
MACROECONOMIC AND STRUCTURAL MEASUREMENTS

Technological Import Dependence of the Russian Economy: An Assessment Using Input–Output Tables

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Abstract—The article analyzes the level of import dependence of Russian industry in relation to the supply of intermediate consumption products from China and in general from all countries of the world. The study was carried out during the period of the increasing spread of coronavirus infection in order to determine the industries that are potentially the most vulnerable to possible disruption of foreign trade. The information base for calculations is the official data on the volume and structure of Russia's foreign trade and the input–output tables of the WIOD. As a result of calculations using several alternative models, it was found that Russian industry, even with significant integration into the world production chains, remains sufficiently resistant to local supply shocks. The analysis of import dependence in terms of imported raw materials and components can be used in the study of any shocks in foreign trade, it makes it possible to more accurately assess the effects of trade agreements or sanctions, as well as the effect of the devaluation of the national currency.

Keywords: import dependence, input-output tables, supply shock

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Introduction. The COVID-19 epidemic, which began in the Chinese province of Wuhan, raised the question of the negative impact of the problems in the PRC on the Russian economy as early as in 2020. China's quarantine measures have led to the shutdown of businesses and the restriction of foreign trade. This inevitably had to affect the activities of both Russian exporters supplying goods to China and enterprises that use Chinese imports to manufacture products in Russia. As the epidemic grew into a pandemic, the question was posed more broadly: how the global shocks caused by the coronavirus can affect the Russian economy.

The emergence of shocks in world trade due to the coronavirus has once again exacerbated the issues of import dependence of the Russian Federation and the place of national industry in the global economy. Both questions have been thoroughly worked out by now in Russian science. In our study¹, the possible impact on the Russian manufacturing industry of violations in foreign trade due to the coronavirus was considered.

Due to the introduction of economic sanctions in 2014–2015, the import dependence of Russian industry was studied from the standpoint of direct damage to the sanctions impact [1–4], from the point of view

of technological dependence [5, 6], assessment of the potential of import substitution of certain industries [7–10], prospects and directions of import substitution policy [11–13] and structural policy [14]. At the same time, import dependence was considered mainly from the point of view of possible damage due to political processes (sanctions), and the substitution of products coming from developed countries with goods of Chinese origin as a way out. Assessments of the place and prospects of Russia in the global economy have so far been formed for both global added value chains [15–19], and for individual regions or areas [20, 21].

Moreover, to analyze intercountry relations and the impact of structural changes on world trade, the system of global input-output tables, World Input–Output Database (WIOD²) is already available and widely used. Table data as a forecasting tool, in particular, are built into the system of models of the Institute of Economic Forecasting of the Russian Academy of Sciences [22, 23]. The WIOD data have already been used by Russian researchers, in addition to analyzing added value chains [15–18, 24], to assess the relationship between structural changes and economic growth [25], to predict the effects of public policy [23, 26] and for other purposes. There are even examples of solving problems close to the one under consideration – for

¹ Calculations and estimates were carried out in February–March 2020.

² <http://www.wiod.org/>

example, in [27], based on the input–output method, the consequences of changes in the structure of demand in China were illustrated.

Characteristics of trade with China. Russian exports to China, as follows from the data of the Federal Customs Service of Russia, in 2019 consisted of 73.1% mineral products; another 5.6% were accounted for by food products and mineral raw materials. The rest (less than a quarter of exports) is relatively evenly distributed among the manufacturing industries with the largest share being wood and pulp and paper products (about 7.7%). Thus, demand shocks are substantially less significant for Russian manufacturing enterprises. The only exception is the timber industry complex of the Far Eastern region, which is entirely focused on Chinese consumers.

As for Russian imports, their dependence on Chinese raw products, materials and components, i.e., goods of intermediate consumption, cannot but be significant. At the same time, as simple modeling shows, this dependence cannot be catastrophic either.

Import dependence: a simple illustration. Hereinafter, we are talking about the technological import dependence of the production process, i.e., the concept, defined, in particular, in [6] through the costs of domestic enterprises for imported raw products, materials and bought items purchased for production activities.

All manufacturing enterprises can be divided into three categories.

—Fully localized production that does not use imports. These companies are not subject to external supply shocks; they can only be affected by the indirect impact of demand shocks from other affected industries.

—Enterprises that carry out industrial assembly entirely from imported parts or processing entirely imported raw materials. In case of supply shock, such productions stop or reduce output in proportion to the effect of the shock.

—Manufactures in which only individual components are imported. The peculiarity of these industries is that the effect of an external shock to the supply of the imported component may affect the ability to produce the final product, even if the share of this component in the cost of the final product is small.

