{t+1} = \psi > 0$, we can verify directly from the equilibrium system that the original equilibrium path of $(C_{Ft}, \mathcal{E}_t, F^*_{t+1})$ still satisfies all equilibrium conditions under the elevated path of B^*_{t+1}.[43] Recall that hats denote deviations of the new equilibrium path from the original equilibrium path without the Ψ_t shocks, and thus in this case $\hat{C}_{Ft} = \hat{\mathcal{E}}_t = \hat{F}^*_t = 0$. This policy requires either large enough initial reserves A^*_0 or the government's ability to borrow foreign currency from the rest of the world at R^*_t.

When the government is passive $\hat{A}^*_t = 0$ and $R^*_{Ht} = R^*_t$, the Ψ_t shock in (6) must be accommodated by the accumulation of B^*_{t+1} along with F^*_{t+1} according to the budget constraint (7). This requires reducing C_{Ft} on impact ($\hat{C}_{F0} < 0$) and featuring a growing path of import consumption in all future periods, $C_{Ft+1} > C_{Ft}$ for $t \geq 0$, to satisfy (6), as the gap between B^*_{t+1}/P^*_{t+1} and Ψ_t declines with accumulation of B^*_{t+1} until $B^*_{t+1}/P^*_{t+1} = \Psi_t$ in the new steady state. Since B^*_{t+1} increases, the new steady state budget constraint allows for a larger level of imports C_{Ft} in the long run, and the initial drop in imports C_{F0} satisfies the intertemporal budget constraint. The path of the exchange rate $\mathcal{E}_t$ tracks that of imports C_{Ft} with elasticity $-1/\theta$ in order to satisfy (5). Thus, a permanent increase in Ψ_t triggers a jump devaluation and a gradual appreciation thereafter to a more appreciated level in the new steady state with greater net foreign assets. There exists $T > 0$ such that for $t \in [0, T]$ we have $\hat{C}_{Ft} < 0$ and $\hat{\mathcal{E}}_t > 0$, while for all $t > T$ we have the reverse, $\hat{C}_{Ft} > 0$ and $\hat{\mathcal{E}}_t < 0$.

Finally, the last policy option is to select a path of $R^*_{Ht} < R^*_t$ such that (6) holds for the original path of $(C_{Ft}, \mathcal{E}_t, B^*_{t+1}, F^*_{t+1})$ with $\hat{\Psi}_t > 0$. Note that no equilibrium condition other than (6) is affected by Ψ_t and R^*_{Ht}, and hence R^*_{Ht} has the ability to perfectly offset any change in Ψ_t. Such policy can be implemented by a variety of financial taxes on FX savings which drive a wedge between R^*_t and R^*_{Ht} in segmented financial markets. ■

C.2 Heterogeneous Households

The use of financial repression is generally suboptimal in a representative agent economy. However, it becomes an important policy instrument for redistribution in an economy with heterogeneous agents. Furthermore, in such economies, the exchange rate still plays an important allocative role even under financial autarky and financial repression. We illustrate these points in an extension of our model that features two types of households — constrained hand-to-mouth and unconstrained Ricardian.

We follow the recent open-economy literature with heterogenous agents (De Ferra, Mitman, and Romei 2020, Guo, Ottonello, and Perez 2020, Auclert, Rognlie, Souchier, and Straub 2021, Fanelli and Straub 2021) and consider a simple extension of the baseline model that allows us to disentangle the role of exchange rates in goods and asset markets. Consider hand-to-mouth (constrained) agents who work in the domestic non-tradable sector and receive as wages a fixed share α of non-tradable revenues, $\alpha P_t Y_t$. These agents split their income to consume home and imported goods, maximizing $u(C_{Ht}, C_{Ft})$, but do not hold any savings and, in particular, do not have foreign currency deposits. The rest of the income in the economy, $(1-\alpha)P_t Y_t + \mathcal{E}_t Q^*_t X_t$, is received by the Ricardian (unconstrained) agents who have access to savings,

[43] Strictly speaking, in a non-stationary environment, FX interventions $\hat{A}^*_{t+1} < 0$ must be such that the new path of $\Psi'_t - B^{*\prime}_{t+1}/P^*_{t+1}$ is the same as in the pre-shock equilibrium with the original path of Ψ_t in order for the Euler equation (6) to be still satisfied.

and in particular can hold foreign currency deposits. These agents are also subject to the precautionary savings shock Ψ_t as described in (1).[44]

Proposition A1 *Assume $\theta = 1$ and hand-to-mouth agents receive a constant fraction α of income in the non-tradable sector. Then keeping constant $\tilde{\kappa}$, the aggregate dynamics of the economy do not depend on α. Given no reserves ($B_t^* = F_t^*$), the use of financial repression $R_{Ht}^* < R_t^*$ to offset the foreign currency demand shock $\Psi_t > 0$ reduces welfare in a representative-agent economy, but increases utilitarian welfare by redistributing from Ricardian to hand-to-mouth agents in a heterogenous-agent economy.*

