Computable general equilibrium model for Belarus: theoretical aspects and practical applications

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ABSTRACT: The paper develops a computable general equilibrium (CGE) model for Belarus to assess the consequences of alternative integration strategies and external shocks. The modeling exercise suggests that Belarus will face difficult choices and substantial risks in the event of geopolitical and economic realignments. Primary raw material processing industries, as well as industrial sectors heavily dependent on the Russian market and low-cost energy, could suffer significant output losses if oil and gas prices rise sharply and Belarus reorients trade away from Russia toward the EU. Export-oriented, higher value-added sectors (mechanical engineering, communications, pharmaceuticals, and light industry) have the potential to increase production and export through labor and capital flows. With carefully designed EU support — focusing on targeted energy subsidies, helping Belarusian firms integrate into European production chains, and providing productivity-oriented financial assistance — the negative short-term effects of energy shocks and the shift in trade from Russia to Europe can be mitigated. While short-term adjustment costs are unavoidable, closer ties with the EU can help Belarus overcome its structural dependence on Russia and secure long-term gains in growth and welfare.

Keywords: CGE, model, simulation, GDP, value added, output, energy, trade, integration, liberalization.

JEL: C68, F15, F14, Q43, O52.

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1. Introduction

For Belarus, one of the most important strategic choices is about its future orientation between continued reliance on Russia and deeper integration with the European Union (EU). At present, the Belarusian economy is strongly integrated with Russia: around 60% of foreign trade turnover is connected to the Russian market, and Belarus benefits from heavily subsidized energy imports. While this arrangement has ensured short-term stability, it creates long-term vulnerabilities. Structural dependence makes Belarus highly sensitive to political or institutional changes in its relations with its eastern neighbor, limits opportunities for productivity gains, and undermines household welfare through lower real income growth relative to neighboring EU countries.

Closer integration with the EU offers a different path. It features both opportunities and risks: opportunities in access to larger markets, advanced technologies, and investment, and risks in the costs of adjusting the sectors currently reliant on protected access to Russian markets, as well as social challenges that may arise as the economy is rebalanced.

Understanding the trade-offs of these strategic choices requires a tool that captures both the immediate disruptions and the broader structural consequences of external shocks. For this purpose, this paper develops and applies a computable general equilibrium (CGE) model for Belarus. CGE models are particularly well-suited to analyze such complex scenarios because they simulate how an entire economy adjusts to shocks in trade, prices, or structural policy measures. CGE models provide a consistent framework that links sectoral interactions, resource allocation, and household welfare within a general equilibrium setting. These models are particularly well-suited for simulating scenarios that involve significant, economy-wide adjustments, such as trade liberalization, integration into new production chains, or energy price shocks. By considering both direct and indirect effects across industries and households, they assess the full range of potential impacts instead of focusing on isolated sectors.

The Belarusian case is a clear example where such modeling is crucial. The economy's dual dependence, on cheap energy imports and on access to the Russian market, creates vulnerabilities that cannot be understood through partial-equilibrium or sectoral analysis alone. Structural shocks, such as a sharp rise in energy prices or a reorientation of trade toward the EU, affect not only the directly exposed sectors but also the broader economy through changes in costs, relative prices, and resource allocation. A CGE framework is therefore indispensable for identifying these connections and providing a comprehensive view of possible outcomes. Existing studies on Belarus that apply CGE models are of limited relevance today, as they rely on outdated data and do not address the potential integration of Belarus into the EU.

This study aims to address this gap by examining the sectoral and macroeconomic consequences of Belarus's policy reorientation from Russia to the EU. For this purpose, simulations were run using the developed CGE model. The simulations focus on three major scenarios that reflect the critical challenges Belarus may face. The first is an energy shock – a sharp rise in energy prices with potential disruptions to the supply of Russian oil and gas. The second is liberalization of trade with the EU without an energy shock – lowering of tariff barriers with the EU accompanied by the complication of trade relations with Russia. The third is liberalization of trade with the EU under an energy shock – a combined scenario where energy prices rise sharply and trade shifts toward the EU. In addition to simulating the aforementioned shocks, the study also examines the potential effects of macro-financial support from the EU.

A key prerequisite for these scenarios is a change in the political situation in Belarus. The current political regime must either collapse or transform into inclusive political institutions that allow for democratic elections. This political transition is beyond the scope of this study. However, it is important to have economically sound estimates of the potential effects of a change in economic policy prepared in advance.

The simulation results emphasize the importance of reducing Belarus's structural dependence on Russia. Energy diversification, participation in European value chains, and productivity-enhancing reforms are essential for long-term resilience and growth. For the EU, the results suggest that targeted energy subsidies and productivity-oriented financial assistance could significantly mitigate short-term losses and lay the groundwork for sustainable growth.

The EU will also experience some economic and, possibly, socio-political effects from building closer ties with Belarus. Assessing these effects has implications for EU policy decisions, but it is beyond the scope of this study.

The structure of the working paper is as follows. Section 2 provides an overview of the CGE modeling framework, and Section 3 describes the CGE model for Belarus. Section 4 outlines the simulation design and elaborates on the key results. Section 5 evaluates the macroeconomic impact of potential economic support from the EU and offers policy recommendations. Section 6 concludes the study with reflections on limitations and directions for future research.

2. Overview of the CGE modelling

2.1 Characteristics of a CGE model

A CGE model is a system of equations that describes an economy as a whole and the interactions among its parts. The standard CGE model accounts for all payments recorded in the social accounting matrix (SAM), which serves as a form of data input for the model. SAM is a square matrix that describes the circular flow of income and spending in a national economy over a specific time period, typically a year. It reports the values of all commodities produced and the income generated from their sales (Burfisher, 2021).

A CGE model follows the SAM disaggregation of economic agents, and it is written as a set of simultaneous equations defining their behavior. In part, this behavior follows simple rules captured by fixed coefficients (for example, ad valorem tax rates). The equations also include a set of constraints that must be satisfied by the system as a whole but are not necessarily considered by any individual actor. These constraints cover markets (for factors and commodities) and macroeconomic aggregates (balances for savings-investment, government, and the balance of payments with the external sector) (Lofgren et al., 2001).

A CGE model includes exogenous and endogenous variables and market-clearing constraints. All the equations in the model are solved simultaneously to find an economy-wide equilibrium in which, at some set of prices, the quantities of supply and demand are equal in every market (Burfisher, 2021). To conduct an experiment, one or more exogenous variables are changed, and the model is then resolved to determine new values for the endogenous variables. Such a simulation aims to draw conclusions about the effects of an exogenous change (or an economic shock).

The key terms in CGE models are defined as follows:

- “Computable” refers to a model’s ability to quantify the effects of a shock on an economy.
- “General” means that a model encompasses all economic activities simultaneously, including production, consumption, employment, taxes, savings, and trade, as well as connections among them.
- “Equilibrium” refers to a state in which all markets in an economy clear simultaneously, meaning that supply equals demand for every good, service, and factor of production.

CGE models have been applied to study a wide and owing range of economic problems, including taxation, economic development, trade policy, climate change, tourism, transportation, and disease.

2.2 Strengths and limitations of CGE models

A major advantage of CGE models is their flexibility. They can be customized to simulate a wide range of economic policies and shocks, including trade agreements, fiscal reforms, or public spending initiatives. Their capacity to reflect both price and quantity adjustments in response to policy interventions makes them a favored tool in government institutions, research organizations, and international bodies. By replicating how an economy functions, CGE models enable more comprehensive assessment of macroeconomic effects of policies and programs, offering richer insights compared to such tools as Input-Output models.

Other important strengths of CGE models include:

- internal consistency of an equilibrium. It ensures that systemic relationships across an economy are reflected, which may be overlooked by simpler frameworks.
- ability to account for price and quantity adjustments. CGE models allow both prices and quantities to dynamically respond to policy shifts.
- representation of behavioral responses. Microeconomic foundations enable these models to reflect the optimizing behavior of households, firms, and governments, yielding more realistic responses to policy changes or external shocks.
- comprehensive economy-wide perspective. CGE models provide an integrated picture of an economy as a whole. They capture both direct and indirect effects of policy changes, offering a robust analysis.
- recognition of connections across sectors and countries. CGE models are effective at mapping inter-industry and international links, which is particularly useful when analyzing trade policies, global value chains, or climate negotiations.

However, CGE models are inherently complex, involving thousands of equations and outputs, and require considerable expertise for effective operation and interpretation.

Generally, CGE modelling has several limitations:

- extensive data requirements and quality concerns. CGE models require vast amounts of accurate data (a social accounting matrix (SAM), input-output tables, trade flows, elasticities, etc.), making them particularly challenging for developing countries or sectors with limited statistical robustness (Devarajan & Robinson, 2013).
- static nature and limited dynamics. Many CGE models are static or comparative-static, focusing on steady states. They often fail to capture evolving dynamics such as technological change or capital accumulation.
- unsuitability for small-scale policy changes. Models' broad scope makes them less effective for evaluating policies or programs with only minor economic consequences.
- sensitivity to parameter values. Results are highly sensitive to parameter choices (e.g., substitution elasticities). Minor adjustments can significantly alter outcomes, raising robustness concerns.

- difficulty in incorporating non-market impacts. Environmental, health, and broader social impacts, along with their distribution consequences, are often reflected inadequately.

Despite these limitations, CGE models remain a highly valuable tool for policy evaluation, particularly when exploring complex, cross-sectoral, or international issues. Their strengths provide deep and realistic insights into economy-wide effects, but their findings should always be interpreted carefully, keeping transparency, sensitivity testing, and context in mind.

2.3 Application of CGE models for assessing integration effects and energy shocks

CGE models have become a key tool for policymakers and researchers seeking to understand the economy-wide impacts of trade, energy, and environmental policies. From evaluating Ukraine's strategic choices between competing integration blocs or free trade agreements (Movchan & Giucci, 2011; Movchan et al., 2023) to assessing Moldova's subsidy responses to energy price shocks (UNDP, 2023) and analyzing the EU's ambitious climate and energy security strategies (Perdana et al., 2022), CGE models offer a consistent framework for quantifying benefits and trade-offs. Recent applications extend further to innovations in energy substitution modelling in Latvia (Benkovskis et al., 2023), highlighting the versatility of CGE approaches for addressing pressing policy challenges in times of uncertainty.

Movchan and Giucci (2011) analyze Ukraine's strategic choice between two major integration paths: signing a deep and comprehensive free trade agreement (DCFTA) with the EU or joining the Customs Union of Russia, Belarus, and Kazakhstan (CU). The authors use a CGE model based on Ukraine's input-output data, distinguishing between competitive and imperfectly competitive industries. Additionally, the model differentiates between skilled and unskilled labor, allowing for a more detailed analysis of labor market impacts. The study concludes that signing a DCFTA with the EU would generate substantial welfare gains for Ukraine by boosting trade, wages, and access to advanced capital goods, while joining the Customs Union would slow modernization and conflict with the country's WTO commitments.

Movchan et al. (2023) evaluate potential economic consequences of a modern free trade agreement (FTA) between Ukraine and Turkey. The authors developed a 45-sector CGE model for Ukraine, incorporating 7 partner regions, including Turkey, the EU, Russia, the US, China, countries that have already signed FTAs with Ukraine, and the rest of the world. The results demonstrate substantial economic benefits for Ukraine if the FTA includes elements of deep integration. Beyond tariff elimination, reforms targeting trade facilitation and FDI liberalization would significantly boost Ukraine's economic performance, improve its competitiveness, and foster long-term growth.

The United Nations Development Programme's research examines how Moldova's economy responds to surging global natural gas prices and evaluates the effectiveness of various government subsidy mechanisms in protecting vulnerable households from energy poverty (UNDP, 2023). The analysis employs a recursive dynamic CGE model specifically calibrated for Moldova. The study finds that Moldova's heavy reliance on imported natural gas and limited diversification of energy sources make its economy extremely vulnerable to external price shocks. A sharp rise in global gas prices leads to lower GDP, reduced private consumption, lower investment, and higher unemployment. The CGE analysis provides clear evidence that while energy subsidies are vital for protecting vulnerable households, their design matters greatly. Cash transfers are a more effective option for sustaining household welfare and supporting economic resilience. However, structural reforms to diversify energy sources and improve energy efficiency are essential for Moldova to reduce its long-term vulnerability to global energy shocks.

Sun et al. (2024) investigate the global economic consequences of the Russia-Ukraine conflict through the lens of international energy price escalation. The authors employ a CGE model specifically built on the GTAPv10 database, which covers 141 countries and regions. The CGE framework is used to simulate exogenous shocks in global energy prices and trace their ripple effects across macroeconomic variables and sectoral outputs. The study concludes that while some energy producers gained short-term advantages, the broader global economy faced inflationary pressures, welfare losses, and increased vulnerabilities. The authors argue that the CGE model is particularly effective in capturing these complex, multi-sectoral interactions, making it a valuable tool for policymakers tasked with enhancing economic resilience amid geopolitical shocks.

Perdana, Vielle, and Schenckery (2022) examine the economic implications of the EU's reduction in energy imports from Russia. The study is set in the context of the EU's simultaneous pursuit of energy security and climate policy goals. The authors employ a multi-country, multi-sector CGE model. The model simulates international trade, energy markets, and greenhouse gas emissions, calibrated with the GTAP-Power database and policy targets. The authors conclude that while sanctions reduce Russia's revenue and support EU's energy diversification, they come with substantial welfare and economic costs for EU citizens, especially under a full gas embargo. The study highlights the CGE model's strength in capturing sectoral interdependencies but also acknowledges its limitations, including an underestimation of infrastructure bottlenecks and household-level distributional impacts.

Beņkovskis, Jaunzems, and Matvejevs (2023) introduce a novel purpose-based energy substitution structure for CGE models. The research is set in the context of the European Green Deal and Latvia's pledge to reduce greenhouse gas emissions by 17% by 2030. The innovation of this study lies in modelling energy substitution within the CGE framework according to the purposes of energy use, such as high- and low-temperature heat, transport, electricity, heating, and hot water. This approach allows energy sources (e.g. coal, gas, biomass, waste, and renewables) to replace one another within specific processes, reflecting technological and economic constraints more realistically. The authors conclude that the purpose-based CGE approach improves both realism and policy relevance, particularly when evaluating green transition strategies and carbon tax design in small open economies like Latvia's.

Taken together, these studies demonstrate the breadth of CGE models in informing critical policy debates across trade liberalization, geopolitical energy disruptions, and climate transition strategies. While the results vary by country and policy design, what unites them is the ability of CGE models to simulate complex policy shocks and their distributional effects at both national and global levels. As economic systems face mounting pressures from geopolitical conflicts, energy crises, and climate commitments, CGE analysis provides not only quantitative insights but also a structured framework for evaluating policy options, anticipating unintended consequences, and guiding decisions toward more resilient and sustainable outcomes.

2.4 Application of CGE models to Belarus

In the context of Belarus, CGE models were used to examine such scenarios as increases in gas prices, the country's accession to the WTO, and the effects of its integration into the Eurasian Economic Union (EAEU).

Tochitskaya and Shymanovich (2007) employ a CGE model to estimate the consequences of a gas price hike for the Belarusian economy. The results show that the growth of gas prices would most negatively affect the chemical, petrochemical, heating, and power industries. At the same time, a decline in these sectors would be accompanied by a redistribution of resources, mostly in favor of such sectors as machine building, light industry, and services.

Astrov et al. (2012) analyze alternative trade integration scenarios for the CIS. Using gravity and CGE modelling, the researchers evaluate the economic impact of the Belarus-Russia-Kazakhstan Customs Union and a potential Ukraine-EU free trade agreement, showing that Belarus benefits from deeper integration with Russia and Kazakhstan, while highlighting the country's vulnerability due to its high reliance on CIS trade and Russian energy imports.

Balistreri et al. (2017) use a CGE model to assess the economic impact of Belarus's joining the WTO and implementing large-scale privatization. The research highlights the crucial role of FDI and services liberalization in driving gains from WTO accession and finds that privatization would generate welfare benefits nearly four times those from WTO accession.

