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Research Article

Investigating the Relationship Between the Dynamics of the Structure of Intermediate Consumption and Output of Industries: Cross-Country Analysis

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Abstract: This paper examines one of the main prerequisites of the inter-industry balance methodology on the proportional dependence of the output of industries and their intermediate consumption. The statistical base of the study is the world input-output tables collected for the period from 2000 to 2014. According to the results of the work, it was revealed that the prerequisite of a proportional change in the vector of intermediate consumption with a change in output is not consistent. However, significant positive relationships were found between intermediate consumption and the output of industries. On the basis of the identified relationships, we conducted a clustering procedure on industries, where, in particular, clusters with strong, medium, and weak relationships between intermediate consumption and output are distinguished. Thus, the paper proposes to expand the input-output methodology by introducing proportionality coefficients for changes in the intermediate consumption of an industry with a change in its output. Proportionality coefficients are proposed to be obtained on the basis of regression equations built on statistical data from the input-output tables. 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, which will facilitate a scenario analysis of the development of the considered economic system. The results of this work can be useful to executive authorities in planning large state economic projects as well as in assessing the impact of external shocks on the country's economy.

Keywords: input-output balance, intermediate consumption, gross output, world economy, input-output tables

MSC: 91B38, 91B62

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 structures. The structure of production, income distribution,

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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, the sources of their formation and directions of use, an assessment of the actual situation, and projections for the future. In order to achieve certain macroeconomic indicators, the relationship between the economies of the modern world is strengthening. In this regard, it is relevant and expedient to conduct research on the topic of identifying significant relationships between the branches of production in the world economy and forecasting the optimal volumes of the product produced.

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 for objectively reflecting the processes at the level of the economy and its 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 around the world. The development of input-output tables has become part of the regular work of statistical agencies in many states wishing to conduct a qualitative assessment of their economic condition.

Hence, we provide a brief historical reference on the origin of the input-output methodology. The development of the input-output method is associated with Valery Leontiev, 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 in 1923-1924 [1]. 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 of the world [2]. So, to date, there is significant experience on this topic, and a fairly broad information base has been laid for its further study [3]. 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 [4, 5].

Modern literature also pays high attention to the input-output methodology. In particular, with the help of the input-output tables, it becomes possible to analyze the degree of import dependence of an industry on the supply of intermediate consumption products from its regions and, in general, trading partner countries [6, 7]. In the course of research, regional tables are built on the basis of national ones and then transformed into a symmetrical input-output table for the region. In the practice of Russian scientists, 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 [7]. In the work of Baranov et al. [8, 9], the possibilities of a modified dynamic intersectoral model of the Russian economy with a balance of payments block are demonstrated, and the results of forecast 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 [10, 11]. The works on the basic prerequisites of the input-output tables are also interesting. Thus, in his writings, Dorfman [13] points out that the hypothesis of linear relationships is one of the main contradictions of the input-output model with the generally accepted economic postulates. As Leontiev [14] notes, the question of the significance of this contradiction should be resolved as a result of checks based on real data and not in the course of theoretical reasoning.

Papers on the input-output methodology are also proposed by international scientists. The practice of using intersectoral balances is also used in research by scientists from China, Taiwan, Japan, and Korea. Authors from Taiwan and Korea use input-output tables to identify value-added exports in the information and communications technology (ICT) industry [15]. Japanese scientists, for example, are transforming the international intersectoral balance to identify the regional contribution of value added and imports to the increase in final demand [16]. In addition, research is being conducted on methods for constructing and using regional input-output tables [17]. Also, as part of the development of comprehensive models describing the development of the national economy, the integration of the intersectoral balance with econometric models of various types is carried out. For example, Kratena and Streicher [18] developed a step-by-step algorithm for constructing a general macroeconomic model based on input-output tables. The authors point out that the model is based on usage and production tables developed by Eurostat. Price changes are calculated based on calculations in the econometric blocks of the production model, trade, and price system.

Summarizing the literature review on the subject considered in this article, we can conclude that the input-output tables are more popular in the works of foreign authors than in the works of Russian scientists. This study, in turn, is intended to contribute to solving the fundamental problem of optimal planning of the investment policies of states in order to achieve the established levels of certain macroeconomic indicators.

