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A commodity exporting economy under financial and trade restrictions: Aggregate and structural changes☆

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Abstract

We study the situation when a commodity-exporting economy is under sanctions and cannot use its accumulated fx-reserves or attract new fx-debt to smooth import restrictions amid slower decline of income flow from a commodity-export. Our study attempts to determine the adequate response of the economy, depending on assumptions about the possibilities of import substitution within a structural dynamic general equilibrium model calibrated on Russian data. We use a modified version of the Ramsey–Cass–Koopmans' model to evaluate aggregate and structural changes in the economy in the shorter and longer run. We consider several scenarios with different assumptions about the efficiency of import substitution, which is defined along two dimensions (for consumers as well as for producers). The results show that trade restrictions make import substitution optimal, but only in those sectors where such substitution is relatively more effective. Limited labour resources in the economy are compensated with higher capital intensity of production in the optimistic and neutral scenarios. Reallocation of resources to build up the necessary capital intensity calls for temporarily higher saving rates. As a result, GDP may be higher, but consumption may be lower comparing to the baseline. The results mean that effectiveness of import substitution should be taken into account in decision making on industrial policy. If efficiency of import-substitution is asymmetric and biased to goods for final consumption relative to goods for investments, the structure of imported goods becomes biased to the latter. The results imply higher relative price of consumer goods.

Keywords: sanctions, financial autarky, structural changes, import substitution, total factor productivity, neoclassical growth model.
JEL: E13, E22, E24, E27, E60.

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1. Introduction

In 2022, the Russian economy faced the so-called "new reality," which was formed as a result of a series of trade and financial restrictions. First there came big financial shocks:

- The West imposed financial sanctions that provoked capital controls measures by the Bank of Russia. As a result, the financial account got almost closed. Import financing became mostly possible directly from export earnings;
- The inability to use the accumulated gold and foreign exchange reserves/net foreign assets (NFA) of the economy to finance consumption or investment.[1]

The result of these shocks, amplified by growing uncertainty, was a significant weakening of the ruble in Q1 2022, which, however, quickly found a new equilibrium (Fig. 1). The Bank of Russia played an important role in the stabilization tightening of the monetary policy: the key rate increased from 8.5% to 20.0%.

In Q2 and Q3 2022, trade balance shocks came to the fore. On the import side these changes were: firstly, the curtailment of the activities of foreign companies represented in Russia and the associated reduction of their imports of materials for production and intermediate products; secondly, the logistics problems of domestic companies with the physical delivery of imports and with payments for imports. It took time for Russian business to set up the logistics. These forces led to a decrease in the value of imports.

On the export side, logistical challenges (physical delivery as well as payments) for the main Russian export goods also were raised, but for some goods they were compensated by rising prices on the world market.[2] So, the total negative effect on exports turned out to be weaker than on imports. As a consequence, the current account grew strongly (see Fig. 1). The results of the shocks at this stage were the strengthening the ruble, which overshot the pre-shock level, and an active reshaping of the foreign trade logistics.[3]

In 2023, the situation reverted to the opposite scenario: the restoration of imports and introduction of new export-oriented sanctions led to a decrease in the current account. An additional factor of the imports increase in 2023 was the growth of domestic demand, financed by government spending and commercial credit. As a result, the economy is approaching the second half of 2024 with a higher level of demand than before the shocks, amid a tight monetary policy. The share of investment and government consumption in the structure of demand have increased.[4]

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[1] The accumulation of NFA resulting from the excess of exports over imports is reflected as a part of GDP, but represents "unconsumed" income, that is, savings. From a theoretical point of view, this fact means that net foreign assets are set to zero and that interest on net assets cannot be earned when assets exceed liabilities. Russia's (net) investment position before the shocks was positive. After the shock, we assume that part of the external obligations in the form of external public debt continues to be serviced. But this is of technical rather than economic significance. Hereinafter, "consumption" and "investment" combine public and private consumption and investment.

[2] For example, in Q3 2022, European natural gas futures prices (Dutch TTF) reached a historical maximum, having increased 4 times since the beginning of the year.

[3] The exchange rate dynamic during this period is modeled and discussed by Itskhoki and Mukhin (2022). It has been demonstrated that an increase in the ruble exchange rate was driven by import sanctions, prevailing over export ones, and capital controls introduced in Russia, which reduced local demand for foreign currency.

[4] At the end of 2023, the share of government consumption in real GDP in 2021 prices was 19% against an average share of 17% for 2015–2019. The share of investments (including change in reserves) increased to 26% against 22% on average for 2015–2019. The share of household consumption increased from 49% to 52%.

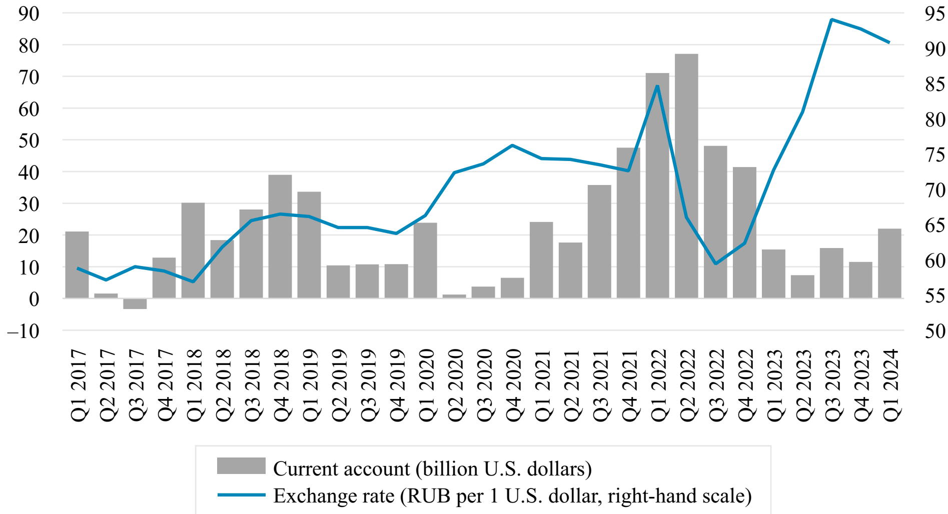

Fig. 1. Current account and exchange rate, Russia, QI 2017 – QI 2024.

Source: Bank of Russia.

To understand further transformation of the new reality and assess future dynamics of the Russian economy, it is important to consider two types of heightening risks: tightening restrictions on Russian imports and decrease in the value of exports.

The first risk is tightening restrictions on Russian imports associated with (secondary) sanctions pressure on Russia's trading partner countries.[5] From a medium-term perspective, the import recovery that has been observed since the second half of 2022 may turn out to be temporary. Thus the scenario of a *permanent* reduction in imports due to its quantitative restrictions becomes relevant. This scenario is considered by Turdyeva (2024) within the framework of a static CGE model.

For modeling purposes, we consider a scenario of physical restriction of all imports by 50% with the 2019 level taken as the base. The imports remaining after the restriction are represented by consumer and/or investment goods. The specific structure of imports in the new conditions is determined endogenously in the new equilibrium.

The second risk is a decrease in the value of exports. In addition to the tightening Western sanctions, in the medium term, the global energy transition may become an important negative risk factor for Russian exports. A key element of this will be the introduction of cross-border carbon emissions regulation in the EU, and then likely in trading partner countries in Asia. Such regulation would mean lower prices for Russian exports, much of which are energy-intensive. In the model scenario, the export restrictions are weakly expressed (minus 10% with the 2019 level taken as the base). In three years, restrictions reach

[5] Anecdotal evidence includes news about new efforts by the U.S. to sanction non-U.S. banks servicing trade flows of Russia with its foreign trade partners. See for example: https://www.wsj.com/politics/national-security/u-s-takes-aim-at-chinese-banks-aiding-russia-war-effort-fcf76dcc, https://www.ft.com/content/9a810c10-c887-40e5-a8c7-02aa0e111c93, https://www.ft.com/content/b4a556b0-0402-4114-9428-869bd49cf23c

50% of exports. The resulting positive trade balance is not spent on consumption and/or investment, which is partly due to the difficulties to increase imports.[6]

The goal of this paper is to assess *optimal* aggregate and structural changes in the economy due to the effect of these risks. In the paper we model the optimal adjustment of a small open commodity-exporting economy to a new equilibrium in the context of the emergence of a new reality: restrictions on imports and a reduction in exports.[7] We use a modified Ramsey model with two types of goods—a consumer good and an investment good.[8] Each type of good is produced domestically by "packaging" two products—domestic and imported. These products could be called "intermediate." Imported intermediate goods can be produced within the country as well. Such domestic products are labelled as "import substituting goods."

In the pre-sanction model world, economic agents make decisions when the economy is embedded in global production and trade chains. The fact that a part of investment and consumer goods is imported in such conditions reflects the economic inefficiency of their domestic production (the inefficiency of import substitution). Economic rationale for this may be economy of scale, for example. The presence of global brands in the domestic market, capable of providing low prices due to their large scale of production, serves as a natural economic barrier for import substitution of such goods. The exception is goods, in which the country has some comparative advantage. In other words, the "old reality" in the model is defined in such a way that the need for domestic production of import-substituting goods does not arise: resources from commodity exports are used to finance the import of consumer and investment goods, which are not economically efficient to produce within the country.

We address the following issues in the paper:

- What adjustment of key macroeconomic parameters is needed to *maximize* the level of household consumption in a scenario of imports and exports restrictions? How do the structural parameters of the model economy change in this scenario?—These are the issues of *optimal* allocation of resources.