Vinokurov et al. (2015) use CGE models to estimate the economy-wide and sector-specific effects of reducing non-tariff barriers (NTBs) for Belarus, Russia, and Kazakhstan. According to the simulation results, among the studied countries, Belarus would benefit most significantly from lower NTBs: in the medium term, real GDP would increase by 2.8%, and welfare – by a total of 7.3%. The distribution of the impact of reducing NTBs across activities supports this conclusion: most of the positive impact would be received by Belarusian mechanical engineering (specifically production of machinery and equipment), production of chemicals, rubber and plastic products, as well as metallurgy.

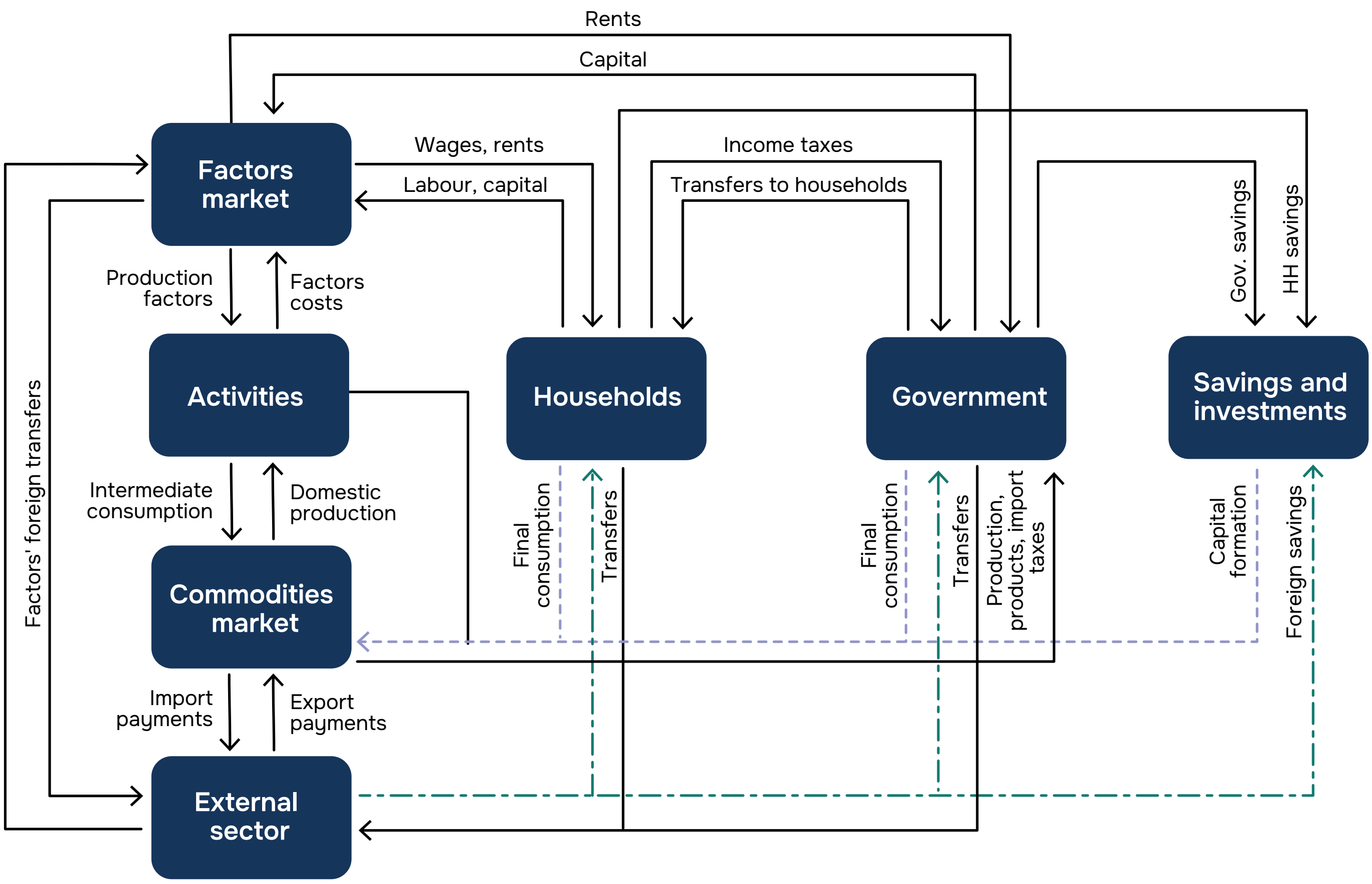
The aforementioned studies that used CGE models for Belarus are currently of limited relevance, as they are based on outdated data and do not account for economic changes that have occurred since Belarus acceded to the EAEU in 2015. Furthermore, the presented studies do not examine the potential integration of Belarus with the EU.

3. CGE model for the Belarusian economy

3.1 Model structure

The model for the Belarusian economy is built on the basic postulates of the CGE modeling. The Belarusian CGE framework is illustrated in Figure 1. The equations describing the relations between the economic agents are described in detail in Appendix A.

Figure 1: CGE model for Belarus: agents and flows



Source: built by the authors

The factors market supplies factors of production, such as labor and capital, to activities. The source of labor is households; capital comes from households and government. For factors utilization, the factors market pays wages for labor to households and rents to households and government. As part of its profit-maximizing decision, each activity utilizes the production factors up to the point where the marginal revenue product of each factor equals its wage or rent. Factor wages and rents may differ across activities, not only when the market is segmented but also for mobile factors. The factors market interacts with the external sector via bilateral international transfers of production factors.

Activities produce commodities (products and services) and are introduced by producers – sectors. Each activity produces one or more commodities according to fixed yield coefficients. It uses labor and capital from the factors market and intermediate inputs from the commodities market as factors of production. For factors utilization the sector pays factors costs. Each sector is assumed to maximize profits, which are the target subject to a production technology: the technology is specified by a constant elasticity of substitution (CES) function and a Leontief function for the quantities of value-added and aggregate intermediate consumption. The commodities are released on the commodities market as aggregate domestic output, generating sales income for activities. Activities pay production taxes to the government at a fixed rate.

The commodities market distributes products and services – commodities – produced by activities. Domestic output enters the commodities market; part of it is exported, while imports, together with domestically consumed domestic output, generate domestic demand. Commodities are purchased for intermediate consumption by activities, for final consumption by households and government, and for capital formation. The prices paid by demanders include the cost of transaction services – transport and trade margins. The prices received by domestic suppliers are net of these transaction costs. From the external sector, the commodities market receives export income and incurs import costs. The government receives product and import taxes from the commodities market at fixed rates.

The external sector is connected to other Belarusian economic agents in many different ways. As mentioned above, the external sector buys Belarusian exports and provides imported commodities through the commodities market.

The decision on export volume is based on the assumption that suppliers maximize sales revenue for any given aggregate output level, subject to imperfect transformability between exports and domestic sales, expressed by a constant elasticity of transformation (CET) function. In the international markets, export demands are infinitely elastic at given world prices. The price received by domestic suppliers for exports is expressed in domestic currency.

The import demands are derived from the assumption that domestic demanders minimize cost subject to imperfect substitutability, which is reflected in the Armington CES function. The demands derived for imported commodities are met by international supplies that are infinitely elastic at given world prices. The import prices paid by domestic demanders also include import tariffs (at fixed ad valorem rates) and the cost of a fixed quantity of transaction services – margins – per import unit.

Moreover, the external sector interacts with the factors market by providing and receiving income on capital, paying wages to domestic labor employed abroad, and receiving wages from foreign labor employed in the Belarusian economy. The external sector is connected to households and government through bilateral transfers. Also, the external sector makes savings in the country, which are the difference between foreign currency spending and receipts. The model assumes a flexible exchange rate, while foreign savings are fixed.

Households provide factors of production – labor and capital – and receive wages and rents as income in return. Households also receive transfers from the government and net transfers from the external sector fixed in foreign currency. They pay income taxes to the government, purchase commodities for final consumption, and make savings. Direct taxes and transfers to other economic agents are defined as fixed shares of household income, whereas the savings share is flexible and depends on households' marginal propensity to save. The households' utility function is evaluated based on the set of commodities they purchase.

Government receives rents for providing capital to the factors market; it also receives tax revenues from households, activities, and the commodities market, as well as net transfers from the external sector. It then spends its income on the final consumption of commodities, provides transfers to households, and saves the residual between revenues and expenditures.

Savings and investments consist of the accumulated savings of households, government, and the external sector, which are subsequently invested in capital formation. Capital formation includes gross fixed capital formation and changes in inventories, with commodities for capital formation purchased from the commodities market.

The Belarusian CGE model is implemented in two specifications. The baseline specification covers 17 production sectors, with the external sector represented by four counterparties – Russia, the EU, China, and the rest of the world. In the alternative specification, activities are disaggregated into 22 production sectors, and the external sector is modeled as a single counterparty without regional differentiation. The description of the sectors is provided in Appendix B.

3.2 Data and parametrization

The core of a SAM is data from the Input–Output table; it is built using the same principle: the intersection of row and column displays the flow from one economic agent to another. The introduced model uses 2019 data published by the Belarusian National Statistical Committee (Belstat) as input. The year was chosen because it is the most recent one with a complete set of available data, and it does not reflect significant external shocks.

Building a SAM also required some additional data. To reflect the division of the external sector into trade counterparties, their shares were calculated using trade data from Belstat. Data on international transfers and factors incomes were taken from the Balance of payments published by the National Bank of the Republic of Belarus (NBRB). For the breakdown of transfers and incomes by country, data on Russia were drawn from the

Balance of payments with the Russian Federation, while the shares of other counterparties were approximated. Data on transaction flows between the government and households were obtained from the IMF Government Finance Statistics database. Tariffs on imported goods were sourced from the World Integrated Trade Solution (WITS) database.

One of the key challenges in preparing data for the CGE model is forming technical substitution elasticities values for production factors and domestic versus imported commodities, which is a separate research task of interest. In this paper, the values of these elasticities are sourced from the Global Trade Analysis Project (GTAP) database, which can be considered universal but is also a limitation of the analysis. The GTAP elasticities for commodity items were averaged using export or import volumes to align with the commodity groups and sectors in the Belarusian model.

4. CGE model-based simulations for Belarus

4.1 Simulations design

The developed CGE model has been used to simulate three scenarios relevant to Belarus.

Scenario 1 "Energy Shock" assumes a sharp increase in the prices of energy resources imported by Belarus, i.e. natural gas and oil. Since 2018, Belarus has been importing natural gas from Russia at a contractual price close to 130 USD per thousand cubic meters. In 2023–2025, the actual import price of gas was lower due to the weakening of the Russian ruble against the US dollar. For comparison, according to the World Bank, the average monthly price of natural gas in Europe was about 388 USD per thousand cubic meters in 2024 and 450 USD in January–August 2025. If Belarus moves closer to the EU and exits the EAEU, the country's import gas price would very likely rise to the European level, regardless of the source of supply. This would mean a powerful shock, roughly equivalent to a threefold increase in the import price of natural gas.

Belarus also imports oil exclusively from Russia, at a price corresponding to Urals crude. Due to the widened discount of Russian Urals relative to the global Brent benchmark since 2022, Belarus received an additional benefit equal to this discount during 2022–2025. In the simulation of the energy shock scenario, it is assumed that Belarus's oil import price rises by the size of the discount, which is roughly equivalent to a 10% increase. Considering the value volumes of oil and natural gas imports, the overall external price increase for the product group "oil & gas, petroleum products" will amount to 60%.

In addition to rising import prices, Scenario 1 also assumes the elimination of interbudgetary transfers between Belarus and Russia. These transfers are primarily connected to obligations within the EAEU, as well as the inflow of reverse excise taxes on crude oil from the Russian budget into the Belarusian budget. Eliminating such transfers seems reasonable in the event of Belarus moving closer to the EU.

Scenario 2 "Integration with the EU" assumes active alignment between Belarus and the EU in the trade of goods. Currently, Belarus and Russia are members of the EAEU and apply zero import tariffs, while tariffs for other countries are set in accordance with EAEU regulations. To simulate the EU integration scenario, it is assumed that import tariffs on goods from the EU to Belarus are reduced to zero, while tariffs for other countries are set equal to the EU's 2021 weighted average tariffs. The year 2021 is used for analysis because, starting from 2022, EU sanctions on Russia and Belarus were significantly tightened, affecting mostly export-import operations. Table 1 presents the resulting changes in Belarus's import tariffs, which were subsequently used in the simulation.

Scenario 2 also assumes a reduction in external prices for Belarusian goods on the Russian market by an amount equal to Belarus's current tariffs on imports from the EU (the same as the tariff reduction with the EU in Table 1). This change reflects the likely imposition of import tariffs on Belarus by Russia should Belarus reorient itself toward the EU. No similar changes were assumed for export prices in the EU market, as there is a significant risk of overestimating the positive effects of trade liberalization with the EU, given the lack of competitiveness of Belarusian producers. Scenario 2 also stipulates the elimination of interbudgetary transfers between Belarus and Russia, similar to the energy shock scenario.

Scenario 2 assumes no increase in external prices for natural gas and oil. This would be possible if political agreements are reached with Russia or if global and European energy prices decline accordingly.

Table 1: Change in import tariffs for Belarus (p.p.)

	Russia	EU	China	Rest
Agriculture	7.9	-5.9	-0.6	2.2
Minerals	0.0	-6.6	-4.8	-0.5
Oil & gas, petroleum	0.0	-4.7	-4.5	-4.6
Food	5.3	-9.9	12.6	4.0
Textile & wood	1.5	-7.0	2.6	-3.8
Chemicals, rubber, pharma	3.9	-4.8	0.4	-1.6
Metals	1.1	-6.3	-4.2	-0.3
Electronics	1.9	-2.1	-0.8	-2.2
Machinery nec	1.9	-2.1	-0.8	-2.2
Motor vehicles	2.8	-8.3	-2.5	-5.4
Manufactures nec	1.0	-4.7	-5.8	-2.2
Utilities	1.9	-2.1	-0.8	-2.2

Source: compiled by the authors based on World Bank WITS data

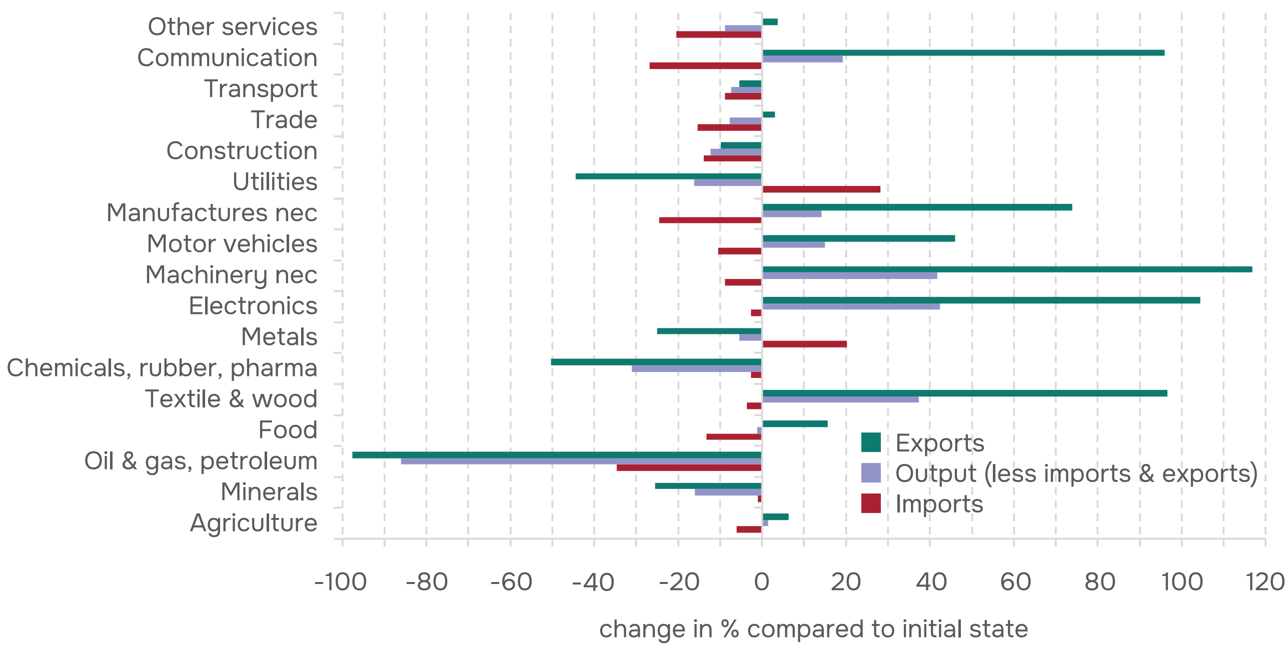
Scenario 3 "Integration with the EU under the energy shock" is a combination of Scenarios 1 and 2. Thus, Scenario 3 incorporates all the shocks from the first and second scenarios. This scenario appears to be the most likely one if Belarus moves closer to the EU and exits the EAEU.

