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Article

Econometric forecasting of production matrix by total output in the framework of interindustry balance: Evidence from European firms

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Abstract: The paper is devoted to testing the core prerequisite of inter-industry balance methodology which states, that intermediate consumption is strictly proportional to the total output of an industry, or, in other words, production matrix is constant over time. The paper uses standard econometric and statistical tools to test the hypothesis of proportionality of intermediate consumption to the total output. The statistical base of the study is the world input-output tables collected for the period from 2000 to 2022 from European firms. By conducting a rigorous empirical analysis, we find that tested prerequisite cannot be considered as valid. We also propose a methodology of point forecasting of production matrices by total output, which helps to make more accurate forecasts compared to the trivial model, when production matrix is assumed to stay unchanged. The proposed methodology is to extend the input-output methodology by introducing the coefficients of proportionality of changes in intermediate consumption and changes in the total output. Proportionality coefficients are proposed to be obtained by regression equations based on statistical data of input-output tables. The results of this work can be useful for executive authorities in planning large state economic projects, as well as in assessing the impact of external shocks on the country's economy.

Keywords: intersectional balance; intermediate consumption; point forecast; world economy; input-output tables

1. Introduction

Over time, the process of economic integration goes forward with increasing speed. The dynamically changing external environment forces states to modify their economic structure. The structure of production, income distribution, industry proportions of prices, etc., are changing. The adoption of managerial decisions by the authorities in the field of economics is associated with the need for an in-depth analysis of the volume, structure and dynamics of available resources, sources of their formation and directions of use, assessment of the actual situation and projections for the future. In this regard, it is relevant and expedient to research the topic of identifying significant relationships among the economic sectors and forecasting their reactions to external shocks (Shaltoni et al., 2018; Santos et al., 2018; Wirtz et al., 2021).

One of the most effective ways to analyze cross-country relationships and structural shifts in the global economy is to use the methodology of intersectoral balance, which allows to objectively reflect the processes at macro level and their sectoral structure. The role of the input–output methodology, which provides a powerful tool for quantitative analysis of proportions in the real economy, has long been recognized in most countries. The development of input-output tables has become a part of the regular work of statistical agencies in many states wishing to conduct a qualitative assessment of their economic condition.

The development of the input-output method is associated with Leontief, who in the 1930s developed and put into practice a method for analyzing the structure of reproduction in the context of individual industries for the US economy. At the same time, the scheme of the input-output model proposed by him was very similar in structure to the scheme of the Balance of the national Economy of the USSR, first built for 1923–1924 (Leontief, 1936).

It is worth noting that the practice of using input-output tables was introduced by scientists about 50–70 years ago and developed with different dynamics in most countries. So, to date, there is a significant experience of Russian and foreign scientists on this topic and a fairly broad information base has been laid for its further study (Almon, 1998). For the most part, the authors focus on identifying the most dependent industries and finding significant relationships between countries in the process of world trade (Aganbegyan, 1972).

In particular, with the help of the input-output tables, it becomes possible to analyze the degree of import dependence of Russian industry on the supply of intermediate consumption products from trading partner countries. In the course of research, regional tables are built on the basis of national ones, and then transformed into a symmetrical input-output table of the region. Interregional intersectoral models were also used for calculations to assess the effectiveness of inter-republican interactions before the collapse of the USSR. The calculations are noteworthy in that they accurately predicted the consequences of this decay. The authors demonstrate possibilities of a modified dynamic intersectoral model of the Russian economy with a balance of payments block. The results of calculations for assessing the prospects for the development of the Russian economy for the period 2012–2015 are analyzed in two versions: moderately optimistic and pessimistic. The works of Russian scientists also highlight works devoted to the use of data from the intersectoral balance to work with production functions.

Authors also find worth noting the works on the basic prerequisites of the input-output tables. Thus, in his writings Dorfman (1954) points out that the hypothesis of linear relationships is one of the main contradictions of the input-output model to the generally accepted economic postulates. As Leontief notes, the question of the significance of this contradiction should be resolved as a result of analysis based on real data, and not in the course of theoretical reasoning (Klein, 1952).