[6] Such a positive balance in the model formally accumulates, but cannot be spent. Formally, in equilibrium, the positive trade balance should be used to pay interest on NFA (when NFA < 0) or to increase the size of NFA (when NFA > 0). In the model, we assume that positive trade balance is used to service external public debt, and the remaining part increases NFA. But this accumulation of NFA does not influence the decision-making of economic agents, who no longer consider these accumulated assets as a source of financing consumption. Undoubtedly, this raises the question of the advisability of accumulating NFA. However, under conditions of import restrictions and the need to fulfill contractual export obligations, a positive balance of foreign trade may not be optimal. Agents would like to increase imports, but they cannot. We propose a technical solution to take this into account in the model: we change the import price relative to the export price, so that the model takes into account this "artificial" (higher) import price, which ensures balanced trade.

[7] We deliberately do not call this *model* economy the "Russian economy," although we use the main indicators of the Russian economy in our calibrations. This is done because our model is stylized enough to take into account the variety of factors that can influence the dynamics of the *real* Russian economy in real life. The model's predictions in such a situation should be correct only for the model economy. In this regard, our calculations do not represent a forecast for the development of the situation in the Russian economy. This is especially important given we choose a hypothetical scenario of economic dynamics as a basis for comparison (the base scenario).

[8] The model is better known as the Ramsey–Cass–Koopmans model (Romer, 2012). We use a centralized version of the model.

- How do assumptions about the effectiveness of import substitution affect optimal adjustment? The effectiveness of import substitution has two dimensions in the paper—effectiveness in consumption and in production. Effectiveness in consumption is the ability of one piece of an import-substituting product to replace one piece of the original import in consumption. For example, the ability of a light bulb or car to work for one year without breaking down, if the original import has such a characteristic. Effectiveness in production is productivity, measured in terms of total factor productivity (TFP), of using import-substituting goods in production. For example, with the same operational reliability, the ability of import-substituting chips to produce the same number of operations per second as that of the imported original. By assumption, the effectiveness of import substitution is fixed (there is no learning by doing or economy of scale).

The simulation results show that trade restrictions (through an increase in the price of imports due to additional logistical costs or a decrease in export earnings to finance imports) makes import substitution optimal, but only in those sectors (goods) where such substitution is *relatively* more effective. These are goods in which prior to the new reality the economy was closer to the efficient production frontier, represented by the global/foreign producers. In the calibrated economy, this is the case for the production of consumer goods. Regarding capital goods (machinery, equipment), our results show that the optimal strategy is to look for channels of preserving their imports as long as possible.

Import substitution requires a reallocation of limited labor resources to the production of goods that were previously imported. If domestic analogues are comparable in their characteristics to original goods, then the optimal strategy involves the accumulation of capital in sectors, producing these goods, and an increase of capital-to-labor ratio to preserve active import substitution. But this optimal strategy is associated with a permanently lower level of consumption. Import substitution requires a buildup of capital as well as its permanent reproduction, and this limits the medium-term possibilities of creating final goods, including import-substituting goods for consumption in an environment when a country cannot increase export of such goods. As a result, GDP may even grow, but consumption will be below the base level (in the absence of shocks), that is, the share of consumption in GDP will decrease.

Asymmetry in the efficiency of import substitution between sectors leads to distortions in the structure of imported and produced goods. The low effectiveness of import substitution of capital goods requires a reorientation of imports towards investment goods. In this case, active import substitution in the consumer goods sector turns out to be optimal, but at the expense of resources reallocation within the sector from the production of original domestic goods.[9] If import substitution is very ineffective in both sectors, then the economy "eats up" capital and degrades.

[9] We do not solve the problem in a decentralized version, and therefore do not find equilibrium relative prices, which in a market economy will ensure the replication of the optimal allocation of resources in the centralized problem. It should be expected that such a change in imports will require an increase in the prices of consumer goods relative to investment goods and consumer imports relative to domestic ones. This limits the import of consumer goods and leads to an increase in the production of import-substituting analogues within the country.

The results mean that effectiveness of import substitution should play an important role in decision making on industrial policy in Russia in order for the economy to optimally adjust to the evolving new reality. Widescale import substitution is generally not optimal.

2. Literature review

Our work contributes to the existing economic research studying the effect of sanctions on the dynamics of Russian economy, including its structural shifts. Earlier estimates have been obtained in the literature using semi-structural and structural models. Pestova and Mamonov (2019) employ a BVAR model to estimate the economic effects of financial sanctions imposed on Russia in 2014. It has been demonstrated that the sanctions led to a depression of GDP growth rate in Russia by 1.2 pps. In Gurvich and Prilepskiy (2015) the impact of financial sanctions on the Russian economy is evaluated by modelling capital flow components. The study shows a significant impact of sanctions on GDP. In a more recent study, Pestova et al. (2022) have evaluated the economic effects of sanctions on Russia using a SVAR model. Findings suggest that industrial production, consumption, and investments should decline short-term; Russian GDP was predicted to decrease by 12.5–16.5% in 2022. Using computable general equilibrium modelling, Mahlstein et al. (2022) explore the effects of trade embargo on Russia. According to the estimates, real GDP of Russia contracts by over 14%. Kumagai et al. (2022) utilize a computable geographic general equilibrium simulation model (IDE-GSM) to evaluate the impact of sanctions on Russia and the global economy. Monastyrenko and Picard (2023) use a static Ricardian trade model to study the implications of trade embargoes which are (or may be) imposed against Russian fossil fuels (coal, gas, crude oil, and refined products of coal and oil) by the G7 countries, the EU countries, the OECD countries, and the union of three coalitions for the welfare and economic activity in Russia. The researchers find that each embargo results in Russia experiencing a trade export loss equivalent to a few percent of its GDP (with cumulative loss amounting to 10%). The demand from sanctioning countries is only partially substituted by the demand from China and India. As for the impacts on welfare, a total ban on all Russian fossil fuels by the coalition of OECD countries diminishes the Russian welfare (total utility) by more than 16%. The sanction sender countries also experience decline in their welfare; however, this adverse effect is lower on average (3.25% for EU-only coalition and less than 1% for other coalitions) but heterogenous across nations.

Imbs and Pauwels (2023) and Hosoe (2023) also concentrate on trade sanctions and reach qualitatively similar conclusions by employing various computable general equilibrium models of world trade.

Notably, all the aforementioned papers use static modelling framework whereas in this paper we resort to a dynamic (albeit highly stylized) model. In particular, it enables us to account for the long-run consequences of disrupted trade such as declining total factor productivity.

Existing estimates for Russia are consistent with the research studies conducted for other countries. Gutmann et al. (2021) have analyzed the impact of sanctions on economic growth in 162 countries from 1960 to 2016. The study identifies significant negative effects of international sanctions on GDP growth and its components (consumption, investment, and government spending), as well as on trade and foreign direct investment. In Ianchovichina et al. (2016) a global general equilibrium simulation model is employed to quantify the effects of lifting economic sanctions on Iran with and without strategic responses. It has been demonstrated that if economic sanctions on Iran are lifted, its average per capita welfare would grow by 3.7%, primarily due to the lifting of the oil embargo imposed by the EU. In Gharehgozli (2017) the economic costs of sanctions on Iran are evaluated using the synthetic control method: over three years, sanctions reduced GDP by 17.3%. A multi-regional computable general equilibrium model is used in Gharibnavaz and Waschik (2018) to evaluate the effects of sanctions on Iran. It has been demonstrated that sanctions led to an uneven welfare decline among households in the Iranian economy by 14–15%.

Comparing to existing papers, which focus on *positive* issues, we also address *normative* issues — try to find the optimal reallocation of resources in the sanctions-hit economy. We do this by considering a centralized equilibrium set by a planner acting to maximize social welfare (flow of consumption). Our study attempts to determine the adequate response of the economy under the new reality of import and export restrictions, depending on assumptions about the possibilities of import substitution within a structural dynamic general equilibrium model calibrated on Russian data.

3. Model description

This paper seeks to explore the equilibrium and equilibrium dynamics in a modified Ramsey model with two types of goods — consumer and investment.[10]

The problem is formulated as follows. An agent acting in the public interest aims to maximise the discounted sum of the utility flow from consumption:

$$\sum_t \beta^t \ln C_t. \tag{1}$$

Fixed volume of labour L, together with capital K_t, is used to create a domestic *intermediate* product Y_t with the Cobb–Douglas production function:

$$Y_t = A_t (L)^{\alpha} (K_t)^{1-\alpha}. \tag{2}$$

The dynamics of capital stock is determined by the standard relationship:

$$K_t = (1-\delta) K_{t-1} + I_t, \tag{3}$$

where I_t is gross investments.

[10] The model is an extension of the one-sector Ramsey model, where consumption good can be instantly and costlessly transformed into capital good, and vice versa. In this case, capital can freely move between the sectors of consumer and investment goods production. A more complex version of the model includes capital adjustment costs. Such costs are an additional factor that creates difficulties for import substitution, the analysis of which is beyond the scope of this study. For instance, see: Uribe and Schmitt-Grohé (2017, ch. 8).

The country imports foreign intermediate goods Imp_t in exchange for export (endowment), Ex_t.[11]

The produced *intermediate* product Y_t is used in several ways:

- as an intermediate product (input) C_t^Y in the production of final consumer goods C_t;
- as an intermediate product (input) I_t^Y for the production of capital goods I_t;
- as a substitute C_t^S for imported intermediate consumer goods C_t^{imp} used in the production of final consumer goods C_t;
- as a substitute I_t^S for imported investment intermediate goods I_t^{imp} used in the production of final investment goods I_t:

$$Y_t = C_t^Y + I_t^Y + C_t^S + I_t^S. \quad (4)$$

Therefore, using labour and capital, the economy *has the potential* to produce import-substituting intermediate consumer and capital goods, but *will not* necessarily do so. It depends on the solution of the optimization problem, whether it is profitable to allocate resources this way. We assume that before the introduction of restrictions, the producers do not spend resources on import substitution due to its inefficiency. To put it simply, we calibrate the efficiency indicators of import substitution as follows: even if we did impose a restriction "the output of import-substituting products is equal to zero" in times of a full economic openness, the restriction would not impact the economy's equilibrium parameters (the restriction is "non-binding").