4.2 Scenario 1 "Energy shock"

A 60% increase in the import prices of energy resources leads to a 35% decrease in their import volumes. Domestic production of petroleum products and their export practically cease to exist – the country's demand for fuel and energy resources is met exclusively through imports (Figure 2). The near elimination of domestic petroleum product production under such a severe price shock indicates that the viability of this sector in Belarus was primarily sustained by the redistribution of oil rent from Russia to Belarus through subsidized oil prices.

A significant increase in energy prices will have a strongly negative impact on industries related to the primary processing of raw materials. The chemical industry (where fertilizer production dominates in Belarus), the production of plastics and rubber products, metallurgy, extraction of non-oil-and-gas natural resources, and the manufacture of other non-metallic products (primarily construction materials), as well as power generation and water supply (utilities), will suffer significant losses in output and exports. Due to the substantial intersectoral effects generated by the oil refining industry, the output volume of wholesale trade, transportation, and other services will also decline. A decrease in construction materials output is also connected to a downturn in construction (Figure 2).

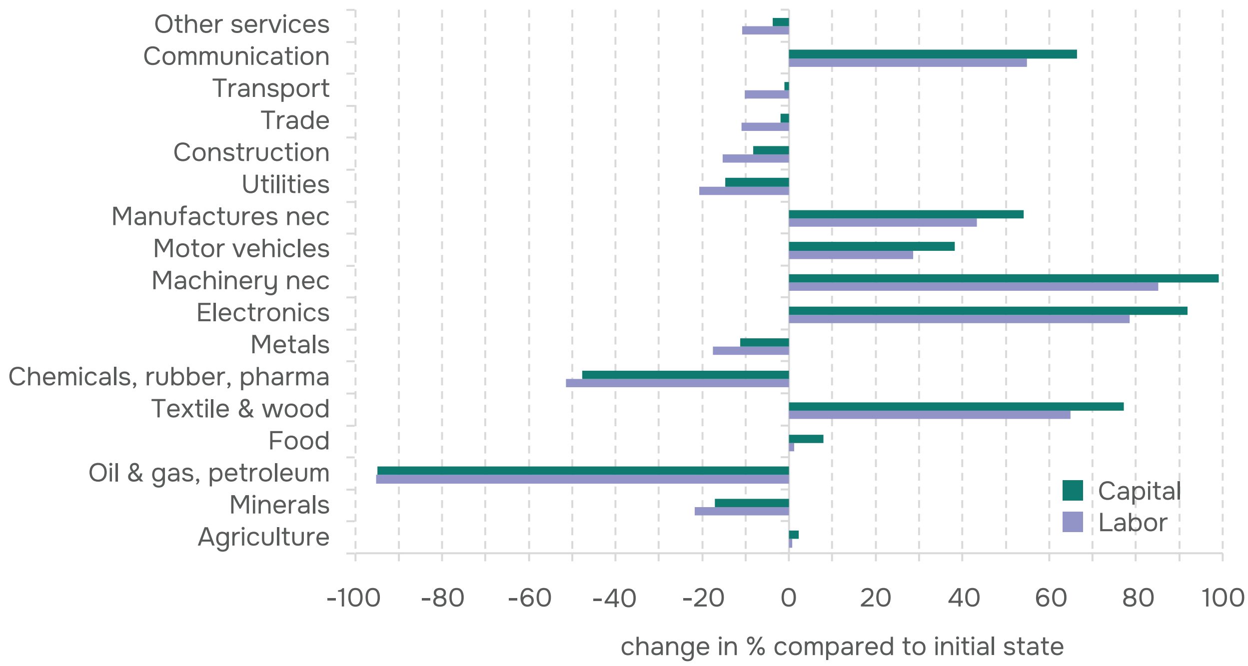
Figure 2: Exports, imports, and domestic production: results of scenario 1 simulation



Source: compiled by the authors

Labor and capital resources from the "losing" industries will be reallocated to sectors with higher export potential (Figure 3). Output and exports will increase significantly in mechanical engineering (including electronic, electrical, and optical devices, machinery and equipment), transportation vehicles, light industry (textile, clothing, and footwear production), woodworking, communication and computer services (Figure 2).

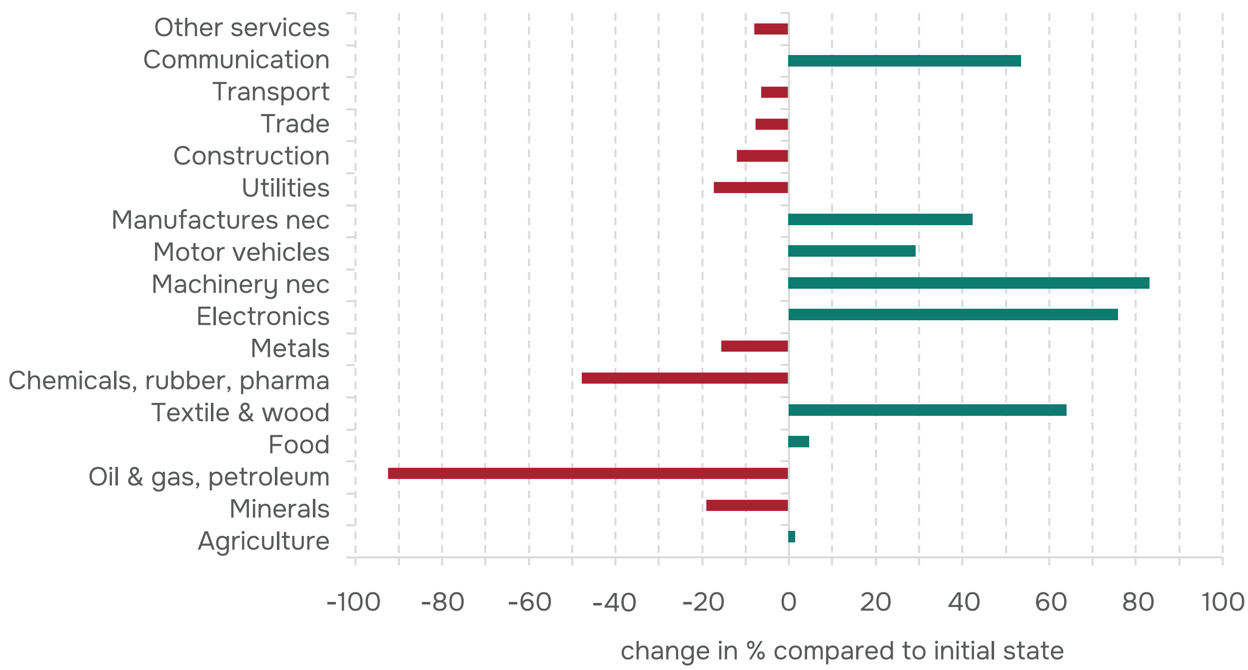
Figure 3: Factors of production: results of scenario 1 simulation



Source: compiled by the authors

As a result, under a severe energy shock, two groups of industries can be distinguished. The oil, gas, and petroleum products sector, extraction of other minerals, production of other non-metallic products, metallurgy, chemical industry, manufacture of rubber and plastic products, power generation and water supply, construction, trade, transportation, and other services will suffer substantial losses (Figure 4). These industries generally produce low- or medium-technology products.

Figure 4: Sectoral value added: results of scenario 1 simulation



Source: compiled by the authors

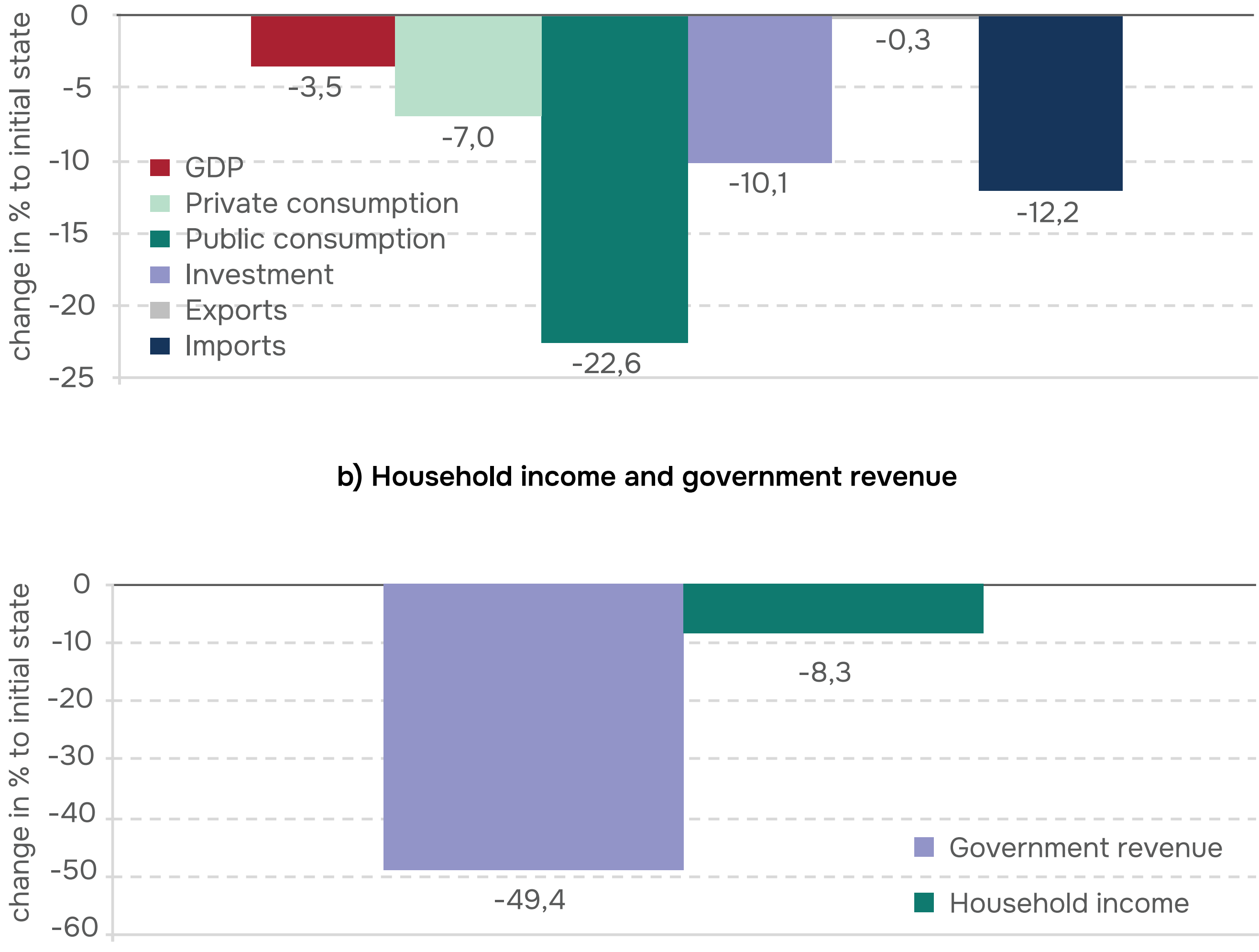
At the same time, due to their export potential, lower dependence on oil and gas, and the inflow of labor and capital resources, sectors such as mechanical engineering, light industry, woodworking, other kinds of manufacturing (mostly furniture production), and information and communications, have the potential for a significant increase in value added (Figure 4). The benefiting sectors are, for the most part, more technologically advanced than the "losing" industries.

The macroeconomic effects of an implemented energy shock scenario will be reflected in declines in government and household income due to unfavorable price effects, loss of interbudgetary transfers from Russia, and reduced volumes of foreign trade operations. As a result, both public and private consumption and investment will decrease. The resulting GDP losses are estimated at 3.5% relative to the baseline period's real GDP (Figure 5). Thus, a sharp increase in the import price of oil and gas by an average of 60% will lead to large-scale but not critical welfare losses for Belarus.

Figure 5: GDP, government and household income: results of scenario 1 simulation

a) GDP and components

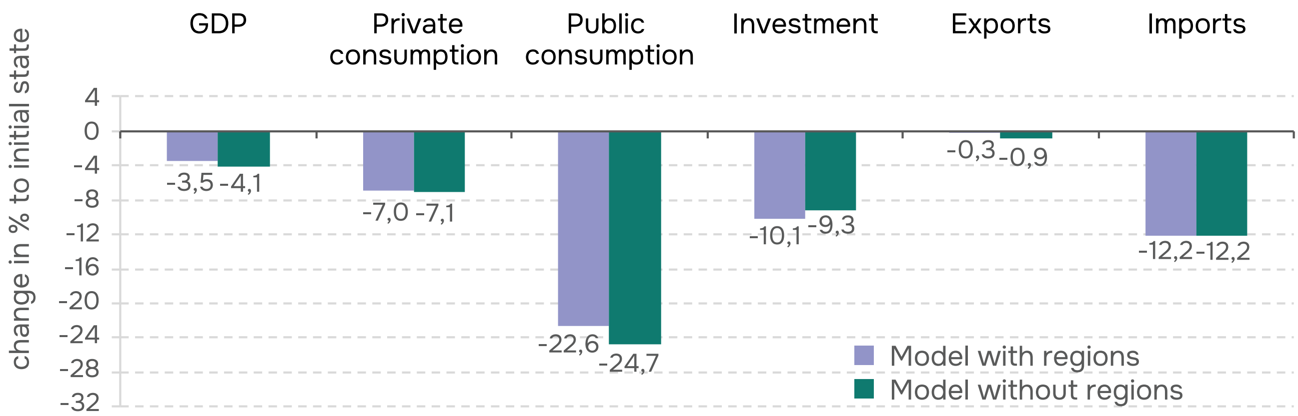
b) Household income and government revenue



Source: compiled by the authors

The macroeconomic consequences of simulating the energy shock scenario using an alternative model (22 sectors, without separate trading partners) are generally close to those of the baseline model (Figure 6). A sharp rise in energy prices, combined with the loss of interbudgetary transfers from Russia, leads to a significant reduction in government and household income and consumption. Investment resources shrink, resulting in a substantial decline in investments. Imports fall by 12%, while exports remain almost unchanged as production factors shift into the export-oriented sectors of the economy. The resulting effect on GDP is a 4.1% reduction relative to the baseline year's real volume (Figure 6).

