Yastremsky, Oleksandr Ivanovych; Kulyk, Volodymyr

**Article**

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**O.Yastremsky**[1]
***V.Kulyk***[2]

# VOLATILITY OF THE STRUCTURE OF INTERSECTORAL RELATIONS OF UKRAINE'S ECONOMY

*The article deals with the volatility of intersectoral flows in Ukrainian economy during 2000–2017. For this purpose, the authors construct a dynamic matrix series of direct cost coefficients in comparable detail (19 economic activities (EAs)); calculate statistical characteristics of 361 dynamics (19x19) and coefficients of direct expenses of Ukraine's intersectoral balance; and analyze the dynamics of cost indicators of Ukraine's economy (the ratio of GDP to total output, the Frobenius – Perron numbers) and those of economic activities (the Brauer – Perron numbers).*

*Construction of the historical series of the matrix of direct costs in comparable detail is achieved by aggregating the "input - output" tables.*

*Volatility is assessed using indicators of variation, relative variation, sample standard deviation, standard deviation per mean, historical volatility, and standard trend error (regression), i.e. trend volatility.*

*Volatility of intersectoral flows in Ukraine is significant. The maximum variation for the coefficients of direct costs for EA "Information ..." for all years of observation was 0.3144, for EA "Water Supply" - 0.3004, and for EA "Art" - 0.2673.*

*Derivative aggregates (Brauer-Solow numbers, relative EA cost) are also volatile. According to estimates of the standard deviation, the agrosector is the most stable, the most unstable - public administration.*

*Economy Ukraine has a significant margin of productivity. A sufficient Brauer-Solow condition for the productivity of the direct cost matrix is guaranteed to be satisfied for all years of observation.*

*Out of 361 coefficients of direct costs, time trends are recorded for 166. Among them, 91 have an upward trend, 65 - a downward trend. To fix the presence of the trend, the authors use the probability of deviation of the hypothesis about the significance of the linear dependence of the coefficients of direct costs on time.*

*The high cost intensity of the economy is a general economic problem of Ukraine. The ratio of GDP to total output in Ukraine is about 40%, while in developed countries, this figure is close to 60%. Reducing costs is a significant resource for economic growth in Ukraine.*

[1] **Yastremsky, Oleksandr Ivanovych –** Doctor of Economics, Professor, Chief Researcher, DNNU "Academy of Financial Management" (46/48, O. Honchara St., Kyiv, Ukraine, 01034), ORCID: 0000-0001-9900-3612, e-mail: yast2005@ukr.net

[2] **Kulyk, Volodymyr Vasyl'ovych –** Ph.D., Senior Researcher, DNNU "Academy of Financial Management"(46/48, O. Honchara St., Kyiv, Ukraine, 01034), ORCID: 0000-0002-2226-2795, e-mail: volodymyr_kulyk@ukr.net

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Research problem, research purpose. Uncertainty is a fundamental factor in economic policy, and fiscal risk analysis. The assessment tools of economic policy impact should take into account uncertainty. Intersectoral balance ("input – output" scheme) is one of these tools. One step in fiscal risk analysis is to identify sources of vulnerability, some of these sources are usually uncertain.

The purpose of the article is to assess the volatility of intersectoral relations in the Ukrainian economy, which is one of the sources of uncertainty. The focus of the analysis is on the relative extent of intersectoral linkages (direct cost matrix).

The analysis of related research. The work of the prominent American economist V. Leontief generated a powerful direction of intersectoral research (see review [1]). Currently, the State Statistics Service of Ukraine annually develops and publishes "input – output" tables for various details of economic activities.

In Ukraine, there are traditions of intersectoral research. First of all, should be noted the contribution of Academician V. Glushkov, who proposed an alternative to the use of W. Leontief's model, namely the computerized planning system (Displan) [2]. The projection of the computerized planning system on the present is in the work [3]. In the structure of the Institute of Cybernetics of the USSR Academy of Sciences, in the 70-80s of the last century there was the laboratory for "Methodical and information support of computerized planning systems" under the guidance of Yu. Arkhangelsky, where selected material balances were developed for the republic's needs of economic planning [4].

