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Assessment of Impact of Trade Wars on Production and Exports of the Russian Federation Using the Agent-Based Model

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Abstract: In this article we consider methods of simulating consequences of trade wars using the agent-based model. The presented model simulates dynamics of trade relations between Russia, the United States, China, the European Union, and the rest of the world. We present event structure of the model which reflects interaction among different types of agents in the model: countries, organizations and residents. International trade is simulated at micro-level, as a set of supplies (purchases and sales) of organizations in different countries. Volume and structure of trade flows is changed annually, based on the algorithm that takes into account existing and newly imposed trade restrictions and the expected change in final demand. For information support of the model we use official statistical sources of the countries included in the model. Before loading these data to the model we process it to the similar sectoral structure and time period. For scenario calculations we consider optimistic and pessimistic scenarios for the world economy dynamics in the context of epidemiological risks and three possible options for world trade policy: preservation, cancellation or imposition of new trade restrictions. Simulation results for the Russian Federation show that current sanctions against it affect exports in a number of industries, but do not have a significant impact on the dynamics of value added, while imposition of new restrictions could slow down the economic growth rate by 0.3-0.5% annually.

Keywords: agent-based model, trade wars, trade restrictions, import, export, scenario calculations

1. INTRODUCTION

Various sanctions measures have increasingly become an instrument of world economic policy in recent years. Imposed restrictions affect various sectors of the economy, access to financial markets, imports and exports of countries. Despite the fact that a number of studies have shown that all participants suffer to a greater or lesser extent from participation in a trade war [4,5,18], restrictions continue to operate and be updated. In particular, since 2014, the Russian Federation has been under sanctions from the United States and the European Union in relation to the financial sector, mining and transportation of minerals. In this regard, the question arises of assessing how much damage the imposed sanctions cause to the industries that fall under their influence, how they affect the output of these industries and the volume of export of their products to various countries.

The subject of this study is trade flows among countries involved in trade conflicts, as well as changes in their volumes and structure under the influence of imposed trade restrictions. This task implies taking into account a large number of factors influencing trade flows, such as the final demand for products, availability of raw materials, utilization of fixed

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assets, access to investments and fluctuations in prices for goods, therefore, to solve it, it is proposed to develop of a computer model for assessing consequences of trade wars.

Agent-based modeling was chosen as the main research method, which makes it possible to evaluate the dynamics of the global system as a result of the interaction of different agents: countries, organizations and residents. In the proposed model interaction among these agents determines the direction and structure of the trade flows among countries and their change under the influence of demand and government regulation. The developed model is based on arrays of real data on the economy and population of its member countries and trade exchange among them, which makes it possible to make reasonable forecasts of trade relations dynamics in various political conditions for each participating country.

2. LITERATURE REVIEW

In the early 2000s most of the scientific publications devoted to analysis of trade wars referred to reviews of events and econometric analysis of retrospective data series [3,11]. Later in 2010s the researcers turned to developing models including sets of abstract countries that do not reflect the characteristics of real countries [2,8,18]. In the last decade the task of forecasting the economic consequences of trade wars for the participating countries is most often solved using computable general equilibrium (CGE) models, in which statistical data for different countries are loaded.The most famous project in the field of developing tools for quantifying trade wars between real countries is the Global Trade Analysis Project (GTAP), which brings together scientific researchers from all over the world [1,7]. GTAP was initiated in 1992 and proposed a unified methodology based on the CGE approach. The model complexes developed using the GTAP methodology include groups of countries (sometimes the whole world) and all sectors of the economy.Within GTAP a set of simulation complexes was developed:

1. WorldScan, which consists of general equilibrium models of 29 products, trading in 30 countries, having the largest weight in world GDP, and consolidated regions that include several countries. In the model, supply and demand for a specific product in a given country are formed taking into account supply and demand of this product in other countries, and the price depends on substitution possibilities, transport costs, trade barriers, and other factors [4].
2. GLOBE multisector model [16], developed by specialists of the Hohenheim University and the US Naval Academy, was used to assess the consequences of trade wars between the countries of the North American free trade zone, regulated by North American Free Trade Agreement.
3. MIRAGRODEP multicountry multisector model, developed at the International Research Institute for Food Policy (Washington, USA), based, in addition to the GTAP methodology, on the more general MIRAGE model (modeling international relationships under applied general equilibrium). The focus of this model is on goods trade between the US, China and Mexico [5].
4. The Center for International Trade and Economics and the Institute of World Economy and Politics of the Chinese Academy of Social Sciences have developed a global model to assess the consequences of the trade war between the United States and China [13].

The largest international organizations have developed their multi-country models: Organization for Economic Co-operation and Development (OECD) и International Monetary Fund (IMF). The OECD’s New Global Model considers 6 groups of OECD countries and 3 groups of non-OECD countries. OECD [12]. The IMF’s Global Macrofinancial Model belongs to the class of dynamic stochastic general equilibrium models (DSGE) and considers more than 40 of the largest economies in the world [20].

The listed models are aimed at considering the world's largest players, most often the USA and China, sometimes also EU countries. Even though in some of the pre-sented model complexes Russia stands out as a separate participant, the available publications do not provide an assessment of the consequences of economic sanctions for Russia, which have been regularly introduced against it since 2014. Thus, developing a model of trade wars, which would include Russia as one of the key participants, remains an urgent task.

3. MATERIALS AND METHODS

3.1. Structure of the model of trade wars

Within the agent-based model of trade wars, we study dynamics of trade relations between Russia, the United States, China, the European Union, and the rest of the world (Fig. 3.1). The model is programmed as a software simulator which represents interactions among three types of agents: organizations, residents and states.