Figure 6: GDP and components: comparison of models for scenario 1 simulation

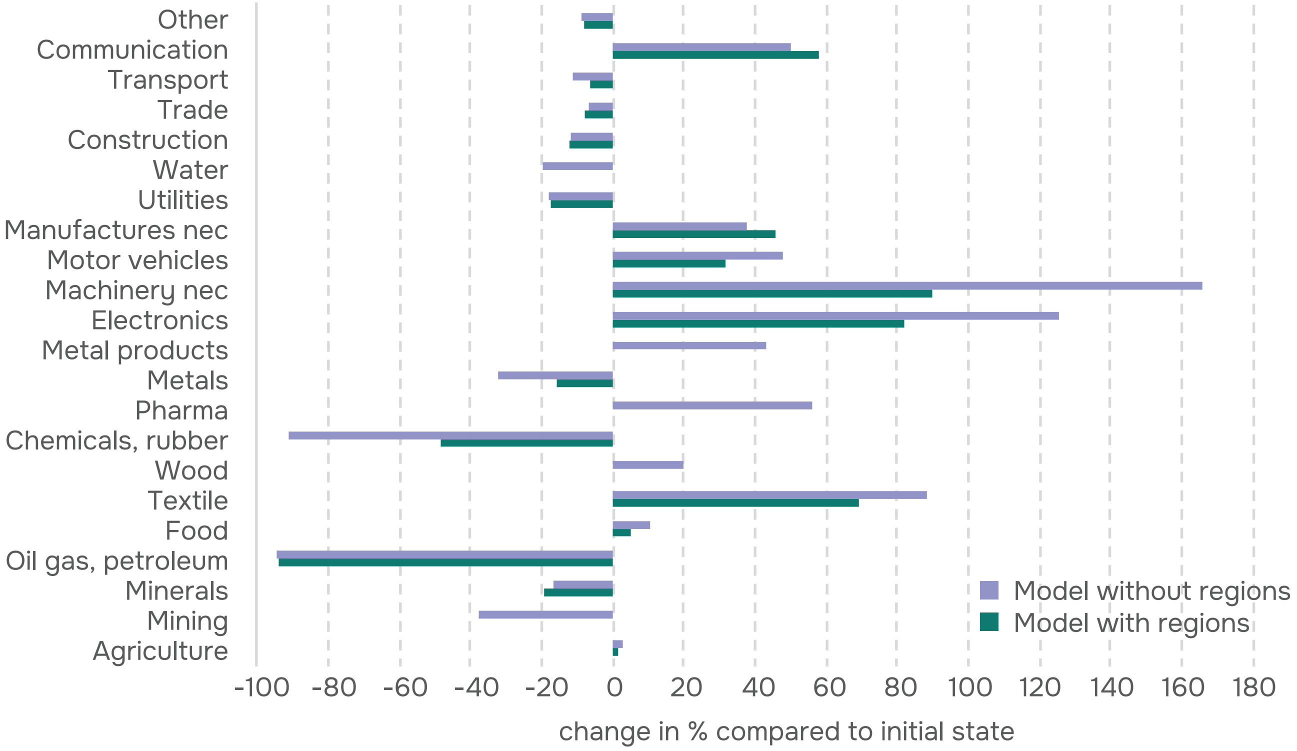


Source: compiled by the authors

The "losing" industries are still those less technologically advanced and related to the primary processing of raw materials: the oil and gas sector, power generation and water supply, chemical industry, production of rubber and plastic products, extraction of non-oil-and-gas minerals, manufacture of other non-metallic products, and metallurgy. Due to the significant intersectoral effects caused by these industries, value added also decreases in construction, trade, transport, and other services (Figure 7).

The "winning" industries are those technologically advanced and export-oriented: mechanical engineering, light industry, woodworking, other kinds of manufacturing, and, to a lesser extent, food industry. The information and communications sector also shows significant potential for value added growth. Moreover, the greater sectoral disaggregation of the alternative model makes it possible to identify two additional industries with potential for output growth: production of fabricated metal products and pharmaceuticals. This result once again proves the fact that with a significant increase in energy costs and losses from raw material exports, labor and capital resources shift into more sophisticated sectors with higher value added. That is why metallurgy and the chemical industry (connected to fertilizer production) suffer economic losses, while the production of fabricated metal products and pharmaceuticals can increase output (Figure 7).

Figure 7: Sectoral value added: comparison of models for scenario 1 simulation



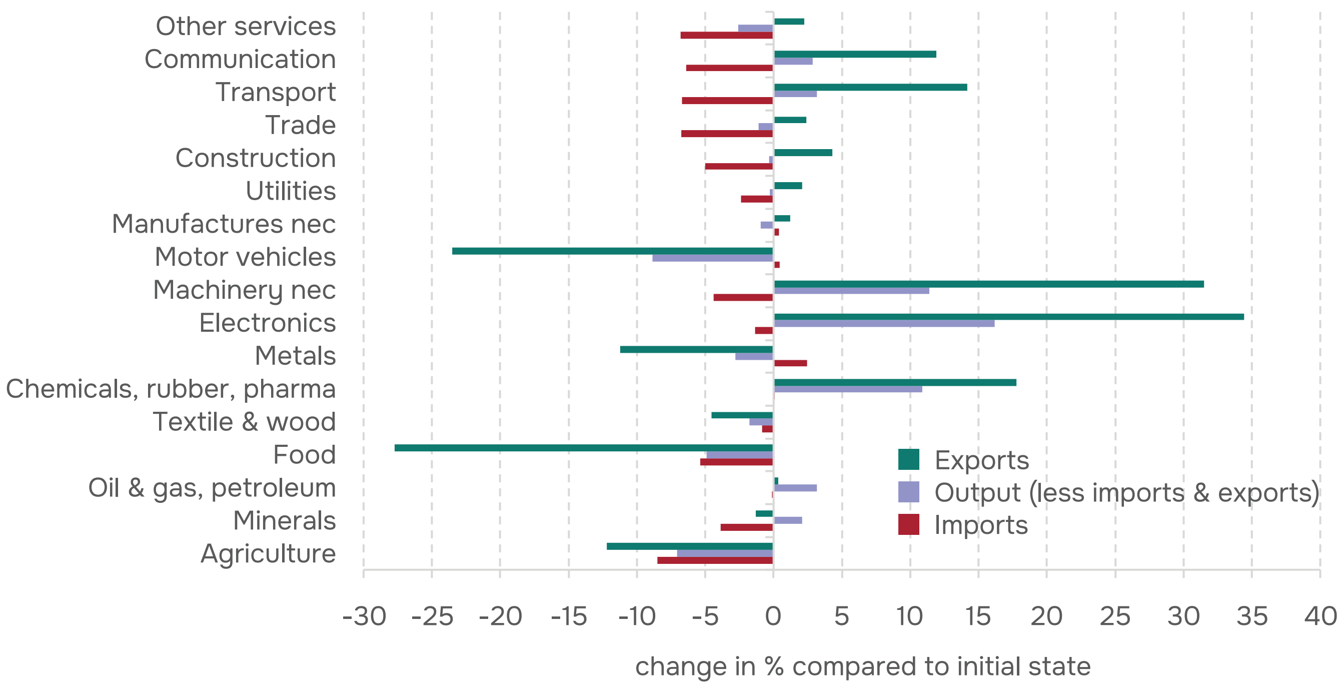
Source: compiled by the authors

4.3 Scenario 2 "Integration with the EU"

The results of the scenario involving trade liberalization between Belarus and the EU, combined with higher import tariffs on supplies from Russia, show that, same as in the energy shock scenario, the mechanical engineering and ICT sectors have the potential to increase output and exports (Figure 8), reflecting their higher capacity to integrate into European markets and adapt to new competitive conditions. The chemical industry and transportation services also have the potential to increase output and exports (Figure 8).

The outsiders in the simulation of this scenario are the food industry, agriculture, metallurgy, and vehicle production (Figure 8), which are currently heavily oriented toward the Russian market and would likely face difficulties adjusting to EU competition and new trade barriers with Russia.

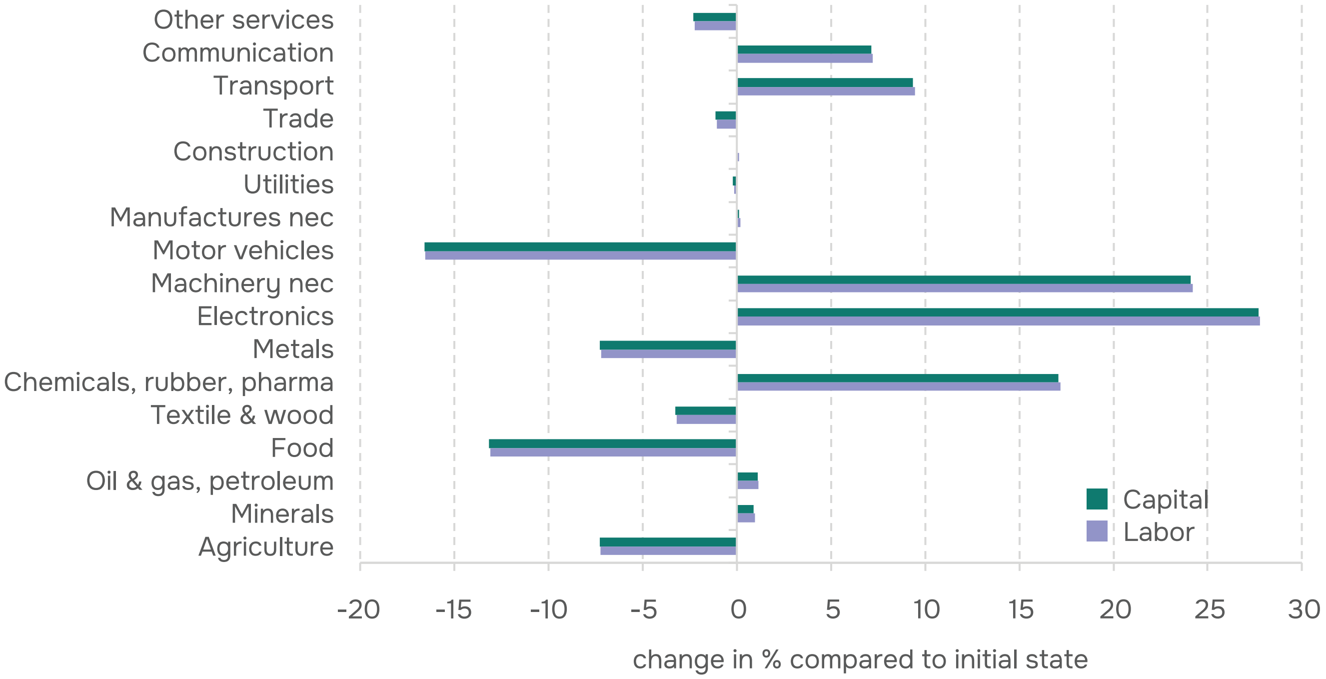
Figure 8: Exports, imports, and domestic production: results of scenario 2 simulation



Source: compiled by the authors

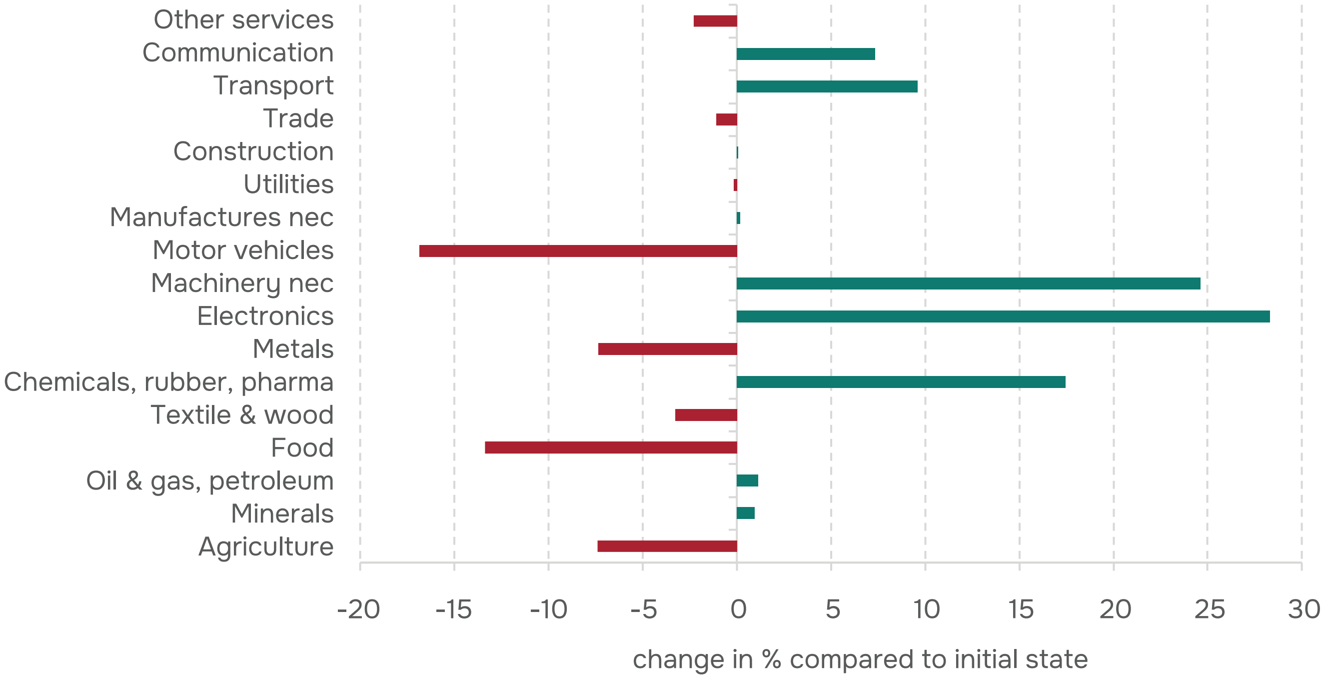
As a result, labor and capital resources flow from the "losing" industries (agriculture, food industry, metallurgy, vehicle production) into the benefiting industries – mechanical engineering, chemical industry, transportation, and ICT (Figure 9). The value added of the economic sectors changes accordingly (Figure 10).

Figure 9: Factors of production: results of scenario 2 simulation



Source: compiled by the authors

Figure 10: Sectoral value added: results of scenario 2 simulation

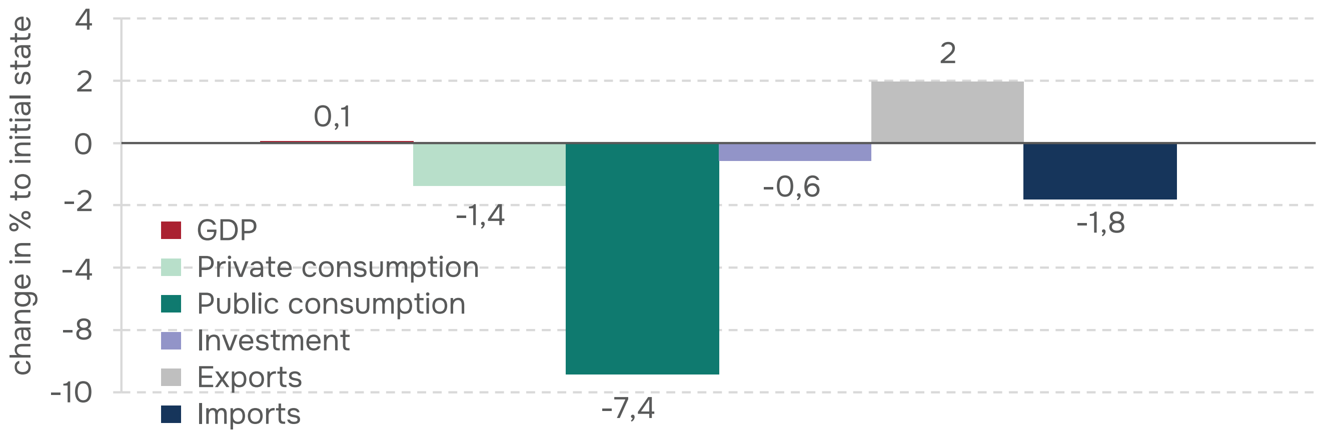


Source: compiled by the authors

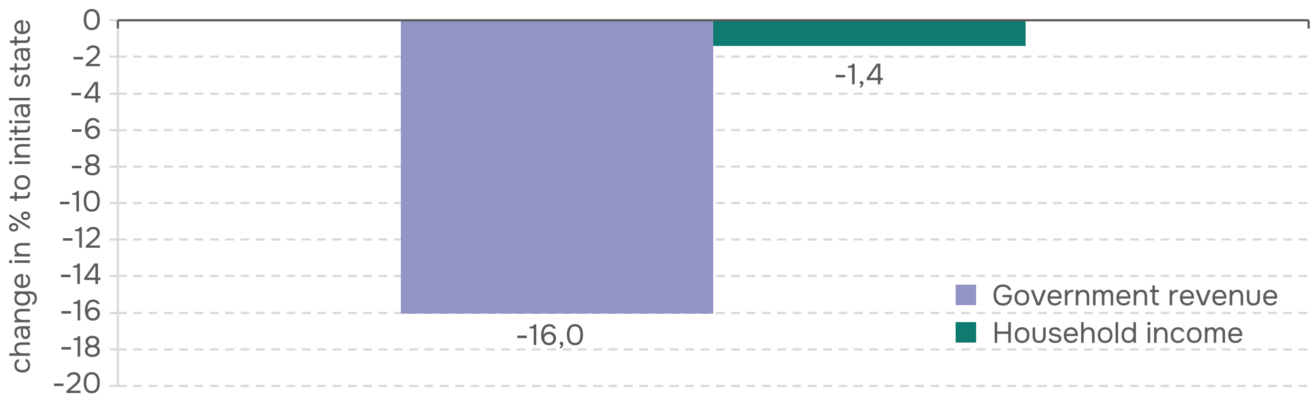
The effects on GDP caused by Belarus's trade reorientation from Russia toward the EU (assuming no energy shock) are expected to be neutral in the long run (Figure 11). Government revenues will decline mainly due to the loss of interbudgetary transfers from Russia, which will reduce public sector consumption. Household income and consumption, as well as investment, will also slightly decrease due to sectoral losses from the increasing complexity of trade with Russia. However, with net exports improved due to the development of export-oriented industries with higher value added, the resulting change in GDP is estimated to be near zero (Figure 11).