Proof of Proposition A1 The constrained agents receive a constant fraction of home output $\alpha P_t Y_t$, make no savings or borrowing, enjoy no utility from holding assets, and are subject to the budget constraint

$$P_t C_{Ht}^C + \mathcal{E}_t P_t^* C_{Ft}^C = \alpha P_t Y_t.$$

In contrast, the unconstrained agents can borrow and save and receive the rest of national income:

$$P_t C_{Ht}^R + \mathcal{E}_t P_t^* C_{Ft}^R + \frac{\mathcal{E}_t B_{t+1}^*}{R_t^*} = \mathcal{E}_t B_t^* + (1-\alpha) P_t Y_t + \mathcal{E}_t Q_t^* X_t.$$

The Euler equation (6) still holds, but only for the unconstrained agents.

The Cobb-Douglas preferences $\theta = 1$ imply that constrained households spend a constant fraction of their income on home and foreign goods:

$$C_{Ht}^C = \frac{\alpha Y_t}{1+\gamma}, \qquad C_{Ft}^C = \frac{\gamma}{1+\gamma} \frac{\alpha P_t Y_t}{\mathcal{E}_t P_t^*}.$$

Given the market clearing condition for local goods $C_{Ht}^C + C_{Ht}^R = Y_t$, consumption of non-tradables by unconstrained agents is equal

$$C_{Ht}^R = \left(1 - \frac{\alpha}{1+\gamma}\right) Y_t.$$

Combine this expression with the optimality condition for unconstrained agents $\frac{C_{Ft}^R}{C_{Ht}^R} = \gamma \frac{P_t}{\mathcal{E}_t P_t^*}$ to solve for

$$C_{Ft}^R = \gamma \left(1 - \frac{\alpha}{1+\gamma}\right) \frac{P_t Y_t}{\mathcal{E}_t P_t^*}.$$

It follows that $C_{Ft} = C_{Ft}^C + C_{Ft}^R = \gamma \frac{P_t Y_t}{\mathcal{E}_t P_t^*}$ and the unconstrained households account for a fixed fraction of total imports

$$C_{Ft}^R = \left(1 - \frac{\alpha}{1+\gamma}\right) C_{Ft}.$$

Substitute this expression into the Euler equation (6) for unconstrained households to rewrite it in terms of the aggregate variables. The equilibrium system for $C_{Ft}, \mathcal{E}_t, B_{t+1}^*$ is then isomorphic to the Euler equation, country's budget constraint, and optimal demand (5) in the baseline model and does not depend on α (up to a renormalization of $\tilde{\kappa}$).

To prove the second part of the proposition, consider the problem of the planner with the Pareto weight

[44] The first part of the proposition extends the logic from Werning (2015) and Auclert, Rognlie, Souchier, and Straub (2021) to a rich set of shocks in an open economy. The second part is closely related to Fanelli and Straub (2021) who study the optimal FX interventions in a model with heterogenous agents.

ω on constrained agents, which corresponds to their share in population in the utilitarian case:

$$\max \quad \mathbb{E}\sum_{t=0}^{\infty}\beta^t\left\{\omega\log C_{Ft}^C+(1-\omega)\left[\log C_{Ft}^R-\frac{\kappa}{2}\left(\frac{B_{t+1}^*}{P_{t+1}^*}-\Psi_t\right)^2\right]\right\}$$

subject to

$$C_{Ft}^C=\frac{\gamma\alpha}{1+\gamma}\frac{P_tY_t}{\mathcal{E}_tP_t^*},\qquad C_{Ft}^R=\gamma\left(1-\frac{\alpha}{1+\gamma}\right)\frac{P_tY_t}{\mathcal{E}_tP_t^*}$$

$$\frac{B_{t+1}^*}{R_t^*}=B_t^*+Q_t^*X_t-P_t^*\big(C_{Ft}^C+C_{Ft}^R\big),$$

where we used the fact that consumption of non-tradables is effectively exogenous and the Euler equation (6) is a side equation that pins down the level of financial repression that is necessary to implement the desired allocation. Substitute out C_{Ft}^C and C_{Ft}^R to simplify the planner's objective:

$$\max \quad \mathbb{E}\sum_{t=0}^{\infty}\beta^t\left\{\log\frac{P_t}{\mathcal{E}_t}-\frac{(1-\omega)\kappa}{2}\left(\frac{B_{t+1}^*}{P_{t+1}^*}-\Psi_t\right)^2\right\}$$

$$\text{s.t.}\quad \frac{B_{t+1}^*}{R_t^*}=B_t^*+Q_t^*X_t-\gamma\frac{P_tY_t}{\mathcal{E}_t}$$