Suppose that Russian industry, which uses Chinese imports in production, entirely consists of enterprises of category 2, and the ratio of output and intermediate consumption is constant and generally for processing industries (based on Rosstat data on product shipment and the structure of gross added cost) is 1.46–2.31 rubles of shipped products for 1 ruble of intermediate consumption (depending on whether taxes on products are included in the calculations).

Separating from the total volume of Chinese imports all goods that (at least theoretically) could be used as an object of industrial demand, at an exchange

rate of 64.7 rubles/US dollar, we get the volume of supplies of intermediate consumption goods in the amount of 2206.3 billion rubles. In this case, the potential for a fall in Russian production with the complete cessation of Chinese deliveries is 3221.2–5096.5 billion rubles, or 7.3–11.5% of the total volume (shipment). Even if all Chinese imports were used exclusively for intermediate consumption, the drop would be 8 trillion rubles, or only 18% of the total output.

The presence of enterprises of category 3 among Russian manufacturers can increase this estimate several times—however, in this case, the question will arise about the uniqueness of Chinese products and the possibility of replacing them with goods from other countries. In any case, already at the level of a simple model, we come to the conclusion about the exaggerated significance of the catastrophic nature of import dependence for the Russian industry as a whole. The transition to the analysis of input–output tables makes it possible to clarify this conclusion as applied to individual industries.

The data used. The calculations we propose are based on the global WIOD table of the 2016 version containing data on world trade in 2014 [28]. For research purposes, the original table was modified at the country level by rearranging the rows and columns. At the same time, the sectoral data for Russia and China were left unchanged, and the data on the sectors of other countries were combined under a single ROW index (other countries) while maintaining the division into sectors (Table 1).

It should be noted that the WIOD calculations generally do not contradict Russian statistics: imports to Russia from China in 2014 were estimated at 65.2 billion US dollars, while according to the Federal Customs Service of Russia and Rosstat, imports amount to 50.8 billion US dollars³. The share of intermediate consumption goods in total imports from China according to the WIOD matrix is 26.3%.

Even when analyzing Russia's position in world trade, it becomes clear that the volume of imports of intermediate consumption goods is not that great. In value terms, Chinese products (CP) account for less than 1% of the resources consumed in production (Table 2).

Shock propagation modeling. Taking into account the noted features, we will consider two options for modeling the propagation of supply shocks in China based on the sequential propagation of the shock and the matrix model, focusing on the effects for individual manufacturing industries.

The modeling was carried out with the allocation of data available in WIOD on 56 industry units for each

³ Russian statistical yearbook. 2017. Table 26.7. Foreign trade of the Russian Federation with non-CIS countries in actual prices, mln USD. https://rosstat.gov.ru/bgd/regl/b17_13/Iss-WWW.exe/Stg/d03/26-07.doc

Table 1. Structure of the matrix used in the calculations*

Indicator	Manufacturing matrix						Consumption			Total output by consumption
	Russia			Abroad			consumption	Russian export	other country CP	
	industry 1	industry 2		China	Other country		Russia CP	China CP		
A			1	2		3	4	5	6	7
	Russia industry 1			<i>Russian exports of raw products and materials to China</i>	Russian exports of raw products and materials to other country		<i>Domestic consumption</i>	<i>Russian exports of consumer goods to China</i>	Russian exports of consumer goods to other countries	
	Russia industry 2									
	China industry 1			<i>Domestic Chinese imports to Russia, consumed in industries: spare parts, equipment, etc.</i>	<i>Chinese imports to other countries</i>		<i>Imports of Chinese consumer goods</i>	<i>Domestic consumption</i>	Imports of Chinese consumer goods	
	China industry 2									
	Other country industry 1			Imports from other countries consumed in Russia	Imports from other countries consumed in China		Imports of consumer goods from other countries consumed in Russia	Imports of consumer goods from other countries consumed in China	Domestic consumption	
	Other country industry 2									
Added value										
Adjustments, etc.										
Total production output										

* Positions of interest to the authors are marked in italics and underlining.
Source: compiled based on [28].

Table 2. Cost volumes of production and trade of Russia and China, million US dollars*

Indicator		Manufacturing matrix			Consumption of CP			Total output by consumption
		Russia	China	Rest of the World	Russia	China	Rest of the World	
Manufacturing matrix	Russia	1500189	29626	420111	1387102	1497	42555	3381079
	China	17179	19971882	1194983	48018	9347756	1165284	31745102
	Rest of the World	139357	1344873	60931773	174325	466841	—	—
Added value and adjustments		1724354	10398720	—				
Total output by consumption		3381079	31745102	—				

* A dash means that the corresponding data were not calculated by the authors.
Source: compiled based on [28].

of the three countries (Russia, China and the “conditional” country “Rest of the World”).

