Estimating the Technological Factor's Contribution in Economic Dynamics

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Abstract

The present paper is a continuation of research on the analysis of spatio-temporal characteristics of the technological coefficients, the results of which were presented at the previous Input-Output conference. This stage of research is characterized, firstly, by the broadening of the database of national economic systems included in the comparative analysis with Russian technological coefficients. Secondly, based on total requirements coefficients, the component determined by changes in technological coefficients in the economic dynamics is singled out as object of research, and the position of Russia on this indicator is estimated using cross-country comparisons. Thirdly, the evaluation of the technological component in the economic dynamics is performed based on global and national input-output tables, including the estimated contribution of technological changes in the world economy. Fourthly, in line with the expansion of the cross-country research base, there is also an extension of the list of industries, the cost structure in which is subjected to scrutiny. This research must result in forecast and analytical calculations with various scenario options of technological coefficients for Russia.

Unfortunately, despite the relevance of this line of research, Russia does not have a sufficiently complete own information database for the analysis of the dynamics of technological coefficients, not to mention the limited possibility of cross-country comparisons using such database. For this reason, in addition to the official data of the state statistical agencies of Russia, we have to use international databases for these purposes, in particular to WIOD.

Decomposition Method of change output through technological factors and due to changes in final demand can be implemented on the basis of national and international Input-Output models (IO models). Each approach has its advantages and disadvantages.

It is known that the IO model of the national economy recorded as

$$\mathrm{X} = \mathrm{AX} + \mathrm{Y} \quad (1)$$

whereX- vector of gross output, Y- final demand of the national economy, A – matrix coefficients of direct expenditures or, technological coefficientsa_{ij}. Accordinglyinv$(I - A)$= B stands forcoefficient matrix of full costs.Soif X_0 , X_1 , Y_0 , $Y_1$are vectors of output and final demand for the base and current years, respectively, the$\Delta\mathrm{X} = \mathrm{X}_1 - \mathrm{X}_0 = \mathrm{B}_1 * \mathrm{Y}_1 - \mathrm{B}_0 * \mathrm{Y}_0 = \Delta B * Y_0 + \mathrm{B}_1 * \Delta\mathrm{Y}$, where$\Delta\mathrm{Y} = \mathrm{Y}_1 - \mathrm{Y}_0$, $\Delta B = B_1 - B_0$, andB_1 , $B_0$are matrix coefficients of full expenditures for current and base years. In assessing the contribution of technological factor in dynamics of the national economythe formula$\Delta X_{\mathrm{T}} = \Delta B * Y_0$ is applied,where$\Delta X_{\mathrm{T}}$is a vector of increments of outputs, which explains the change in the matrix of the coefficients of full expenditures, which, in turn, caused by changes in technological coefficientsa_{ij}. Note that the measurement of the contribution of technologicalfactor in economic dynamics can be carried out at least on the basis of the two approaches.1. As$\Delta X_{\mathrm{T}}^{B} = \Delta B * Y_0$ 2. As$\Delta\mathrm{A}X^{A} = \Delta\mathrm{A} * \mathrm{X}_0$, where$\Delta\mathrm{A}X^{A}$- the vector of intermediate demandchange, which occurred due to changes in the technological matrix elements for the study period,ΔA- the technological matrixchange, which occurred during the study period, X_0 - vector output for the base year. Both indicators characterize the result of technological changes on the scale of a national or global economy. In factY_0andX_0act as some weights, allowing to determine the overall result of the changes of the matrix.In fact, it is possible to use any other local indicators of technological contribution. For example, looking ahead, we can say that the estimates are available for the r-th diagonal block of global technological matrix and the vector of production or final demand r-th country. We can also view individual elements of the vectorsΔX^{B}or$\Delta\mathrm{A}X^{A}$.

It is absolutely clear that the change in the coefficients a_{ij} is reflected b_{ij} - becausea_{ij}isdirectly a part of theb_{ij}[1]. Moreover, the change of a_{ij}affects all elements of the matrixB.Therefore, the legitimate is a generalized assessment of the impact of technological factors on the issues of the coefficients of the full costs.