Figure 11: GDP, government and household income: results of scenario 2 simulation

a) GDP and components



b) Household income and government revenue

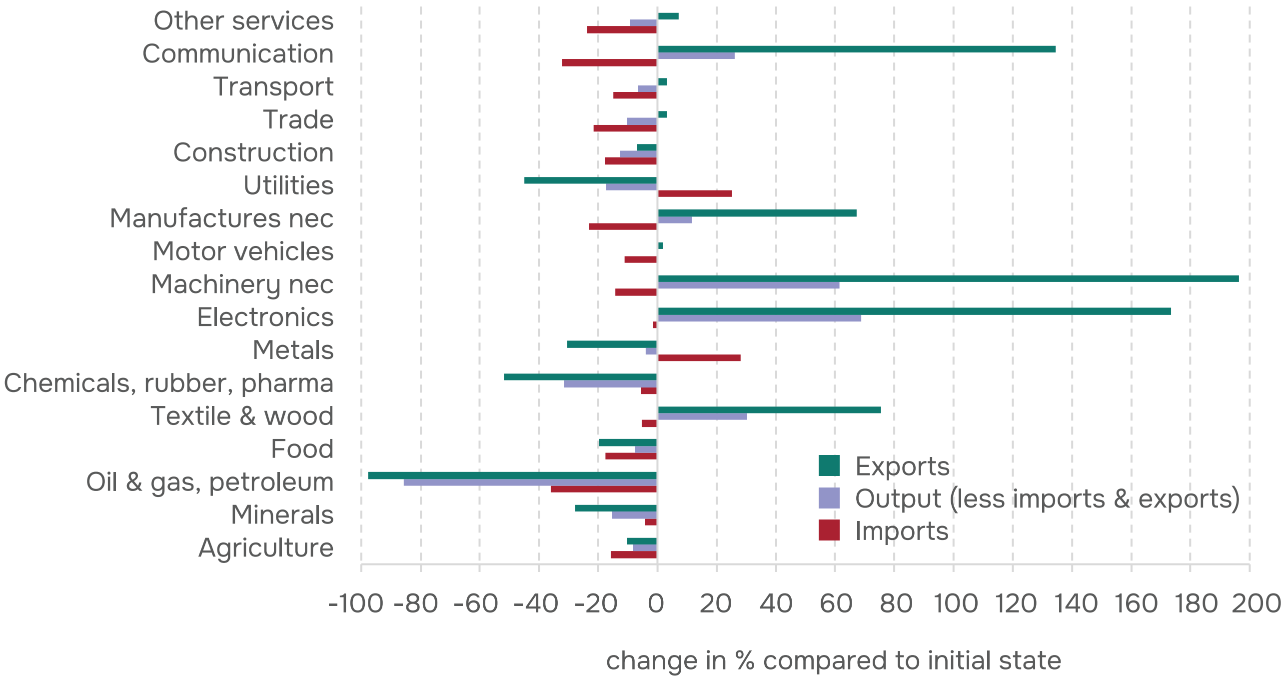


Source: compiled by the authors

4.4 Scenario 3 “Integration with the EU under an energy shock”

The liberalization of trade in goods with the EU, combined with a significant increase in oil and gas import prices for Belarus, generally has sectoral consequences similar to the first scenario. Domestic production and exports of petroleum products practically cease to exist, while the country’s demand for energy resources is met entirely through imports (Figure 12).

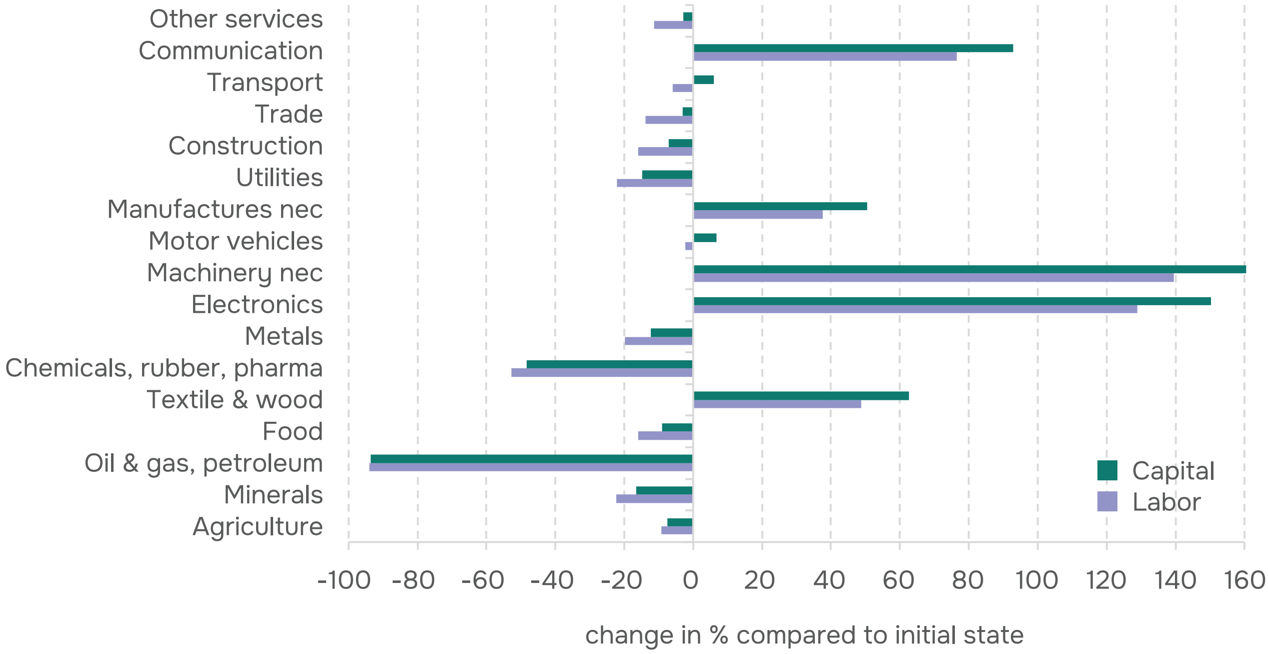
Figure 12: Exports, imports, and domestic production: results of scenario 3 simulation



Source: compiled by the authors

The outsiders are industries engaged in the primary processing of raw materials, for which fuel resources are highly significant: the chemical industry, production of plastic and rubber products, metallurgy, extraction of non-oil-and-gas minerals, and production of other non-metallic products (Figure 12). Output also declines in the power and water supply sectors, construction and trade. Agriculture and food industry also suffer losses in output, value added and exports due to their dependence on the Russian market (Figures 12 and 14).

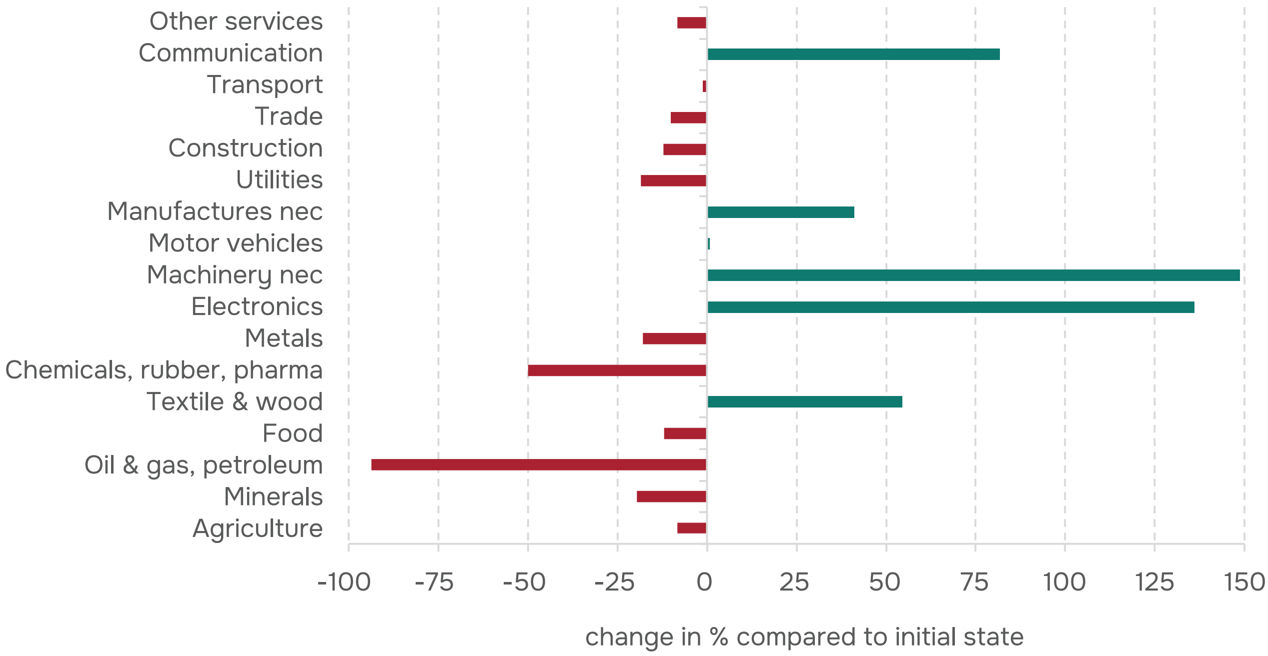
Figure 13: Factors of production: results of scenario 3 simulation



Source: compiled by the authors

Labor and capital resources from the predominantly low- or medium-technology industries mentioned above flow into sectors with higher value added and export potential (Figure 13).

Figure 14: Sectoral value added: results of scenario 3 simulation



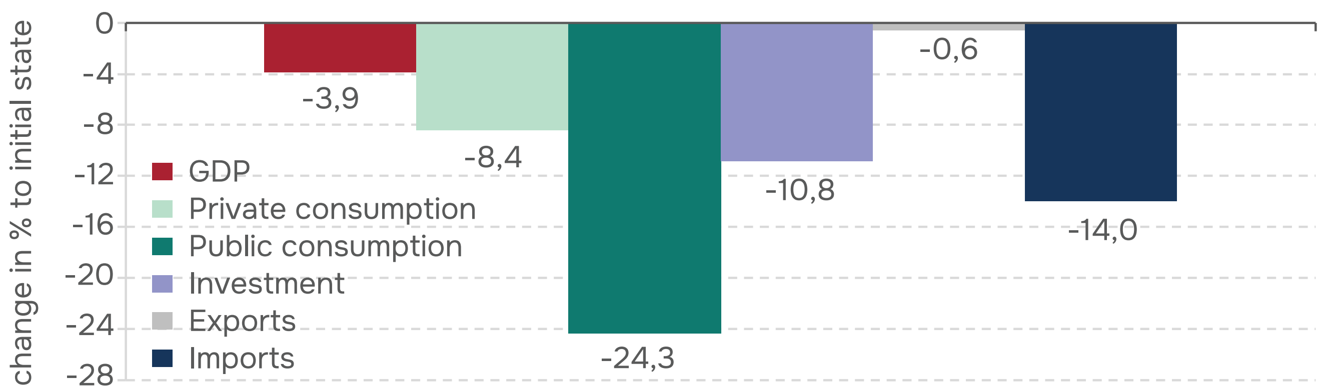
Source: compiled by the authors

As a result, the pool of beneficiaries remains roughly the same as in the simulations of Scenarios 1 and 2. Output, exports, and value added increase in the sectors of mechanical engineering, other kinds of manufacturing, light industry, woodworking, and information and communications (Figures 12 and 14). Notably, these industries expand production and exports while reducing imports, which indicates a decline in their import intensity.

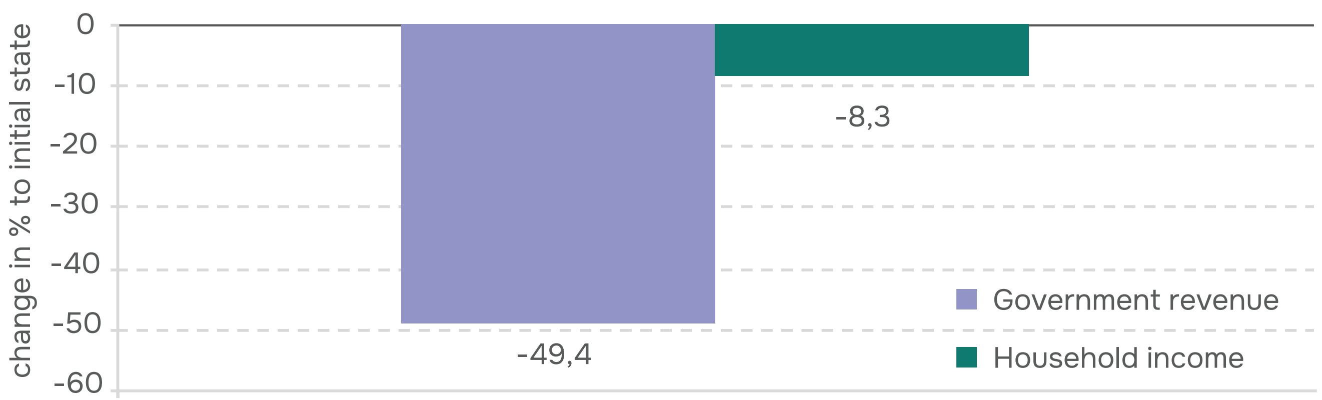
The macroeconomic effects of Belarus's trade liberalization with the EU and complication of its trade relations with Russia under an energy shock will be reflected in declining government and household income, which will result in reduced public and private consumption and investment (Figure 15). As a result, GDP will reduce by 3.9% in the long run.

Figure 15: GDP, government and household income: results of scenario 3 simulation

a) GDP and components



b) Household income and government revenue



Source: compiled by the authors

A comparison of the simulation results across different scenarios allows to draw the following conclusions.

Firstly, Belarus's energy and trade dependence on Russia creates significant risks for the country's macro-economic stability. A deterioration in the terms of trade in energy resources would lead to a sharp decline in household welfare and a reduction in GDP (Table 2).