In a model with a representative household $\omega=0$, we get the same optimality condition (6) as in the laissez-faire equilibrium with $R_{Ht}^*=R_t^*$, i.e. it is suboptimal to use financial repression. On the other hand, in a model with two types of agents, the social losses from suboptimal savings $\frac{(1-\omega)\kappa}{2}$ are lower than the private ones. As a result, the optimal intervention requires setting $R_{Ht}^*<R_t^*$, with the financial repression wedge increasing in ω. ■

C.3 FXI as a fiscal tool

The government can accumulate FX reserves with the goal of balancing its fiscal positions by means of a non-monetary exchange rate devaluation. To see this, rewrite the government budget (4) as follows:

$$\mathcal{E}_t\left(\frac{A_{t+1}^*}{R_t^*}-A_t^*\right)-\left(\frac{B_{t+1}}{R_t}-B_t\right)=TR_t-W_t,$$

where, for simplicity, we assume the same foreign-currency interest rate at home as abroad, $R_{Ht}^*=R_t^*$. Consider policies that simultaneously increase FX reserves $A_t^*\equiv F_t^*-B_t^*$ and raise the local-currency debt B_t leaving the net asset position of the government unchanged.

On the one hand, the Ricardian equivalence holds for local-currency debt. That is, such a change in B_t leaves the permanent income of households and their consumption decisions unchanged, as they expect an offsetting adjustment in future income commitments W_{t+j} which keeps the intertemporal budget constraint unchanged. As a result, this policy does not compromise the ability of the central bank to control domestic producer price inflation P_t by setting the required path of the nominal rate R_t. On the other hand, Ricardian equivalence does not hold for foreign currency assets in the presence of foreign-currency savings demand by the households. As a result, the change in the composition of government debt — an increase in FX reserves A_t^* and a corresponding increase in home-currency debt B_t — affects the foreign-currency bond holdings of private agents B_t^*. In turn, this influences the equilibrium exchange rate because FX reserve accumulation by the government makes the foreign currency scarce in the domestic market. In sum, sterilized FX interventions, and specifically accumulation of FX reserves, depreciate the exchange rate and boost fiscal revenues in home-currency terms without any monetary inflation.

While sterilized FX interventions can be used to temporarily eliminate fiscal deficit, this policy is associated with its own costs. Two arguments clarify why FX interventions are not a silver bullet. First, FX interventions cannot change real national income. Indeed, any decline in imports C^*_{Ft} that supports the FXI-induced depreciation of the exchange rate has symmetric first-order effects on country's nominal income TR_t and the aggregate price index $\mathcal{P}_t$ from equation (13). Thus, abstracting from the utility of holding assets, managing the exchange rate only generates a redistribution between the government and the household budget constraints. This results in the reallocation of expenditure over time — and, in this case, shifts the real consumption of imports over time — generating a welfare loss. In an economy with heterogeneous households, this intervention has additional redistributional effects between savers and consumers, as discussed above. Second, the proposed way of boosting fiscal revenues requires that the government accumulates foreign reserves. However, this policy can be risky when other countries may impose additional financial sanctions on the government. Instead, current FX revenues should be spent on purchasing additional imports or, at least, sold to private agents that face a lower risk of being sanctioned.

D Quantitative Analysis

Steady state Consider a steady state with a zero net foreign asset position and demand for bonds $F^* = B^* = \Psi = 0$, $R^* = R^*_H = 1/\beta$ and all other prices equal one $\mathcal{E} = P = P^w = Q^* = 1$. Normalizing some variables, we get that the equilibrium conditions (5)-(7), (17), (18) are satisfied for the following values of output and consumption:

$$C_H = Y = n, \quad C_F = X = \gamma n, \quad C^*_F = 1 - \gamma^*, \quad \mathcal{C}^* = X + X^* = \gamma^*,$$

where γ parametrizes the openness of Home, n corresponds to the relative size of the Home economy, and γ^* determines the size of commodity market:

$$\frac{C_F}{C_H + C_F} = \frac{\gamma}{1+\gamma}, \qquad \frac{Y + X}{Y + X + X^* + Y^*} = \frac{(1+\gamma)n}{1+n}, \qquad \bar{s} = \frac{X}{X + X^*} = \frac{\gamma n}{\gamma^*}.$$

Calibrating these three moments to 20%, 2.5% and 12.5%, we get $\gamma = 0.25$, $n = 0.02$ and $\gamma^* = 0.04$. This also implies that the consumption share of Russia in foreign goods is equal $\bar{\gamma} \equiv \frac{C_F}{C^*_F + C_F} = \frac{\gamma n}{1-\gamma^*+\gamma n} \approx 0.5\%$.