In the so-called "Canadian" model of Ukraine, the block of intersectoral balance is a component of the forecasting model [5]. The work [6] considers an applied model of general equilibrium, which is contained in an intersectoral block and used to analyze the consequences of Ukraine's entry into the World Trade Organization. In the works of M. Mikhalevich, I. Sergienko [7] and O. Dovgy [8, 9] the model of intersectoral balance is systematically used for analysis and forecasting of Ukraine's economy. In the work by Yu. Arkhangelsky, a short-term forecasting of output volumes with the use of the "input – output" model is considered [10]. In the work of B. Paskhaver [11], interbranch relations in agro-industrial complex of Ukraine are analyzed. The works by G. Kudin, V. Kudin and A. Onishchenko [12, 13] investigate the Leontief-Ford model, which is aimed at studying intersectoral interactions with the environment.

In the work [14], an interbranch "chessboard" of uncertainty between US industries was constructed. It is concluded that the degrees of uncertainty of intersectoral flows are significant. The starting point of the study were the calculations of the historical volatility of the coefficients of direct costs of the W.Leontief's "input – output" scheme. The significant volatility of these coefficients gives grounds to consider them random. Similar studies were conducted for other countries [15, 16] under simplified assumptions. In particular, it was assumed that the standard deviations of the coefficients of the random matrix of direct costs were proportional to their expected values.

In the works [17, 18] detailed reviews of publications are given, where the uncertainty and randomness in the schemes "input – output" are investigated. In the article [19], the optimization intersectoral model is generalized in case of randomness of the direct cost matrix. In the work [20], calculations of variants of this model using direct probabilistic methods of stochastic optimization are described [21].

Novelty. The article analyzes for the first time the volatility of intersectoral flows of the Ukrainian economy. To achieve this goal:

– a dynamic matrix series of direct cost coefficients in comparable detail was constructed (19 economic activities (hereinafter, EAs);

– statistical characteristics of 361 dynamics (19x19) coefficients of direct expenses of interbranch balance of Ukraine are calculated.

This made it possible to analyze the dynamics of expenditure indicators in Ukraine's economy and individual economic activities, determine their statistical characteristics, compare them with similar indicators of other countries, and draw conclusions about the resource for economic growth that may result from the reduction of costs in Ukraine's economy.

Presenting main material.

Information base. The information base of the study was the statistics from the State Statistics Service of Ukraine on intersectoral relations, such as "input-output" tables in basic prices [22], as well as methodological materials on sectoral statistics [23], and statistical materials of international organizations [24].

Statistical data for 2000–2017 are grouped into 19 types of economic activity, according to the classification given in [23, p. 30]. In different periods, "input-output" tables were developed in slightly different forms of presentation in accordance with: 1) aggregation of sectoral statistics (2000–2011 for 38 economic activities (EAs), in 2012 – for 35 economic activities (EAs), in 2013–2017 – for 42 economic activities (EAs)); 2) display of trade and transport statistics in "input-output" tables (with a separate line or not); 3) unification of names of separate EAs at different times, etc. Therefore, all "input-output" tables data for 2000–2017 had to be brought to a single standard in order to compare data on both intersectoral flows and elements of final consumption, value added (GDP at basic prices), etc. The results of aggregation were checked by matching the sums of column and raw totals (the sums of outputs in basic resource prices and the sums of their use for each economic activity).

Data aggregation standard for 2013–2017 is taken as a basis (Table 1), where 42 EAs are distinguished, and trade and transport margins are included in the respective EAs (G and H, respectively).

*Table 1*

**The scheme of aggregation of input-output table data in basic prices for 2014–2017 from 42 EAs to 19 EAs**

| № item number | Statistical codes of EAs | № item number |
|---|---|---|
| 1. | A | Agriculture, Forestry and Fisheries (AFF) Agriculture, Forestry and Fisheries |
| 2. | B | Mining and quarrying (1. Extraction of coal and lignite; 3. Extraction of crude petroleum and natural gas; 4. Mining of metal ores, other minerals and quarrying; provision of ancillary services in the field of mining and quarrying) |
| 3. | C | Processing industry (5. Manufacture of food products; beverages and tobacco; 6. Textile and apparel manufacturing, leather and other materials; 7. Manufacture of wood, paper, printing and reproduction; 8. Coke industry; 9. Production of petroleum products; 10. Manufacture of chemicals and chemical products; 11. Manufacture of basic pharmaceutical products and pharmaceutical preparations; 12. Manufacture of other non-metallic mineral products; 13. Manufacture of other non-metallic mineral products; 14. Metallurgical production; 15. Manufacture of fabricated metal products, except machinery and equipment; 16. Manufacture of computers, electronic and optical products; 17. Manufacture of electrical equipment; 18. Manufacturing machinery and equipment and parts, not elsewhere classified; 19. Manufacture of motor vehicles, trailers and semi-trailers; 20. Manufacture of other transport equipment; 21. Manufacture of furniture; other products; repair and installation of machinery and equipment). |