Table 2: Comparison of scenarios (change in % compared to the initial situation)

	Scenario 1	Scenario 2	Scenario 3
GDP	**-3.5**	**0.1**	**-3.9**
Private consumption	-7.0	-1.4	-8.4
Public consumption	-22.6	-7.4	-24.3
Investment	-10.1	-0.6	-10.8
Exports	-0.3	2.0	-0.6
Imports	-12.2	-1.8	-14.0
Government revenue	**-49.4**	**-16.0**	**-54.2**
Household income	**-8.3**	**-1.4**	**-9.8**

Source: compiled by the authors

Secondly, the near-total orientation of several large sectors of the Belarusian economy toward the Russian market will result in economic losses if Belarus reorients toward the EU. If liberalization of trade with the EU and complication of trade with Russia are not accompanied by an increase in factor productivity, the economic effectiveness of such a strategy for Belarus will remain debatable.

Thirdly, the Belarusian economy does have certain resilience even to severe energy and trade shocks. With the reallocation of labor and capital resources from the industries producing raw materials into sectors with higher levels of technology and value added, losses in household welfare and GDP would be significant but not catastrophic (Table 2). However, the large-scale intersectoral flows of labor highlight the need to develop social support and retraining measures for the population in advance.

5. Economic support from the EU: potential effects and policy implications

The EU may activate a large aid package for Belarus once the country embarks on a path of democratic transition. The EU Commission has stated that it will provide both immediate and long-term support to help stabilize the economy and reform institutions, making them more democratic and capable of benefiting citizens and society as a whole (EU Commission, 2021).

The EU intends to support five key areas:

1. An innovative and competitive economy (macro-financial assistance of up to €350 million).

2. Improved transport connectivity and facilitation trade at the EU–Belarus borders (up to €200 million).

3. Boosting innovation and digital transformation (up to €20 million).

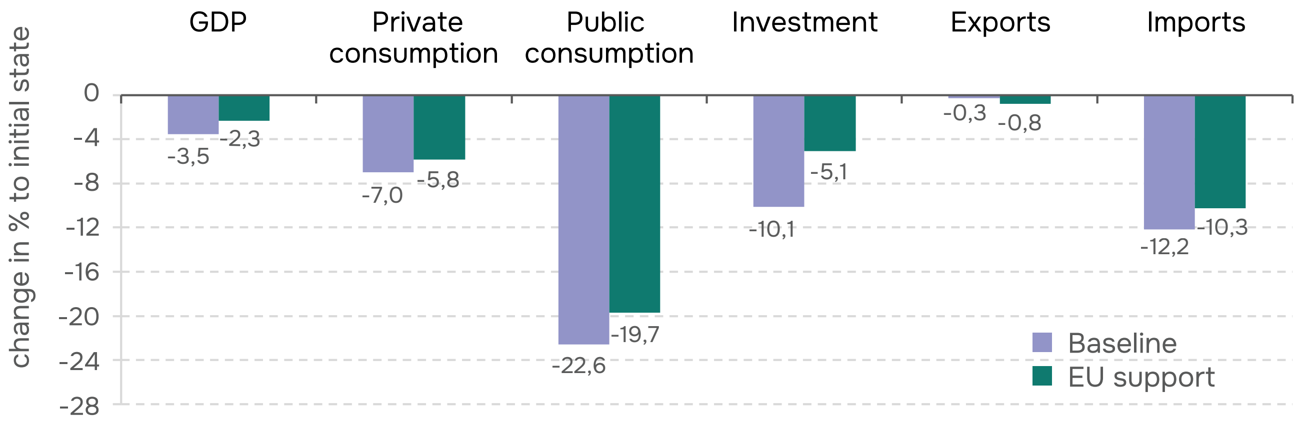
4. Supporting a green economy (up to €200 million).

5. Investing in a democratic, transparent, and accountable Belarus (up to €100 million).

Economic support from the EU could partially offset the negative consequences of an energy shock for Belarus. To assess this compensatory effect, additional simulations were carried out. Support in the first area is accounted for in the scenario as an increase in the EU transfers to the Belarusian government. Half of this aid is assumed to be directed to investment, leading to an increase in the capital stock, while the other half will be redistributed to households. Support in the second and fourth areas is modeled as an increase in the EU savings (directly leading to higher investment in Belarus), combined with a corresponding increase in the capital stock of the Belarusian economy. Support in the third and fifth areas is modeled as an increase in transfers from the EU to the Belarusian government. Overall, the simulation scenario accounts for the EU's €870 million in assistance.

The results of simulating the energy shock scenario with the EU's financial support indicate that €870 million in European aid can offset approximately 1.2 p.p. of Belarus's GDP decline (Figure 16). This is achieved mainly due to a smaller reduction in household consumption and investment compared to the baseline scenario – by 1.2 p. p. and 5.1 p. p., respectively. At the same time, net exports decline compared to the baseline scenario due to a relative increase in imports, given the high initial import intensity of investment and consumption in Belarus.

Figure 16: Effects of EU's economic support: results of scenario 1 simulation

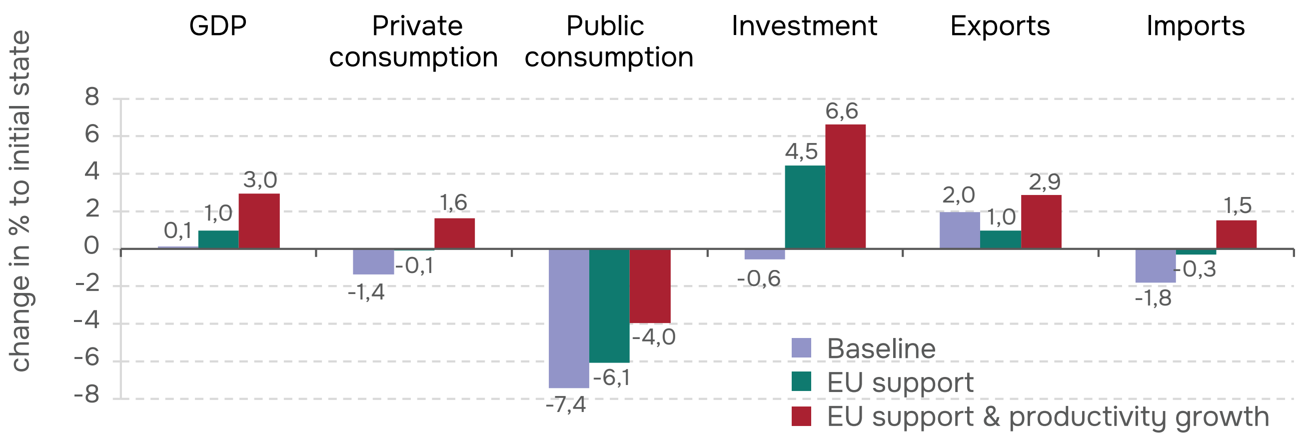


Source: compiled by the authors

When modeling the effects of the EU's economic support under scenarios 2 and 3, an additional assumption was considered: a 2% increase in factor productivity. The integration of Belarusian producers into European value chains and the likely transfer of advanced technologies could contribute to improving the efficiency of the Belarusian economy. The productivity increase of 2% assumed in the simulation is modest and largely conditional. The purpose of simulating such a scenario is to demonstrate the direction of the economic consequences of effectively implementing the EU's integration strategy rather than to obtain precise quantitative estimates of GDP and changes in other macroeconomic indicators.

The results of simulating scenarios 2 and 3 with the EU's assistance generally correspond to those from scenario 1. Without assuming factor productivity gains, EU's €870 million in financial support makes it possible to reduce GDP losses by mitigating the decline in private consumption and investment (Figures 17 and 18).

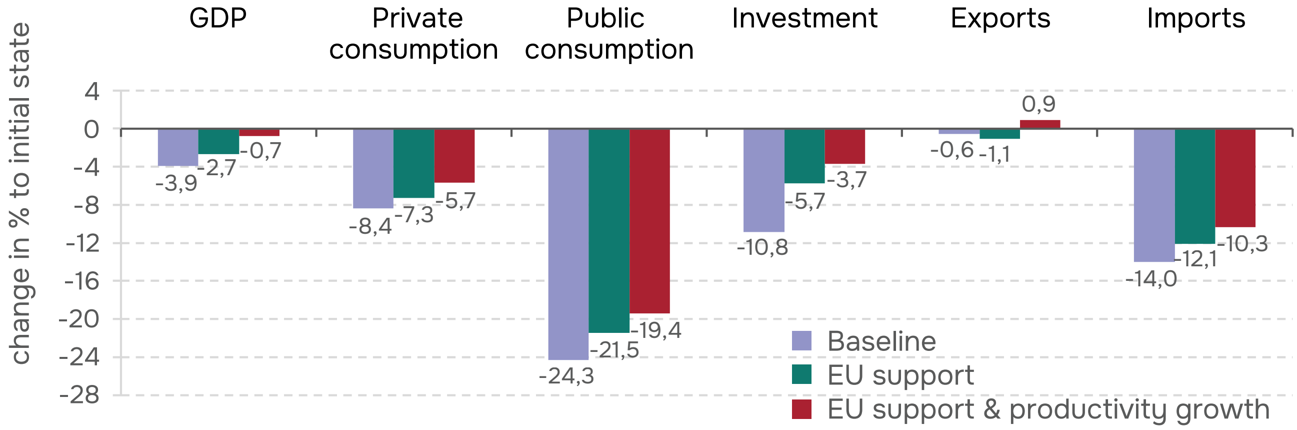
Figure 17: Effects of EU's economic support: results of scenario 2 simulation



Source: compiled by the authors

If the liberalization of trade with the EU is accompanied by even a small increase in factor productivity, then, in the absence of an energy shock, Belarus will gain substantial benefits, despite complications in access to the Russian market. GDP and investments will grow significantly, and household consumption will also increase (Figure 17). If such liberalization occurs during an energy shock, the productivity gains will substantially mitigate the negative effects on GDP and citizens' welfare (Figure 18).

Figure 18: Effects of EU's economic support: results of scenario 3 simulation



Source: compiled by the authors

These findings carry the following policy implications:

1. Integration into European value chains should be accelerated. Removing barriers to the participation of Belarusian firms in EU production networks would offset the costs of disintegration from Russia and create long-term growth potential. Access to EU markets, standards, and technologies would provide Belarus with a sustainable alternative growth model.

2. Financial support should focus on productivity. Direct EU's financial assistance can play a decisive role in offsetting GDP and welfare losses. However, to achieve lasting results, such support should be targeted toward raising factor productivity through investments in human capital, digitalization, and modern infrastructure. In scenarios without energy shocks, this could lead not only to recovery but to growth in GDP and household welfare.

3. Energy support is essential. Targeted subsidies or preferential financing for energy imports during the initial adjustment period would mitigate the large-scale negative effects of rising prices, preventing sudden collapses in key industries and ensuring social stability.

4. Social cushioning is required. The transition will inevitably involve sectoral losses and displacement of workers. EU's assistance should therefore also support retraining, labor mobility, and social protection mechanisms to ensure that adjustment costs do not translate into long-term social instability.

6. Conclusion

This study has proposed and tested the CGE model for Belarus. The model captures the structural features of the Belarusian economy, which remains highly dependent on Russian energy supplies, strongly connected to Russian markets, and only partially integrated into European production chains.

The application of the CGE model to the Belarusian economy has made it possible to conduct a systematic study of the potential consequences of different external shocks and integration scenarios. The model-based simulations highlight both vulnerabilities and opportunities for economic adjustment under scenarios of an energy shock and liberalization of trade with the European Union.

The first major finding concerns the impact of a severe energy shock, which is highly likely to follow if political relations between Belarus and Russia worsen. The simulations demonstrate that while such a shock would have a large-scale negative impact on output and consumption, it would not result in an existential collapse of the Belarusian economy. The most significant losses would be concentrated in the industries connected to the primary processing of raw materials – oil refining, metallurgy, mineral extraction and production of building materials, chemical industry, electric power, and water supply. These sectors are highly dependent on cheap imported natural gas and oil, and their competitive position would deteriorate sharply under significantly higher energy prices. The construction, transportation, and trade sectors will also suffer losses in value added due to significant intersectoral effects generated by the affected industries. Nevertheless, other industries, such as mechanical engineering, light industry, pharmaceuticals, and ICT, may benefit from the reallocation of production resources. This suggests that the economy exhibits structural resilience, where certain sectors are able to absorb resources and expand, even as traditional industries contract. In the medium term, this reallocation can mitigate the overall economic losses, although the transition process would be socially and politically challenging.

The second key finding concerns the liberalization of trade with the European Union under the assumption of stable energy supplies. Here, the model indicates relatively small overall welfare losses due to the negative effects of the complication of relations with Russia, but the distribution of effects across industries is uneven. The most vulnerable sectors would be the food industry, agriculture, metallurgy, and vehicle production, which are currently heavily oriented toward the Russian market and would probably face difficulties adjusting to EU competition and new trade barriers with Russia. By contrast, mechanical engineering and ICT emerge as potential winners, reflecting their higher capacity to integrate into European markets and adapt to new competitive conditions. Importantly, these outcomes highlight that the Belarusian economy would not uniformly benefit from or suffer under EU integration; rather, the gains and losses would depend critically on sectoral structures, trade patterns, and the ability of companies to adapt.

The scenario in which trade liberalization with the EU is combined with a severe energy shock will result in significant losses in both output and household welfare. A sharp rise in energy prices would exacerbate the vulnerability of energy-intensive industries, while the simultaneous deterioration of relations with Russia would undermine existing trade flows. The most severely affected sectors would include oil refining, energy supply, metallurgy, chemical industry, food industry, and services closely tied to industrial demand, such as construction and trade. However, some sectors could gain: mechanical engineering, light industry, woodworking, and ICT show the capacity to expand as production factors shift toward export-oriented activities with higher value added. This again highlights the structural heterogeneity of the Belarusian economy and the importance of identifying sectors with genuine long-term growth potential.

One source of uncertainty in Belarus's deeper integration with the EU and the complication of its relations with Russia is the movement of Russian capital, which is currently present in the Belarusian market (including the banking system, industry, and information and communication services). A certain degree of Russian capital outflow cannot be ruled out, which could have negative economic consequences in the short term. In the long term, Russian capital may be replaced by European capital.

From a policy perspective, these findings suggest several recommendations. Firstly, targeted energy subsidies from the European Union could play a crucial role in cushioning the immediate impact of higher energy prices. Such subsidies would prevent an abrupt collapse of energy-intensive industries and allow time for structural adjustment. Secondly, efforts to remove barriers to the participation of Belarusian firms in European value chains could significantly mitigate the adverse short-term effects of deteriorating trade relations with Russia. By facilitating access to new markets, technologies, and standards, integration into European supply chains could not only soften the transition but also enhance long-term competitiveness. Thirdly, direct financial support from the EU has the potential to offset a substantial part of GDP and welfare losses. If such support is strategically targeted to raise factor productivity, through investment in technology, human capital, and infrastructure, the result could be positive growth of both output and welfare, at least in scenarios without severe energy shocks. Fourthly, social safeguards are essential. A shift toward the EU will unavoidably bring sectoral declines and job displacements. EU's support should therefore extend to retraining programs, measures that promote labor mobility, and social protection systems, ensuring that the short-term adjustment costs do not lead to lasting social instability.

At the same time, it is essential to acknowledge the limitations of the CGE modeling applied in this study. Firstly, the data used to construct the benchmark equilibrium is incomplete and, in some cases, not fully up to date. Issues such as the aggregation of tariffs, absence of non-tariff barriers, and incomplete information on foreign transfers and trade flows reduce the precision of the results. Secondly, the key parameters, such as elasticities of substitution, are borrowed from GTAP rather than estimated directly for Belarus. This ad hoc calibration introduces uncertainty and reduces the extent to which the results reflect the unique structural characteristics of the Belarusian economy. Thirdly, the aggregation of sectors itself introduces potential biases: results may be sensitive to the level of disaggregation, and important in-sector heterogeneity may not be accounted for.