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[1]Recall that the coefficients of the full costs are the sum of the coefficients of direct and indirect costs

It is known that the effect of a change in onecoefficienta_{ij}on acoefficient$b_{kl}$is estimated on the basis of the formula

$$\partial b_{kl} = b_{ki} \partial a_{ij} b_{jl}$$

Accordingly, by changing the coefficients of the direct costs we get the formula

$$db_{kl} = \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ki} \partial a_{ij} b_{jl}$$

This formula is valid only for small increments of coefficients of direct expenditures. In general, we have the formula

$$\Delta b_{kl} = \frac{b_{ki} \Delta a_{ij} b_{jl}}{1 - b_{ji} \Delta a_{ij}}$$

If Δx_i – change oftheoutput of i-th industry needed to provide final demand Y_0 is negative, it is believed that technological changes taken place have led to the saving of resources, as a permanent final demand provides less output. It is clear that negativity of$\Delta x_i$is achieved by negativeΔb_{ij}.

World Inter-RegionalInput-OutputModel (IRIO) lookslike

$$x_i^r = \sum_{s=1}^{m} \sum_{j=1}^{n} a_{ij}^{rs} x_j^s + \sum_{s=1}^{m} \bar{y}_i^{rs}, (i = 1, \dots, n; r = 1, \dots, m) \qquad (2)$$

where, x_i^r - output of the i-th product to r-th country, a_{ij}^{rs} - direct costs coefficients of i-th product r-th country per unit of j-th product s-th country, n- number of products (branches), m- number of countries, $\bar{y}_i^{rs}$ - i-th final product supplied by r-th country in the s-th country, $\sum_{s=1}^{m} \bar{y}_i^{rs}$delivery of i-product of r-th country to the needs of the end-use and stockpiling of all countries. Let denote the last figure as f_i^r, and vector with dimensionnxmwith elementsf_i^r asFand call it (conditionally) the vector of the final demand. Then the coefficient of full costl_{ij}^{rs}shows the full costs of the product of i-r-th country in the j-th unit of the final demand of s-th country.Denote the matrix with elementsl_{ij}^{rs}byL. Accordingly, $\Delta X^l = \Delta L * F_0$, by analogy with the national Input-Output model, shows the change in the vector of world outputs (vector X with dimension nxm with elementsx_i^r) due to technological changes. (AndF_0vector does not include a component of imports, all of its elements are positive, so there is no negative import problems and, as a consequence, with a positive contribution to the$\Delta X^l$by imports.)

Applying of Inter-Regionalmodel of interbranch balance causes a problem with the trade relations between countries. After the coefficientsl_{ij}^{rs} when r $\neq$ s are not technological and intensity dependent on the export of the i-thproduct from r-thcountry to s-thcountry, and only slightly reflect s-thcountry's technology. Of course, we remember that l_{ij}^{rs}depends not only on export intensity, by and large - from all the world's technological coefficientsof Input-OutputModel.However, a decisive contribution in l_{ij}^{rs} brings eponymous technological coefficienta_{ij}^{rs}.In particular, Δx_i^rshows the increase (decrease) of the volume of the i-th product of r-th country caused by technological changes in the r-th country, and to some extent technological change in other countries, as well as changes in trade relations between countries. By reducing trade coefficients,Δx_i^rwill decrease regardless of changes in technology, and vice versa to grow, with an increase in the intensity of trade between countries.Thus, the assessment of the contribution of technological factor in economic dynamics based on world IO bears the imprint of the impact of trade coefficients.But in this case, the formulation of the question can be changed - whether changes in trade relations effective in terms of the world economy? Did they lead changes to the reduce the total release of the i-th industry needed to provide given the global final demand? Then on the total efficiency of technological changes and shifts in trade relations on a global scale can be judged by$\sum_{r=1}^{m} \Delta x_i^r$. Then the matrix A worldInput-OutputModel can be seen as a technological matrix.