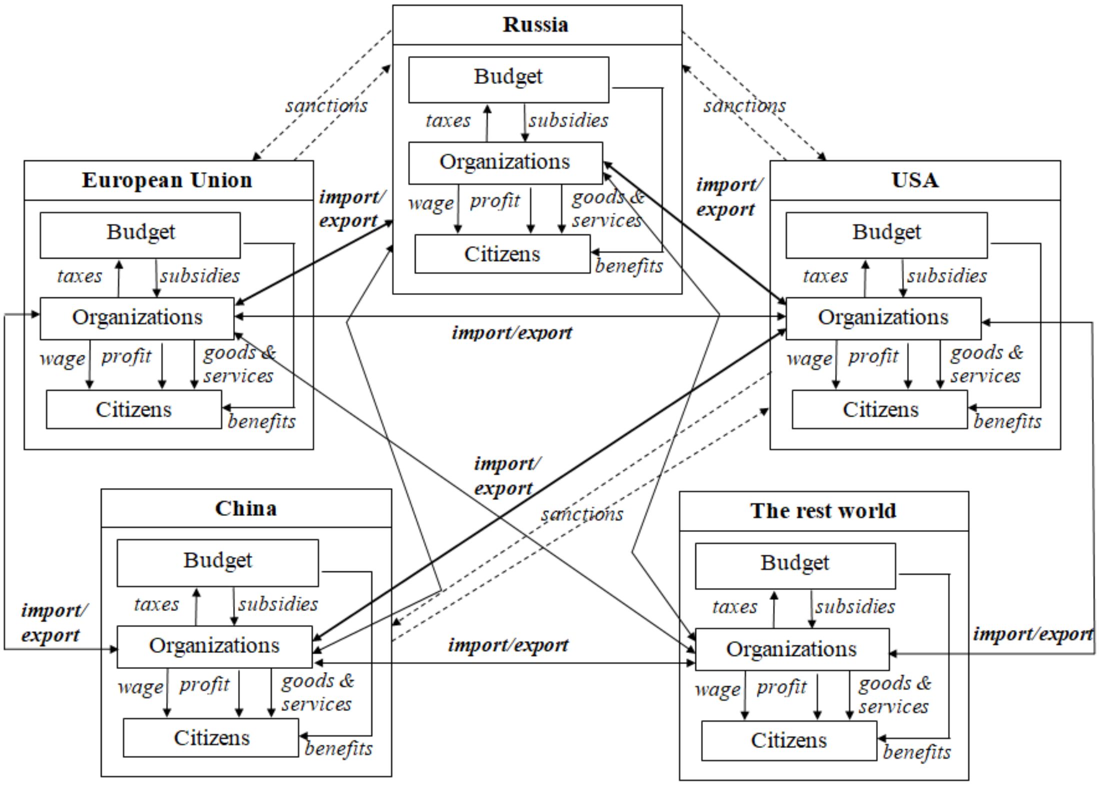

Fig. 3.1. Concept of the model

Resident agents act as employees of organizations, on the one hand, and consumers of goods and services, on the other. Agents' income goes to the accumulator, from which purchases of the final product are then paid.

Trade relations in the model are simulated at the level of individual organizations, and states regulate the processes of commodity exchange by introducing and canceling restrictions and changing tariffs on imports and exports of products. For agent-organizations, the current volume of output, the price in national currency, the number of workers and the volume of fixed assets are set. Organizations interact with each other through supplies that reflect purchases and sales, including international ones. The suppliers in the model are agent-organizations, and the buyers can be other agent-organizations, the state, or the agents-residents. Supplies are divided into three types:

1. Intermediate. Intermediate supplies include supplies of raw materials, components and services to other organizations. For the convenience of further calculations, intermediate

supplies are divided into basic (directly dependent on the dynamics of the organization's output) and additional (general business needs and accompanying services).

2. Investment supplies, which include various types of fixed assets. Investment supplies are also divided into basic (equipment and buildings) and additional (other supplies of products that are put on the balance sheet of organizations as fixed assets).

3. Final products supplies purchased by resident agents.

For each supply, the identifier of the supplier and the buyer is specified, as well as volume of supply in standard units, selling and purchase prices. The selling price is set in the currency of the state in which the supplier agent is located, excluding taxes. The purchase price consists of the sales price, sales taxes, export and import taxes (for international shipments), and is set in the currency of the country in which the agent-buyer is located.

The states in the model regulate tax rates, benefits to the population, amount of financing of public sector organizations and subsidies, and also adjust the existing sanctions on commodity exchange with other countries. Trade restrictions on import r_i^{imp} and export r_j^{exp} are set as the share of the turnover of industry j that falls under their influence, while $r_j^{imp} \in [0;1]$; $r_j^{exp} \in [0;1]$.

Interaction of various agents in the model within its main events is presented on Fig. 3.2. In the event “Benefits payment”, the state transfers benefits to resident agents, while the corresponding accumulators (state budget and residents' funds) are changed. The event "Public sector financing" implements transfer of funds from the budget to public sector organizations to pay their expenses. Also, the state makes payments on the federal debt and may impose sanctions to other countries in the form of trade restrictions.