In order to obtain reliable results from the models constructed on statistics from input-output tables, one should verify whether the main prerequisite of this methodology holds, i.e., that the intermediate consumption of industries is linearly dependent on the production of products by consuming industries. If this hypothesis is true, then developed methods are sufficient to conduct an adequate analysis, but if it is not, a more sophisticated approach should be elaborated. In this respect, the main aim of this paper is to test this hypothesis and propose a method of forecasting a production matrix for more reliable analysis.

The paper is organized as follows: Section 2 is devoted to the development of a new approach to forecasting a production matrix based on regression analysis of statistics from input-output tables; Section 3 is devoted to testing the hypothesis on proportionality between the total output and intermediate consumption; and Section 4 summarizes the insights and points out directions for further research.

2. Research 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 in the unity of its natural material and value composition according to the detailed classification of branches of the national economy [19].

The intersectoral balance can be compiled in two variations: in value and in natural terms. They differ from each other in that indicators of the input-output table in value terms can be added in columns; however, this procedure cannot be done with intersectional balance in natural terms. The prices used in the table in value terms only play the role of weights, so you can use any other meters. In world practice, monetary tables are most often found. In this study, only inter-industry balances in value terms were used.

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					

Source: [20]

The general view of the intersectoral balance is shown in Table 1. It is divided into four constituent parts called quadrants. Let's analyze each quadrant separately.

The first quadrant is the most important part of the input-output table, as it reflects the intersectoral relationships in the economy. This section contains information about 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. At the intersection of the ith row and the jth column, the number of products that were produced by industry i and directed to consumption by industry j is represented. 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 and consumption of all branches of material production [20].

The second quadrant of the table reveals the total output. Considering the country-scale table, we can say that here are the components of gross domestic product (GDP) calculated by the end-use method: consumer spending of citizens, investment in the economy, government spending, and net exports.

The third section contains the cost structure of gross value added. The components of the gross value added are the income of the population, depreciation, profits of enterprises, taxes and subsidies related to production, and state revenues.

The fourth section characterizes redistributive relations in the economy carried out through the financial and credit systems.

Thus, input-output tables comprise extensive information about the structure of the economy, which allows us to build very detailed models based on general provisions of economic theory.

Next, let's move on to the arithmetic component of the tables. Let's analyze the rows and columns of the intersectoral balance separately. The intersectoral balance rows show that:

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

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 products in industry j; y_i – the final product of industry i.

This equation gives an idea of the distribution of products produced 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,

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

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

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

Also, the balanced nature of the input-output table is manifested in the fact that the overall results for the second and third quadrants are the same:

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

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

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

Equation (4) shows that for the production of products of the jth branch of volume x_j, it is necessary to use the products of the ith 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 us 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 little over time and can be considered constant.

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

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

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

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.

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. The use of this assumption significantly simplifies calculations and allows for the analysis of the economic system with any level of detail available in practice by industry.

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 of perception of the final result of calculations.

One of the main aims of this research is to check the feasibility of the hypothesis on the proportional change in the vector of intermediate consumption of each industry relative to the growth of output.

To test the hypothesis about the feasibility of the second prerequisite of the methodology of intersectoral balance, regression models of the following types were constructed:

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

where b_i – the angular coefficient of proportionality of the change in consumption of the ith industry by the jth industry when the total output of the jth industry changes, $e_{tij} \sim N(0, \sigma_i)$ – the error of the model.

Thus, in order to refute the tested premise, it is necessary to show a significant difference between the obtained angular coefficients from unity.

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

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

From the formula (8), it can be seen that the point forecast for the period t can be obtained as follows:

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

It can be seen from formula (9) that with an extremely strong relationship between the growth of consumption of the ith industry by the jth industry and the growth of output of the jth 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 jth industry. If the output of the jth branch does not change, then $\hat{a}_{tij} = a_{(t-1)ij}$ regardless of the coefficient b_i.