Model 1: Sequential propagation of shocks The starting point in the functioning of the model is the introduction of quarantine to prevent the COVID-19 epidemic and the fall in demand for own manufactured goods in China, which, in accordance with the construction of the WIOD table, is equivalent to a fall in the output of Chinese manufactured goods for domestic consumption. Further, we assume that the rate of decline in exports from the country is equivalent to the rate of drop in production in the country. In this case, a drop in production in China leads to *effect No. 1*: a drop in exports of interindustry consumption goods from China to Russia and other countries.

Having designated the initial volume of production of interindustry goods in China Q_0^{CHN} , the volume of export of these goods from China⁴ $E_0^{CHN \rightarrow \text{RUS}/\text{ROW}}$ production decline rate *Prod*, where $\text{Prod} \in [0, 100\%]$ and the export decline rate *Exp*, where $\text{Exp} = \text{Prod}$, estimates can be calculated for the new output level in China (Q_1^{CHN}), as well as new values of exports to Russia ($E_1^{CHN \rightarrow \text{RUS}}$) and other countries ($E_1^{CHN \rightarrow \text{ROW}}$). The formulas for calculating new parameter values are as follows:

$$Q_1^{CHN} = Q_0^{CHN} * (1 - \text{Prod}), \quad (1)$$

$$E_1^{CHN \rightarrow \text{RUS}} = E_0^{CHN \rightarrow \text{RUS}} * (1 - \text{Exp}), \quad (2)$$

$$E_1^{CHN \rightarrow \text{ROW}} = E_0^{CHN \rightarrow \text{ROW}} * (1 - \text{Exp}). \quad (3)$$

The introduction of the assumption that the drop in production in the country corresponds to the decline in imports of intermediate consumption goods into the country (we still consider all enterprises to be in category 2), allows us to estimate *effect No. 2*. It is assumed that the decline in exports from China leads

to a corresponding drop in production for domestic intersectoral consumption in Russia and other countries. Denoting the share of imported components in the total intersectoral consumption of Russia as $\text{Share}^{\text{RUS}}$, and other countries as $\text{Share}^{\text{ROW}}$, where $\text{Share} \in [0, 100\%]$, we obtain estimates of the new level of production:

$$Q_1^{\text{RUS}} = Q_0^{\text{RUS}} * (1 - \text{Exp} * \text{Share}^{\text{RUS}}), \quad (4)$$

$$Q_1^{\text{ROW}} = Q_0^{\text{ROW}} * (1 - \text{Exp} * \text{Share}^{\text{ROW}}). \quad (5)$$

After a drop in production in Russia and other countries, *effect No. 3* follows, which essentially repeats effect No. 1 and is based on the initial assumption: a drop in production leads to a decline in exports. More specifically, exports from Russia and other countries are falling. The following formulas describe effect No. 3 in the model:

$$E_1^{\text{RUS} \rightarrow \text{CHN}} = E_0^{\text{RUS} \rightarrow \text{CHN}} * (1 - \text{Exp} * \text{Share}^{\text{RUS}}), \quad (6)$$

$$E_1^{\text{RUS} \rightarrow \text{ROW}} = E_0^{\text{RUS} \rightarrow \text{ROW}} * (1 - \text{Exp} * \text{Share}^{\text{RUS}}), \quad (7)$$

$$E_1^{\text{ROW} \rightarrow \text{RUS}} = E_0^{\text{ROW} \rightarrow \text{RUS}} * (1 - \text{Exp} * \text{Share}^{\text{ROW}}), \quad (8)$$

$$E_1^{\text{ROW} \rightarrow \text{CHN}} = E_0^{\text{ROW} \rightarrow \text{CHN}} * (1 - \text{Exp} * \text{Share}^{\text{ROW}}). \quad (9)$$

Effect No. 3 is the last effect in the model, despite the fact that, actually, after a decline in exports to China, the country's production should decrease, restarting the cycle of effects. However, the calculation shows that in this case the level of drop in interindustry consumption goods in China is about 0.1% of the initial level of decline, which makes the effects 1–3 on the “second circle” nearly equal to zero. Therefore, the absence of secondary effects in the model does not significantly affect its results.