Therefore, the input-output table methodology is a great tool for analyzing the interdependencies among different industries. However, it cannot be considered complete since its main prerequisite is yet to be verified by empirical analysis. Therefore, this research, is intended to test the provision of intersectoral balance, which states that intermediate consumption is strictly proportional to the total output of an industry. Thus, the obtained results can contribute to solving the fundamental problem of optimal planning of the investment policy of states in order to achieve the established levels of certain macroeconomic indicators (Abakah et al., 2023; Alshater et al., 2024; Hasan et al., 2024; Naeem et al., 2023).

The rest of the paper is organized as follows. Section 2 contains the literature review. Section 3 contains the methodology (method). Section 4 contains the results. Section 5 contains the conclusions and recommendations.

2. Data and methodology

According to the definition, the intersectoral balance is an economic and mathematical model that characterizes intersectoral production relationships in the economy. The main feature of this balance is that the reproduction of the aggregate social product is considered according to the detailed classification of branches of the national economy (Ghosh, 2011).

The general form of the intersectoral balance is shown in **Table 1**.

Table 1. Cross-industry balance of production and distribution of public product.

		Production sector					**Intermediate output**	**Final demand**	**Total output**
		1	**...**	**j**	**...**	**n**			
Production sector	1								
	...								
	i			X_{ij}			$X_{i.}$	Y_i	X_i
	...								
	n								
Intermediate input				$X_{.j}$					
Value added				V_j				Y = V	
Total input				X_j					

Intersectoral balance is divided into 4 constituent parts called quadrants. In this research the data only from the 1st quadrant will be used. The first quadrant is the most important part of the I-O table, as it reflects the intersectoral relationships in the economy. This section contains information about the intermediate consumption. The branches of production listed in the same order on the left and top of the first quadrant border the matrix of product redistribution. One can see at the intersection of the i-th row and the j-th column the number of products that were produced by industry i and directed to consumption by industry j. The diagonal, originating from the upper left corner of the matrix, represents the material production of each industry for its own consumption. As a result, the first section of the table gives a general picture of the distribution of products for the current production consumption of all branches (Kalinina et al., 2021).

The intersectoral balance rows show as Equation (1):

$$x_i = \sum_{j=1}^{n} x_{ij} + y_i \tag{1}$$

where x_i—total cost of production of industry *i*, where *i* = 1, 2, …, *n*;

x_{ij}—the cost of industry i products for the production of goods in industry j;

y_i—the final product of industry i.

This equation gives an idea of the distribution of products created by each industry. It shows that part of the gross product of industry i goes to consumption by other industries, and the other part (y_i) goes to final consumption.

As can be seen from the intersectoral balance columns as Equation (2):

$$x_j = \sum_{i=1}^{n} x_{ij} + z_j \tag{2}$$

where z_j—value added by each industry j, where j = 1, 2, …, n.

Equation (2) characterizes the production costs of the industries. It shows that the cost of the products of the j-th industry consists of the cost of the products of other industries used in production in this industry, as well as depreciation, payroll and profit of this industry.

Also, the balance nature of the I-O table is manifested in the fact that the overall results for the second and third quadrant are the same as in Equation (3):

$$\sum_{j=1}^{n} y_j = \sum_{j=1}^{n} z_j \tag{3}$$

Quantitatively, the relationship between the branches of production can be derived using direct cost coefficients calculated according to the following formula as Equation (4):

$$a_{ij} = \frac{x_{ij}}{x_j} \tag{4}$$

Equation (4) shows that for the production of the j-th branch of unit volume, it is necessary to use the products of the i-th branch of volume a_{ij}, where a_{ij} are constant coefficients called direct cost coefficients or technological coefficients. These coefficients are of great importance, since they allow to determine the average costs of some products for the production of a unit of other products, i.e., characterize the structure of material costs for individual industries. It is assumed that the values of a_{ij} change a little over time and can be considered constant (Ammar and Chereau, 2018; Clark and Harrison, 2018; Toscano et al., 2018; Šebestová et al., 2018).

Using technological coefficients, Equations (1) and (2), respectively, can be interpreted as follows Equations (5) and (6):

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + y_i \tag{5}$$

$$x_j = \sum_{j=1}^{n} a_{ij} x_j + z_j \tag{6}$$

There are two main prerequisites of the input-output model:

1) Each product is produced by only one industry.