Linearized system Although this is not really necessary if one focuses on deterministic paths of shocks, we use linearized conditions to speed up estimation. The equilibrium allocation in the Russian economy is characterized by country's budget constraint

$$\beta f^*_{t+1} - f^*_t = q^*_t + x_t - p^*_t - c_{Ft} \tag{A2}$$

and the Euler equation for foreign bonds

$$\mathbb{E}_t \left[\Delta p^*_{t+1} + \frac{1}{\theta} \Delta c_{Ft+1} \right] = r^*_{Ht} + \bar{\kappa}(\psi_t - b^*_{t+1}), \tag{A3}$$

and is supported by the exchange rate determined from the optimal demand in goods market

$$c_{Ft} - c_{Ht} = -\theta(e_t + p^*_t - p_t), \tag{A4}$$

where $c_{Ht} = y_t$ from the market clearing condition and $\bar{\kappa} \equiv \tilde{\kappa} C_F^{\frac{1}{\theta}}$. The global equilibrium requires market clearing for commodities

$$q_t^* = -\frac{1}{\eta}\big(\bar{s}x_t + (1-\bar{s})x_t^*\big) + p_t^w \tag{A5}$$

and foreign goods

$$y_t^* = (1-\bar{\gamma})c_{Ft}^* + \bar{\gamma}c_{Ft}. \tag{A6}$$

Given monetary policy in each country that pins down price levels p_t, p_t^w, output shocks y_t, y_t^*, x_t^*, export sanctions x_t, import sanctions $p_t^* - p_t^w$, financial shocks ψ_t, FXI policy $a_t^* = f_t^* - b_t^*$ and financial repression r_{Ht}^*, the system (A2)-(A6) determines the equilibrium paths of $f_t^*, c_{Ft}, c_{Ft}^*, q_t^*, e_t$. Finally, to measure welfare effects, we use the first-order approximations of consumption aggregates $u_t = \frac{1}{1+\gamma}c_{Ht} + \frac{\gamma}{1+\gamma}c_{Ft}$, $u_t^* = (1-\gamma^*)c_{Ft}^* + \gamma^* c_t^*$ and the corresponding price indices $cpi_t = \frac{1}{1+\gamma}p_t + \frac{\gamma}{1+\gamma}(e_t + p_t^*)$, $cpi_t^* = (1-\gamma^*)p_t^w + \gamma^* q_t^*$.[45]

Data We use monthly and quarterly data for Russia and the U.S. from January 2021 to September 2024 that can be freely downloaded from IFS (2024), FRED (2024), ROSSTAT (2024), CBR (2024). Given the start of the war on February 22-24, 2022, we interpret the end of February – beginning of March as the initial period $t = 0$ and use data for 2021 only for normalizations and interpolations.

1. *NER* e_t is measured is using daily ruble-dollar exchange rate provided by the CBR, which tracks closely the market rate. Except for Figure 4, our analysis uses a log average of daily exchange rates at monthly frequency. However, to incorporate large swings in the first weeks after the beginning of the war, we adjust monthly series using the peak of the ruble depreciation in early March 2022 as a February value and end-of-month values for March and April.

2. *Price indices* p_t, p_t^w are measured in logs relative to February 2022 using monthly CPI for Russia and the seasonally-adjusted CPI for All Urban Consumers in the U.S.

3. *Commodity prices* q_t^* correspond to a log of monthly Commodity Price Index for Russian exports constructed by the IMF, except for the last few months with missing values where we use the Global Commodity Price Index instead. The series is smoothed using the Hodrick-Prescott filter and normalized by a mean value in 2021.

4. *Imports and exports* im_t, ex_t are available at monthly frequency from the CBR and are measured in dollars. The log series are normalized by mean values in 2021 and smoothed using the Hodrick-Prescott filter.

5. *Real output* y_t, y_t^* in both countries is approximated with the real GDP. The quarterly series for Russia are adjusted manually for seasonality. We then accumulate output by a given date, interpolate and extrapolate to monthly values, and take the first difference to recover monthly real GDP. The algorithm for U.S. real GDP is similar, but does not require manual seasonal adjustment.

6. *FX reserves* a_t^* are reported by the CBR in dollars. The end-of-month values are normalized by country's average exports in 2021. We manually adjust foreign reserves down starting from February 2022 by the amount equivalent to 12 months of exports frozen by other countries. The resulting series should be interpreted with cation: data limitations do not allow us to adjust for changes in reserves' values due to fluctuations in exchange rates. In addition, there is anecdotic evidence that some FXI interventions have been done by government-controlled exporters on behalf of the central bank.

[45] Note that welfare effects from bonds-in-the-utility are of the second order and therefore, can be ignored.