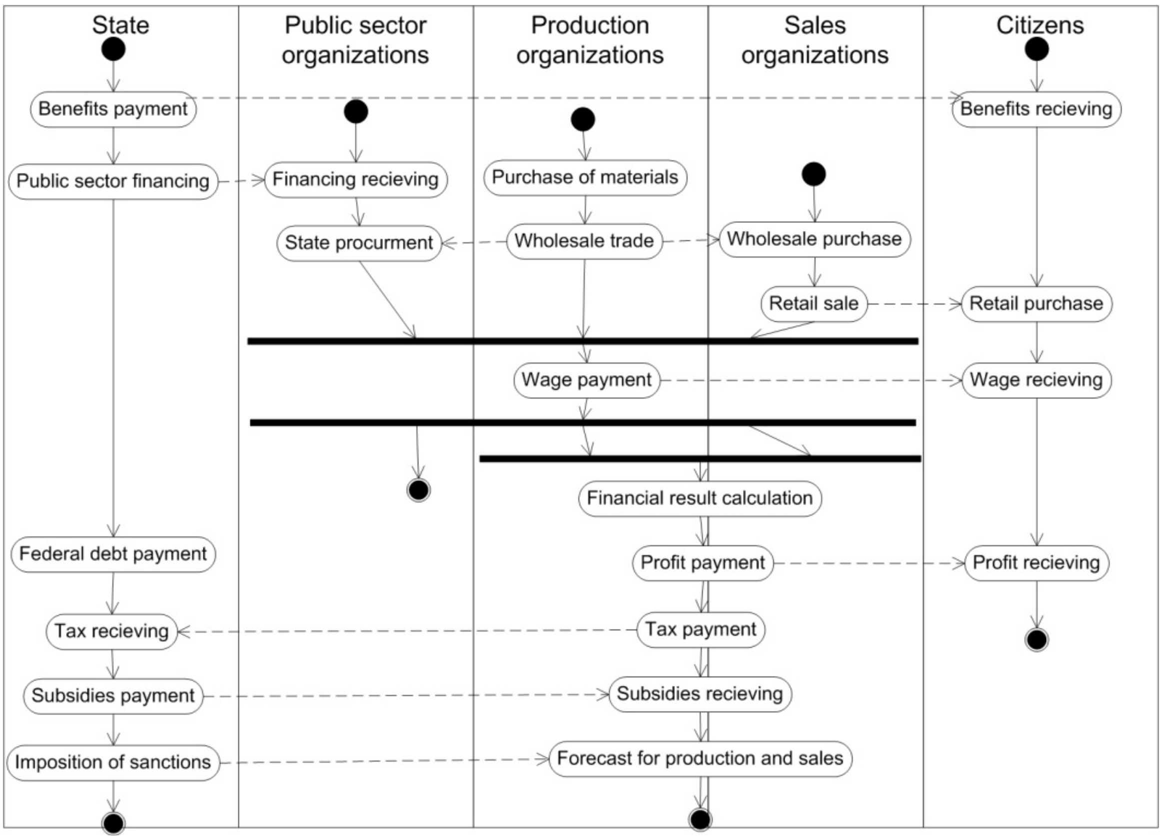

Fig. 3.2. Event structure of the model

The event "Purchase of materials" simulates supply of intermediate products among production organizations, including import and export of products. When the product is sold, the payment is credited to the account of the agent-supplier at the selling price in the currency of sale and debited from the account of the agent-buyer in the currency of purchase.

Trade organizations act in the same way in the event "Wholesale purchase", resident agents in the event "Retail purchase", and public sector organizations in the event "State Procurement".

After the completion of sales, taxes are transferred to the budgets of countries: internal taxes are charged on supplies where the supplier and the buyer were from the same country, and import / export taxes are charged on the international supplies.

The event "Wage payment" is implemented by organizations of all types, these funds are transferred to the accumulators of resident agents.

For commercial organizations, the financial result is calculated. Profit is defined as the difference between sales and costs of intermediate supplies, salaries and taxes. The profit is divided into two parts: the first is distributed as personal income from entrepreneurial activities, the second is used to pay for investments, along with subsidies received from the state.

The production and sales forecast is carried out taking into account the existing and newly imposed trade restrictions and the expected change in final demand, which, in turn, entails a change in the output of raw materials and components.

3.2. Algorithms

The actions of organizations in countries, which became subject to trade restrictions, are based on a number of assumptions:

- Supplies from countries that have imposed restrictions may be replaced by domestic supplies or supplies from other countries of products of a similar industry.
- Purchasing organizations of various industries have equal priority in the procurement of raw materials, that is, the resulting shortage of some materials and components would be proportionally distributed among all buyers.
- Substitution of supplies that have fallen under trade restrictions for supplies from available sources is carried out in proportion to the share of available sources in the initial distribution of supplies. That is, if the supply of products of industry *j* from country *B* accounted for 60% of the supply of this industry to country *A*, then in replacing the missing supplies from other countries, suppliers from country *B* would also account for 60% of the deficit in industry *j*.

The algorithm below shows the sequence of recalculation of supplies under the influence of trade restrictions in accordance with the introduced assumptions:

1. Calculation of permitted supplies for organizations in industry *j*, for products of which trade restrictions has been imposed:

$$V_{bs}^{y+1} = V_{bs}^{y} * \left(1 - r_j^{imp}\right) * (1 - r_j^{exp}) \tag{3.1}$$

where V_{bs}^{y+1} – volume of supply of organization-buyer *b* available from organization-supplier *s* of industry *j* in the next modeling year (*y*+1), V_{bs}^{y} – volume of supply of organization-buyer *b* delivered from organization-supplier *s* in the current modeling year *y*; r_j^{imp} – trade restriction on import of products of industry *j*, imposed in the modeling year (*y*+1); r_j^{exp} ,r_j^{imp} – trade restriction on export of products of industry *j*, imposed in the modeling year (*y*+1).

2. Calculation of lacking supplies for organizations:

$$V_{bs}^{y+1}(lack) = V_{bs}^{y} - V_{bs}^{y+1} \tag{3.2}$$

where $V_{bs}^{y+1}(lack)$ – volume of lacking supply of organization-buyer *b* from organization-supplier *s* in the next modeling year (*y*+1); V_{bs}^{y+1} – volume of supply of organization-buyer *b* available from organization-supplier *s* in the next modeling year (*y*+1), V_{bs}^{y} – volume of supply of organization-buyer *b* delivered from organization-supplier *s* in the current modeling year *y*.