An imported product Imp_t is an intermediate good, a portion of which C_t^{imp} is used in the production of final consumer goods, while the remainder I_t^{imp} is used in the production of investment goods (physical capital):

$$Imp_t = C_t^{imp} + I_t^{imp}. \quad (5)$$

The final consumer good is derived by "packaging" of two types of products *without any labour or capital costs*: intermediate consumer products and imported consumer goods. The creation of a final consumer good can be described as follows: consumption necessitates the merging of an imported good with a domestic one. For instance, this could involve establishing a network of car dealerships (domestic service) that sell imported cars (imported goods), factories that assemble cars from imported parts, or a facility for packaging imported medicines. Prior to "packaging," imported consumer goods can be substituted by domestic equivalents. The production function, or "packaging," of the final consumer goods is a constant elasticity of substitution (CES) function:

$$C_t = A_C\left[\gamma_C^{\frac{1}{\eta_C}}\left(C_t^Y\right)^{\frac{\eta_C-1}{\eta_C}} + \left(1-\gamma_C\right)^{\frac{1}{\eta_C}}\left(C_t^{imp} + \kappa_C C_t^S\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}. \quad (6)$$

[11] World prices for exports and imports are determined exogenously. This means that the supply of imports is completely elastic in terms of its price, that is, the economy can import as much as it wants at a given price, provided the budget constraint is met.

According to the model calibration, a domestic intermediate product C_t^Y and an imported intermediate product C_t^{imp} are imperfect substitutes. Imported consumer goods and import-substituting goods are perfect substitutes but adjusted for the quality of the domestic import-substituting product.

The parameter κ_C will play a significant role in the subsequent evaluation of the aggregate and structural effects of the economic adjustment to the new reality. This parameter determines the comparability of imports and their domestic equivalents. Let κ_C be equal to 0.1. Therefore, to replace one unit of imported goods, we need to use ten units of its equivalent. In economic terms, this can be explained as follows: imported goods last longer than domestic ones. Or, from a consumer's perspective, imported goods are of higher quality (more delicious, etc.).[12]

A capital good is obtained by "packaging" two products without labour or capital costs: an intermediate capital product, which requires labour and capital, and an imported capital good. Before packaging, imported capital goods can be substituted by domestic equivalents:

$$I_t = A_I\left[\gamma_I^{\frac{1}{\eta_I}}\left(I_t^Y\right)^{\frac{\eta_I-1}{\eta_I}} + \left(1-\gamma_I\right)^{\frac{1}{\eta_I}}\left(I_t^{imp} + \kappa_I I_t^S\right)^{\frac{\eta_I-1}{\eta_I}}\right]^{\frac{\eta_I}{\eta_I-1}}. \tag{7}$$

In the absence of specific restrictions, an imported product Imp_t is exchanged on the foreign market for an export product that is constantly available and requires no production costs Ex (endowment).[13] The condition for exchange with the external world is defined as:

$$P_t^{ex}Ex_t + B_t - (r+1)B_{t-1} = P_t^{im}Imp_t, \tag{8}$$

where: P_t^{ex}, P_t^{im} are the externally set real export and import prices; r — is the constant interest rate on foreign assets/liabilities.[14]

A key assumption concerns net foreign assets (NFA, or net external debt, if $B_t > 0$):

$$B_t \le B_{lim}. \tag{9}$$

We sequentially perform several types of calculations. As a starting point for model calculations, we use data on the Russian economy in 2019. We chose this year instead of 2022 because the volume and structure of the economy were not distorted by the pandemic effects. To determine the basis for comparison — the dynamics of the economy in the absence of restrictions, we make a simplifying assumption. We assume that in a completely open economy (open financial account), the amount of NFA in the model economy in 2019 is at a level corresponding to the long-run equilibrium. From 2019 onwards, the model

[12] A more rigorous explanation of the economic intuition is the following. For instance, the scrap level of an import-substituted product is higher, or it fails faster, in the case of technical appliances. Let us assume the probability of a domestic equivalent failure to be equal to $1-\kappa_C$, while for an imported one — zero. If the goods malfunction, the consumption is zero, but if they are operational, it is one. Therefore, to ensure the mathematical expectation of a unit of consumption of a domestic equivalent, to make sure the product "works" (consumption equals 1), we need to have $1/\kappa_C$ units of the domestic equivalent. In our example, this equates to ten units.

[13] Exports could fluctuate over time (see Section 4).

[14] No risk premium is assumed. For simplicity, we disregard changes in the country premium in the scenarios.

economy stopped accumulating or spending NFA. Since the volume of NFA was positive in 2019 ($490 billion), the economy could use NFA revenues to finance the foreign trade deficit, i.e. increase imports.[15] This implies a change in the consumption of imported goods, as well as a corresponding restructuring of production and fixed capital stocks.[16] For other scenarios, we assume this equation (9) is met, but for a different reason: according to our description of the new reality, the model economy remains with NFA equal to the external public debt, which continues to be served, but positive NFA do not accumulate and the external debt does not increase.[17]

Ultimately, the planner's problem is to maximise (1) under constraints (2)–(9) setting variables C_t, Y_t, I_t, Imp_t, K_t, C_t^Y, I_t^Y, C_t^{imp}, B_t. In the model, for some scenarios, we assume that the production function parameter responsible for TFP could decrease with an increased share of import substitution in GDP:[18]

$$A_t = \omega \times e^{-\theta(C_t^S + I_t^S)/GDP}. \tag{10}$$

The following simple observation serves as empirical evidence of the following premise: in the absence of import restrictions, firms import a large number of intermediate goods. This implies that for firms it is more advantageous (from a cost or quality perspective) than acquiring domestic equivalents (import substitution).[19]

We examine two mechanisms of import substitution efficiency:

- Quality comparability with imported goods from a consumption/investment perspective. Lower comparability implies increased consumption/investment of domestic equivalents;

[15] This was equivalent to ₽29 trillion (see Table A1 in Appendix A).

[16] In an open economy model without restrictions, starting from a base year (in our model 2019), the economy could accumulate external liabilities (spend accumulated gold and foreign exchange reserves) to finance the import of fixed capital investment, or "consume" (sell, reduce) part of the capital to increase consumption or reduce the volume of external debt (accumulate foreign exchange reserves). In the long-run equilibrium in such an economy, the volume of net foreign assets should stabilize at a level where the amount of net foreign assets remains unchanged: with positive NFA, interest income from NFA is used to purchase imports (trade deficit); with negative NFA, the country should have a trade surplus for settlements on external debt. The immediate response of fixed capital investments and the volume of external debt/assets is the key issue of realistic interpretation of the dynamics to equilibrium in such models. Realistic interpretation of the dynamics of such economy requires the introduction of certain rigidities in the response of capital or external debt — their slow adjustment toward equilibrium.

We leave aside an economy that needs to "grope" toward equilibrium level of NFA, as a basis for comparison, because the calculation of the convergence trajectory to equilibrium in a small open economy model is somewhat arbitrary and heavily depends on the parameters of the rigidity of the external debt (capital) response. For this reason, we abstain from declaring how the closure of the financial account itself changed the dynamics of the open economy on the way to a new equilibrium, but we can show how it changed the long-run equilibrium of the economy (see Appendix B).

[17] Regarding corporate external debt (non-financial and financial sectors), we imply restrictions on servicing this debt due to the introduced capital controls, which significantly complicate settlements with non-residents. The net debt of "other sectors" was only $8 billion at the end of 2019, while the banks' net position was positive at the level of $100 billion.

[18] More generally, this assumption means that total factor productivity decreases under conditions of structural shocks that require the reallocation of production factors (particularly to the import-substituting sector). During periods of such reallocation costs escalate, either temporarily or permanently. For example, see Davis and Haltiwanger (2001), Pratap and Urrutia (2012).

[19] This logic is based on the assumption that production occurs on the production possibilities frontier. As highlighted by Harberger (1998), the escalation of real costs is equivalent to a decline in total factor productivity.

- Cost escalation (reduction in total factor productivity) due to use of domestic import substitutes in production. The endogeneity of TFP implies that the more an economy produces import-substituting goods, which are subsequently packaged for final consumption or investment, the farther it is from the global frontier of maximum possible productivity. This premise is backed by simple logic: when a firm has the option to either import or substitute imports, and it chooses to import, it indicates that this option is more beneficial for it (as it allows for cost reduction). Consequently, when there are no alternatives and only a less favoured option remains, choosing it ends up with cost escalation (and productivity decline).