This approach is performed on the basis ofWIOD database. In WIOD database industry symmetrical 35x35 dimension tables for 40 countries are published from 1995 to 2011. According to them it is possible to calculate the direct cost of the matrix coefficient A or otherwise, technological matrix. The difficulty of the analysis of 35x35 dimension tables is the high degree of aggregation of industries. For the Russian Federation it is particularly problematic to analyse the coefficients of the most important sectors of oil and gas, metal ores, coal and other non-metallic ores - all of these activities combined into one mining industry. At the same time, in WIOD database time series 1995-2011 of supply and usage tables for the 40 countries are published. The dimension of the supply and usage tables 59x35, i.e. they are designed for 59 types of products and 35 industries. Availability of supply and usage tables 59x35 dimension makes it possible to calculate food matrices A with the technological dimension 59x59 (in the old terminology - matrices for pure branches). The calculation of these matrices is possible on the basis of the method of branch technologies (ITA - Industry Technology Assumption). In addition to the National Input-Output Tables, WIOD published global cross-industry balances (WIOT) for the 40 countries and the rest of the world in the context of 35 branches from 1995 to 2011-th. Thus, the technological matrix of the WIOD is a table with 1435x1435 dimension. The tables are published at current prices. It is clear that the application of the formula

$$\Delta \boldsymbol{X}_{\mathrm{T}} = \Delta \boldsymbol{B} * \boldsymbol{Y_0} \qquad (3)$$

for assessing the contribution of technological factor in economic dynamics requires conversion tables at constant prices. The named database also shows the base (to the 1995-th year) price indices from 1996go to 2009 years in the context of 35 branches. The latter allowed to recalculate WIOT and the matrix coefficients of full expenditures at constant prices of 1995 by using the following algorithm. Let $A, \widetilde{A}$ and $B, \widetilde{B}$ be thematrix of coefficients of direct and total costs in prices of basic and k-th year; $I_1, ..., I_n$-price indices of k-thyear relative to the base year. Then the matrix coefficients of direct expenditures in the k-year price is calculated by the formula $\widetilde{A} = IAI^{-1}$ and $\widetilde{a}_{ij} = a_{ij}\frac{I_i}{I_j}$, where I is the diagonal matrix formed from price indices. The coefficients of total costs in the k-th year prices $\widetilde{B}$ arecalculated as:

$$\widetilde{B} = (E - \widetilde{A})^{-1} = (E - IAI^{-1})^{-1} = (IEI^{-1} - IAI^{-1})^{-1} = (I(E - A)I^{-1})^{-1} = I(E - A)^{-1}I^{-1} = IBI^{-1},$$

(it is known that the condition for the non-singular matrices is $(ABC)^{-1} = C^{-1}B^{-1}A^{-1}$). Then

$$\widetilde{B} = IBI^{-1} \Rightarrow \widetilde{b}_{ij} = b_{ij}\frac{I_i}{I_j}$$

Recalculation of the matrices A and B in the comparable prices also requires taking into account the difference of the dollar to the national currency for the base and end years in each country.

As noted above, changes in the technological coefficients of the world input-output balance model depend on the actual technological developments, as well as from changes in the country's place in the global technological chain. Country’s block meets the coefficients of direct costs of domestic products on the domestic output vector. Reduced processing coefficients, resulting in lower consumption of the intermediate under national IO model generally considered as technological progress. However, the situation is somewhat different for the WIOD. Domestic technological factors may decline due to the substitution of domestic import costs. On the other hand, the intermediate demand for domestic products may increase due to the growth of exports of goods intended for intermediate consumption, thereby increasing the processing coefficients, which depend on commercial factors. Thus, the import and export of intermediate products are in different directions in the interim changes in demand for domestic issues. The final result of the contribution of changes in coefficients of direct expenditures on economic dynamics consists of the technological changes and shifts in the international division of labor.