3. Grouping of lacking supplies by industry *j* across all organizations:

$$V_j^{y+1}(lack) = \sum_{b=1}^{n}\sum_{s=1}^{m} V_{bs}^{y+1}(lack) \tag{3.3}$$

where $V_j^{y+1}(lack)$ – volume of lacking supply of organization-buyer *b* from organization-supplier *s* in the next modeling year (*y*+1); $V_{bs}^{y+1}(lack)$– total volume of lacking supply of organizations-buyers $b = \overline{1,n}$ from organizations-suppliers $s = \overline{1,m}$ of industry *j* in the next modeling year (*y*+1).

4. Choice of organizations for increase of supplies of industry *j* from countries that have not imposed trade restrictions.

5. Calculation of increase of supplies of organizations from countries that have not imposed trade restrictions:

$$V_{bs}^{y+1}(add) = V_j^{y+1}(lack) * P_s^j * P_b^j \tag{3.4}$$

where $V_{bs}^{y+1}(add)$ – volume of additional supply of organization-buyer *b* available from organization-supplier *s* of industry *j* in the next modeling year (y+1), $V_j^{y+1}(lack)$ – total volume of lacking supply by industry *j* in the next modeling year (y+1); P_s^j – share of organization *s* in supplies of products of industry *j*; P_b^j – share of organization b in purchase of products of industry *j*.

6. Recalculation of supplies of organizations from countries that have not imposed trade restrictions:

$$V_{bs}^{y+1} = V_{bs}^{y} + V_{bs}^{y+1}(add) \tag{3.5}$$

where V_{bs}^{y+1} – volume of supply of organization-buyer *b* delivered from organization-supplier *s* of industry *j* in the next modeling year (*y*+1), V_{bs}^{y} – volume of supply of organization-buyer *b* delivered from organization-supplier *s* in the current modeling year *y*; $V_{bs}^{y+1}(add)$ – volume of additional supply.

The change in trade flows between countries is also greatly influenced by the change in demand for the products of industries from organizations and consumers. To model this process, the following assumptions are made in the model:

- The starting point for changing the output and supplies of organizations is the final consumer demand, and the intermediate demand for materials and components is considered as a derivative of the final one.
- The industry structure of supply organizations is considered unchanged throughout the modeling period.
- Intermediate supplies of organizations are divided into basic and additional, and within the framework of the sales adjustment algorithm, only basic intermediate supplies are changed. Supplies are divided in such a way so that in the terminal sectors of the algorithm (agriculture and mining), all intermediate supplies would be additional. This assumption makes it possible to avoid the infinite recursion of the algorithm, since the organizations of industries that do not have basic supplies are processed at last.

The algorithm below shows the sequence of recalculation of supplies due to change in final demand is carried out in accordance with the introduced assumptions:

The work of the algorithm begins with assessing of the expected change in final demand on the wholesale purchases of the final products (Fig. 3.3). For this, the demand for the final product is recalculated:

$$FD_i^{y+1} = FD_i^y * (1 + \Delta d) \tag{3.6}$$

where FD_i^{y+1} – final demand for products of industry i in the next modeling year (y+1); FD_i^y – final demand for products of industry i in the current modeling year y; Δd – yearly dynamics of final demand.