*Table 1 (end)*

| | | |
|---|---|---|
| 4. | D | Electricity, gas, steam and air conditioning supply (22. Electricity, gas, steam and air conditioning supply) |
| 5. | E | Water supply; sewerage, waste management (23. Water supply; sewerage, waste management) |
| 6. | F | Construction (24. Construction) |
| 7. | G | Wholesale and retail trade; repair of motor vehicles and motorcycles (25. Wholesale and retail trade, *including trade margins*; repair of motor vehicles and motorcycles) |
| 8. | H | Transportation, storage, postal and courier activities (26. Transportation, *including transportation margin*; storage; 27. Postal and courier activities) |
| 9. | I | Temporary accommodation and catering (28. Temporary accommodation and catering) |
| 10. | J | Information and telecommunications (29. Motion picture, video and television programme production, sound recording and music publishing; radio and television activity; 30. Telecommunication; 31. Computer programming, consulting and provision of information services (telecommunications)) |
| 11. | K | Financial and insurance activities (32. Financial and insurance activities) |
| 12. | L | Real estate transactions (33. Real estate transactions) |
| 13. | M | Professional, scientific and technical activities (34. Activities in the field of law and accounting; activities of the main departments (head offices); management consulting; activities in the fields of architecture and engineering; technical tests and research; 35. R&D; 36. Advertising and market research; scientific and technical activities; veterinary activity) |
| 14. | N | Administrative and support service activities. (37. Administrative and support service activities.) |
| 15. | O | Public administration and defense; compulsory social insurance (38. Public administration and defense; compulsory social insurance) |
| 16. | P | Education (39. Education) |
| 17. | Q | Health care and social assistance (40. Health care and social assistance) |
| 18. | R | Health care and social assistance (41. Health care and social assistance) |
| 19. | S, T97 | Provision of other services (part of section T (section 98) is not included in interproduction activities under the System of National Accounts) (42. Provision of other services) |

*Source*: According to recent data [23, p. 30].

In previous years, the data aggregation scheme had its own characteristics.

2013 – trade and transport margins are highlighted on a separate line. Therefore, these statistics are added to EAs "Trade" (G) and "Transport" (H), respectively. Similarly, the data for 2000–2012 are summarized.

2012 – "input-output" tables in basic prices contains 35 EAs. A number of EAs contain aggregate data that are comparable to the above classification: 1. "Mining and quarrying" includes EAs listed under 2–4 (see Table 1); 2. "Coke industry and refined petroleum products" (8–9); 3. "Manufacture of rubber and plastic products and other non-metallic mineral products" (12–13); 4. "Manufacture of basic metals and fabricated metal products, except machinery and equipment" (14–15); 5. Manufacture of motor vehicles, trailers and semi-trailers and other vehicles (19–20); 6. "Transportation, storage, postal and courier activities" (26-27).

2000–2011 – the "input-output" table contains 38 EAs classified according to the previous classification of EAs [25]. When bringing statistical data to the nineteen-branch data structure, the Methodological developments of the State Statistics Committee were used [26]. The scheme of aggregation of "input-output" table in the basic prices of 2000–2011 was used, similar to the scheme given in Table 1.

In general, the official publications of "input-output" table in basic prices [22] provide an opportunity for detailed research and study of other aspects of sectoral reproduction related

to taxation and subsidies, the use of imported goods in production and final consumption, research on the use of domestic products, etc.

Unfortunately, in 2014, the concept of "temporarily occupied territories" was introduced into Ukrainian statistics. Using the method of T. Picketty [27] in the work of A. Aslund, even Ukraine's material losses from the aggression of the Russian Federation alone were estimated at about 100 billion dollars USA [28]. In the work of R. Pustoviit [29] the issue of estimating military expenditures and their impact on the national economy, in particular Ukraine's, is considered. The estimated costs of military conflicts in the world in 2014 amounted to 14,3 trillion dollars USA, or 13,4% of world GDP.