It should be noted that forecasts $\hat{a}_{tij}$ if there is a limit on the sum of production coefficients $\sum_{i=1}^{n+1} a_{tij} = 1$, where $a_{t(n+1)j}$ – value added, are not wealthy and need a procedure for approving forecasts (forecasts reconciliation). Adapting the method proposed in [21] and [22] to the forecasts obtained according to formula (9), we have that the consistent forecasts for the production coefficients $\tilde{a}_{tij}$ will maximize the logarithm of the likelihood function, see formulas (10) and (11).

$$LogLH_{tj} = \sum_{i=1}^{n+1} \text{In}\left(\frac{1}{\sqrt{2\pi\sigma_i}}\right) - \sum_{i=1}^{n} \frac{(\ln(a_{tij}) - \ln(\hat{a}_{tij}))^2}{2\sigma_i^2} - \frac{\left(\ln\left(1 - \sum_{i=1}^{n} a_{tij}\right) - \ln\left(\hat{a}_{t(n+1)j}\right)\right)^2}{2\sigma_{n+1}^2} \tag{10}$$

$$\tilde{a}_{tij} = \underset{a_{tij}}{\text{argmax}}\left(LogLH_{tj}\right) \tag{11}$$

Thus, according to formula (11), it is possible having information about the structure of output and consumption of industries for period $t-1$, to obtain an estimate of production coefficients for period t, which should be more accurate than a simple transfer of the production matrix from period $t-1$ to period t.

However, if the task is to calculate the output of industries for the production of a certain level of final consumption, it cannot be solved by means of a standard analytical expression:

$$X_t = (I - \widetilde{A}_t)^{-1} Y_t \tag{12}$$

as can be seen in formulas (9-11) $\widetilde{A}_t$ depends on X_t. In this regard, it is proposed to obtain a solution for the system of equations (12) using the following numerical algorithm:

- Step 1. Assume that $\widetilde{A}_t = A_{t-1}$;
- Step 2. With the current production matrix $\widetilde{A}_t$ and given vector of final consumption Y_t find X_t by the formula (12);
- Step 3. When the value X_t is obtained, calculate $\widetilde{A}_t$ by formulas (9-11), and proceed to Step 2.
- Step 4. Stop the algorithm when the convergence condition X_t is reached (the norm of this vector has changed by less than the specified value Δ).

Due to the implementation of this algorithm, it is possible to obtain more accurate estimates of the required production of industries to meet a given vector of final consumption.

To obtain interval estimates of the vector of production of industries, you can use the Monte Carlo method, generating random implementations of a_{tij} from their marginal probability distribution.

$$pdf(a_{tij}) = \int\int_0^{\infty} \prod_{i=1}^{n} \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{(\ln(a_{tij}) - \ln(\hat{a}_{tij}))^2}{2\sigma_i^2}\right) \frac{1}{\sqrt{2\pi}\sigma_{n+1}}$$

$$\times \exp\left(-\frac{\left(\text{In}\left(1 - \sum_{i=1}^{n} a_{tij}\right) - \text{In}(\hat{a}_{t(n+1)j})\right)^2}{2\sigma_i^2}\right) da_{t1j} \ldots a_{t(i-1)j} a_{t(i+1)j} \ldots a_{tnj} \tag{13}$$

Thus, the proposed methodology makes it possible to obtain both point and interval estimates of the production matrix in the future for calculations based on the methodology of the intersectoral balance. Similar methods are very popular in the scientific literature; see, for example, [23-28].

3. Description of source data and research process

The statistical base of the study was the world database of input-output tables [30]. The study used tables covering data from 44 countries in the world for the period 2000-2014. Unfortunately, the data after 2014 is in closed access. 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).

All uploaded tables have the same structure and look as follows:

Intercountry Input-Output Table				A01	A02	A03	B	C10-C12	C13-C15	C16	C17	C18	C19
43 countries, in current prices				Crop and animal production, hunting and related service activities	Forestry and logging	Fishing and aquacultur e	Mining and quarrying	Manufactur e of food products, beverages and tobacco products	Manufacture of textiles, wearing apparel and leather products	wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Manufacture of paper and paper products	Printing and reproducti on of recorded media	Manufactur e of coke and refined petroleum products
(industry-by-industry)				AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS
(millions of US$)				c1	c2	c3	c4	c5	c6	c7	c8	c9	c10
M69_M70	ing activities; activities of head offices; management consultancy activities	ROW	r45	11	0	0	62	8	0	1	3	3	67
M71	Architectural and engineering activities; technical testing and analysis	ROW	r46	0	0	0	0	0	0	0	0	0	0
M72	Scientific research and development	ROW	r47	0	0	0	1	0	0	0	0	0	0
M73	Advertising and market research	ROW	r48	0	0	0	1	1	0	0	0	0	0
M74_M75	Other professional, scientific and technical activities; veterinary activities	ROW	r49	0	0	0	0	0	0	0	0	0	0
N	Administrative and support service activities	ROW	r50	49	0	3	186	27	1	3	7	8	2
O84	Public administration and defence; compulsory social security	ROW	r51	2	0	0	15	4	0	1	1	1	13
P85	Education	ROW	r52	1	0	0	14	5	0	0	1	1	0
Q	Human health and social work activities	ROW	r53	1	0	0	3	4	1	1	2	2	0
R_S	Other service activities	ROW	r54	2	0	0	13	5	0	0	1	1	0
T	ıtiated goods- and services-producing activities of households for own use	ROW	r55	0	0	0	2	0	0	0	0	0	0
U	Activities of extraterritorial organizations and bodies	ROW	r56	0	0	0	0	0	0	0	0	0	0
II_fob	Total intermediate consumption	TOT	r65	39 039	925	1 205	72 426	58 385	2 605	5 553	5 386	4 672	19 240
TXSP	taxes less subsidies on products	TOT	r66	502	68	52	298	632	66	36	8	16	583
EXP_adj	Cif/ fob adjustments on exports	TOT	r67	0	0	0	0	0	0	0	0	0	0
PURR	Direct purchases abroad by residents	TOT	r68	0	0	0	0	0	0	0	0	0	0
PURNR	Purchases on the domestic territory by non-residents	TOT	r69	0	0	0	0	0	0	0	0	0	0
VA	Value added at basic prices	TOT	r70	30 489	1 570	1 895	98 315	24 247	2 336	3 383	2 463	3 042	3 752
IntTTM	International Transport Margins	TOT	r71	262	22	24	946	240	57	28	68	53	880
GO	Output at basic prices	TOT	r73	70 292	2 585	3 175	171 985	83 504	5 064	9 000	7 925	7 784	24 455

Figure 1. World «input-output» table for 2014 in current prices, expressed in millions of US dollars
Source: World «input-output» database [30]

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, the data were aggregated for the same industries in different countries. In other words, we sum up the intermediate consumption for the same industries in different countries. This process is performed in order to offset the nonrepresentative influence of insignificant consumption of imported goods for some industries.

Further, to identify the growth rates of each of the sectors of the economy, the change in the output of each branch of production was calculated by dividing the data of the nth 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 following formula:

$$x = \frac{x_{ij}^{n}}{x_{ij}^{n-1}} \tag{14}$$

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, relative changes in the industry's expenditures as well as their aggregate output from year to year were obtained. In the last step, we found a change in the indices for 14 years, i.e., from 2000 to 2014, by using the following multiplicative model:

$$\frac{x_i^{2001}}{x_i^{2000}} * \frac{x_i^{2002}}{x_i^{2001}} * \frac{x_i^{2003}}{x_i^{2002}} * \ldots * \frac{x_i^{2014}}{x_i^{2013}} = \frac{x_i^{2014}}{x_i^{2000}} \tag{15}$$

Further, a correlation and regression analysis were carried out using the logarithms of the obtained growth rates of the costs of industries and their total output. It should be particularly noted that absolutely all the obtained correlation coefficients were positive and statistically significant at the 95% reliability level. On the one hand, this result indicates some rationality in the tested premise of the methodology of intersectoral balance, but on the other hand, absolutely all angular coefficients are significantly less than one, which indicates its insolvency.

The highest correlation coefficient with the gross output of industries was shown by the following industries: activities in the field of financial services, except insurance and pension provision (0.71); land transport; transportation by pipelines (0.70); production of chemicals and chemical products (0.70); wholesale trade, except for trade in cars and motorcycles (0.74). The least dependence was noted among the following industries: household activity as employers; undifferentiated household activities for the production of goods and services for their own use (0.25); fishing and aquaculture (0.30); research and development (0.33); forestry and logging (0.35).

Thanks to the data obtained, it is possible to estimate the strength of the dependence of gross output on changes in the output of producing industries, as well as quantify the changes in the variables under consideration using the angular coefficients of the linear regression equation. For greater clarity, the table below shows the dispersion diagrams of consumption for some industries with gross output (Table 2).