2) Intermediate consumption of industries is linearly dependent on the production of products of consuming industries. For example, this hypothesis can be expressed as

follows: in order to increase the output of a certain industry by *n* times, it is necessary to proportionally increase all the costs of producing the corresponding products by *n* times. Usage of this assumption significantly simplifies calculations and allows to analyze the economic system at any level available.

It is noteworthy that during the appearance of the first works devoted to the input-output method, the situation was radically different from the current one. Earlier, the hypothesis of linearity was put forward due to the technical impossibility of making calculations based on other hypotheses. At the present time, the premise is accepted due to the relative simplicity.

However, nowadays many studies on the I-O tables topic showed that this prerequisite is not fully consistent. Taking into account that premise, this study is intended to propose a methodology of a point forecast of the production matrix and test its accuracy on the real data.

Firstly, we construct the regression models of the following type as Equation (7):

$$\ln\left(\frac{a_{tij}x_{tj}}{a_{(t-1)ij}x_{(t-1)j}}\right) = b_i \ln\left(\frac{x_{tj}}{x_{(t-1)j}}\right) + e_{tij} \quad (7)$$

where b_i—the angular coefficient of proportionality of the change in consumption of the *i*-th industry by the *j*-th industry when the total output of the *j*-th industry changes, $e_{tij} \sim N(0, \sigma_i)$—the error term of the model.

To obtain a model based on the production coefficients a_{tij} explicitly from Equation (7), we obtain the following expression as Equation (8):

$$a_{tij} = a_{(t-1)ij}\left(\frac{x_{(t-1)j}}{x_{tj}}\right)^{1-b_i} exp\left(e_{tij}\right) \quad (8)$$

From Equation (8) it can be seen that the point forecast for the period t can be obtained as follows in Equation (9):

$$\hat{a}_{tij} = a_{(t-1)ij}\left(\frac{x_{(t-1)j}}{x_{tj}}\right)^{1-b_i} \quad (9)$$

Equation (9) shows that with an extremely strong relationship between the growth of consumption of the *i*-th industry by the *j*-th industry and the growth of output of the *j*-th industry (b_i is close to one), the predicted value of the production coefficient is simply equal to the production coefficient for the previous period, namely: $\hat{a}_{tij} = a_{(t-1)ij}$. In other cases, the forecast for the production coefficient depends on the change in the output of the *j*-th industry. If the output of the *j*-th branch does not change, then $\hat{a}_{tij} = a_{(t-1)ij}$ regardless of the coefficient b_i (An et al., 2020; An and Mikhaylov, 2020; Mikhaylov et al., 2023a, 2023b; Moiseev, 2019). Thus, the proposed methodology makes it possible to obtain point estimates of the production matrix in the future for calculations based on the methodology of the intersectoral balance. The statistical base of the study is the world database of intersectional balances (World Input-Output Database, 2016). We used tables covering data for 44 countries for the period 2000–2022 as the data after year 2022 unavailable.

Data on 56 sectors of the economy are classified in accordance with the fourth revised version of the International Standard Industrial Classification of All Types of

Economic Activity from 2009 (ISIC 4). The classification of industries is presented below (**Table 2**).

Table 2. The classification of industries.

1.	Crop and animal production, hunting and related service activities
2.	Forestry and logging
3.	Fishing and aquaculture
4.	Mining and quarrying
5.	Manufacture of food products, beverages and tobacco products
6.	Manufacture of textiles, wearing apparel and leather products
7.	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
8.	Manufacture of paper and paper products
9.	Printing and reproduction of recorded media
10.	Manufacture of coke and refined petroleum products
11.	Manufacture of chemicals and chemical products
12.	Manufacture of basic pharmaceutical products and pharmaceutical preparations
13.	Manufacture of rubber and plastic products
14.	Manufacture of other non-metallic mineral products
15.	Manufacture of basic metals
16.	Manufacture of fabricated metal products, except machinery and equipment
17.	Manufacture of computer, electronic and optical products
18.	Manufacture of electrical equipment
19.	Manufacture of machinery and equipment n.e.c.
20.	Manufacture of motor vehicles, trailers and semi-trailers
21.	Manufacture of other transport equipment
22.	Manufacture of furniture; other manufacturing
23.	Repair and installation of machinery and equipment
24.	Electricity, gas, steam and air conditioning supply
25.	Water collection, treatment and supply
26.	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
27.	Construction
28.	Wholesale and retail trade and repair of motor vehicles and motorcycles
29.	Wholesale trade, except of motor vehicles and motorcycles
30.	Retail trade, except of motor vehicles and motorcycles
31.	Land transport and transport via pipelines
32.	Water transport
33.	Air transport
34.	Warehousing and support activities for transportation
35.	Postal and courier activities
36.	Accommodation and food service activities
37.	Publishing activities
38.	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities

Table 2. (*Continued*).

39.	Telecommunications
40.	Computer programming, consultancy and related activities; information service activities
41.	Financial service activities, except insurance and pension funding
42.	Insurance, reinsurance and pension funding, except compulsory social security
43.	Activities auxiliary to financial services and insurance activities
44.	Real estate activities
45.	Legal and accounting activities; activities of head offices; management consultancy activities
46.	Architectural and engineering activities; technical testing and analysis
47.	Scientific research and development
48.	Advertising and market research
49.	Other professional, scientific and technical activities; veterinary activities
50.	Administrative and support service activities
51.	Public administration and defense; compulsory social security
52.	Education
53.	Human health and social work activities
54.	Other service activities
55.	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
56.	Activities of extraterritorial organizations and bodies

The first quadrant of each table contains information on the intermediate consumption of 56 industries in 44 countries. Data from the second, third and fourth quadrants were not used in the study, so the data were reduced to the first quadrant. One of the rows of the tables contains the total value for all rows, that is, the total output of all branches of production. In order to increase the interpretability of the calculation results, data were aggregated for the same industries in different countries.

Further, to identify the growth rates of each sector, the change in the output of each branch of production was calculated by dividing the data of the n-th year by the corresponding data of the year $n - 1$. At the same time, in order to obtain data on changes in physical consumption directly, the impact of price changes on the products of industries was excluded using input-output tables in the prices of the previous year. The calculation of the physical volume index was carried out according to the

The calculation of the physical volume index was carried out according to the following formula as Equation (10):

$$x = \frac{x_{ij}^{n}}{x_{ij}^{n-1}} \tag{10}$$

where x_{ij}^{n}—value of industry costs in current year prices; x_{ij}^{n-1}—value of industry costs in previous year's prices.

Thus, we obtained relative changes in the industry's expenditures as well as their aggregate output from year to year. In the last step, the change in the indices for 7 years, i.e., from 2000 to 2007, was found by the following multiplicative model shown as Equation (11):

$$\frac{x_{ip}^{2001}}{x_{ic}^{2000}} \times \frac{x_{ip}^{2002}}{x_{ic}^{2001}} \times \frac{x_{ip}^{2003}}{x_{ic}^{2002}} \times \dots \times \frac{x_{ip}^{2007}}{x_{ic}^{2006}} = \frac{x_{ip}^{2007}}{x_{ic}^{2000}} \quad (11)$$

where x_{ip}^{2001}—is a value of industry costs in previous year prices; x_{ip}^{2001}—is a value of industry costs in current year prices.

3. Results and discussion

In order to find the point forecast of the production matrix, the angular coefficients of the linear regression equation were found using the logarithms of the obtained growth rates of the costs of industries and their total output. The results of the calculations were structured in the table below (**Table 3**):

Table 3. Angular coefficients of linear regression equation for all branches of economy.