GDP measured by the output method is composed of the value added at all stages of production, including intermediate and final goods. Since no added value is created in the production of final goods (there are no labour and capital costs), the GDP in such an economy will be made up of the value added in the production of intermediate goods. None of these goods are exported. Exports should be added as another component of GDP—this represents the flow of commodity income created without labour with specific capital, which remains constant in further calculations:[20]

$$GDP_t = Y_t + Ex_t. \tag{11}$$

For the optimization problem defined by the objective function (1), constraints (2)–(9), and non-negativity constraints on the control variables, we construct a Lagrangian and compute its first derivatives with respect to control variables and dual variables. For simplicity, we omit the full list of first-order conditions (which also includes "complementary slackness" conditions for removing inequality-type constraints), considering only a few of them. Under the conditions of the Baseline Scenario (see below) for all variables, except B_t, C_t^S, I_t^S, the solution will be internal, meaning the first-order conditions are the corresponding Lagrangian derivatives equalling zero. From the system of equations and "complementary slackness" conditions obtained in this way, it easily follows that if $1/\beta > 1 + r$, then $B_t = B_{lim}$.[21]

Furthermore, it follows from the first-order conditions that for $\kappa_C \neq \kappa_I$ both variables C_t^S, I_t^S cannot be positive simultaneously.[22] Numerical modelling can be used to confirm that:

$$\kappa_C < \kappa_I \Rightarrow C_t^S = 0,\ \ \kappa_I < \kappa_C \Rightarrow I_t^S = 0, \tag{12}$$

since consumption is higher if import substitution only occurs in the sector where it is most efficient (the problem is to maximise the increasing consumption function). To account for this situation, we replace the conditions:

[20] In this formula, we compute the real GDP using a methodology that closely mirrors practical application, similar to how Russian Federal State Statistics Service (Rosstat) does it, by fixing relative prices at the level of a specific (base) year and "weighing" the quantities in these base prices. Assuming no loss of generality, we assume that in the base year, the relative price of exports and domestic production was 1. Given that Y_t already represents the value added created within this economic territory, there is no need to subtract imports when calculating GDP.

[21] We have intentionally chosen this calibration to directly set the level of external debt in the economy.

[22] If the variables C_t^{imp}, I_t^{imp} are positive, which is observed in the real economy.

$$\frac{\partial \mathcal{L}}{\partial I_t^S} = 0,\ \frac{\partial \mathcal{L}}{\partial C_t^S} = 0, \tag{13}$$

$$I_t^S \times \frac{\partial \mathcal{L}}{\partial I_t^S} = 0,\ C_t^S \times \frac{\partial \mathcal{L}}{\partial C_t^S} = 0, \tag{14}$$

where $\mathcal{L}$ represents the Lagrangian.[23]

Hereinafter, when calibrating, we use the characteristics of the Russian economy in 2019: Russia's exports, according to the data of Rosstat's System of National Accounts (SNA), amounted to ₽32 trillion ($419 billion according to the Bank of Russia), the NFA level was $491 billion according to the Bank of Russia (₽29 trillion at the exchange rate of ₽60 per US dollar). We assume the real interest rate to be 2.5%, so the annual income in equilibrium will be 0.025 × ₽29 trillion. The capital stock was assumed to be ₽250 trillion, which is the average of two Rosstat estimates.[24] The labour stock was assumed to be equal to the average annual size of the labour force in 2019, at 75.4 million people. Collectively, this represents the resources available to the economy when it is in equilibrium (prior to shocks). The economy had a surplus in foreign trade, continuing to accumulate NFA. The list of calibrated parameters, their values, and sources of calibration are provided in Appendix A (Tables A1–A2). The model operates on a quarterly frequency, but we present all results on an annual basis.

4. Scenario descriptions

Firstly, we calculate the basic equilibrium and the path of convergence to this equilibrium from the starting point (2019). We call it the Baseline Scenario. In the basic equilibrium, the economy ceases to accumulate net foreign assets, maintaining them at the 2019 level. The problem is solved in all cases under the assumption of perfect foresight: at the moment of the shock, economic agents are aware of the entire future trajectory of exports, imports, and NFA. Since NFA in 2019 were positive, the economy annually received interest income from them, which could be directed towards consumption and investment. (For simplicity, we disregard a more complex problem as a basic option: the search for the best possible NFA size. This would require additional assumptions about future trajectories of income from commodity exports.) Our basic equilibrium is a hypothetical trajectory of macroeconomic indicators that corresponds to the maximum level of public welfare, under the condition of cessation of NFA accumulation from 2020. The main parameters of the basic equilibrium and other

[23] To find the model's equilibrium, we assume all variables remain constant over time and numerically solve the system of first-order conditions using the *lsqnonlin* function from MATLAB (minimizing the sum of squares of errors across all equations). Next, to simulate the paths along which the economy converges to a steady state, we use Dynare version 4.6.3, passing this steady state as an *endval* to a .mod file that describes our model. See the model's code in the Supplementary material: https://doi.org/10.32609/j.ruje.10.127850.suppl

[24] It is the average between "Availability of fixed assets at the residual book value for the full range of organizations (in million rubles)," which was ₽217,407,222 million in 2019, and "Availability of fixed assets at the end of the year in average annual prices by types of economic activity (in million rubles)" which was ₽491,622,984 million, taking into account a depreciation rate of 40% at the end of 2019 (492 × 0.6 = 295.2).

scenarios are given in Appendix A (Table A3). All subsequent scenarios will be presented in relation to the baseline equilibrium.

First, we calculate an alternative that involves only closure of the financial account, without imposing restrictions on the export-import flows — this is Scenario A or "reduction of NFA." In comparison to the Baseline Scenario, the only change in such a long-run equilibrium is the NFA size. NFA shift from positive to negative, at a level equivalent to the size of the public external debt.[25] We compute the equilibrium and the optimal trajectory towards it. This scenario allows us to examine the economic and structural implications solely associated with the inability to expend NFA and earn income from them.[26]

We then compute the Shock Scenario in three variations of the model parameters, which are responsible for the effectiveness of import substitution. In this scenario, not only does the financial account "close" and NFA decrease, but export and import flows also decline. Furthermore, the decrease in imports is more abrupt and significant than that of exports.

Therefore, the shock that we examine for the three variations of the model parameters is, firstly, characterised by restrictions on capital flows and the freezing of NFA, and secondly, by limitations on imports and exports. As a result, the economy loses the ability to use both the income from previously accumulated NFA and the NFA reserve itself to finance imports. Hence, the results of Scenario A are taken into account in subsequent calculations as part of the Shock Scenario.

In each option of the scenario, we introduce an import volume restriction (without restricting the import structure) and an export value restriction. These restrictions ensure that the economy maintains a positive trade balance after they are imposed, but it does not accumulate NFA (as per the first part of the Shock Scenario). Economic agents would like to use the export resources, though reduced, for imports, but they are unable to do so due to sanctions on import. Therefore, the central planner is challenged to find a steady state under these restrictions, where the economy formally has a positive trade balance but does not use the NFA stock: does not spend it to repay external debt (debt principal) or does not accumulate assets, but only uses a portion of it to pay interest on the external public debt.[27] In such circumstances, we examine three alternatives for the efficiency of import substitution:

- Scenario B (Optimistic) assumes the ease of creating full equivalents of imports and no TFP losses when using import-substituting goods in production.

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[25] We assume that the economy will continue to serve the public external debt and do not equal it to zero. This is a minor deviation from the zero debt level, which does not significantly affect the result. See footnotes 16 and 17.

[26] We only analyze the long-term consequences for the economy, which in practice may be amplified by additional effects, in particular, the inability to use NFA to smooth out exchange rate fluctuations and ensure financial stability when such smoothing through interventions may be necessary in the event of shocks (Adrian and Gopinath, 2020; Agénor and da Silva, 2019; Itskhoki and Mukhin, 2022), or to smooth out import consumption in the events of commodity price fluctuations (Medina and Soto, 2007; Pieschacon, 2012; Vlasov, 2020).

[27] This is in conflict with the concept of long-run equilibrium. Technically, we resolve this contradiction by exogenously altering the import price, so that foreign trade is balanced under zero debt in equation (8). We set the import price in such a way that the price hike compensates for the foreign trade surplus that has arisen due to the restrictions. If we wish to omit this, additional export reductions will be required during the optimisation process, as these revenues cannot be used for imports, contradicting our scenario.

- Scenario C (Neutral) suggests incomplete import substitution in terms of quality and the presence of asymmetry in the ability to replace imports: it's more difficult to replace investment goods than consumer goods; in addition, there are losses in total factor productivity due to the use of domestic import equivalents.[28]
- Scenario D (Pessimistic) suggests low import substitution in terms of quality with symmetry of import substitution in the investment and consumer sectors.[29] Scenario conditions for each scenario are presented in Appendix A (Table A3).

5. Results

The dynamics in *the Baseline Scenario* are presented in Appendix B. An economy that ceases to accumulate NFA when having positive trade balance has the potential to significantly increase consumption. It is optimal to direct additional resources primarily towards consumption and, whatever remains, towards investments. Once the accumulation of NFA from the foreign trade surplus ceases, a "permanent income" emerges, which can be properly used to enhance the standard of living over a long-term horizon. In the Baseline, net investments are positive and facilitate the accumulation of capital, an increase in capital intensity, leading to a higher level of production and income. In this case, due to the ability to import goods and investments, there is no need for import substitution. Moreover, in the Baseline Scenario, the proportion of imports in investments is increasing.

In Scenario A, which involves restrictions only in a form of reduced NFA through asset freezing, the changes compared to the Baseline Scenario are not very significant (see Appendix C). The economy loses access to the available NFA but continues to service the public debt from NFA revenues (significantly less than the initial NFA amount). Meanwhile, an increase in external borrowing is impossible. Why do the results turn out to be close regardless of actual nullifying of the previously positive NFA? For a country that decides to stop accumulating NFA in the Baseline Scenario, the NFA amount no longer changes, and only interest income is spent on NFA. When a country loses access to such NFA, from the perspective of equilibrium dynamics, only the income from NFA changes — the country loses them (but payments for servicing the external public debt remain). In the Baseline Scenario, the economy did not plan to spend the foreign asset stock in the future, only the income from the stock. Therefore, when the economy loses access to the foreign asset stock, it only loses the income from these assets. Thus, the differences in the best possible dynamics in the asset freeze scenario compared to the basic equilibrium are minor.