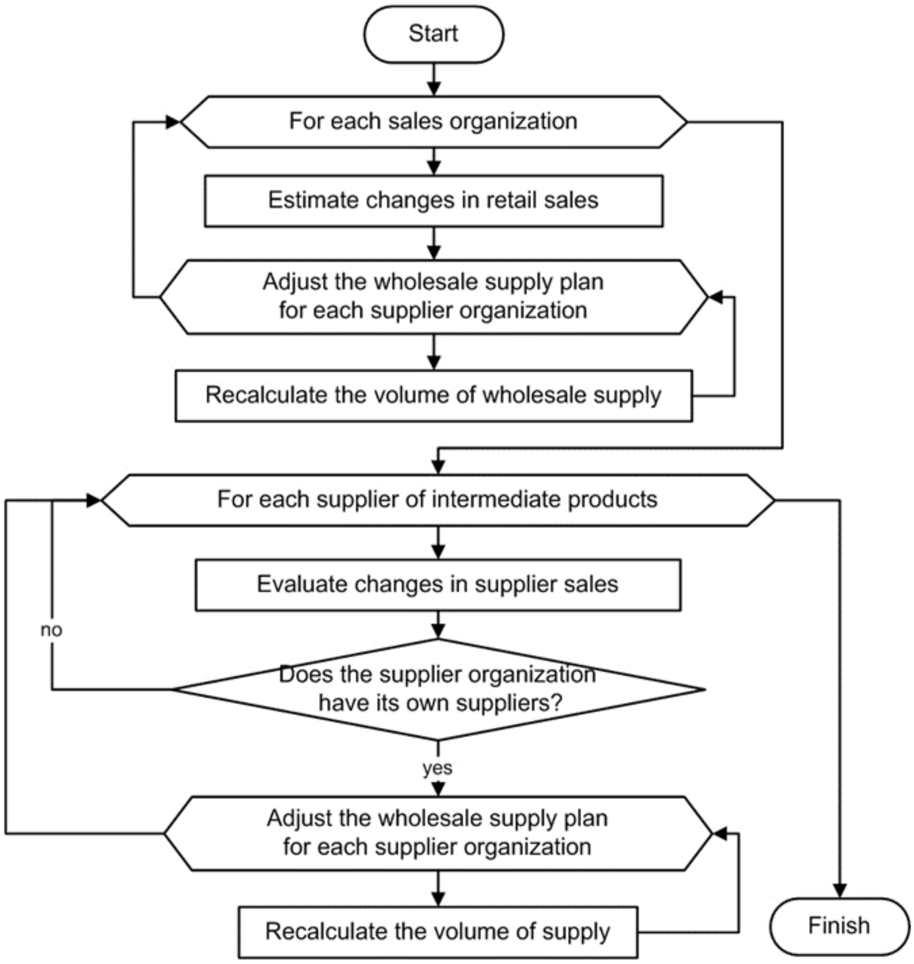

Fig. 3.3. Algorithm for changes in sales due to the dynamics of final demand

Then there is a sequential processing of organizations supplying the final product, within which the values of their sales are adjusted due to changes in final demand for their product:

$$S_i^{y+1} = FD_i^{y+1} + IntD_i^y + InvD_i^y \tag{3.7}$$

where S_i^{y+1} – total sales of products of industry i in the next modeling year (y+1); FD_i^{y+1} – final demand for products of industry i in the next modeling year (y+1); $IntD_i^y$ – intermediate demand for products of industry i in the current modeling year y; $InvD_i^y$ – investment demand for products of industry i in the current modeling year y.

The coefficient of change of intermediate supplies is calculated:

$$\Delta s_i = \frac{S_i^{y+1}}{S_i^y} - 1 \tag{3.8}$$

where Δs_i – yearly dynamics of sales of products of industry i; S_i^{y+1} – total sales of products of industry i in the next modeling year (y+1); S_i^y – total sales of products of industry i in the current modeling year *y*.

The values of intermediate deliveries of organizations-suppliers of final products are recalculated:

$$IntD_{ij}^{y+1} = IntD_{ij}^{y} * (1 + \Delta s_i) \tag{3.9}$$

where $IntD_{ij}^{y+1}$ – intermediate demand for products of industry *j* from organizations of industry *i* in the next modeling year (*y*+1); $IntD_{ij}^{y}$ – intermediate demand for products of industry *j* from organizations of industry *i* in the current modeling year *y*; Δs_i – yearly dynamics of sales of products of industry *i*.

For each organization-supplier of intermediate products, the values of their sales are adjusted, due to the cumulative change in final and intermediate demand for their product:

$$S_i^{y+1} = FD_i^{y+1} + IntD_i^{y+1} + InvD_i^{y} \tag{3.10}$$

where S_i^{y+1} – total sales of products of industry i in the next modeling year (y+1); FD_i^{y+1} – final demand for products of industry i in the next modeling year (y+1); $IntD_i^{y+1}$ – intermediate demand for products of industry i in the next modeling year (y+1); $InvD_i^{y}$– investment demand for products of industry i in the current modeling year *y*.

The corresponding coefficients of change in intermediate supplies and their new values are calculated by the formulas (3.8) and (3.9). The procedure for checking supplier organizations is determined by their industry affiliation: first, organizations that produce final products (light industry), then intermediate (production of fuel, materials and chemical products), and at the end - raw materials (agriculture and mining).

3.3. Information support of the model

Initial modeling data is based on official sources presented on the portals of the Russian Federation Federal State Statistics Service [19], Bureau of Economic Analysis of the United States Department of Commerce [6], National Bureau of Statistics of China [17] and Eurostat [9]. From these sources tables of GDP structure, input-output tables, structure of import and export between different countries is used.

Sectoral classifiers of the economy differ significantly in different countries, therefore, in the model, aggregated industries were identified, representing commodity groups that are significant for international trade:

1. Agriculture & Food production.
2. Mining.
3. Fuel production.
4. Public sector.
5. Chemical production.
6. Production of materials.
7. Production of equipment and transport.
8. Light industry.
9. Service.
10. Trade.
11. Construction

Table 3.1 presents industries in different countries included in the aggregated industry “Production of materials”.

The time periods for which production information is available also differ. The most relevant input-output tables for the EU and the United States are presented for 2019, for China and Russia - for 2017, therefore, for the last two countries, the tables were recalculated in proportion to the change in value added in the respective industries in 2018 and 2019.

Table 3.1. Structure of aggregated industry "Production of materials"

Aggregated industry in the model	*Industries in the EU*	*Industries in Russia*	*Industries in the USA*	*Industries in China*
Production of materials	Manufacture of wood and of products of wood and cork, except furniture;	Manufacture of wood and of products of wood and cork, except furniture;	Wood products	Manufacture of wood and wood products, paper and paper products; publishing and printing
	Manufacture of pulp, paper and paper products	Manufacture of paper and paper products	Paper products	
	Publishing, printing and reproduction of recorded media	Publishing, printing and reproduction of recorded media	Printing and related support activities	Manufacture of basic metals and fabricated metal products
	Manufacture of basic metals	Manufacture of basic metals	Primary metals	
	Manufacture of fabricated metal products, except machinery and equipment	Manufacture of fabricated metal products, except machinery and equipment	Fabricated metal products	

Initial data was loaded into the agent-based model of trade wars in the form of Excel spreadsheets.

3.4. Program realization

The presented model of trade wars was programmed in Microsoft Visual Studio using C# and PostgreSQL as the database management system. This instrument was chosen instead of specified multi-agent simulation platform, since the model works with large arrays of data and quite a large number of agents (about 800 thousand), and programming in C# allows to reach high-performance computing.

Fig. 3.4 shows the software architecture of the trade wars model, which includes the model database and two main procedures: generation of model objects based on source data and simulation procedure that reproduces the dynamics of trade flows between countries in accordance with the algorithms described above.