One can clearly see from Table 1 that the intermediate consumption of some industries is very closely related to the change in total output, but the dependence between the consumption of other industries and total output is quite low. That fact states that the proportionality assumption is more than optimistic.

Referring to the data from the correlation analysis, the existing industries can be divided into three clusters:

- 1 cluster-correlation coefficient from 0 to 0.5;
- 2 cluster-correlation coefficient from 0.5 to 0.7;
- 3 cluster-correlation coefficient from 0.7 to 1.

The resulting clusters can be found in the appendix to this article (Appendix).

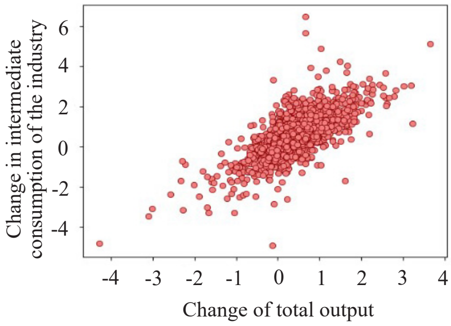
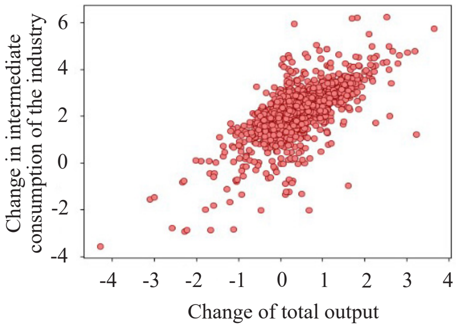
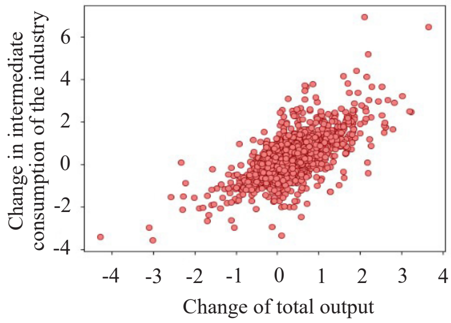
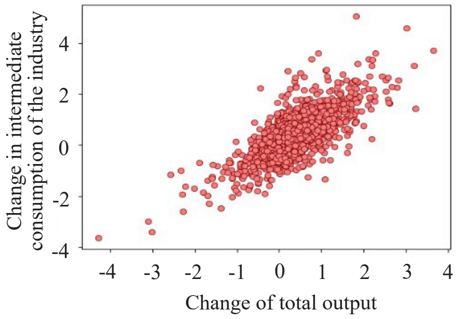
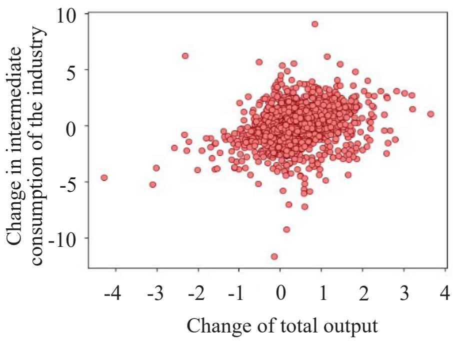
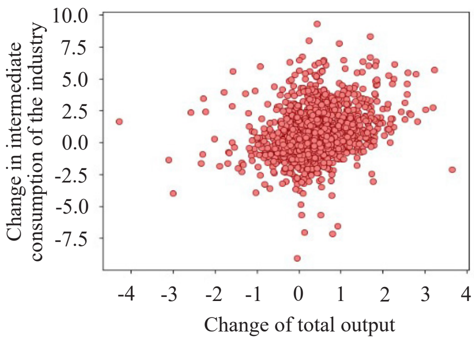
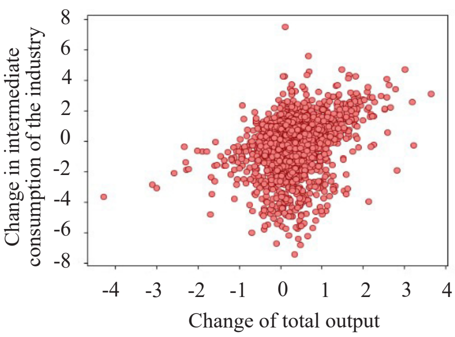
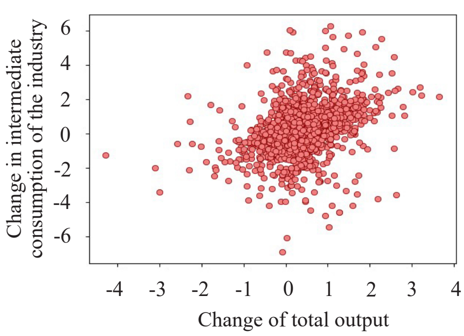
Special attention should be paid to the analysis of the relationship between changes in intermediate consumption and value added from changes in the gross output of the industry (see Figures 2 and 3).