5.1. Scenario B — Optimistic

In Scenario B, we imply the most optimistic assumptions about the effectiveness of import substitution (see Appendix D). Calculations show that GDP on

[28] We also consider the case where parameter A, the total factor productivity, remains unchanged.

[29] Additionally, we calculated scenarios that were not included in this paper. Scenario D: this is Scenario B, but with added losses in total factor productivity due to the use of import-substituted goods in production.. Scenario F: this is Scenario D, but the restriction does not apply to all imports, only to investment ones. This scenario assumes the possibility of redirecting trade flows of consumer imports to other areas.

the optimal path first decreases and then slowly recovers over the course of 15 years and even exceeds the baseline. The economy reallocates resources: the production of original domestic goods (including non-tradable ones) decreases, and the production of import-substituting goods increases. This allows balancing consumption under conditions where households prefer to consume a basket in which the import component has significantly decreased. In other words, those employed in the production of original domestic goods or import packaging (for example, the assembly of foreign cars) are reoriented to the production of import-substituting goods (for example, automotive components). A similar situation is observed in the investment sector. Overall, the economy manages to replace the entire volume of retired imports at the cost of diverting resources from sectors engaged in original production. The reduction of GDP in the model economy over the next five years after the shock will be the result of both a smaller volume of exports and reduced consumption, which is only partially offset by the growth of investments. Reducing consumption will be the appropriate strategy at the macro level considering the need to increase the production of import-substituting goods. It is impossible to implement without investments and capital accumulation. As a result, the savings rate should grow.[30] The economy accumulates substantial capital (the capital intensity of production is growing relative to the Baseline Scenario) in order to be able to maximise the standard of living in the context of import substitution. Thus, this scenario means a temporary "sacrifice" in the form of reduced consumption, which should ensure the accumulation of capital, recovery of the GDP, and improvement of living standards in the longer term. Should the economy not be in a state of financial autarky with frozen assets, capital accumulation, intended to boost output amidst limited labour resources, could be made through imported goods financed with foreign loans (or using the resources of the National Wealth Fund (NWF) as part of NFA). An economy with no such option is required to redirect labour resources towards the investment sector and accumulate capital.[31] Over the long run, this strategy proves to be reasonable.

5.2. Scenario C—Neutral

Initially, the GDP shrinks, but subsequently only partially recovers[32] (see Appendix E). Firstly, in this scenario, the production of a unit of a comparable substitute for imported raw materials and components, which could replace the original imports, requires more labour and capital expenditure than the pro-

[30] In a decentralised economy, this would correspond to a significant increase in equilibrium real interest rates due to the expected return on capital growth (capital shortage), under conditions where the economy needs to increase domestic production. As capital accumulates, the rates will decrease.

[31] Since we do not solve a decentralized problem, we do not find equilibrium prices in the labour, capital, and goods markets. We assume that such an equilibrium can be replicated in a market economy through a higher return on capital (high equilibrium real interest rates). In practice, high real rates may result from expected deflation, i.e., a very strong *initial* price growth in the consumer sector and on the labor market. High rates discourage consumption and provoke lower relative prices and wages in the consumer sector compared to the investment sector. Moreover, wages and prices in the import-substituting sector should be higher than in the traditional domestic sector.

[32] If import substitution has no effect on productivity, the GDP goes down at its peak by 13% and 8% in the long run, compared to a cut of 18% at its peak and 16% in the long run when TFP is endogenous.

duction of other domestic goods. Secondly, due to assumed higher complexity, the production of import-substituting investment goods is anticipated to be twice as costly as the production of import-substituting consumer goods. There is the asymmetry between the sectors. Thirdly, creating a substitute for imported goods only provides the potential to replace the imported item, but does not guarantee quality match. For instance, an import-substituted remote control of equipment may fit the equipment, but it may not necessarily ensure the same quality of operation. According to the assumptions of the scenario, the wider use of domestic import substitutes in production results in lower efficiency of such production, i.e. decline in TFP.

As a result, firms do not substitute investment goods; all available financial resources (from exports) are directed towards purchasing imported investment goods. Consequently, the import of investments, along with the domestic production of complementary investment goods, which together form the basket of final investment goods, is on the rise. The capital intensity of GDP grows as well. In such an economy, there is no investment boom, as an increase in capital intensity under expensive import substitution cannot ensure GDP growth compared to the Baseline Scenario given the limited labour resources. While the capital intensity of GDP is increasing, it is significantly less than in the optimistic Scenario B.

The significant reduction in imports of consumer goods is partially offset by the production of import-substituting consumer goods. This requires cutting back on the production of original domestic goods. As a result, overall consumption decreases. Without imports or import-substituting goods, the consumption basket will be incomplete, and the consumer welfare will be even lower. Since complete import substitution is inefficient, unlike Scenario B, the economy lacks the resources to maintain the pre-shocks social welfare.[33]

5.3. Scenario D—Pessimistic

In the pessimistic scenario, the inefficiency of import substitution in the production of consumer goods is as significant as in the substitution of investment goods (see Appendix F). The economy partially replaces imports of consumer goods (45% of the initial imports) and completely substitutes investment goods. While exports are decreasing, the GDP does not start recovering over the entire horizon and ultimately decreases (by a third of the Baseline Scenario). The inefficiency in this scenario turns out to be so high that “eating out” the capital stock becomes more profitable: not to direct resources towards capital renewal. As a result, the capital stock and capital intensity go down relative to the Baseline Scenario. Given the low efficiency of import substitution in the consumer sector in this scenario, the share of substituted goods in consumption is the smallest of all three scenarios. Limited export resources are directed towards purchasing predominantly imported consumer goods. Due to a lack of resources for purchasing imported investment goods, their imports are initially reduced to

[33] In a market economy, such equilibrium will necessitate a substantial increase in the cost of imported consumer goods, as well as rising wages and prices in the import-substituting consumer sector. Both factors will lead to a price increase in the consumer sector.

zero. Subsequently, the import of investment goods resumes, but compared to the Baseline Scenario, domestic investment goods dominate in structure of investments. In this scenario, the economy is unable to cope with increased costs due to inefficiency. Additional costs of import substitution in the consumer sector (relative to Scenario C) create undesirable side effects for the investment sector: reallocation of export income to consumer goods (caused by the cost of replacing imported goods) leads to a shortage of resources for importing investment goods. This necessitates an increase in import substitution of investment goods. Its cost does not allow for an increase in capital and capital intensity of output. Given limited labour resources, a decrease in capital intensity restricts the ability to create value and income. This has a negative impact on the potential output of the economy. However, such a reduction in income limits the demand for consumer goods, thus acting as a stabilizing mechanism.

The GDP losses in this scenario are due to several factors. Firstly, the forced use of labour and capital for import substitution, when using import substitutes in production is less efficient in terms of productivity. Secondly, a reduction in export earnings decreases aggregate demand and income. Thirdly, the shrinking economy makes substantial investments in capital unprofitable for firms as well as for society: gross investments do not cover the depreciated capital.

6. Conclusions

We have modelled the effects of financial autarky (with net foreign assets frozen) and a significant reduction in imports, and later exports, for a commodity-exporting economy in general equilibrium using a modified centralised Ramsey model. We assume that imported goods are used for "packaging" along with domestic goods in the production of final consumer goods and investment goods. We highlight differences in the optimal dynamics that maximise a standard social welfare metric, which may arise due to variation in efficiency of import substitution. By this, we imply both the comparability of domestic substitutes with imports (the higher it is, the higher the efficiency is) for the consumers and the dependence of total factor productivity on the use of substituted intermediate goods.

Trade balance sanctions make import substitution preferable, but only in sectors where such substitution is relatively more efficient. In our study, this is the production of consumer goods. If domestic substitutes are comparable to the original products in their characteristics, the best strategy involves capital accumulation, increased capital–labour ratio, and intensive import substitution (in both sectors). This is associated with a decrease in the social welfare due to limited resources in the wake of decreasing exports. As a result, GDP may increase, but consumption will be below the baseline, i.e., the share of consumption in GDP will drop.

Asymmetry in the efficiency of import substitution between sectors leads to distortions in the structure of imports and production. Inefficient import substitution of capital goods necessitates a reorientation of imports towards investment goods. If import substitution is inefficient in both sectors, the economy "eats out" its capital stock and degrades.

Our model economy is centralized, but we can speculate on the inflation response in a decentralized formulation of it. Thus, in a market economy, a shift in import demand towards import of investments, as in the neutral Scenario C, needs a significant increase in the cost of production of domestic (import-substituting) investment goods relative to consumer goods. This contributes to the reorientation of the economy towards intensive import substitution of consumer goods, which should lead to an increase in wages and prices in the consumer sector. Therefore, the asymmetry in the efficiency of import substitution favouring the consumer sector is likely to generate unwelcome inflation effects.

There is room for further research in this area. Our findings may prove beneficial not only for a realistic comprehension of the potential paths of economic development in the new reality, but also when examining the green transition effects in economies heavily reliant on hydrocarbon exports.

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Appendix A. Calibration

Table A1
Parameters to model an unrestricted equilibrium.