Thus, except for e_t, f_t^*, a_t^*, all variables are equal to zero in February 2022. To make the series consistent with the model, nominal variables are adjusted by the corresponding inflation (q_t^*, ex_t, im_t by p_t^w and e_t by $p_t - p_t^w$), so we set $p_t = p_t^w = 0$ in the derivations below.

Shocks In contrast to ex-ante calibration of shocks that is only loosely based on observed dynamics of macro variables in the first half of 2022, the ex-post calibration uses the realized paths of all exogenous shocks as inputs. Whereas monetary shocks p_t, p_t^w, domestic output y_t, y_t^* and FX interventions a_t^* are directly measured in the data, the other shocks are inferred from trade data and exchange rates. In particular, commodity exports are given by $x_t \equiv ex_t - q_t^*$. Using the expression for commodity prices (A5), foreign endowment of commodities is estimated as $x_t^* = -(\eta q_t^* + \bar{s}x_t)/(1-\bar{s})$. The import price index can, in turn, be computed from the optimal demand: combining $im_t \equiv p_t^* + c_{Ft}$ with equation (A4), we get $p_t^* = -(im_t - y_t + \theta e_t)/(\theta - 1)$. We set $r_{Ht}^* = 0$ given conflicting evidence on dollar returns in Russia with the government imposing a temporary tax on buying foreign currency and banks offering high interest rates on foreign currency deposits in the first months after the start of the war and stimulating households to convert their savings into rubles in the rest of the period. Finally, financial shocks ψ_t cannot directly be estimated from the data without additional assumptions as this requires knowing agents' expectations about future exchange rates $\mathbb{E}_t e_{t+1}$. Instead, as explained below, we compute movements in the exchange rate attributed to financial shocks as a residual not explained by other shocks and then back out the underlying path of ψ_t that rationalizes this dynamics. Figure O2 shows the resulting series that we use as inputs in our analysis.

Ex-ante analysis Substitute q_t^* from static condition (A5) into dynamic system (A2)-(A3):

$$\begin{aligned}\frac{1}{\theta}\mathbb{E}_t c_{Ft+1} + \bar{\kappa} f_{t+1}^* &= \frac{1}{\theta} c_{Ft} + p_t^* - \mathbb{E}_t p_{t+1}^* + \bar{\kappa}\psi_t + \bar{\kappa} a_{t+1}^* + r_{Ht}^*, \\ \beta f_{t+1}^* &= f_t^* - c_{Ft} - p_t^* + \left(1 - \frac{\bar{s}}{\eta}\right) x_t - \frac{1}{\eta}(1-\bar{s}) x_t^*.\end{aligned} \tag{A7}$$

Denote the vectors of endogenous and exogenous variables respectively with $w_t = (c_{Ft}^* \ f_t^*)'$ and $z_t = (p_t^* \ \mathbb{E}_t p_{t+1}^* \ x_t \ x_t^* \ y_t^* \ \psi_t \ a_{t+1}^* \ r_{Ht}^* \ y_t)'$. With some abuse of the notation, write down dynamic system in vector form $\mathbb{E}_t w_{t+1} = A w_t + B z_t$, diagonalize matrix $A = Q\Lambda Q^{-1}$ and rewrite the system as $\mathbb{E}_t Q^{-1} w_{t+1} = \Lambda Q^{-1} w_t + Q^{-1} B z_t$. From this system for $Q^{-1} w_t$, use the equation that corresponds to an eigenvalue $\lambda > 1$:

$$\mathbb{E}_t m_{t+1} = \lambda m_t + D z_t, \tag{A8}$$

where m_t is a linear combination of c_{Ft}^* and f_t^* and D is some vector. Iterate forward:

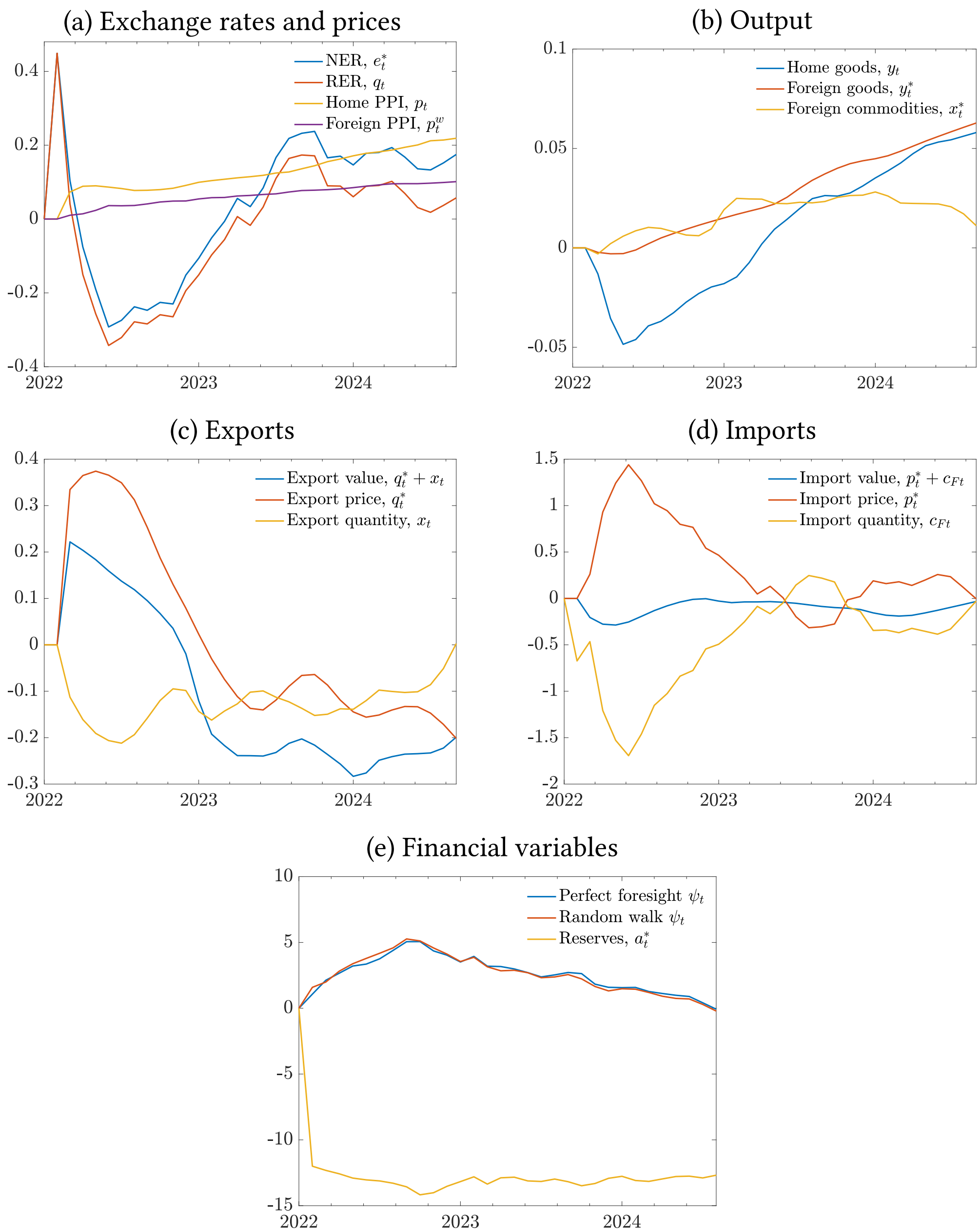
$$m_t = -\frac{D}{\lambda}\mathbb{E}_t \sum_{j=0}^{\infty} \lambda^{-j} z_{t+j}.$$

In the ex-ante calibration, we assume that shocks follow AR(1) $z_t = R z_{t-1} + \varepsilon_t$ and get

$$m_t = -\frac{D}{\lambda}\sum_{j=0}^{\infty} \lambda^{-j} R^j z_{t+j} = -\frac{D}{\lambda}(I - R/\lambda)^{-1} z_t, \tag{A9}$$

where $I - R/\lambda$ is a diagonal matrix with elements on the main diagonal given by $\frac{1}{1-\rho_i/\lambda}$ and ρ_i is the autoregressive coefficient of the corresponding shock.

Figure O2: Data and inferred shocks



Note: The figure plots time series for the exchange rate, price indexes, GDP, commodity prices, exports and imports, and FX reserves from the data that have been de-meaned by the pre-February 2022 values and (in some cases) smoothed out using HP filter and interpolated from quarterly to monthly values. The figure also shows series of shocks to import prices, supply of commodities, and currency demand ψ_t inferred from observables using the equilibrium system. "Perfect foresight ψ_t" and "Random walk ψ_t" show financial shocks under two ex-post calibrations with perfect foresight and shocks following a random walk. See Appendix D for details.

Perfect foresight Assume that the initial freeze of assets f_0^*, the path of FXI a_t^* and financial shocks ψ_t are revealed at $t = 0$, while the information about the paths of all other shocks arrives unexpectedly at $t = 1$. To do variance decomposition one needs to compute counterfactual paths of endogenous variables, which depend on expectations of shocks after the terminal period $t = T$. To avoid making any additional assumptions about future shocks, we keep these expectations fixed across all exercises and only alter the paths of shocks between $t = 0$ and $t = T$. The main disadvantage of this approach is that part of the exchange rate in every period will be due to terminal expectations that cannot be allocated to structural shocks. However, a high discounting $\lambda \approx 2$ under our baseline calibration implies that the effect of terminal expectations is negligible, except for the last three months that we exclude when reporting the results.