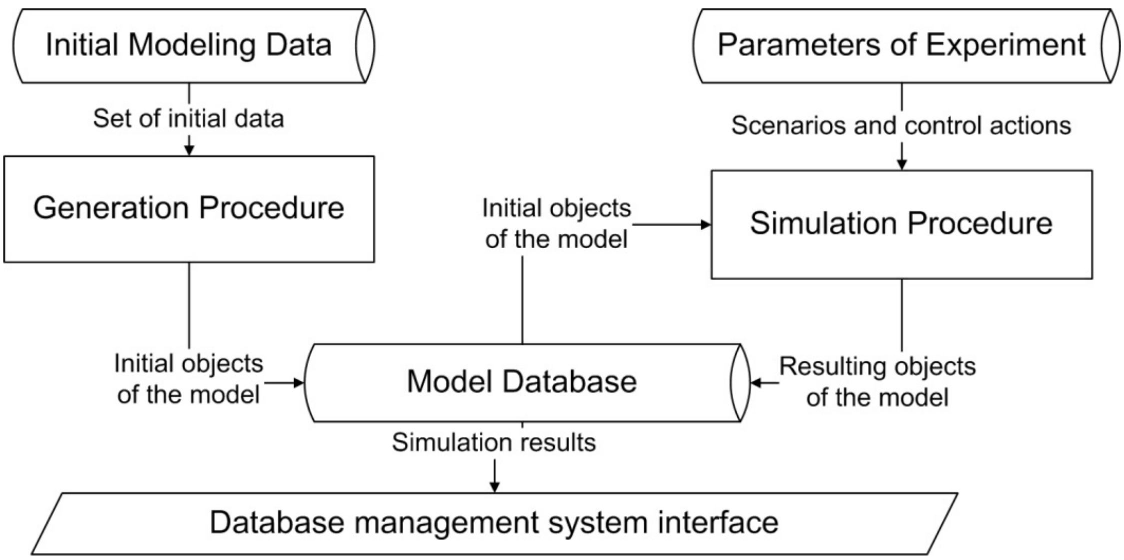

Fig. 3.4. Software architecture of the model

Generation procedure is the link from aggregated statistical data to the objects of the agent-based model, stored in the model database. Within generation procedure population and organizations are created and interconnections among them are set. Population in both models is reproduced taking into account gender-age structure, as discussed in [15]. One agent in the model stands for 10000 of residents in the real world, which results in 779400 agents living in 5 countries in the model (Table 3.2).

Table 3.2. Count of agents in countries of the model

Country	*Resident count in 2020, mln*	*Agents count*
Russia	146,75	14675
The USA	331,45	33145
The European Union	447	44700
China	1411,78	141178
The rest world	5457,1	545710
Total	7794	779400

Organizations in the model of trade wars are aggregated: one organization in the model responds to a set of organizations of one aggregated industry in one country. Thus, in the developed model, there are 55 organizations of 11 industries in 5 countries, which create and maintain more than 2000 interconnected trade flows. Agents of working age are assigned to organizations through workplaces. These issues are discussed in more detail in [14].

The generated objects are stored in the model database and used for multivariate calculations using the procedure for simulation of the dynamics of trade flows between countries under the conditions of imposed restrictions, which are set as the control parameters of the model. The obtained results are also stored in the database, and are available for further analysis via the PostgreSQL database management system interface.

4. RESULTS AND DISCUSSION

Based on the developed software model, a series of calculations was carried out to assess the impact of trade restrictions on the output and export of organizations in countries under sanctions restrictions.

In the first year of modeling, corresponding to 2020, the fall in the countries' GDP was reproduced, corresponding to the official estimates of their statistical offices. In particular, for Russia, the Federal State Statistics Service estimates the decline in GDP at 3.1% [19]. Based on the algorithms of the model, a corresponding recalculation of supplies among organizations was made. Thus, the forecast simulation period starts from 2021.

To make forecasts of dynamics of production and commodity exchange, a medium-term period of 5 years was chosen, which is associated, first of all, with the significant uncertainty of the global epidemiological situation. In the context of this uncertainty, two scenarios are considered: an optimistic one, assuming a global economic recovery in 2021-2022, and a pessimistic one, in which a repetition of waves of coronavirus infection would lead to slowdown in the recovery of production and demand.

Within each scenario, three options for trade relations among countries are considered:

1. Cancellation of all existing restrictions on the import and export of products. Under these conditions, the dynamics of commodity exchange would be determined only by speed of economic recovery.
2. Preservation of existing restrictions. Currently, there are EU and US restrictions packages against Russia, Russian restrictions against the EU and the United States, and reciprocal sanctions between the United States and China. For Russia, the imposed restrictions affect sectors of agriculture and food production (aggregated industry #1 in the model), aircraft and rocketry (aggregated industry #7) [10]. The EU, and especially the United States, restrict the construction of the Nord Stream 2, which affects industries of mechanical engineering, mining and fuel production (aggregated industries #2, #3 and #7 in the model).
3. Imposition of new restrictions since 2022 affecting about 5% of trade volume in key industries.

Within the framework of scenario calculations, the model was used to compare the dynamics of Russia's GDP and export volumes under various variants of world trade policy.

Consider the results obtained under the optimistic scenario. As the data in Fig. 4.1 show, the cancellation or preservation of existing trade restrictions does not have a significant effect on the dynamics of GDP, while imposition of new restrictions leads to slowdown in annual economic growth rates by 0.5%, and in the first two years of after imposition of restrictions, their influence is more noticeable.