The correlation coefficient for changes in intermediate consumption and changes in the total output of the industry is 0.925. Such a high indicator suggests that, despite the fact that the change in costs for a particular industry may be extremely disproportionate to output, the change in aggregate intermediate consumption is almost linearly interrelated with output. That fact suggests that industries try to reallocate the disposable budget according to the current economic situation, leaving the proportion of total intermediate consumption almost unchanged.

The correlation coefficient for changes in value-added and changes in gross output of the industry is also very high and is equal to 0.862, which reflects an almost proportional relationship between changes in intermediate consumption and output. It suggests that industries try to keep their margins unchanged despite the change in the economic environment.

Thus, based on the analysis of the world input-output tables, it can be concluded that the tested premise of the methodology of the intersectoral balance is not fully consistent, and the proposed method of obtaining forecasts of the production matrix will allow to obtain more accurate estimates of it in comparison with the trivial transfer of the production matrix of the previous period unchanged.

Table 2. Intermediate consumption and gross output scatter diagrams

Industry name	Scatter diagram	Industry name	Scattter diagram
Financial service activities, except insurance and pension funding		Land transport and transport via pipelines	
Manufacture of chemicals and chemical products		Wholesale trade, except of motor vehicles and motorcycles	
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use		Fishing and aquaculture	
Scientific research and development		Forestry and logging	

Source: Compiled by the authors.

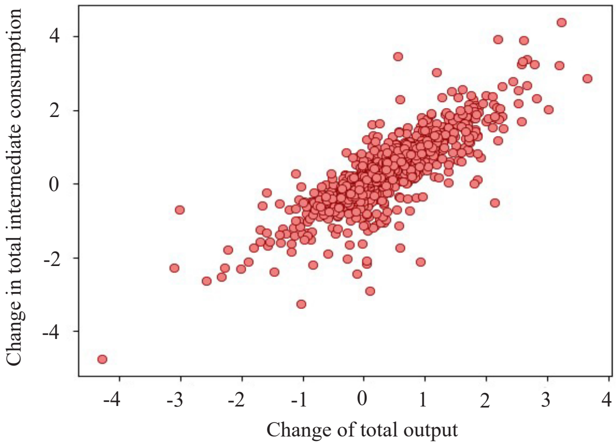


Figure 2. Scatter diagram of changes in intermediate consumption relative to changes in total output
Source: Compiled by the authors

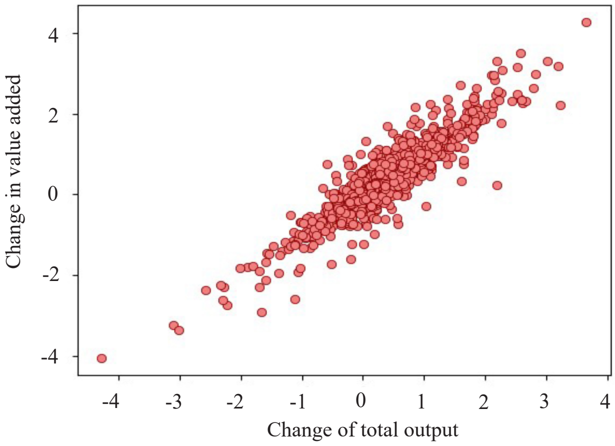


Figure 3. Scatter diagram of changes in value-added relative to changes in total output
Source: Compiled by the authors

4. Conclusion

In the course of this study, we carried out a cross-country analysis of the relationship between the dynamics of the structure of intermediate consumption and the output of world production industries. It was revealed that the hypothesis of a proportional change in the vector of intermediate consumption with a change in output is not fully consistent. Despite the fact that the relationships found are positive and significant, the angular coefficients are significantly different from one another, which forces us to reject the tested hypothesis. On the basis of the revealed interrelations, we carried out the procedure of clustering of industries, where, in particular, clusters with strong, medium, and weak interrelations of intermediate consumption with output are distinguished.