Parameter	Description	Value	Source
r	Income from Russia's Net Foreign Assets, % per annum	0.625	Quarterly yield of U.S. 10-year Treasury bonds (2.5% per annum)
β	Discount factor for consumption flow	0.99375	Chosen to meet the following $1/\beta > 1 + r$
α	Labour share in income	0.67	HSE (2019)
A	Total factor productivity (TFP)	0.176	For given K, L and α to obtain $Y = GDP$ – exports-2019 (79 trillion RUB per year, equal to 20 trillion RUB per quarter)
L	Labour force, in millions of people	75.4	Rosstat (2021)
δ	Depreciation rate, %	5.0	Standard value
κ_C	Comparability of import substituted consumer product with imported, % of match	70.0	Determined by experts
κ_I	Comparability of import substituted capital product with imported, % of match	40.0	Determined by experts
η_C	Elasticity of substitution (the required price change) of domestic intermediate consumer goods with imports	0.5	Determined by experts
η_I	Elasticity of substitution of domestic intermediate investment goods with imports	0.3	Determined by experts
γ_C	Share of the intermediate domestic goods in the production of the final product	0.65	Determined by experts
γ_I	Share of intermediate domestic goods in the production of investment goods	0.25	Determined by experts
A_C	TFP in the "packaging" function of consumer goods	1.15	Calculated using equation (6) and data on C_Y, C_{imp} [a)]

(continued on next page)

Table A1 *(continued)*

Parameter	Description	Value	Source
A_I	TFP in the "packaging" function of investment goods	1.3925	Calculated using equation (7) and data on I_Y, I_{imp} [b)]
P^{ex}	Export price	1	For simplicity[c)]
P^{im}	Import price	1	For simplicity
B_{lim}	Maximum level of Net Foreign Assets (– assets, + debt), trillion rubles	–29	Bank of Russia. NFAs at the start of 2020 amount to $490 billion, at the exchange rate of 60 RUB/USD[d)]
Ex	Exports, trillion rubles	8	System of National Accounts 2019, annual average, Rosstat
ω	Baseline TFP	0.176	Calibrated as A
θ	TFP elasticity to changes in the import substitution share in GDP	0.125	Determined by experts[e)]

[a)] For the baseline year of 2019, the consumption volume is available (according to Rosstat SNA data, ₽76 trillion, Table A2). Table A2 provides estimates for intermediate consumer and imported goods. Based on this, using formula (6) and knowing the values of the substitution elasticity coefficients (Table A1), we have derived an estimate for the value of A_C.
[b)] For the baseline year of 2019, the investment volume is available (according to Rosstat SNA data, ₽25 trillion, Table A2). Table A2 provides estimates for intermediate investment and imported goods. Based on this, using formula (7) and knowing the values of the substitution elasticity coefficients (Table A1), we have derived an estimate for the value of A_I.
[c)] In the baseline year, exports and imports in the System of National Accounts (SNA) are expressed in the same currency (in trillion rubles for 2019). These values are taken as real values. The value of money in monetary terms is 1. Moving forward, when calculating scenarios (Table A3), the import price may deviate from 1 and adjust endogenously to maintain balance of payments equilibrium.
[d)] Net external debt position (by economic sectors) was taken from the data of the Bank of Russia. See http://www.cbr.ru/vfs/statistics/credit_statistics/debt_sector/61-debt_sector_19.xlsx (in Russian).
[e)] Practically, there are no data series for the import substitution share to evaluate this elasticity.
Source: Compiled by the authors.

Table A2
Calibration of the economy in 2019 (trillion rubles).

Indicator	Value	Source
GDP, Y	110	SNA Rosstat (hereinafter in current prices)
Intermediate consumer goods, C_Y	65	See "Consumption" below
Import-substituting consumer goods, C_S	–	Not available, therefore assumed to be zero
Intermediate investment goods, I_Y	13	
Import-substituting investment goods, I_S	–	Not available, therefore assumed to be zero
Export, Ex	32	SNA Rosstat[a)]
Consumption, C	76	SNA Rosstat
Consumption of domestic goods, $C_Y + C_S$	65	Derived from C and C_{imp}: $C - C_{imp}$
Consumption of imported goods, C_{imp}	11	Derived from imports: $Imp - I_{imp}$
Investments, I	25	SNA Rosstat
Domestic investment goods, $I_Y + I_S$	13	Derived from: $I - I_{imp}$
Imported investment goods, I_{imp}	12	See "Import" below
Import, Imp	23	SNA Rosstat
Consumer goods, C_{imp}	11	Derived from imports: $Imp - I_{imp}$
Investment goods, I_{imp}	12	Investment goods and services made up around 50% in the import structure[b)]
Capital stock, K	250	The mean of the valuation based on the residual value of 220 and the valuation based on the volume of fixed assets of 500, considering depreciation of 40%
Quality-adjusted consumption, C	–	
Savings rate, %	30	$(Y - C)/Y$

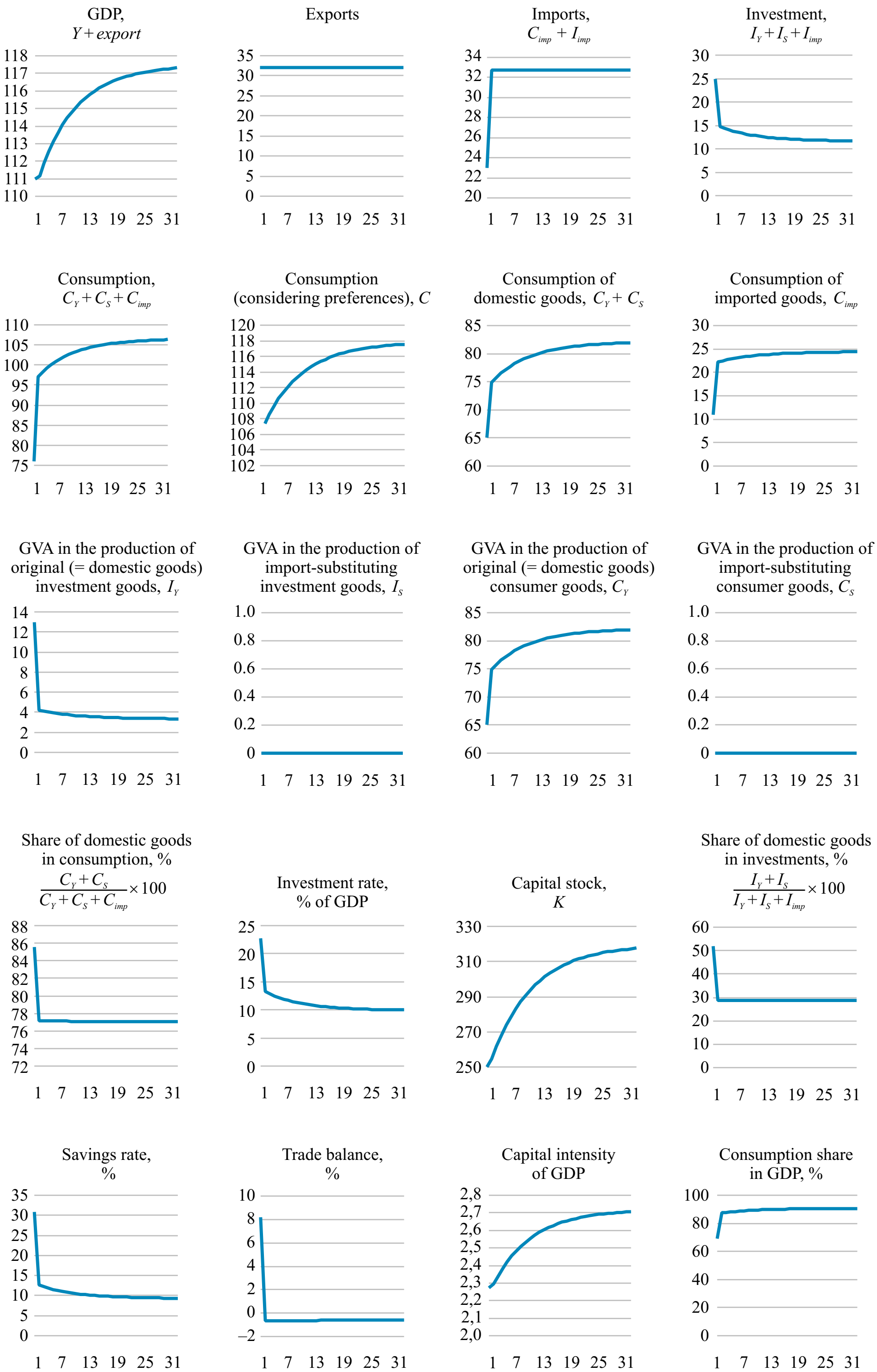
[a)] Data on exports and imports are from the SNA statistics, not from the Bank of Russia balance of payments, to ensure comparability with other expenditure indicators (consumption, investments).
[b)] According to Rosstat, in the commodity structure of imports in 2019, investment goods (machinery, equipment, vehicles) made up 47% of imports.
Sources: Rosstat; Federal Customs Service; author's calculations.

Table A3
Results for the scenarios.