	Industry name	**Angular coefficient**
1	Accommodation and food service activities	0.5014
2	Activities auxiliary to financial services and insurance activities	0.2283
3	Activities of extraterritorial organizations and bodies	0.3236
4	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	0.1644
5	Administrative and support service activities	0.4375
6	Advertising and market research	0.3510
7	Air transport	0.3206
8	Architectural and engineering activities; technical testing and analysis	0.4020
9	Computer programming, consultancy and related activities; information service activities	0.3369
10	Construction	0.3884
11	Crop and animal production, hunting and related service activities	0.2007
12	Education	0.3242
13	Electricity, gas, steam and air conditioning supply	0.5012
14	Financial service activities, except insurance and pension funding	0.4409
15	Fishing and aquaculture	0.1197
16	Forestry and logging	0.1369
17	Human health and social work activities	0.4188
18	Insurance, reinsurance and pension funding, except compulsory social security	0.4019
19	Land transport and transport via pipelines	0.4858
20	Legal and accounting activities; activities of head offices; management consultancy activities	0.2913
21	Manufacture of basic metals	0.3275
22	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.3938
23	Manufacture of chemicals and chemical products	0.5074
24	Manufacture of coke and refined petroleum products	0.5239
25	Manufacture of computer, electronic and optical products	0.3608

Table 3. (*Continued*).

	Industry name	Angular coefficient
26	Manufacture of electrical equipment	0.4128
27	Manufacture of fabricated metal products, except machinery and equipment	0.4391
28	Manufacture of food products, beverages and tobacco products	0.2424
29	Manufacture of furniture; other manufacturing	0.3722
30	Manufacture of machinery and equipment n.e.c.	0.4169
31	Manufacture of motor vehicles, trailers and semi-trailers	0.2759
32	Manufacture of other non-metallic mineral products	0.4098
33	Manufacture of other transport equipment	0.2864
34	Manufacture of paper and paper products	0.4351
35	Manufacture of rubber and plastic products	0.4461
36	Manufacture of textiles, wearing apparel and leather products	0.3918
37	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.3922
38	Mining and quarrying	0.3005
39	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	0.1904
40	Other professional, scientific and technical activities; veterinary activities	0.3839
41	Other service activities	0.3823
42	Postal and courier activities	0.3242
43	Printing and reproduction of recorded media	0.4676
44	Public administration and defense; compulsory social security	0.3081
45	Publishing activities	0.3513
46	Real estate activities	0.3640
47	Repair and installation of machinery and equipment	0.3939
48	Retail trade, except of motor vehicles and motorcycles	0.4890
49	Scientific research and development	0.3110
50	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	0.3137
51	Telecommunications	0.3649
52	Warehousing and support activities for transportation	0.3310
53	Water collection, treatment and supply	0.3702
54	Water transport	0.1492
55	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.4332
56	Wholesale trade, except of motor vehicles and motorcycles	0.5743

After that we constructed the production matrices for years 2007 and 2022 from European firms. The latter is the matrix for 2022 year in prices of 2007 year which was calculated using the same multiplicative model Moreover, the value of output for all industries was also computed in prices of 2007 year.

At time all the necessary data is prepared, the point forecast according to the equation 9 is carried out using coefficients b_i. To assess the accuracy of the performed forecast, different quality metrics were used, particularly mean absolute error (MAE), mean absolute percentage error (MAPE), mean squared error (MSE) and root mean squared error (RMSE). Metrics were applied to two variations of deviations: the deviation of matrix forecasted by authors of 2022 from the real matrix for year 2022 and the deviation from the real matrix for year 2007 from the real matrix for year 2022. The results are presented in the figure below (**Figure 1**).