The structural assumptions of the CGE framework also impose constraints. The model assumes perfect competition, full utilization of resources, and frictionless adjustment. Similarly, the static nature of the model means that it cannot capture dynamic processes such as technological progress or expectations of households and companies. The absence of a financial sector is another important drawback, particularly in an economy where monetary and exchange rate policies play a central role. As a result, while the model provides useful insights into the direction and relative magnitude of impacts, it should not be interpreted as a precise forecasting tool.

Despite these limitations, the CGE model remains a valuable instrument for policy analysis. It offers a consistent and transparent framework for evaluating complex interactions among sectors, households, and external shocks. For a small, open, and structurally dependent economy like Belarus's, such tools are essential for assessing the trade-offs of alternative policy choices. The results highlight both the risks caused by external shocks – particularly energy shocks and complications of trade with Russia – and the potential opportunities of gradual integration into the European economic space. They also emphasize the importance of carefully designed compensatory policies, including targeted subsidies, integration support, and financial assistance to enhance productivity.

The developed CGE model makes one step toward a deeper understanding of these processes and policies, and future work should aim to refine the database, estimate country-specific parameters, incorporate dynamic features, and explore the role of institutions and market frictions. Such efforts would enhance the robustness of the analysis and provide even more relevant guidance for policymakers facing the challenges of integration, adjustment, and development. Exploring the potential effects of Belarus's rapprochement with the EU is also an important area for further research.

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Appendix A

Description of equations in the CGE model for Belarus

Appendix A introduces the equations of the CGE model and calibrations of exogenous parameters. In calibration, the index 0 indicates the initial value of a variable from SAM.

Activities

The intermediate consumption of product i by sector j is described by the Leontief production function:

$$IO_{i,j} = \theta_{i,j}^{IO} q_j^{IO}, \tag{1}$$

where $\theta_{i,j}^{IO}$ is the share of product i used in intermediate consumption by sector j, an exogenous parameter with the following calibration:

$$\theta_{i,j}^{IO} = \frac{IO_{i,j}^{0}}{q_j^{IO0}}, \tag{2}$$

q_j^{IO} is the volume of intermediate consumption by sector j.

The breakeven condition for intermediate consumption by sector j:

$$p_j^{IO} q_j^{IO} = \sum_{i=1}^{N} p_i IO_{i,j}, \tag{3}$$

where p_j^{IO} is the price of intermediate consumption by sector j (equal to 1 in the initial state),

p_i is a consumer price of product i (equal to 1 in the initial state).

Intermediate consumption in the production of sector j – Leontief function:

$$q_j^{int} = \theta_j^{int} q_j^A, \quad (4)$$

where θ_j^{int} is the share of intermediate consumption in the production of sector j, an exogenous parameter with the following calibration:

$$\theta_j^{int} = \frac{q_j^{IO0}}{q_j^{A0}}, \quad (5)$$

q_j^A is the volume of production of sector j.

Value added in the production of sector j – Leontief function:

$$q_j^{VA} = \theta_j^{VA} q_j^A, \quad (6)$$

where θ_j^{VA} is the share of value added in the production of sector j, an exogenous parameter with the following calibration:

$$\theta_j^{VA} = \frac{q_j^{VA0}}{q_j^{A0}}, \quad (7)$$

Breakeven condition for sector j's production:

$$\left(1 - t_j^A\right) p_j^A q_j^A = p_j^{VA} q_j^{VA} + p_j^{IO} q_j^{IO}, \quad (8)$$

where t_j^A is a production tax rate for sector j, an exogenous parameter with the following calibration:

$$t_j^A = \frac{SAM(tax^A, j)}{SAM(Total, j)}, \quad (9)$$

p_j^A is a basic price in sector j (equal to 1 in the initial state).

Factors market

The distribution of production factors' utilization in sector j is based on the CES production function:

$$q_j^{VA} = A_j \left[\delta_j L_j^{\frac{\varepsilon_j - 1}{\varepsilon_j}} + (1 - \delta_j) K_j^{\frac{\varepsilon_j - 1}{\varepsilon_j}} \right]^{\frac{\varepsilon_j}{\varepsilon_j - 1}}, \tag{10}$$

where δ_j is the share of labor's factor, an exogenous parameter with the following calibration:

$$\delta_j = \frac{w_{L0} L_{0j}^{\frac{1}{\varepsilon_j}}}{\left(w_{L0} L_{0j}^{\frac{1}{\varepsilon_j}} + w_{K0} K_{0j}^{\frac{1}{\varepsilon_j}} \right)}, \tag{11}$$

A_j is an exogenous parameter of production factors' allocation efficiency with the following calibration:

$$A_j = \frac{q_{0j}}{\left(\delta_j L_j^{0 \frac{\varepsilon_j - 1}{\varepsilon_j}} + (1 - \delta_j) K_j^{0 \frac{\varepsilon_j - 1}{\varepsilon_j}} \right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}}}, \tag{12}$$

L_j is a volume of labor used by sector j,

w_L is a price of labor (equal to 1 in the initial state),

K_j is a volume of capital used by sector j,

w_K is a price of capital (equal to 1 in the initial state),

ε_i is elasticity of factors' substitution, set exogenously.

According to the abovementioned CES production function:

Condition for efficiency maximization of labor utilization in sector j:

$$L_j = \frac{q_j}{A_j} \left(\frac{\delta_j}{w_L} \right)^{\varepsilon_j} \left[\delta_j^{\varepsilon_j} w_L^{1 - \varepsilon_j} + (1 - \delta_j)^{\varepsilon_j} w_K^{1 - \varepsilon_j} \right]^{\frac{\varepsilon_j}{1 - \varepsilon_j}}, \tag{13}$$

Condition for efficiency maximization of capital utilization in sector j:

$$K_j = \frac{q_j}{A_j}\left(\frac{1-\delta_j}{w_L}\right)^{\varepsilon_j}\left[\delta_i^{\varepsilon_j} w_L^{1-\varepsilon_j} + (1-\delta_j)^{\varepsilon_j} w_K^{1-\varepsilon_j}\right]^{\frac{\varepsilon_j}{1-\varepsilon_j}}. \tag{14}$$

Breakeven condition for production factors:

$$p_j^{VA} q_j^{VA} = w_L L_j + w_K K_j. \tag{15}$$

Commodities market

Condition for distribution of commodity i produced by sector j:

$$q_i^D = \sum_{j=1}^{N} \theta_{j,i} \; q_j^A, \tag{16}$$

Condition for setting a price of commodity i produced by sector j:

$$p_i^D = \sum_{j=1}^{N} \theta_{j,i} \; p_j^A, \tag{17}$$

where $\theta_{j,i}$ is the mapping coefficient, an exogenous parameter with the following calibration:

$$\theta_{j,i} = \frac{SAM_{j,i}}{q_j^{A0}}. \tag{18}$$

External sector

Commodity i's export price for country r is set as follows:

$$p_{i,r}^{ER} = \overline{pw_{i,r}^{ER}} EXR_r \tag{19}$$

$\overline{pw_{i,r}^{ER}}$ is commodity i's world export price for country r (equal to 1 in the initial state),

EXR_r is an exchange rate with country r (amount of foreign currency per unit of domestic currency, equal to 1 in the initial state).

Commodity i's distribution to country r is described by the CET function:

$$E_i = A_i^{ER} \left[\sum_{r=1}^{R} \delta_{i,r}^{ER} E_{i,r}^{R\;\frac{\varepsilon_i^{ER}-1}{\varepsilon_i^{ER}}} \right]^{\frac{\varepsilon_i^{ER}}{\varepsilon_i^{ER}-1}}, \tag{20}$$

where E_i is commodity i's export volume,

$E_{i,r}^{R}$ is commodity i's volume of export to country r,

$\delta_{i,r}^{ER}$ is the share of commodity i's export to country r, an exogenous parameter with the following calibration:

$$\delta_{i,r}^{ER} = \frac{p_{i,r}^{ER0} E_{i,r}^{R0\;\frac{1}{\varepsilon_i^{ER}}}}{\left(\sum_{rc=1}^{RC} p_{i,r}^{ER0} E_{i,r}^{R0\;\frac{1}{\varepsilon_i^{ER}}} \right)}, \tag{21}$$

A_i^{ER} is the efficiency of commodity i's export to country r, an exogenous parameter with the following calibration:

$$A_i^{ER} = \frac{E_{0i}}{\left(\sum_{r=1}^{N} \delta_{i,r}^{RE} E_{i,r}^{R0\;\frac{\varepsilon_i^{ER}-1}{\varepsilon_i^{ER}}} \right)^{\frac{\varepsilon_i^{ER}}{\varepsilon_i^{ER}-1}}}, \tag{22}$$

ε_i^{ER} is the elasticity of technical substitution of commodity i's export to country r, set exogenously.

According to the abovementioned function, maximization of distribution efficiency for commodity i's export to country r is set as follows:

$$E_{i,r}^{R} = \frac{E_i}{A_i^{ER}} \left(\frac{\delta_{i,r}^{ER}}{p_{i,r}^{ER}} \right)^{\varepsilon_i^{ER}} \left[\sum_{rc=1}^{RC} \delta_{i,rc}^{ER\,\varepsilon_i^{ER}} p_{i,rc}^{ER\,1-\varepsilon_i^{ER}} \right]^{\frac{\varepsilon_i^{ER}}{1-\varepsilon_i^{ER}}}. \tag{23}$$

Commodities' export breakeven condition:

$$p_i^E E_i = \sum_{r=1}^{R} p_{i,r}^{ER} E_{i,r}^R, \tag{24}$$

where p_i^E is commodity i's export price (equal to 1 in the initial state).

At the same time, the distribution of commodities produced domestically for export and domestic consumption is also described by the CET function:

$$q_i^D = A_i^E \left[\delta_i^E E_i^{\frac{\varepsilon_i^E - 1}{\varepsilon_i^E}} + \left(1 - \delta_i^E\right) q_i^{DD^{\frac{\varepsilon_i^E - 1}{\varepsilon_i^E}}} \right]^{\frac{\varepsilon_i^E}{\varepsilon_i^E - 1}}, \tag{25}$$

where δ_i^E is the share of export of domestically produced commodity i, an exogenous parameter with the following calibration:

$$\delta_i^E = \frac{p_i^{E0} E_{0i}^{\frac{1}{\varepsilon_i^E}}}{\left(p_i^{E0} E_{0i}^{\frac{1}{\varepsilon_i^E}} + p_i^{DD0} q_i^{DD0^{\frac{1}{\varepsilon_i^E}}}\right)}, \tag{26}$$

A_i^E is the commodity i's export efficiency, an exogenous parameter with the following calibration:

$$A_i^E = \frac{q_i^{D0}}{\left(\delta_i^E E_i^{0^{\frac{\varepsilon_i^E - 1}{\varepsilon_i^E}}} + (1 - \delta_i^E) q_i^{DD0^{\frac{\varepsilon_i^E - 1}{\varepsilon_i^E}}} \right)^{\frac{\varepsilon_i^E}{\varepsilon_i^E - 1}}}, \tag{27}$$

ε_i^E is the elasticity of technical substitution of commodity i's export, set exogenously.

Condition for efficiency maximization of domestically produced commodity i's export allocation:

$$E_i = \frac{q_i^D}{A_i^E} \left(\frac{\delta_i^E}{p_i^E} \right)^{\varepsilon_i^E} \left[\delta_i^{E^{\varepsilon_i^E}} p_i^{E^{1-\varepsilon_i^E}} + \left(1 - \delta_i^E\right)^{\varepsilon_i^E} p_i^{DD^{1-\varepsilon_i^E}} \right]^{\frac{\varepsilon_i^E}{1-\varepsilon_i^E}}, \tag{28}$$

Condition for efficiency maximization of domestically produced commodity i's domestic consumption allocation:

$$q_i^{DD} = \frac{q_i^D}{A_i^E}\left(\frac{1-\delta_i^E}{p_i^{DD}}\right)^{\varepsilon_i^E}\left[\delta_i^{E\,\varepsilon_i^E} p_i^{E\,1-\varepsilon_i^E} + \left(1-\delta_i^E\right)^{\varepsilon_i^E} p_i^{DD\,1-\varepsilon_i^E}\right]^{\frac{\varepsilon_i^E}{1-\varepsilon_i^E}}, \tag{29}$$

Breakeven condition for domestically produced commodity i:

$$p_i^D q_i^D = p_i^E E_i + p_i^{DD} q_i^{DD}, \tag{30}$$

where p_i^{DD} is the price of domestic consumption of domestically produced commodity i (equal to 1 in the initial state).

Import prices for commodity i from country r are set as follows:

$$p_{r,i}^{MR} = \left(1 + t_{r,i}^M\right)\overline{pw^{MR}}_{r,i} EXR_r, \tag{31}$$

where $\overline{pw_{i,r}^{MR}}$ is commodity i's world price for import from country r (equal to 1 in the initial state), $t_{r,i}^M$ is the commodity i's tax rate for import from country r, an exogenous parameter with the following calibration:

$$t_{r,i}^M = \frac{SAM\left(tax_r^M, i\right)}{SAM(RoW_r, i)}. \tag{32}$$

Trade and transport margins are included in the consumer price of commodity i:

$$p^{margin} = \sum_{i=1}^{N} sh_i^{margin} p_i, \tag{33}$$

where sh_i^{margin} is the share of trade and transport margins generated by demand on commodity i, an exogenous parameter with the following calibration:

$$sh_i^{margin} = \frac{SAM(i, margin)}{SAM(total, margin)}. \tag{34}$$

The distribution of commodity i's import among trade partner countries is described by the Armington CES function:

$$M_i = A_i^{MR}\left[\sum_{r=1}^{R}\delta_{r,i}^{MR} M_{r,i}^{R\ \frac{\varepsilon_i^{MR}-1}{\varepsilon_i^{MR}}}\right]^{\frac{\varepsilon_i^{MR}}{\varepsilon_i^{MR}-1}}, \tag{35}$$

where M_i is commodity i's import volume,

$M_{r,i}^{R}$ is commodity i's volume of import from country r,

$\delta_{r,i}^{MR}$ is the share of commodity i's import from country r, an exogenous parameter with the following calibration:

$$\delta_{r,i}^{MR} = \frac{p_{r,i}^{MR0} M_{r,i}^{R0\ \frac{1}{\varepsilon_i^{MR}}}}{\left(\sum_{rc=1}^{RC} p_{r,i}^{MR0} M_{r,i}^{R0\ \frac{1}{\varepsilon_i^{MR}}}\right)}, \tag{36}$$

where A_i^{MR} is the efficiency of commodity i's import from country r, an exogenous parameter with the following calibration:

$$A_i^{MR} = \frac{M_{0i}}{\left(\sum_{r=1}^{R}\delta_{r,i}^{MR} M_{r,i}^{R0\ \frac{\varepsilon_i^{MR}-1}{\varepsilon_i^{MR}}}\right)^{\frac{\varepsilon_i^{MR}}{\varepsilon_i^{MR}-1}}}, \tag{37}$$

ε_i^{MR} is the elasticity of technical substitution of commodity i's import from country r, set exogenously.

According to the abovementioned function, the function of efficiency maximization for commodity i's import from country r is as follows:

$$M_{r,i}^{R} = \frac{M_i}{A_i^{MR}}\left(\frac{\delta_{r,i}^{MR}}{p_{r,i}^{MR}}\right)^{\varepsilon_i^{ER}}\left[\sum_{rc=1}^{RC}\delta_{rc,i}^{MR\ \varepsilon_i^{MR}} p_{rc,i}^{MR\ 1-\varepsilon_i^{MR}}\right]^{\frac{\varepsilon_i^{MR}}{1-\varepsilon_i^{MR}}}. \tag{38}$$

Commodity i's import breakeven condition:

$$p_i^M M_i = \sum_{r=1}^{R} p_{r,i}^{MR} M_{r,i}^{R}, \tag{39}$$

where p_i^M is commodity i's import price.