Scenario parameters	Baseline calculation	Scenario A: Financial autarky and asset freeze	Scenario B: Optimistic	Scenario C: Neutral	Scenario D: Pessimistic	Additional[a)]	
						Scenario E	Scenario F
External debt (NFA), ₽ trillion of 2019	–29	0.5	0.5	0.5	0.5	0.5	0.5
Exports, ₽ trillion of 2019 per quarter	8	8	7.2 up to 2023Q1 5.4 up to 2024Q1 3.6 up to 2025Q1	7.2 up to 2023Q1 5.4 up to 2024Q1 3.6 up to 2025Q1	7.2 up to 2023Q1 5.4 up to 2024Q1 3.6 up to 2025Q1	7.2 up to 2023Q1 5.4 up to 2024Q1 3.6 up to 2025Q1	7.2 up to 2023Q1 5.4 up to 2024Q1 3.6 up to 2025Q1
Imports, ₽ trillion of 2019 per quarter	Endogenously	Endogenously	2.875[b)]	2.875	2.875	2.875	Unlimited
Import of investment goods	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unlimited	0.5
P^{im}, import cost	1	1	Endogenous	Endogenous	Endogenous	Endogenous	1
A (TFP)	Constant	Constant	Constant	$A_t = \omega \times e^{-\theta(C_t^S + I_t^S)/GDP}$	$A_t = \omega \times e^{-\theta(C_t^S + I_t^S)/GDP}$	$A_t = \omega \times e^{-\theta(C_t^S + I_t^S)/GDP}$	$A_t = \omega \times e^{-\theta(C_t^S + I_t^S)/GDP}$
Production of import-substituting consumer goods, C_S, ₽ trillion of 2019 per quarter	Non-binding constraint: $C_S = 0$	Non-binding constraint: $C_S = 0$	$C_S = 0$ or $C_S > 0$	$C_S = 0$ or $C_S > 0$	CS = 0 or CS > 0	$C_S = 0$ or $C_S > 0$	$C_S = 0$ or $C_S > 0$
Production of import-substituting investment goods, I_S, ₽ trillion of 2019 per quarter	Non-binding constraint: $I_S = 0$	Non-binding constraint: $I_S = 0$	$I_S = 0$ or $I_S > 0$	$I_S = 0$ or $I_S > 0$	IS = 0 or IS > 0	$I_S = 0$ or $I_S > 0$	$I_S = 0$ or $I_S > 0$
$\kappa_C \times 100$, Comparability of import substitution for consumer goods with imports, % of match	70	70	100	70	35	100	70
$\kappa_I \times 100$, Comparability of import substitution for capital goods with imports, % of match	40	40	100	40	35	100	40

a) Additional scenarios calculation included in Supplementary material: https://doi.org/10.32609/j.ruje.10.127850.suppl
b) Annual imports during the baseline period amount to ₽23 trillion (Table A1), equivalent to ₽5.75 trillion of imports per quarter (seasonality disregarded). Half of this volume equals 2.875.
Source: Compiled by the authors.

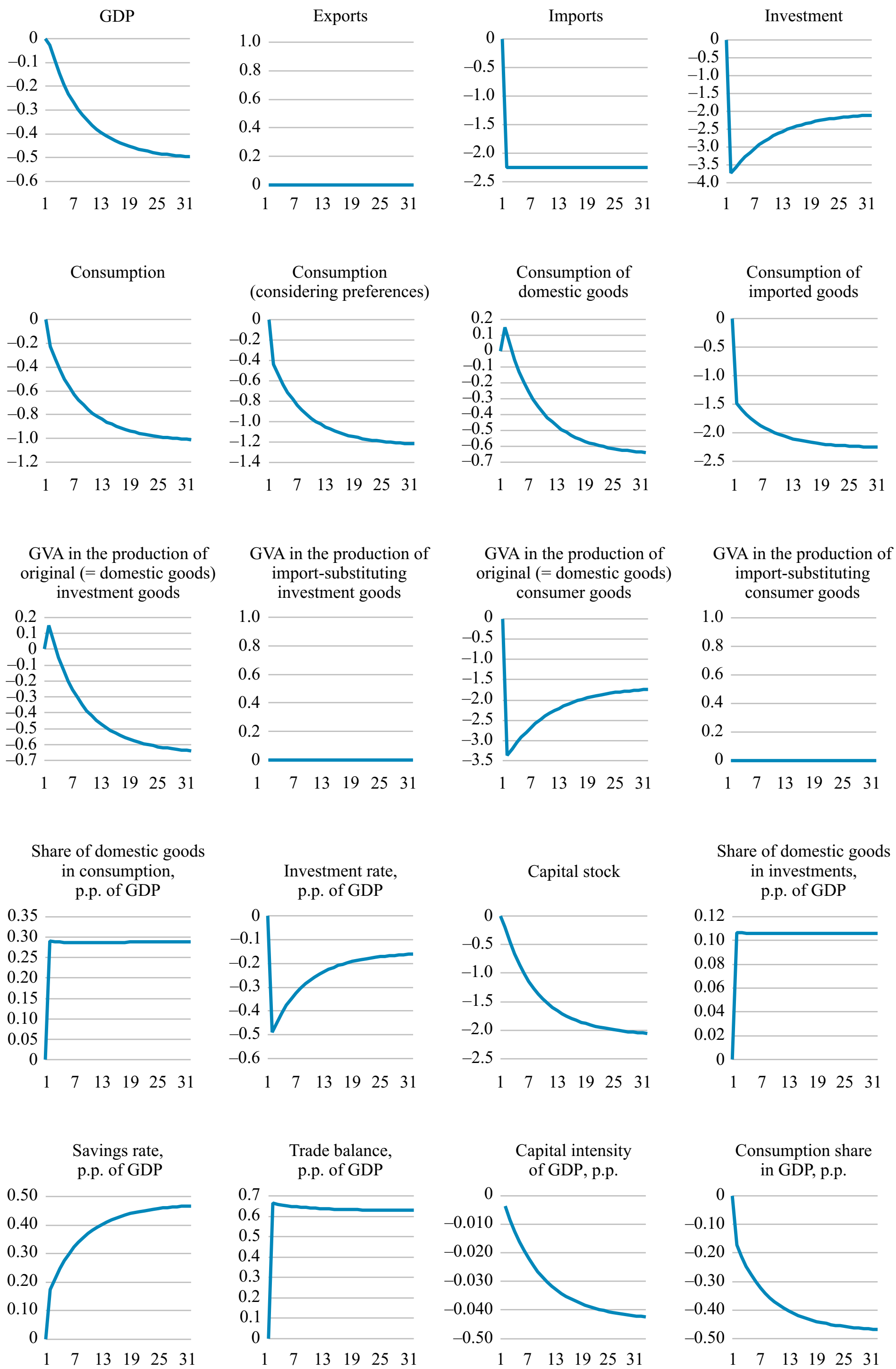
Appendix B. Results for the Baseline Scenario



Note: All values, unless otherwise stated, are in trillion rubles of 2019. The x-axis represents the year since “the new reality” beginning. GVA—Gross Value Added.

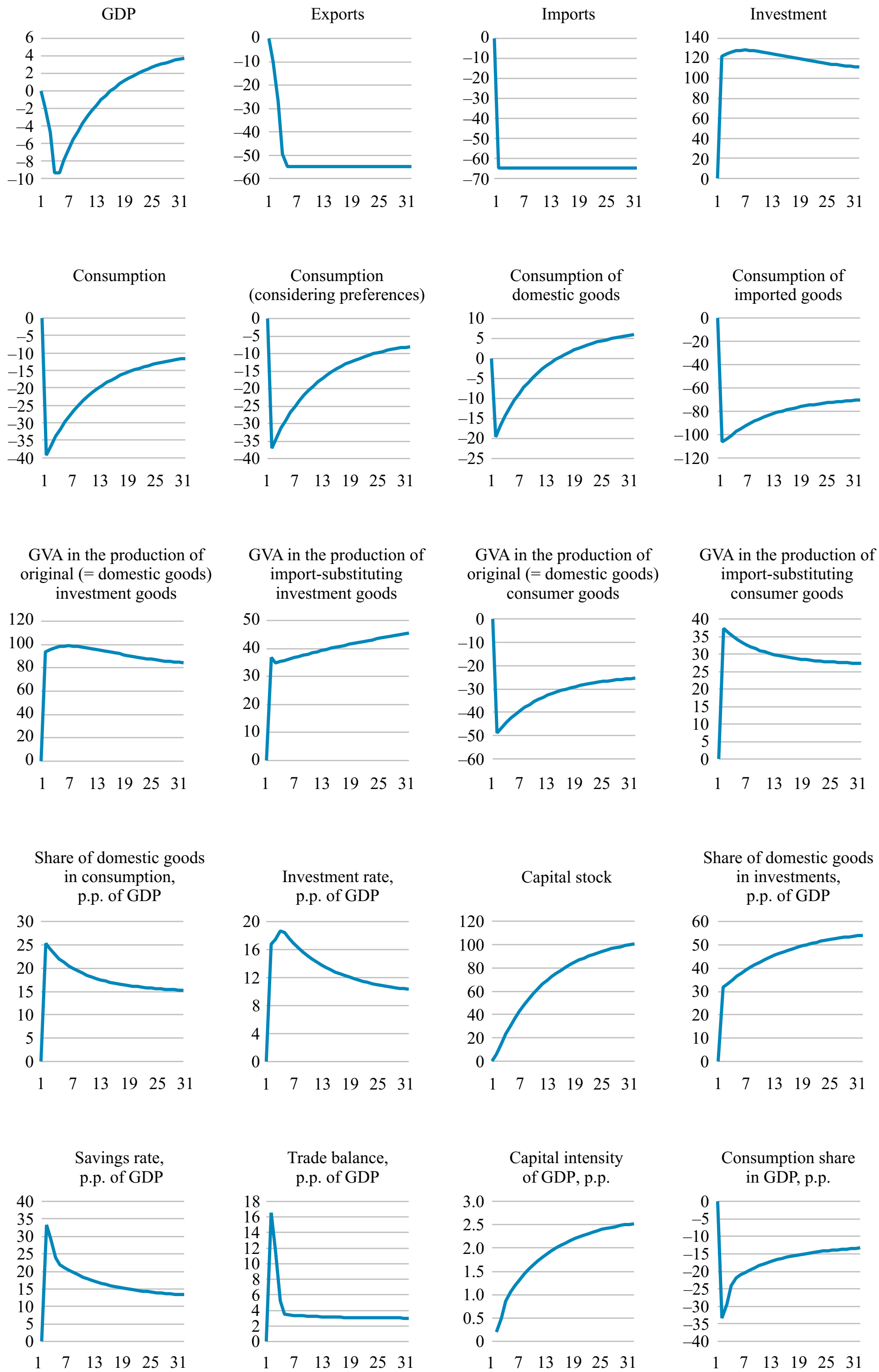
Sources: Rosstat; author’s calculations.