However, compared to 2013, the direct expenditure matrix has not changed significantly. This is evidenced by comparisons of matrices *A*2013 and *A*2014 and some aggregates of their components. They are shown below in Fig. 1, 2 and 5. For example, Fig. 5 indicates the following cost characteristics of the Ukrainian economy: intermediate consumption to total output in 2013 was 57,17%, in 2014 – 57,72%; Frobenius – Perron number in 2013 was 0,6103, in 2014 – 0,6157. There are changes, but they are insignificant and incomparable with changes in the absolute values of Ukraine's losses from Russian aggression. This is partly due to the fact that the matrix contains relative values.

*Analysis of the calculations*. Let us pay attention to direct costs matrices for 19 EAs for 2000–2017. The following indicators were calculated for each element $a_{ij}$ and some of their aggregates:

– average ($a$),
– standard deviations ($s$),
– coefficient of variation ($s/a$),
– maximum values for the observation period (max $a_{ij}$ $(t)$),
– minimum values for the observation period (min $a_{ij}$ $(t)$),
– variations (max $a_{ij}$ $(t)$ − min $a_{ij}$ $(t)$),
– relative variations,
– significance of trends (*F significance*, the probability of rejection of the hypothesis of significance),
– coefficients of determination ($R_2$),
– slope, intersection of trends,
– forecast for 2019,
– standard forecast error,
– trend volatility, etc.

Among 361 elements $a_{ij}$, trends were recorded for 166 (the presence of a trend was determined if *F significance* < *0,05*), among them 91 had an upward trend, 65 – a downward one. Other elements (195) did not have a trend.

Historical volatility for a given indicator is defined as $s/\sqrt{T}$, where $s$ is the sample standard deviation, and $T$ is the period of time. Since $T$ is fixed, the volatility is determined by $s$.

Fig. 1 and 2 show the dynamics of some coefficients of direct costs.

Visual analysis, the values of the coefficients of determination R2, as well as the results of calculations to estimate the time regression, indicate the absence of trends for the coefficients of direct costs in Fig. 2. Trend dependencies (Fig. 1) allow to reduce the relative volatility. That is, the measure of volatility is not a change in the indicators themselves, but a deviation from the trend. A well-known practice for estimating historical volatility is to use a sample standard deviation. Visual analysis, the values of the coefficients of determination R2, as well as the results of calculations to estimate the time regression, indicate the absence

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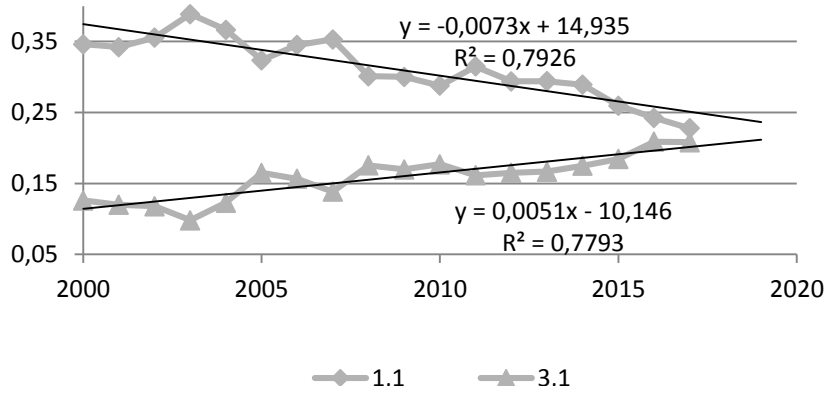


**Fig. 1. Dynamics of trend coefficients (a11, a31) and their forecast**

*Source:* compiled by the authors.