The paper also develops an extension of the methodology of the intersectoral balance by taking into account the coefficients of proportionality of changes in the intermediate consumption of the industry when its output changes, calculated using regression analysis of statistical data from the world input-output tables. It should be particularly 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 due to Monte Carlo simulations based on the constructed regression equations, which will allow for a scenario analysis of the development of the considered economic system.

Thus, based on the proposed methodology, it is possible to forecast the structure of intermediate consumption in industries with some degree of uncertainty, which will improve the accuracy of economic planning at the state level. Moreover, the results of the analysis can be used as an example for conducting similar studies at the intercountry level.

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Conflict of interest

The authors declare no competing financial interest.

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Appendix: Clusters by the extent of dependence on changes in industry output and consumption

A.1 $0 < R < 0.5$

Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (0.25)

Crop and animal production, hunting, and related service activities (0.36)

Fishing and aquaculture (0.30)

Forestry and logging (0.35)

Human health and social work activities (0.35)

Scientific research and development (0.33)

Water transport (0.39)

Activities auxiliary to financial services and insurance activities (0.44)

Motion picture, video and television program production, sound recording, and music publishing activities; programming and broadcasting activities (0.43)

Other professional, scientific, and technical activities; veterinary activities (0.48)

Publishing activities (0.47)

Real estate activities (0.49)

A.2 $0.5 < R < 0.7$

Advertising and market research (0.50)

Air transport (0.58)

Architectural and engineering activities; technical testing and analysis (0.50)

Computer programming, consultancy, and related activities; information service activities (0.58)

Education (0.51)

Insurance, reinsurance, and pension funding, except compulsory social security (0.55)

Legal and accounting activities; activities of head offices; management consultancy activities (0.53)

Manufacture of basic metals (0.58)

Manufacture of motor vehicles, trailers, and semi-trailers (0.59)

Mining and quarrying (0.53)

Postal and courier activities (0.50)

Public administration and defense; compulsory social security (0.59)

Repair and installation of machinery and equipment (0.52)

Sewerage; waste collection, treatment, and disposal activities; materials recovery; remediation activities and other waste management services (0.56)

Telecommunications (0.54)

Water collection, treatment, and supply (0.50)

Taxes less subsidies on products (0.58)

Accommodation and food service activities (0.67)

Administrative and support service activities (0.68)

Construction (0.66)

Electricity, gas, steam, and air conditioning supply (0.64)

International Transport Margins (0.69)

Manufacture of basic pharmaceutical products and pharmaceutical preparations (0.65)

Manufacture of coke and refined petroleum products (0.67)

Manufacture of computer, electronic, and optical products (0.66)

Manufacture of electrical equipment (0.68)

Manufacture of fabricated metal products, except machinery and equipment (0.66)

Manufacture of food products, beverages, and tobacco products (0.60)

Manufacture of furniture; other manufacturing (0.63)

Manufacture of machinery and equipment not elsewhere classified (0.65)

Manufacture of other non-metallic mineral products (0.62)

Manufacture of other transport equipment (0.60)

Manufacture of paper and paper products (0.66)

Manufacture of rubber and plastic products (0.69)

Manufacture of textiles, wearing apparel, and leather products (0.67)

Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (0.62)

Other service activities (0.60)

Printing and reproduction of recorded media (0.64)

Retail trade, except for motor vehicles and motorcycles (0.62)

Warehousing and support activities for transportation (0.64)

Wholesale and retail trade and repair of motor vehicles and motorcycles (0.66)

A.3 $0.7 < R < 1$

Financial service activities, except insurance and pension funding (0.71)

Land transport and transport via pipelines (0.70)

Manufacture of chemicals and chemical products (0.70)

Wholesale trade, except for motor vehicles and motorcycles (0.74)

Value added at basic prices (0.86)

Total intermediate consumption (0.93)