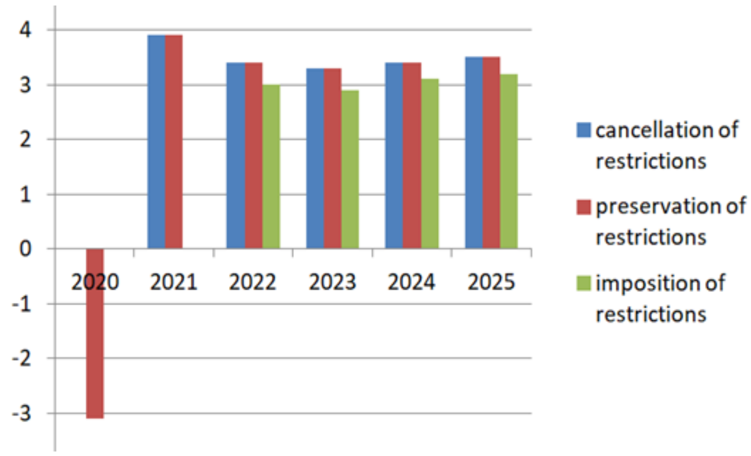

Fig. 4.1. Dynamics of Russian GDP within alternative trade policy (optimistic scenario)

Fig. 4.2 shows the forecast for the dynamics of export volumes under the optimistic scenario. Here, the comparatively weak influence of the existing restrictions is also noticeable, however, the effect of imposition of new ones is more noticeable: from 3-3.5% growth, the dynamics of exports falls to 1-2% after imposition of new restrictions.

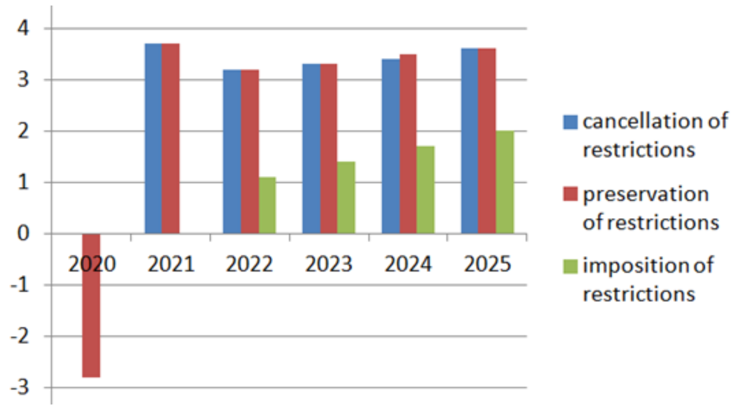

Fig. 4.2. Dynamics of Russian exports within alternative trade policy (optimistic scenario))

In general, the results presented in Fig. 4.1 and 4.2 indicate a fairly high degree of stability of the Russian economy and a relatively weak impact of the current sanctions on its development. The results obtained as a result of computer calculations can also be presented in a more detailed form, for separate exporting industries (Table 4.1). The obtained data demonstrates that, while maintaining the existing restrictions, the export of the industry "Production of machinery and equipment" suffers insignificantly, while growth rates of products of other industries stay at the same level. After imposition of new restrictions in 2022, the export of mining industry changes the growth rate from positive (3-4%) to negative (about -1%), while fuel sales continue to grow at a slower pace (1- 2% instead of 4%). Also the export of the "Manufacturing of machinery and equipment" sector shows a slowdown in growth rates by about 0.5% annually.

Table 4.1. Dynamics of export by industry, percents relative to the previous year (optimistic scenario)

Industry	*Year*					
	2020	*2021*	*2022*	*2023*	*2024*	*2025*
Cancellation of restrictions						
Agriculture & Food production	-5,3	5,1	4,6	5	5,6	5,9
Mining	-3,9	4,7	3,5	3,6	3,6	3,7
Fuel production	-4,3	4,9	3,9	4,1	4,3	4,5
Chemical production	-3,4	3,9	3,6	3,7	3,9	4
Production of materials	-1,1	3	2,9	3,1	3,2	3,4
Production of machinery and equipment	0	3	3,1	3,3	3,4	3,5
Miscellaneous manufacturing	-8,8	7,4	6	6,2	6,3	6,5
Preservation of restrictions						
Agriculture & Food production	-5,3	5,1	5,3	4,9	5,9	5,6
Mining	-3,9	4,7	3,5	3,6	3,6	3,7
Fuel production	-4,3	4,9	3,9	4,1	4,3	4,5
Chemical production	-3,4	3,9	3,6	3,7	3,9	4
Production of materials	-1,1	3	2,9	3,1	3,2	3,4
Production of machinery and equipment	0	2,7	2,9	3	3,2	3,4
Miscellaneous manufacturing	-8,8	7,4	6	6,2	6,3	6,5
Imposition of restrictions						
Agriculture & Food production	-5,3	5,1	4,6	5	5,4	5,7
Mining	-3,9	4,7	-1,2	-1	-0,7	-0,3
Fuel production	-4,3	4,9	1,1	1,5	1,9	2,2
Chemical production	-3,4	3,9	3,6	3,7	3,9	4
Production of materials	-1,1	3	3	3,1	3,3	3,4
Production of machinery and equipment	0	2,7	2,4	2,6	2,8	3,1
Miscellaneous manufacturing	-8,8	7,4	6,1	6,2	6,4	6,5

In the context of the pessimistic scenario, there is also no significant effect of cancellation of trade restrictions on the dynamics of GDP compared to their preservation, while imposition of new ones slows down the economic growth rate by 0.3% annually (Fig. 4.3).