The next stage in the formation of the model is the calculation of the values of final consumption and added value. Final consumption is calculated as a fixed share of the volume of intermediate consumption goods produced by a particular country, deter-

⁴ Hereinafter, superscripts like $\text{ROW} \rightarrow \text{RUS}$ indicate the direction of import: in this example, import to Russia from the rest of the world.

mined on the basis of the initial intersectoral balance matrix. This premise seems reasonable due to the fact that final consumption directly depends on production in the country: the less goods and services were produced, the lower the profit of producers and, consequently, the income of both business and households. Therefore, with a drop in production in the country, household consumption, investment by companies and government costs decrease.

The components of value added are calculated as fixed shares of the value of intermediate consumption by industries in countries. This approach is simple and at the same time optimal, since taxes and margins, which average about 95% of the added value in the WIOD table, are essentially a fraction of the cost of production and have a low probability of significant changes.

Model 2: matrix calculation. Instead of consistently reflecting shocks, an assessment of the consequences of import dependence can be presented using the properties of the input–output balance matrix. The classical interindustry balance equation can be written as:

$$X = A * X + Im + Y', \quad (10)$$

where Im is the vector of imports attracted to the intermediate (intersectoral) consumption of the country, i.e., the vector of products of all industries from all other countries consumed by the country's industries; Y' is the vector of total final consumption in the absence of industrial imports, i.e., that is the total consumption that is possible to provide on their own.

The combination of these two equations allows writing down the dependence of the change in output in the country (ΔX) from changes in imports involved in its intersectoral consumption (ΔIm) as the following formula:

$$\Delta X = (E - A)^{-1} * \Delta Im, \quad (11)$$

where E is the identity matrix.

Thus, the assessment of the change in the value of imports entering Russian intersectoral consumption allows predicting the change in production in the country. Note that although (11) specifies the change in production in absolute values, on the basis of this formula it is easy to obtain indices of change in production, which are more useful for forecasting.

The model calculation was carried out in two stages. At the first stage, a decrease in output in the rest of the world was determined following a decline in Chinese imports in intermediate consumption and a resulting decline in intersectoral imports of the rest of the world in Russia. At the second stage, the initial reduction in industrial imports of Russia from China and intersectoral imports from ROW were summed up (i.e., the total drop in intersectoral imports of Russia was determined), then the reduction in production in Russia was calculated. In doing so, a number of assumptions were made.

First, the calculation of the coefficient matrices is based on the assumption of the linear dependence of the output on the intermediate consumption of the products of their own industries: each element of the matrix a_{ij} is obtained by dividing a similar element of the quadrant of their own intermediate consumption of the WIOD matrix by the value of the output of the industry of the country in which this element is placed.

Second, the value of the reduction in imports of intermediate products from China for both Russia and the rest of the world was set through a single scalar coefficient $r \in [0, 100\%]$ ($r = 0\%$ is no reduction in imports, and $r = 100\%$ means the import completely “disappears”):

$$\Delta Im^{CHN} = (100\% - r) * Im^{CHN}, \quad (12)$$

where Im^{CHN} is the vector of imports from China attracted to interindustry consumption.

Third, the reduction in imports of intermediate products by Russia from the rest of the world was assessed as follows. The reduction in the output of the rest of the world as a result of the reduction in imports of intermediate consumption goods from China was determined by the formula (11). On this basis, it is possible to calculate the changed value of the total final consumption of products, extracting the vector Z from it, which sets the share of industrial exports to Russia in the total final consumption of the rest of the world. Then, under the assumption that the distribution of total final consumption by type will not change (i.e., Z remains constant), the new value of exports of intermediate consumption products of the rest of the world to Russia will be calculated as:

$$Z * (X_{\text{new}} - A * X_{\text{new}}). \quad (13)$$

Accordingly, the reduction of interindustry imports by Russia from ROW taking into account the linearity of the interindustry balance equation is given by the formula:

$$\Delta Im^{ROW \rightarrow \text{RUS}} = Z * \Delta Im^{CHN \rightarrow \text{ROW}}. \quad (14)$$

Thus, the final reduction in production in Russia should be estimated by the formula:

$$\Delta X = (E - A)^{-1} * (\Delta Im^{CHN \rightarrow \text{RUS}} + Z * \Delta Im^{CHN \rightarrow \text{ROW}}). \quad (15)$$

Results of model calculations. Model calculations showed similar results in general. With a sequential spread of effects, a 10% decline in industrial imports from China leads to a decrease in the total output of all sectors of the Russian economy by 0.1%, when using a matrix calculation, by 0.14%. The complete cessation of imports of intermediate consumption goods from the PRC, respectively, means a drop in output within 1% for the first model and 1.37% for the second. At the same time, for the manufacturing industry as a whole, the loss of Chinese imports would mean a reduction

from 1.29% in the first model to 4.53% in the second, and for certain industries the “sensitivity” turned out to be much higher. When ranking industries according to the level of dependence on Chinese imports, it turned out that the composition of the most dependent types of activities in the manufacturing industry is generally similar. Both models showed that light industry is the leading one in terms of dependence; the loss of imports from China results in a slowdown by 12.7% in the first model and by almost 35% in the second. To a lesser extent, the automotive industry, mechanical engineering, the chemical industry and production of rubber and plastic products, as well as other industries, depend on imports.