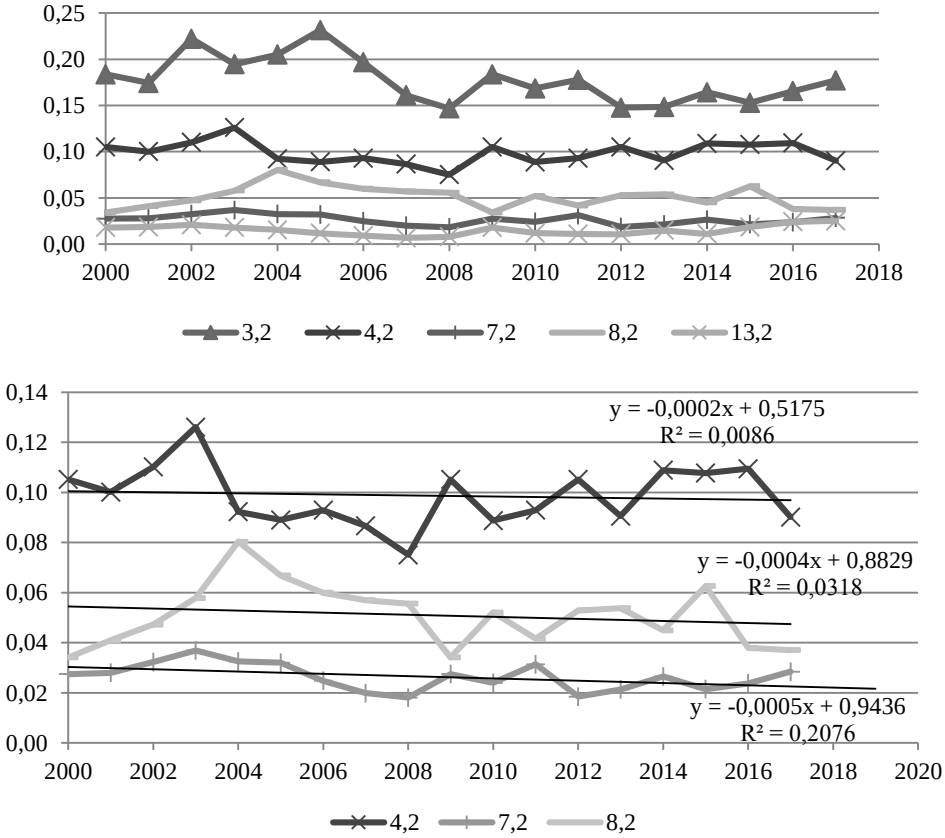


**Fig. 2. The dynamics of direct cost ratios without a trend**

*Source*: compiled by the authors.

In other words, the measure of volatility is not a change in the indicators, but a deviation from the trend. A well-known practice for estimating historical volatility is to use a sample

standard deviation. If this approach is used, then the sample deviation of the historical observations of the coefficient a11is found, whose standard deviation of the historical observations of the coefficient $a_{11}$is found, whose value is 0,0437, and when taking into account the trend – the sample standard deviation of the time regression residues is found, whose value is by more than twice lower (0,0199). The latter is the value of trend volatility. In fact, this concept was introduced in [14], but did not receive such a name in that work.

Fig. 3 displays information about the coefficients with the largest variations according to EAs.

Additional information to Figure 3 is provided in Table 2.

The second line shows the number *k* of the coefficient $a_{ik}$.. The first column, for example, reads as follows: "the coefficient $a_{11}$ has the maximum variation among the coefficients $a_{11}$, … $a_{19}$". These data, as well as calculations of other indicators reflected in the list, indicate a significant volatility of most direct cost ratios. The threshold significance in the level of volatility determines the normalization of the coefficients of direct costs, they are all less than unit. In addition, Brauer-Solow number condition, in other words, the sum of the coefficients of direct costs per column is less than unit too.

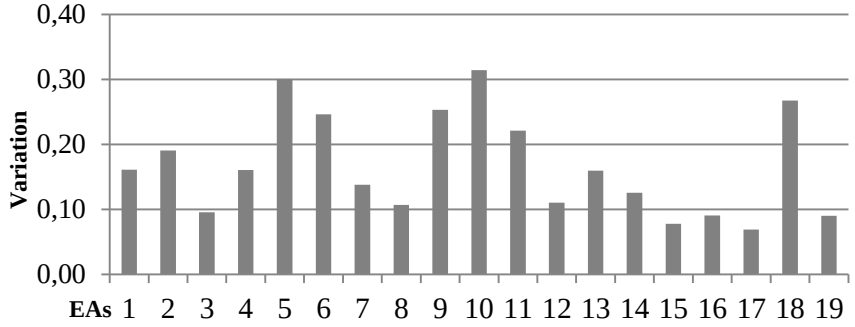


**Fig. 3. Maximum variations of direct cost coefficients by economic activities (EAs) in 2000–2017.**

*Source:* compiled by the authors.

*Table 2*

**Table of direct cost coefficients with the maximum variation by EAs**

| EAs | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* | *18* | *19* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coef-fi-cient | 1 | 2 | 2 | 2 | 5 | 6 | 3 | 3 | 3 | 10 | 11 | 3 | 13 | 3 | 3 | 3 | 17 | 18 | 18 |

*Source:* compiled by the authors.