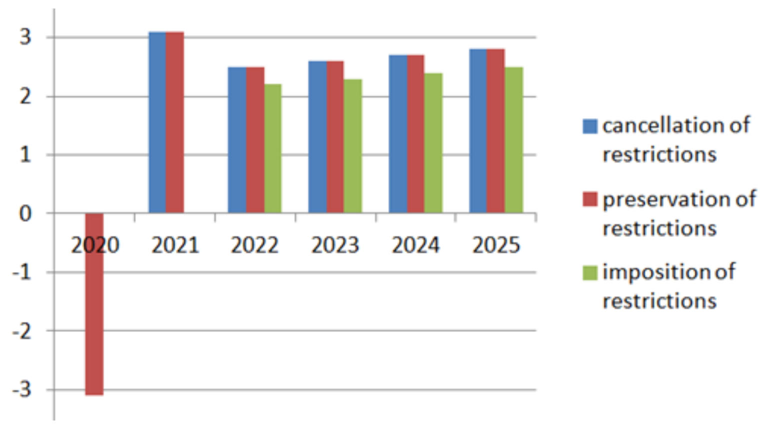

Fig. 4.3. Dynamics of Russian GDP within alternative trade policy (pessimistic scenario)

In 2022, the preservation of restrictions leads to even greater growth in Russian export volumes compared to their cancellation, which is associated with restrictions to other countries resulting in rise of orders to suppliers from Russia (Fig. 4.4). Imposition of new restrictions in the context of the pessimistic scenario leads to a drop in export growth rates to 0.8-1.2%.

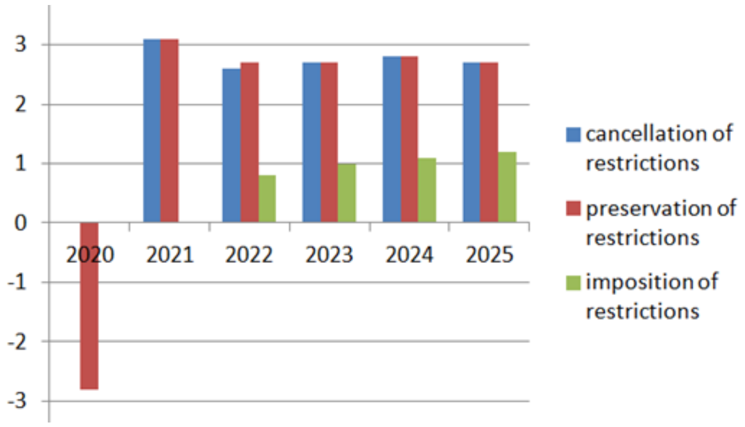

Fig. 4.4. Dynamics of Russian GDP within alternative trade policy (pessimistic scenario)

Calculations based on the presented agent model of trade wars for the Russian Federation show that the imposed sanctions affect agriculture, mining and fuel production to a greater extent, however, only the mining industry has a negative dynamic with the introduction of new restrictions (up to -1,2%). The rest of the industries maintain a positive growth rate, losing only a little in its speed (from 4,5% to -2,2% for the fuel production). As for the general economic situation, sanctions do not have a significant impact on the dynamics of value added, and the income of the population.

The results obtained as a result of modeling reflect possible changes in trade turnover between countries in the sectoral context, as well as the impact of these changes on the overall economic indicators of countries, in particular, GDP. This structure of the modeling output data coincides with the structure of the results of the models based on the GTAP methodology.

The results obtained are directly related to the assumptions of the model, the most important of which are the following:

- We consider goods from one industry are interchangeable and do not take into account preferences of the customers to goods from a particular country. Such assumptions are widespread in economic models [3,4].
- Investment in fixed assets is considered elastic, directly proportional to the change in output, which makes it possible to neglect the delays associated with expansion of production.
- In the calculations performed, the change in trade volume in prices of the base year is estimated, excluding inflation and fluctuations in the exchange rates.
- Direct bans on the import of certain categories of products are considered as sanctions measures, and the increase in customs tariffs that affect the price of products for buyers is not taken into account.

The assumptions made generally exclude price competition as a factor influencing international trade, and shift the main emphasis to the fundamental availability of supplies of products of certain industries in the required quantity. The assumption of the interchangeability of goods from different countries makes it possible not to take into account such a problem as the complete unavailability of raw materials and materials of a certain type. Thus, the model does not assess the effects of trade wars, such as reduced output or production interruptions due to lack of required materials. The assumption that there are no delays associated with the expansion of production is supposed to be removed in subsequent works to take into account the impact of investment processes in different countries on international trade.

5. CONCLUSION

This article examined issues of developing a model of trade wars, including as the main participants Russia, the European Union, the United States and China, as well as the united rest of the world. For the development, an agent-based approach was chosen, which distinguishes the presented model from known analogs based on the principles of computational general equilibrium. The chosen method makes it possible to study international trade relations at the micro level, in the context of supplies of individual organizations, purchases of residents and state procurements.

The article presents a number of results obtained, among which the most significant are:

1. The event structure of the model of trade wars, reflecting interaction of state, public sector organizations, manufacturers, trade agents and residents.
2. The algorithm reflecting annual change in the volume of sales and supplies of organizations, which, in turn, determines change in the volume of imports, exports and added value of industries.
3. The sectoral structure of the model, leading to a general view of sectoral classifiers in different countries.
4. Parametrization of scenario calculations, including two scenarios for the restoration of the world economy in the context of epidemiological risks (optimistic and pessimistic) and three options for world trade policy (preservation, cancellation or imposition of new trade restrictions).
5. Forecasts of the dynamics of GDP, volumes and sectoral structure of Russian exports in the context of various scenarios and a comparative assessment of the consequences of trade restrictions.

As a direction for further research in this area, a more detailed analysis of the impact of investing in expanding production on the consequences of trade restrictions for different countries was chosen.

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