The simulation results represent the lower bound of the estimate of the real values of the fall in output under external supply shocks. This is due to the impossibility of taking into account in the models the actual dependence of the branches of Russian industry on Chinese components based on the data contained in the table of the input–output balance. The models take into account only the share of products of the Chinese industry in the total volume of materials, but do not allow taking into account the criticality of specific units. Consequently, when the import of components from China stops, Russian manufacturing industries are likely to suffer significantly more serious losses. At the same time, if we assume that the probability of the presence of “critical” elements in the technological chain grows with an increase in the share of imports, then the results obtained in the models can be used to identify industries that are potentially most vulnerable from the point of view of import dependence.

Possibilities of using WIOD to assess the effect of a pandemic and global shocks. The mitigation of country shocks is provided by the possibility of replacing inaccessible imports from one country with substitute goods from other countries, albeit at a higher price. In the case of multiple exclusions of countries from world trade, the prospect of substitution becomes more and more dubious, up to a situation in which there is no available source of material or semifinished product.

The expansion of our two models to a 100% reduction in all world trade is, in fact, another assessment of the dependence of the Russian economy on imports, made using input–output tables. It can be considered that such calculations most accurately illustrate the “loss” of materials and components that have no analogs. Based on the calculations, all manufacturing sectors were divided into four groups depending on the effect obtained.

The first group is critically import-dependent industries, for which the loss of imports will lead to a drop in output by more than 40% or to a “stop” of the industry: light industry, automotive, mechanical engineering, and the chemical industry.

The second group is import-dependent industries, for which import restrictions may be significant. At least one of the models showed a drop in their production by more than 15%. These are metallurgy, production of rubber and plastic products, woodworking, furniture and other goods.

The third group is industries for which the effect of restrictions is insignificant. These are the food industry, production of alcohol and tobacco, the pulp and paper industry, production of coke and petroleum products, production of nonmetallic mineral products, production of computers, electronic and optical products.

Finally, the fourth group is the industries for which the WIOD models do not contain the necessary data: printed products, pharmaceuticals, metal products, electrical equipment, and transport engineering.

Conclusions and their use in public policy. The modern economy, including the Russian economy, even with significant integration into world production chains, remains sufficiently resistant to local supply shocks, which may be due to the quantitatively small role of imported intermediate consumption in general and the possibilities of using alternative supply options. Without denying the existence of “weak links,” especially in the field of high-tech imported products, we note that the industry as a whole (with the exception of a fairly narrow set of industries and segments) is quite capable of adapting to changes in the world market. Global shocks, however, due to the impossibility of using alternatives, cause an inevitable negative reaction of domestic production.

The impossibility of estimating the number and distribution of cases of critical dependence of production on imports using WIOD is a significant drawback of the method, which can be overcome by empirical assessments of the significance of imports for the production process. Such polls have already been conducted. In particular, in [19] it was indicated that a critical dependence on import supplies was noted for 36% of the surveyed small and medium-sized businesses, while the most significant import dependence is characteristic of exporting firms to the far abroad. Probably, with the accumulation of information about the actual impact of global shocks on Russian production, it will become possible to build more accurate forecasting models based on the observed reaction of industries and enterprises and econometric methods of analysis.

The main directions that can become the object of state efforts aimed at solving the problem of technological import dependence are the diversification of imports, the development of their own production facilities or the creation of material reserves to compensate for temporary “gaps.” At the same time, production, in which only a part of the production chain is localized, remains unstable to external shocks. The efforts of the state should be aimed at horizontal diver-

sification in terms of bottlenecks, i.e., on the creation of industries that compete with importers and produce products almost entirely based on local sources of raw materials and domestic components. Here, we can agree with the conclusion presented in [5] that the intermediate demand industries act as a reserve for expanding the process of import substitution in the Russian economy, as well as with the remark in [19] that the Russian policy of import substitution is predominantly vertical and not related to horizontal measures. Import substitution within the production chains of enterprises solves the task only if the final outcome is a completely Russian product, which seems appropriate only in the military-industrial complex in the context of “proactive import substitution” [29].

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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