Noted above we will explain with the example of 3-country the world input-output model(without loss of generality). Then Leontev's inverse matrix can be written in block form, where L^{cd} (c=r,s,t; d=r,s,t) submatrix corresponding coefficients complete product costs (branches) of the country with food production (branches) of the country d. The diagonal of the matrix corresponds to the national units of the world input-output balance.

$$L = \begin{pmatrix} L^{rr} & L^{rs} & L^{rt} \\ L^{sr} & L^{ss} & L^{st} \\ L^{tr} & L^{ts} & L^{tt} \end{pmatrix} \qquad (4)$$

In the ratio $\Delta X^{l} = \Delta L * F_0$, determining of increase of the outputs due to changes in the technological coefficients country c (c=r,s,t) corresponds to $\Delta X^{lc} = \Delta L^{c} * F_0$, where ΔL^{c} is a submatrixof blocks L^{cr}, L^{cs}, L^{ct}. Then ΔX^{lc} is the increase of outputs due to changes in technological coefficients – depend on domestic technological coefficients,as reflected inL^{cc}, as well as the country c, as reflected inL^{cd} (c$\neq d$).In turn, $L^{cc}$is dependent on imports from the country c, so at the lastL^{dc} (d$\neq c$) . Thus, $\Delta X^{lc}$is defined as the result of technological change in the c-th country and the dynamics of its export and import flows.That is, theoretically, if the intermediate export growth prevails over growth of intermediate imports, the component $\Delta X^{lc} = \Delta L^{c} * F_0$of c-thcountry within the world input output model should be significantly positive.

Analysis of$\Delta L^{c} * F_0$for the domestic and export units, corresponding to the c-th country within the world balance, suggests that the change in the world balance of cost factors better reflects changes in trade relations, rather than technological change. Especially convincing is the statement is due to the fact that$\Delta B * Y_0$for the national input output model, tends to take low positive values, that is, technological change didn't play a significant role in the economic dynamics of the country. A greater contribution is from the growth of final demand.

Table 1

Evaluation of technological input into dynamics of the outputs basis on the WIOD					
	The contribution of changes in the specific cost coefficiants in the increase in total outputs (1995-2009 gg., %)			The ratio to the total increase of outputs (1995-2009 gg., %)	
Country	Basis on WIOD	Basis on national block in WIOD	Basis on export block in WIOD	Intermediate export	Intermediate import
Austria	33,1	13,5	19,6	24,6	15,2
UK	5	2,9	2,1	13,8	11,6
Germany	12,2	-4,9	17,2	34,8	19,8
France	14,6	8,1	6,5	12,3	7

India	5	0,1	5,1	5	8,9
Canada	9,4	9	0,4	7,2	9,7
China	12,9	3,5	9,4	5,9	9,7
Russia	11,9	5,2	6,7	9,5	7
USA	-0,7	0,5	-1,2	6,9	0,6
Japan	2,6	15,7	-13,1	102,9	18,3

The growth of intermediate exportsand intermediate imports has a different effect on the cost factors of c-th country in the framework of the global balance. The growth of intermediate imports decreases, all other conditions being equal, the national unit cost ratios in the world balance. All other conditions being equal the growth of intermediate exportsincreases the export part of the lines of c-th country in the framework of the world balance (export block). Thus, according to the data in Table 1 show similar results, such countries as Austria, Germany and France. They are closely integrated into the process chain of the European Union countries (the contribution of the export unit for Austria is 1.5 times of the contribution of the national block in $\Delta L^c * F_0$, for Germany's contribution to the national unit is negative.It should be noted that, increase in intermediate exports and intermediate importsis essential for these countries, respectively the share of contribution$\Delta L^c * F_0$to the output growth is significantly different from the similar figure calculated on the basis of the national balance. For example, for Germany: on the world input output balance, the figure is 0.12, according to the National input output balance - twice as high. That is, the increase in imports of intermediate flows reduced the contribution of technological change ratios in Germany output increase in world input output balance. On the other hand, a significant contribution to output of growth factors for changes in trade exports.