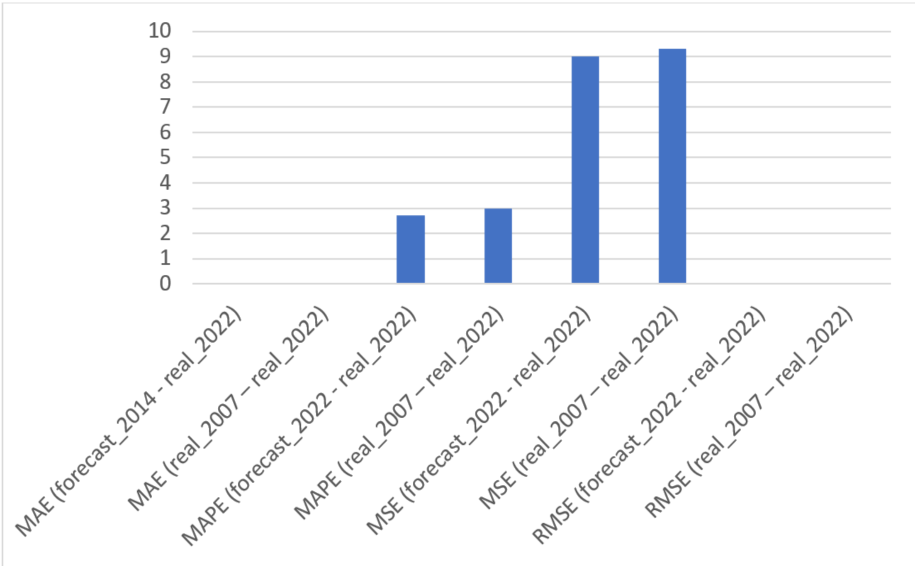

Figure 1. Quality metrics of regression models.

Thus, according to the study, the forecast performed by the authors on the basis of the proposed methodology shows more accurate results than the real production matrix according to every quality metric. As for them, forecasted model is better than real production matrix by 9.7% according to mean average error and by 7.4% as for the mean absolute percentage error.

Thus, based on the analysis of the world input-output tables, it can be concluded that the proposed method of obtaining forecasts of the production matrix will allow to obtain more accurate estimates in comparison with the trivial transfer of the production matrix of the previous period.

In this paper we conduct a cross-country analysis of the relationship between the dynamics of the structure of intermediate consumption and output of production sectors. It was revealed that the premise of a proportional change in the vector of intermediate consumption when output changes is not fully consistent. Despite the fact that the detected relationships are positive and significant, the slopes are significantly different from unity, which forces us to reject the hypothesis that the stated premise is correct. Based on the identified relationships, we can conduct a clustering procedure for considered industries, where we identify, in particular, clusters with strong, medium and weak relationships between intermediate consumption and output.

The cluster with week correlations includes such industries as activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (correlation coefficient is 0.25), crop and animal production, hunting and related service activities (correlation coefficient is 0.36), fishing and aquaculture (correlation coefficient is 0.30), forestry and logging (correlation coefficient is 0.35), human health and social work activities (correlation coefficient is 0.35), scientific research and development (correlation coefficient is 0.33), water transport (correlation coefficient is 0.39), activities auxiliary to financial services and insurance activities (correlation coefficient is 0.44), motion picture, video and television program production, sound recording and music publishing activities; programming and broadcasting activities (correlation coefficient is 0.43), other professional, scientific and technical activities; veterinary activities (correlation coefficient is 0.48), publishing activities (correlation coefficient is 0.47), real estate activities (correlation coefficient is 0.49). The intermediate consumption of these industries is least affected by the change in the total output of an industry (Khan et al., 2023; Navratil and Kolkova, 2019; Tipu, 2018; Żyminkowska, 2018).

The cluster with strong correlations includes such economic sectors as financial service activities, except insurance and pension funding (correlation coefficient is 0.71), land transport and transport via pipelines (correlation coefficient is 0.70), manufacture of chemicals and chemical products (correlation coefficient is 0.70), wholesale trade, except of motor vehicles and motorcycles (correlation coefficient is 0.74). The intermediate consumption of these industries is most affected by the change in the total output of an industry, i.e., changes almost proportionally to the change in total output.

4. Conclusion and recommendations

The paper is devoted to testing the prerequisite of inter-industry balance methodology which states, that intermediate consumption is strictly proportional to the total output of an industry, or, in other words, production matrix is constant over time. We also develop an extension of the inter-industry balance methodology incorporating the proportionality coefficients of changes in intermediate consumption of an industry when its output changes, calculated using regression analysis of statistical data from world input-output tables.

Thus, based on the proposed methodology, it is possible to forecast the structure of intermediate consumption of industries with a certain degree of uncertainty, which will improve the accuracy of economic planning at the state level. Moreover, the main limitation is that the results of the analysis can be used as an example for conducting similar studies at the cross-country level.

5. Potential future research directions

It should be especially noted that in addition to obtaining point forecasts of intermediate consumption for each industry when its output changes, it is also possible to obtain probability distributions for the gross output of each industry, their value added, wages, taxes and profits through Monte Carlo simulations based on the constructed regression equations. This will allow for scenario analysis of the development of the economic system under consideration.

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