The implementation works as follows: given the equilibrium values of $w_t = (c_{Ft}^* \; f_t^*)'$, we can compute the terminal value m_T, i.e. the first element of $Q^{-1}w_T$. Leveraging the fact that under perfect foresight the whole path of shocks is revealed at t_0, for any alternative path of shocks $\tilde{z}_t$ and terminal expectations $\tilde{m}_T$, we can iterate backwards the first equation from system (A8)

$$\tilde{m}_t = \frac{1}{\lambda}(\tilde{m}_{t+1} - D\tilde{z}_t)$$

to solve for $\tilde{m}_{t_0}$. Given its value and $f_{t_0}^*$, recover c_{Ft_0}. The budget constraint and the path of $\tilde{m}_t$ are then sufficient to calculate the counterfactual paths of $\tilde{c}_{Ft}$, $\tilde{f}_t^*$ and hence, of all other endogenous variables.

In additon to variance decomposition, this method also allows to recover financial shocks. First, compute the paths of c_{Ft}^*, f_t^* using optimal demand (A4) and the budget constraint (A2). Second, take the difference between these data-implied values and the corresponding paths under all other shocks to get the components attributed to financial shocks. Finally, use the Euler equation (A3) to back out currency demand shocks assuming perfect foresight $\mathbb{E}_t\tilde{c}_{Ft+1} = \tilde{c}_{Ft+1}$ and shutting down other shocks $p_t^* = r_{Ht}^* = a_t^* = 0$

$$\psi_t = \frac{1}{\theta\bar{\kappa}}\Delta\tilde{c}_{Ft+1} + \tilde{f}_{t+1}^*.$$

Of course, one can also use the Euler equation rewritten in terms of the exchange rate.

MIT shocks As a complementary approach, we also consider the case when agents perceive all shocks as permanent. The advantage of this method relative to the previous one is that it does not leave unexplained the terminal value of the exchange rate and decomposes it into the structural drivers. This benefit comes at the cost of a stronger assumption about dynamics of shocks. The implementation uses the Blanchard-Kahn solution (A9) with all autoregressive coefficients equal one $\rho_i = 1$.

E Validation of Financial Shocks

In this appendix, we bring in additional data to provide empirical evidence on the recovered currency demand shocks ψ_t in the ex-post calibration of Section 4:

Interest rate spread Interest rates r_{Ht}^*, r_t^* are available at monthly frequency and provided by the CBR and the ECB. In particular, r_{Ht}^* corresponds to the average interest rate on *euro* deposits with a maturity of up to one year offered by Russian banks. In turn, r_t^* is a one-year EURIBOR (Euro Interbank Offered Rate), a reference rate at which European banks lend euros to one another. Given our convention that February 2022 corresponds to the events at the end of the month, we adjust the monthly averages from the original series using the values from March.

Figure O3 shows the dynamics of the spread between the euro interest rates in Russia and in international financial markets (red solid line). This is a premium required to make investors hold their capital in Russia rather than taking it abroad. The spread spikes after the start of the war and stays elevated for the next several months reflecting a premium paid by Russian banks to avoid capital outflows and associated currency mismatch. The spread comes down in the second half of 2022 and remains suppressed in 2023–24. This interest rate spread series, which we did not use in our calibration, tracks closely the model-based component of the exchange rate driven by the financial shock ψ_t (blue bars in Figure O3, same as in Figure 5b). A high demand for and limited supply of foreign currency in the domestic market leads to a short-term depreciation and a long-term appreciation of the ruble. We also compute the wedge in the Euler equation (6) driven by excess demand for foreign currency, $\bar{\kappa}(\psi_t - b^*_{t+1})$, and take a moving average over the following six months to make it comparable to medium-term interest rates in the data (red dashed line in the figure). In contrast to the exogenous shock ψ_t, this wedge evolves endogenously due to the accumulation of foreign assets b^*_t. Although this is not exactly the same spread as the one measured in the data, they are closely related. Both wedges spike in the first months and go down afterwards as foreign currency demand is gradually saturated via currency inflows from trade surpluses. The two series depart from each after mid-2023 which likely reflects the re-emergence of financial repression in the Russian currency market towards the end of the summer 2023 after it was rolled back in April-May 2022.

International capital flows are measured at a quarterly frequency using the Balance of Payment provided by the CBR. All "net acquisitions" and "net incurrences" in the Financial Account are aggregated respectively into outflows (changes in foreign assets) and inflows (changes in external liabilities). By definition, these flows reflect changes in ownership of financial assets (net purchases and sales) and do not include valuation effects. The flows are normalized by mean imports in 2021, but are not converted into logs because they can take negative values. For some exercises, we interpolate flows to monthly values. Furthermore, to incorporate large swings in the first weeks after the beginning of the war, we assume that $2/3$ of inflows/outflows of the first quarter of 2022 happened in February.