Similar calculations were performed for indicators for all $\Sigma_i a_{i,j}$, j = 1,…, 19 (see Table 3). These indicators are of fundamental importance for the analysis of intersectoral flows. First of all, they characterize the levels of costs for EAs; secondly, the indicators $1 - \Sigma_i a_{i,j}$ characterize the share of value added in EAs; third, the inequality $\Sigma_i a_{i,j} < 1$ for all j is a sufficient condition for the performance of the direct cost matrix A [30]. The latter is part of the so-called sufficient conditions for Brauer-Solow performance. Note that they are fulfilled for the intersectoral balances of Ukraine for all years and all levels of detail. The same can be said about all known to the authors intersectoral balances of other countries. Therefore, we will call the indicators $\Sigma_i a_{i,j}$ Brauer-Solow numbers. Their dynamics for some foreign EAs and for years is shown in Fig. 4. In addition to the dynamics of these numbers, Fig. 4 also illustrates the fulfillment of a sufficient Brauer-Solow condition for all EAs and years of observation, i.e. the fulfillment of inequality for all EAs.

According to the calculations (Table 3), the highest level of costs for the study period was recorded for EAs 3 (0,8229). This indicates a significant margin of productivity for Ukraine's economy. The largest variation is for EAs 2 (0,2473), the following positions are occupied

by EAs 5, 18 (respectively 0,2345, 0,2375). The top three in terms of historical volatility are EAs 2 (0,0795), 6 (0,0767), and 18 (0,0647). EAs 2 is also the third in terms of relative volatility, in terms of this indicator the first are EA 15 and 11. These EAs can be classified as the most unstable in terms of costs. The most stable is EA 1 (agriculture) in terms of absolute and relative volatility, variation and relative variation.

The presence of a trend over time ($p < 0,05$) was recorded for 11 EAs, among them – 7 with a positive trend. EAs 4, 6, 8, and 13 have the most pronounced trend in time in terms of $R^2$ (the share of changes in the resulting indicator explained by changes in time), and p (the probability of rejection of the hypothesis about dependent significance).

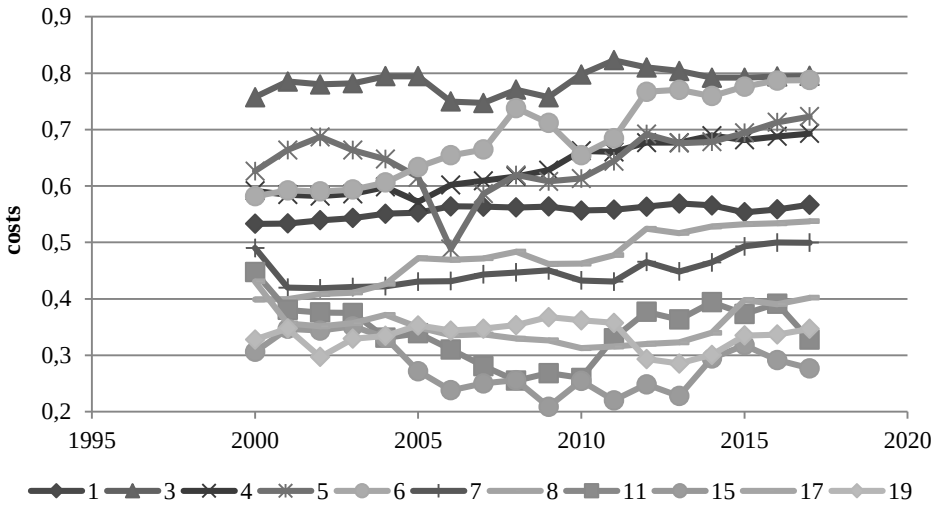


**Fig. 4. Dynamics of costs levels (Brauer – Solow numbers) by EAs and by year**

*Source:* compiled by the authors.

*Dynamics of total costs in Ukraine's economy.* Measuring the costs of national economies can be done in several ways, such as:

– the ratio of intermediate consumption to total output;
– the Frobenius – Perron number.

According to [30], the Frobenius – Perron number is defined as the maximum number λ where $|\lambda E - A| = 0$. The maximum level of aggregation of both indicators coincide. Calculations based on detailed models indicate the closeness of these indicators (Fig. 5).