Noted works in theory, but in practice, other things being equal, conditions are not met and, therefore, different countries show different results. For example, in Austria, Germany, France, Britain, the United States the growth of intermediate exports prevail over the growth of intermediate imports to Austria, Germany, France, Great Britain, which are closely integrated into global production chains,$\Delta L^c * F_0$in international input output model really have significant positive values (see. Table 1). The situation is somewhat different for Japan and the United States. Although Japan has already built in other countries in the process chain for the world input output model has a small value$\Delta L^c * F_0$, equal 2,6%. (It should be noted that Japan has a special position among the analyzed countries because of low rates of growth during the study period. Smaller values of increase in output in the denominator leads, in turn, to a large absolute values of the studied parameters, indicating that fundamental structural changes in Japanese economy.)for the US, the world's embeddedness in technological chains is not as high, respectively $\Delta L^c * F_0$ takes even a small absolute value of a negative value, likely due to technological factor of the national economy.This fact is also correlates with $\Delta B * Y_0$on the USA national balances (index takes a small positive value equal to 3%). We can say that the influence of the internal technological factor is close to zero, and the cost factors that corresponds to the US lines of the global balance insignificantly changes, even with the participation of export. For Canada, China, India, Russia, the situation is somewhat different. For these countries low ratio increments intermediate exports and intermediate imports to gain outputs. Accordingly, the contributions $\Delta L^c * F_0$are not as high within the world input-output model outputs in increments of these countries. Although China and Russia, are rather closer to the first group of countries.

Thus, the analysis shows that for the estimation of the contribution of technological factor in the dynamics of the outputs of the national economy the national input output model is more suitable. As mentioned above, when considering trade relations as part of the production technology, the world's input-output model can be used to assess the dynamics of technological input into outputs.

Table 2 shows the contribution of technology changes in the issues of growth for the world equal to 11% of the total growth outputs worldwide. This means that in general the change of technological factors does not ensure a reduction of outputs, providing a fixed final demand. There was not also saving primary resources, although their contribution to total of output growth is very small - 0.1% to the increase in total outputs. That is, figuratively speaking technological breakthroughs have not happened that would ensure production of gasoline without oil or any production without electricity. However, for certain types of primary resources there is a negative contribution to growth outputs, that is, cost factors for these types of resources in general and allow for decreased fixed world demand for smaller final outputs of these resources. This applies to agricultural products, wood, non-metallic mineral resources, metals. World energy consumption has increased and amounted to 18% of the increase in output power.

In the analysis of the contribution of technological factors in the economic performance it is necessary to pay attention to sectors such as communications and telecommunications, financial services and R&D (research and development) and high-end business services. Accordingly, the increase in the unit costs of these industries in the world production outputscaused growth in these sectors by 24%, 18% and 37%. Thus, most research intensity increased world production and was more than one third of the increase in output due to changes in the technological factors.

The data in Table 2 demonstrate eloquently, which countries meet the growing costs of these industries.

Table 2

Technological contribution to the world economic dynamics and the share of branches in the amount of increase in output for the 1995-2009 gg. (In comparable prices,%)								
Industries	Technology contribution of industries to the world economic dynamics	The share of branches in the amount of increase in output for the 1995-2009 gg. (In comparable prices,%)						
		Average world	Russia	USA	Japan	China	Germany	India
Agriculture, Hunting, Forestry and Fishing	-9,7	2,0	3,8	0,9	-8,9	2,3	1,0	3,8
Mining and Quarrying	8,9	1,7	1,7	0,2	-5,1	1,4	-1,7	0,7
Food, Beverages and Tobacco	7,6	3,3	7,7	0,7	-15,4	5,2	-2,4	3,5
Textiles and Textile Products	-8,2	1,6	-0,2	-2,0	-37,2	5,5	-1,6	5,2
Wood and Products of Wood and Cork	-20,7	0,4	0,1	-0,1	-23,2	1,5	-0,7	-0,1
Coke, Refined Petroleum and Nuclear Fuel	12,3	1,4	0,6	0,5	-9,8	1,3	1,4	3,3
Chemicals and Chemical Products	-0,2	2,9	0,9	0,7	-7,0	4,2	1,3	4,0
Basic Metals and Fabricated Metal	-4,2	3,5	3,1	-0,4	-69,2	10,0	2,2	4,8
Electrical and Optical Equipment	23,6	12,8	0,9	8,8	128	17,9	11,6	4,6