Another way to validate the recovered series for the financial shock ψ_t is to contrast it with capital flows. While our model is calibrated to match the paths of imports and exports and, therefore, almost perfectly reproduces *net* capital flows, we can use additional information from *gross* capital flows. In particular, a notable feature of the Russian economy in 2022 is the large fall in its foreign liabilities (excluding any valuation effects) with only minor changes in foreign assets relative to the pre-war level. In fact, the only other times the country experienced comparable in size and persistence drops in its external *liabilities* were the global financial crisis of 2008–09 and the first wave of sanctions in 2014.[46] These patterns are consistent with sudden stops in other economies and suggest that the sales of Russian assets by foreigners can be interpreted as capital flows driven by a financial shock ψ_t.[47]

With this in mind, we present two pieces of evidence that validate our quantitative results. First, we ask if (net) capital flows generated by currency demand shock ψ_t under the ex-post calibration are consistent with changes in liabilities observed in the data. Panel (a) of Figure O4 shows that the two series are quite similar with large outflows in the first quarters after the start of the war and moderation afterwards, with the model slightly overpredicting the speed of the reversal. Note that the model captures accurately the magnitude of capital flows, reported in terms of annualized imports in the figure.

Second, in the ex-post calibration of the model, we adjust the path of ψ_t to match the path of capital outflows in the data as reported in panel (a) of the figure, instead of targeting the path of the exchange rate.

[46]In contrast, most other negative shocks, including drops in commodity prices, are typically associated with a fall in foreign assets.

[47]The model extension with domestic assets B_t in foreign utility shows that a negative foreign demand shock for home assets is isomorphic to ψ_t in terms of its implications for net capital flows and the exchange rate.

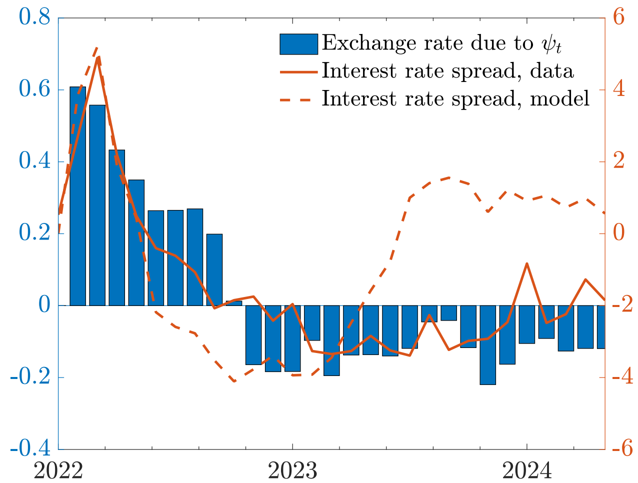


Figure O3: Interest rate spreads and exchange rate dynamics

Note: The figure shows the path of the exchange rate driven exclusively by ψ_t shocks in the ex-post calibration (blue bars, left y-axis, same as blue bars in exchange rate decomposition in Figure 5b), the spread between euro interest rates in Russia and abroad in the data (red solid line, right y-axis), and the six-month moving average of the Euler equation wedge $\bar{\kappa}(\psi_t - b^*_{t+1})$ in the ex-post calibration of the model (dashed red line, right y-axis).

Figure O4: Capital outflows and exchange rate dynamics

Note: Panel (a) shows net sales of Russian assets by foreigners (blue line) and capital outflows driven by ψ_t shocks in the model under the ex-post calibration (measured at quarterly frequency and expressed in terms of annualized imports). Panel (b) shows the path of the exchange rate from the data and in the ex-post model calibration where we adjust the path of ψ_t to reproduce capital outflows in the data as reported in panel (a).

In doing so, the implicit assumption is that other shocks also affect net capital flows but via foreign assets rather than external liabilities (as we discussed above). Panel (b) of Figure O4 shows the resulting path of the exchange rate in this alternative calibration of the model. While the model can no longer perfectly match the path of the exchange rate, the predicted dynamics are similar to the data. In particular, the model reproduces a sharp initial depreciation of the ruble and its gradual appreciation in spring and summer of 2022. The main discrepancy from the data is that the model predicts a more short-lived appreciation because of continued outflows around the start of 2023. The calibration does not take into account the fact that these outflows were partially offset by increased sales of foreign assets by Russian residents in this period, arguably due to a high risk of further asset freezes and new sanctions on foreign holdings of Russian residents that lowered their demand for foreign assets. This notwithstanding, the figure shows that calibrating ψ_t to match capital outflows (namely, increases in external liabilities) without targeting the exchange rate results in a rather accurate prediction for the equilibrium path of the exchange rate.