The distribution of domestically consumed commodities to domestically produced and imported commodities is also described by the Armington CES function:

$$q_i = A_i^M \left[\delta_i^M M_i^{\frac{\varepsilon_i^M - 1}{\varepsilon_i^M}} + \left(1 - \delta_i^M\right) q_i^{DD\,\frac{\varepsilon_i^M - 1}{\varepsilon_i^M}} \right]^{\frac{\varepsilon_i^M}{\varepsilon_i^M - 1}}, \tag{40}$$

where δ_i^M is the share of commodity i's import in its domestic consumption, an exogenous parameter with the following calibration:

$$\delta_i^M = \frac{p_i^{M0} M_{0i}^{\frac{1}{\varepsilon_i^M}}}{\left(p_i^{M0} M_{0i}^{\frac{1}{\varepsilon_i^M}} + \left(1 + t_i^C\right) p_i^{DD0} q_i^{DD0\,\frac{1}{\varepsilon_i^M}} \right)}, \tag{41}$$

where t_i^C is commodity i's product tax rate, an exogenous parameter with the following calibration:

$$t_i^C = \frac{SAM(tax^c, i)}{\sum_{j=1}^{N} SAM(j,i) - \sum_{r=1}^{R} SAM(r,i)}, \tag{42}$$

A_i^M is commodity i's import efficiency, an exogenous parameter with the following calibration:

$$A_i^M = \frac{q_i^0}{\left(\delta_i^M M_i^{0\,\frac{\varepsilon_i^M - 1}{\varepsilon_i^M}} + \left(1 - \delta_i^M\right) q_i^{DD0\,\frac{\varepsilon_i^M - 1}{\varepsilon_i^M}} \right)^{\frac{\varepsilon_i^M}{\varepsilon_i^M - 1}}}, \tag{43}$$

ε_i^M is the elasticity of technical substitution of commodity i's import, set exogenously.

Condition for efficiency maximization of commodity i's import allocation:

$$M_i = \frac{q_i}{A_i^M}\left(\frac{\delta_i^M}{p_i^M}\right)^{\varepsilon_i^M}\left[\delta_i^{M\,\varepsilon_i^M} p_i^{M\,1-\varepsilon_i^M} + \left(1-\delta_i^M\right)^{\varepsilon_i^M}\left((1+t_i^c)p_i^{DD}\right)^{1-\varepsilon_i^M}\right]^{\frac{\varepsilon_i^M}{1-\varepsilon_i^M}}, \quad (44)$$

Condition for efficiency maximization of domestically produced commodity i's domestic consumption allocation:

$$q_i^{DD} = \frac{q_i}{A_i^M}\left(\frac{1-\delta_i^M}{(1+t_i^c)p_i^{DD}}\right)^{\varepsilon_i^M}\left[\delta_i^{M\,\varepsilon_i^M} p_i^{M\,1-\varepsilon_i^M} + \left(1-\delta_i^M\right)^{\varepsilon_i^M}\left((1+t_i^c)p_i^{DD}\right)^{1-\varepsilon_i^M}\right]^{\frac{\varepsilon_i^M}{1-\varepsilon_i^M}}, \quad (45)$$

Commodity i's domestic consumption breakeven condition:

$$p_i q_i = p^{margin} t_i^{margin} q_i + p_i^M M_i + \left(1+t_i^C\right) p_i^{DD} q_i^{DD}, \quad (46)$$

where t_i^{margin} is commodity i's trade and transport margins' rate, an exogenous parameter with the following calibration:

$$t_i^{margin} = \frac{SAM(margin, i)}{q_i^0}. \quad (47)$$

Trade balance equation:

$$\sum_{i=1}^{N} \overline{pw^{MR}}_{r,i} EXR_r M_{r,i}^R + trf_r^{RoWLab} EXR_r + trf_r^{RoWCap} EXR_r + trf_r^{RoWHH} EXR_r + trf_r^{RoWGov} EXR_r =$$

$$\sum_{i=1}^{N} \overline{pw^{ER}}_{i,r} EXR_r E_{i,r}^R + trf_r^{LabRow} EXR_r + trf_r^{CapRow} EXR_r + trf_r^{RoWHH} EXR_r + trf_r^{GovRow} EXR_r + \overline{S^{RoW}}_r EXR_r, \quad (48)$$

where trf_r^{RoWLab}, trf_r^{RoWCap}, trf_r^{RoWHH}, trf_r^{RoWGov} are transfers of production factors (labor and capital) from households and government to the country r respectively,

trf_r^{LabRoW}, trf_r^{CapRoW}, trf_r^{HHRoW}, trf_r^{GovRoW} are transfers of production factors (labor and capital) to households and government from country r respectively,

$\overline{S^{RoW}}_r$ is savings of country r, fixed amount.

Households

In the CGE model, households own labor and capital. Brutto income of households consists of wages, rents, net transfers with the external sector, and government transfers:

$$Y^{HH} = w_L\overline{L} + \sum_{r=1}^{R} trf_r^{LabRoW} EXR_r - \sum_{r=1}^{R} trf_r^{RoWLab} EXR_r +$$
$$+sh^{CapHH}\left(w_K\overline{K} + \sum_{r=1}^{R} trf_r^{CapRoW} EXR_r - \sum_{r=1}^{R} trf_r^{RoWCap} EXR_r\right) + \tag{49}$$
$$+\sum_{r=1}^{R} trf_r^{HHRoW} EXR_r - \sum_{r=1}^{R} trf_r^{RoWHH} EXR_r +$$
$$+trf^{HHGov} CPI,$$

where $\overline{L}$ is labor supply in an economy, fixed amount,

sh^{CapHH} is the share of households in rents' distribution, an exogenous parameter with the following calibration:

$$sh^{CapHH} = \frac{SAM(HH, Cap)}{w_K\overline{K} + \sum_{r=1}^{R} trf_r^{CapRoW} EXR_r^0 - \sum_{r=1}^{R} trf_r^{RoWCap} EXR_r^0}, \tag{50}$$

$\overline{K}$ is capital supply in an economy, fixed amount,

trf_r^{HHGov} is government transfers to households.

The income of households is broken into final consumption, savings, and income tax. The function of households' final consumption of commodity i is set as follows:

$$p_i h_i = \alpha_i^{HH}\left(1 - t^{Y^{HH}}\right)(1 - mps)Y^{HH}, \tag{51}$$

where h_i is commodity i's households' final consumption volume,

α_i^{HH} is the share of households' income spent on commodity i's final consumption, an exogenous parameter with the following calibration:

$$\alpha_i^{HH} = \frac{p_i^0 h_i^0}{(1 - mps)\left(1 - t^{Y^{HH}}\right) Y^{HH0}}, \tag{52}$$

mps is households' marginal propensity to save, an exogenous parameter with the following calibration:

$$mps = \frac{SAM(IS, HH)}{Y^{HH0}\left(1 - t^{Y^{HH}}\right)}, \tag{53}$$

$t^{Y^{HH}}$ is an income tax rate, an exogenous parameter with the following calibration:

$$t^{Y^{HH}} = \frac{SAM(Gov, HH)}{Y^{HH0}}. \tag{54}$$

Households' savings function:

$$S^{HH} = mps\left(1 - t^{Y^{HH}}\right) Y^{HH}. \tag{55}$$

The change in consumer prices level is described by the following equation:

$$CPI = \sum_{i=1}^{N} \gamma_i^{CPI} p_i, \tag{56}$$

where γ_i^{CPI} is commodity i's share of input into the overall change of consumer prices level, with the following calibration:

$$\gamma_i^{CPI} = \frac{p_i^0 h_i^0}{\sum_{ic=1}^{N} p_{ic}^0 h_{ic}^0}. \tag{57}$$

The variable of households' utility was implemented as a parameter and is described by the Cobb-Douglas function:

$$U = \prod_{i=1}^{N} {h_i}^{\alpha_i^{HH}}. \tag{58}$$

Government

In the CGE model government's income consists of tax income from activities, commodities market, households, rents, and net transfers with the external sector:

$$
\begin{aligned}
Y^{Gov} = {} & t^{Y^{HH}} Y^{HH} + \sum_{i=1}^{N}\sum_{r=1}^{R} t_{r,i}^{M} \overline{pw^{MR}}_{r,i} EXR_r M_{r,i}^{R} + \sum_{j=1}^{N} t_j^A p_j^A q_j^A + \sum_{i=1}^{N} t_i^C p_i^{DD} q_i^{DD} + \\
& + sh^{CapGov}\left(w_K \overline{K} + \sum_{r=1}^{R} trf_r^{CapRoW} EXR_r - \sum_{r=1}^{R} trf_r^{RoWCap} EXR_r \right) + \\
& + \sum_{r=1}^{R} trf_r^{GovRoW} EXR_r - \sum_{r=1}^{R} trf_r^{RoWGov} EXR_r - \\
& - trf^{HHGov} CPI,
\end{aligned}
\tag{59}
$$

where sh^{CapGov} is the share of government's distribution of rents, an exogenous parameter with the following calibration:

$$
sh^{CapGov} = \frac{SAM(Gov, Cap)}{w_K \overline{K} + \sum_{r=1}^{R} trf_r^{CapRoW} EXR_r^0 - \sum_{r=1}^{R} trf_r^{RoWCap} EXR_r^0}. \tag{60}
$$

Government's income is broken into government's final consumption and savings. The function of government's final consumption of commodity i is set as follows:

$$
p_i g_i = \alpha_i^{Gov}\left(Y^{Gov} - \overline{S^{Gov}} CPI \right), \tag{61}
$$

where g_i is the volume of government's final consumption of commodity i,

α_i^{Gov} is the share of government's income spent on commodity i's final consumption, an exogenous parameter with the following calibration:

$$
\alpha_i^{Gov} = \frac{p_i^0 g_i^0}{Y^{Gov} - \overline{S^{Gov}}}, \tag{62}
$$

$\overline{S^{Gov}}$ is government savings, fixed amount.

Savings and investments

In the CGE model, savings consist of households', government's, and external sector's savings; they are invested into capital formation. The function of commodity i's purchase for capital formation is set as follows:

$$p_i inv_i = \alpha_i^{inv} \left(S^{HH} + \overline{S^{Gov}} + \sum_{r=1}^{R} \overline{S^{RoW}}_r EXR_r \right), \tag{63}$$

where inv_i is the volume of commodity i purchased for capital formation,

α_i^{inv} is the share of investments which are allocated for the purchase of commodity i aimed at capital formation, an exogenous parameter with the following calibration:

$$\alpha_i^{inv} = \frac{p_i^0 inv_i^0}{S^{HH0} + \overline{S^{Gov}} + \sum_{r=1}^{R} \overline{S^{RoW}}_r}. \tag{64}$$

The variable of real GDP is implemented as a parameter and calculated based on the expenditure approach:

$$GDP = \sum_{i=1}^{N} h_i + \sum_{i=1}^{N} g_i + \sum_{i=1}^{N} inv_i + \sum_{i=1}^{N} E_i - \sum_{i=1}^{N} M_i. \tag{65}$$

Markets equilibrium

Commodity i's market equilibrium equation:

$$\sum_{j=1}^{N} IO_{i,j} + h_i + g_i + inv_i = q_i, \tag{66}$$

Labor market equilibrium equation:

$$\sum_{j=1}^{N} L_j = \overline{L}, \tag{67}$$

Capital market equilibrium equation:

$$\sum_{j=1}^{N} K_j = \overline{K}. \tag{68}$$

Appendix B

Description of sectors and commodities

Table A.1: Baseline model

Designation	Transcription
Agriculture	Plant growing and livestock breeding, provision of services in these areas; Hunting and provision of hunting services; Forestry and logging; Fisheries and fish farming.
Minerals	Coal mining; Mining of metal ores; Mining of other minerals; Providing services in the mining industry; Production of other non-metallic mineral products.
Oil & gas, petroleum	Crude oil and natural gas production; Production of coke and petroleum products.
Food	Production of food, beverages and tobacco products.
Textile & wood	Production of textiles, clothing and fur products; Production of leather, fur, leather products, except clothing, and production of footwear; Manufacture of wood processing products, wood and cork products, except furniture, straw products, and wicker materials; Production of pulp, paper, and paper products; Printing activities and replication of recorded media.

Chemicals, rubber, pharma	Production of chemical products; Production of basic pharmaceutical products and pharmaceutical preparations; Production of rubber and plastic products.
Metals	Metallurgical production; Production of finished metal products.
Electronics	Production of computing, electronic, and optical equipment; Production of electrical equipment.
Machinery nec	Production of machinery and equipment not included in other categories, except machinery for agriculture and forestry.
Motor vehicles	Production of machines for agriculture and forestry; Production of cars, trailers, and semi-trailers; Production of other vehicles and equipment.
Manufactures nec	Production of other finished products; Repair and installation of machines and equipment.
Utilities	Production, transmission, and distribution of electrical energy; Production and distribution of gaseous fuels; Production, transmission, distribution, and sale of steam and hot water, air conditioning; Collection, treatment, and distribution of water; Wastewater collection and treatment; Collection, treatment, and disposal of waste; recycling of materials; Cleanup activities and other waste disposal services.
Construction	Construction activities.
Trade	Wholesale and retail trade in cars, motorcycles, and their repairs; Wholesale trade, except trade in cars and motorcycles; Retail trade, excluding trade in cars and motorcycles.

Transport	Activities of land and pipeline transport; Water transport activities; Air transport activities; Warehousing and auxiliary transport activities; Postal and courier activities.
Communication	Publishing activity; Production of films, videos, and television programs, activities in the field of sound recording and publishing of musical works; Program creation activities. Radio and television broadcasting; Activities in the field of telecommunications; Computer programming, consulting, and other related services; Activities in the field of information services.
Other services	Other services.

Source: compiled by the authors

Table A.2: Alternative model

Designation	Transcription
Agriculture	Plant growing and livestock breeding, provision of services in these areas; Hunting and provision of hunting services; Forestry and logging; Fisheries and fish farming.
Minerals	Coal mining; Mining of metal ores; Mining of other minerals; Providing services in the mining industry.
Oil & gas, petroleum	Crude oil and natural gas production; Production of coke and petroleum products.

Food	Production of food, beverages and tobacco products.
Textile	Production of textiles, clothing, and fur products; Production of leather, fur, leather products, except clothing, and production of footwear.
Wood	Manufacture of wood processing products, wood and cork products, except furniture, straw products, and wicker materials; Production of pulp, paper and paper products; Printing activities and replication of recorded media.
Chemicals, rubber	PProduction of chemical products; Production of rubber and plastic products.
Pharma	Production of basic pharmaceutical products and pharmaceutical preparations.
Metals	Production of other non-metallic mineral products.
Electronics	Production of computing, electronic, and optical equipment; Production of electrical equipment.
Machinery nec	Production of machinery and equipment not included in other categories, except machinery for agriculture and forestry.
Motor vehicles	Production of machines for agriculture and forestry; Production of cars, trailers, and semi-trailers; Production of other vehicles and equipment.
Manufactures nec	Production of other finished products; Repair and installation of machines and equipment.
Utilities	Production, transmission, and distribution of electrical energy; Production and distribution of gaseous fuels; Production, transmission, distribution, and sale of steam and hot water, air conditioning.

Water	Collection, treatment, and distribution of water; Wastewater collection and treatment; Collection, treatment, and disposal of waste; recycling of materials; Cleanup activities and other waste disposal services.
Construction	Construction activities.
Trade	Wholesale and retail trade in cars, motorcycles, and their repairs; Wholesale trade, except trade in cars and motorcycles; Retail trade, excluding trade in cars and motorcycles.
Transport	Activities of land and pipeline transport; Water transport activities; Air transport activities; Warehousing and auxiliary transport activities; Postal and courier activities.
Communication	Publishing activity; Production of films, videos, and television programs, activities in the field of sound recording and publishing of musical works; Program creation activities. Radio and television broadcasting; Activities in the field of telecommunications; Computer programming, consulting, and other related services; Activities in the field of information services.
Other services	Other services.

Source: compiled by the authors