Transport Equipment	9,1	4,0	-0,7	0,4	2,2	6,4	13,3	3,3
Electricity, Gas and Water Supply	18,3	2,4	1,0	-0,1	5,4	2,5	4,4	3,5
Construction	3,4	4,0	11,4	-0,1	-150	7,2	-7,9	9,0
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	2,3	8,2	25,6	15,7	-101	3,6	7,8	7,7
Post and Telecommuni cations	23,7	4,9	2,6	5,3	60,9	1,3	6,1	9,7
Financial Intermediatio n	18,2	7,9	5,8	19,5	-12,3	1,7	11,8	6,7
Renting of M&Eq and Other Business Activities	36,8	10,2	6,6	19,1	221	1,9	17,0	4,2
Education	8,9	1,1	-0,3	0,5	-10,8	1,2	1,8	2,1
Health and Social Work		4,0	0,7	7,8	55,5	1,0	11,8	0,8
Other industries		23,7	28,4	22,6	76,5	23,9	23,0	23,4
Total	11	100	100	100	100	100	100	100

As you can see, the branch structure of increase of outputs is diverse. Firstly, the most rapid growth of the R&D industry and knowledge-intensive business services is observed in Japan, USA and Germany. In other countries, including Russia, this sector shows a level lower than the average, that is, structural changes that occurred during the study period, take a moderate position. In the international classification by NACE, used in base WIOD data, knowledge-intensive business services include design services for manufacturing, designing and marketing new products, patent activity, architectural, engineering geological and some other services. The share of other services is low. On this basis, the cost of this industry in the production together with the R & D can be considered as knowledge-intensive production. The data in Table 2, thus, indicate which countries, of those surveyed, meet structural changes ofthe growing worldwide knowledge-intensity of production - in Japan, USA, Germany. The second place on the growth of the cost per unit of output takes electronic and optical equipment industry. Global average growth issues of the industry due to the growth of its unit cost of production was 23.6

Especially the proportion of convex on R&D cost and knowledge-intensive business services in the context of the country can be seen in individual industries. For example, for high-tech medical and optical equipment unit costs of R&D and knowledge-intensive business services are presented in Figure 1.