Appendix C. Results for Scenario A: A combination of financial autarky and asset freezing



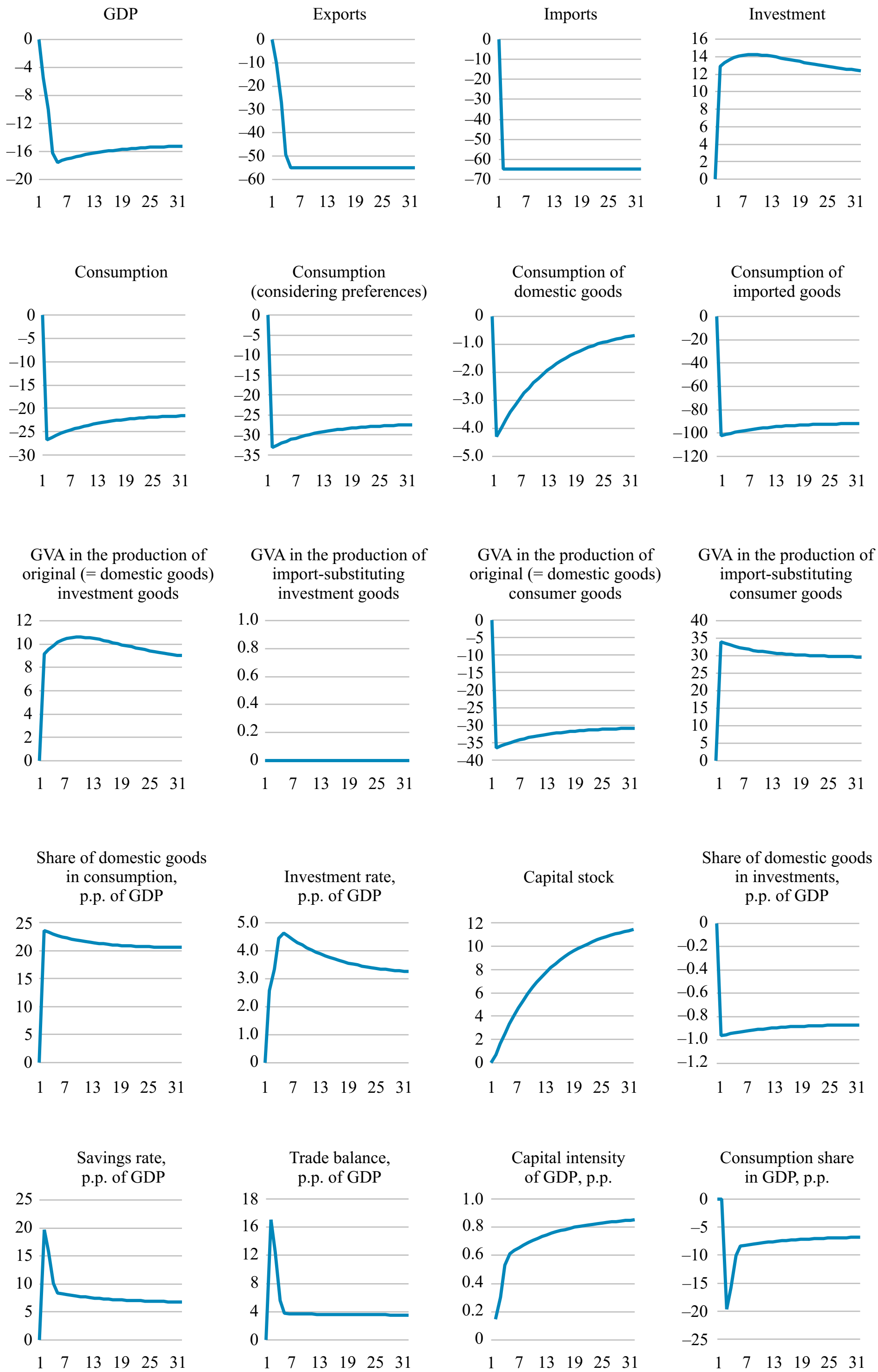
Note: All values, unless otherwise stated, are in percentage relative to the Baseline Scenario. The x-axis represents the year since "the new reality" beginning. GVA—Gross Value Added.
Sources: Rosstat; author's calculations.

Appendix D. Results for Scenario B: Optimistic



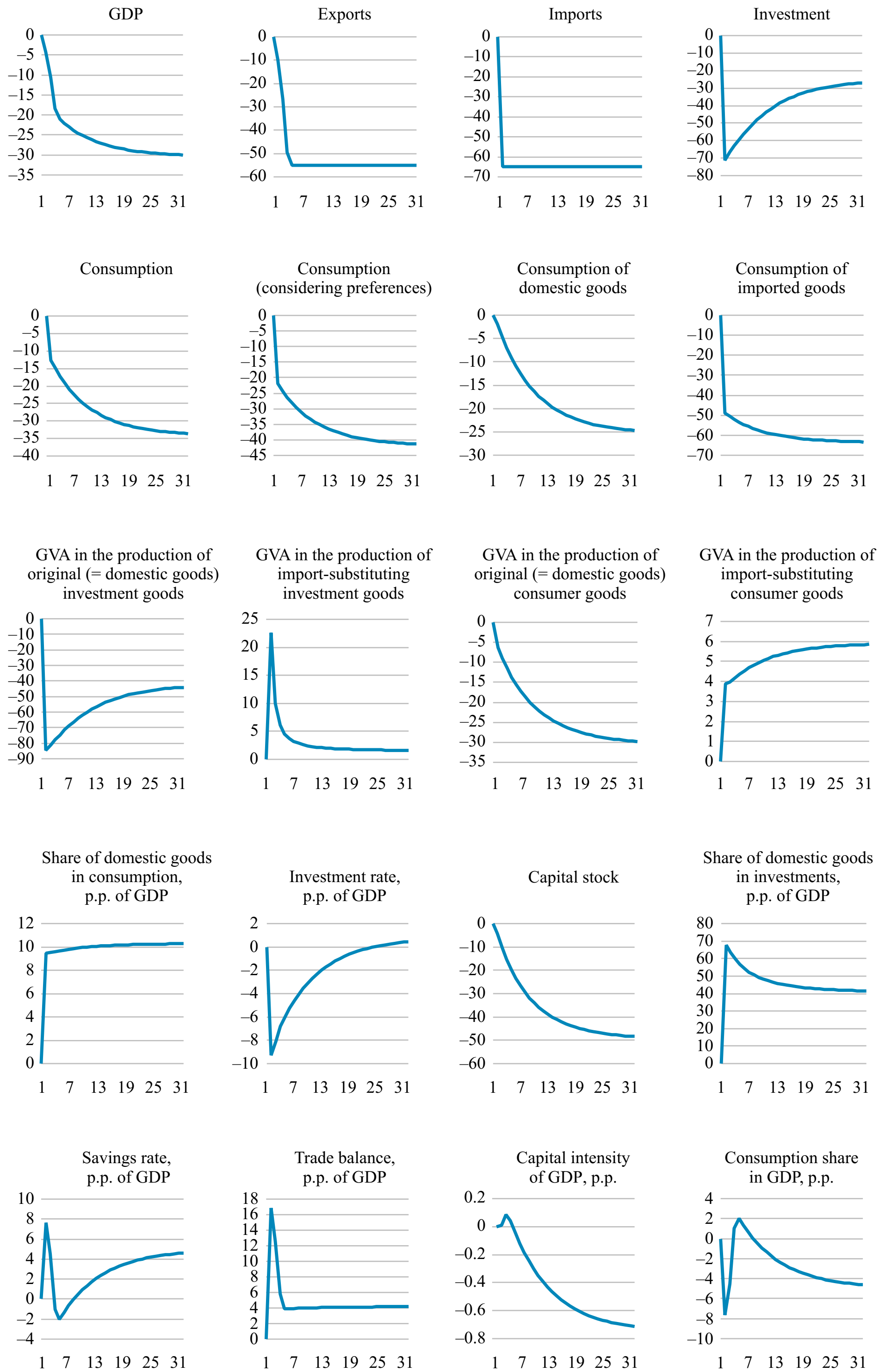
Note: All values, unless otherwise stated, are in percentage relative to the Baseline Scenario. The x-axis represents the year since "the new reality" beginning. GVA—Gross Value Added.
Sources: Rosstat; author's calculations.

Appendix E. Results for Scenario C: Neutral



Note: All values, unless otherwise stated, are in percentage relative to the Baseline Scenario. The x-axis represents the year since “the new reality” beginning. GVA—Gross Value Added.
Sources: Rosstat; author’s calculations.

Appendix F. Results for Scenario D: Pessimistic



Note: All values, unless otherwise stated, are in percentage relative to the Baseline Scenario. The x-axis represents the year since "the new reality" beginning. GVA—Gross Value Added.
Sources: Rosstat; author's calculations.

Supplementary material

MATLAB code

Authors: Maria S. Lymar, Alexander A. Reentovich, Andrey A. Sinyakov

Data type: Archive

Explanation note: The RAR archive contains MATLAB files used to calculate the model's steady state and transition dynamics to it from a given starting point. Two versions are included: with and without import restrictions.

Link: https://doi.org/10.32609/j.ruje.10.127850.suppl