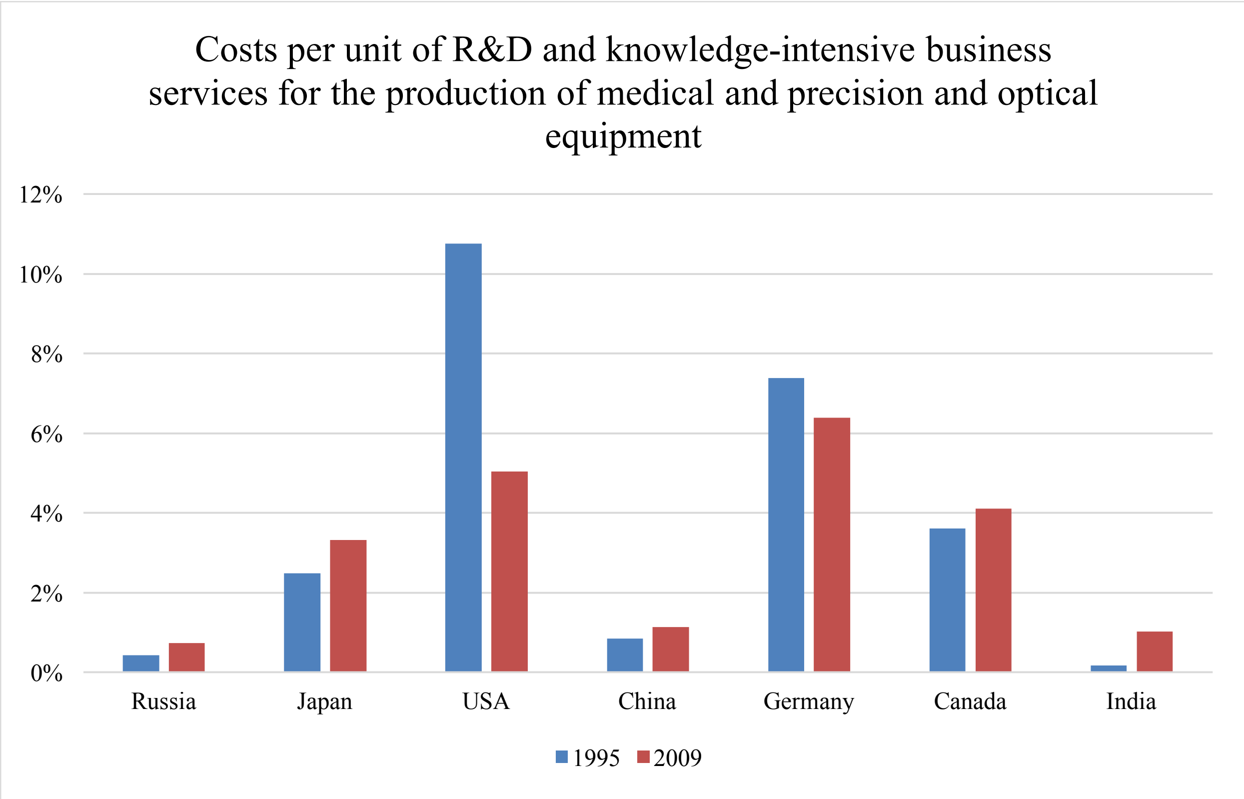

Figure 1

With such a high-tech production in the developed countries we should expect a large amount of indirect imports of "science" in Russia through imports of other goods and services. Evaluation of indirect imports of R&D and knowledge-intensive business services can be based on the model of the world input-output balance. The first approach to the assessment of indirect imports of "science" is to estimate coefficients of indirect costs of "science"$c_{30,j}^{im}$based onthe world input output model:

$$c_{30,j}^{im} = \sum_{s \neq r}^{m} (b_{30,j}^{sr} - a_{30,j}^{sr}),$$ where r– index Russia

Accordingly, multiplying the vector of final demand in the Russian domestic issues, supplemented by import vector for the coefficients of indirect costs of "science" we get the amount of indirect imports of R&D and knowledge-intensive business services. Calculations made on the basis of the world input-output data for the year 2011 show that the volume of imports of indirect R&D and knowledge-intensive business services in Russia through imports of other goods and services amounts to 680 bn. rub.

Another approach to the assessment of indirect imports of "science" is not the assessment of imports in gross dimension, in terms of added value(Imp_{ad})[3]For example, the estimated value added created by the US industry R&D and knowledge-intensive business services to meet the final demand of the Russian Federation. The amount of added values for all countries (except Russia) and the import of "science" in terms of value added[2]. The formal expression of this approach on the example of the three countries (without loss of generality) is written as

$$Imp_{ad} = (0, v^s, v^t) \begin{pmatrix} L^{rr} & L^{rs} & L^{rt} \\ L^{sr} & L^{ss} & L^{st} \\ L^{tr} & L^{ts} & L^{tt} \end{pmatrix} \begin{pmatrix} f^{rr} & +0 & +0 \\ f^{sr} & +0 & +0 \\ f^{tr} & +0 & +0 \end{pmatrix}$$

where$v^s, v^t$are row vectors of value added share in the outputs industry of the countries s and t,f^{rr}, f^{sr}, f^{tr}column vectors of the final demand of the Russian Federation (r index) for domestic products and imports from the s and t. The other variables are in the previous notation. The volume of imports into the Russian R&D industry and knowledge-intensive business services for the year 2011 in terms of value added is 1.4% of the GVA of industries (GVA of industries WIOD data). The country structure of the import is shown in Table 3.

Table 3

Industry import structure of R&D and knowledge-intensive business services

Indirect imports of Russian R&D and knowledge-intensive business services of	
Germany	19,2%
USA	10,8%
France	8,2%
Italy	7,1%
China	6,4%
Japan	6,2%
United Kingdom	6,0%
South Korea	3,5%
Other countries	32,6%

[2] Strictly speaking, as calculated by the full import of "science" in terms of value added. Since the direct import of "science" in the Russian Federation is a small amount, it can be neglected.

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