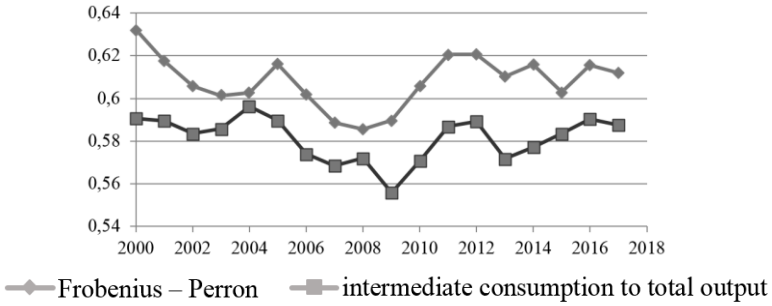


**Fig. 5. Costs dynamics of the Ukrainian economy**

*Source:* compiled by the authors.

*Table 3*

**Statistical characteristics of Brauer - Solow numbers $\Sigma_i a_{ij}$ by EAs for the period 2000–2017**

| EA | max for the period | min for the period | max-min | A | s | s/a | (max-min)/a | R^2 | P | Slope | Forecast for 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5690 | 0.5328 | 0.0362 | 0.5553 | 0.0113 | 2.03% | 6.52% | 0.5872 | **0.0002** | 0.0016 | 0.5723 |
| 2 | 0.6483 | 0.4010 | 0.2473 | 0.5092 | 0.0730 | 14.34% | 47.67% | 0.5300 | **0.0006** | -0.0099 | 0.4046 |
| 3 | 0.8229 | 0.7471 | 0.0758 | 0.7848 | 0.0210 | 2.67% | 9.66% | 0.2063 | 0.0583 | 0.0018 | 0.8035 |
| 4 | 0.6928 | 0.5718 | 0.1211 | 0.6332 | 0.0442 | 6.98% | 19.12% | 0.8996 | **0.0000** | 0.0079 | 0.7157 |
| 5 | 0.7230 | 0.4885 | 0.2345 | 0.6467 | 0.0553 | 8.55% | 36.27% | 0.1814 | 0.0780 | 0.0044 | 0.6930 |
| 6 | 0.7878 | 0.5818 | 0.2059 | 0.6863 | 0.0767 | 11.17% | 30.00% | 0.8944 | **0.0000** | 0.0136 | 0.8290 |
| 7 | 0.4997 | 0.4187 | 0.0810 | 0.4504 | 0.0285 | 6.32% | 17.98% | 0.3957 | **0.0052** | 0.0034 | 0.4856 |
| 8 | 0.5376 | 0.3989 | 0.1388 | 0.4730 | 0.0488 | 10.31% | 29.34% | 0.9097 | **0.0000** | 0.0087 | 0.5645 |
| 9 | 0.6188 | 0.4869 | 0.1319 | 0.5355 | 0.0325 | 6.06% | 24.64% | 0.5816 | **0.0002** | -0.0046 | 0.4868 |
| 10 | 0.5071 | 0.3443 | 0.1628 | 0.4658 | 0.0498 | 10.70% | 34.94% | 0.3349 | **0.0119** | 0.0054 | 0.5226 |
| 11 | 0.4472 | 0.2549 | 0.1922 | 0.3432 | 0.0529 | 15.41% | 56.00% | 0.0128 | 0.6555 | -0.0011 | 0.3315 |
| 12 | 0.4263 | 0.2690 | 0.1573 | 0.3557 | 0.0541 | 15.20% | 44.21% | 0.4283 | **0.0032** | -0.0066 | 0.2861 |
| 13 | 0.5060 | 0.3344 | 0.1716 | 0.4426 | 0.0559 | 12.63% | 38.78% | 0.6717 | **0.0000** | 0.0086 | 0.5326 |
| 14 | 0.5556 | 0.4393 | 0.1163 | 0.4923 | 0.0337 | 6.84% | 23.62% | 0.0206 | 0.5701 | 0.0009 | 0.5018 |
| 15 | 0.3511 | 0.2085 | 0.1425 | 0.2796 | 0.0454 | 16.25% | 50.97% | 0.1813 | 0.0781 | -0.0036 | 0.2416 |
| 16 | 0.3049 | 0.2337 | 0.0712 | 0.2614 | 0.0210 | 8.04% | 27.24% | 0.1582 | 0.1022 | 0.0016 | 0.8290 |
| 17 | 0.4309 | 0.3126 | 0.1183 | 0.3525 | 0.0337 | 9.57% | 33.56% | 0.0039 | 0.8063 | -0.0004 | 0.3484 |
| 18 | 0.5754 | 0.3379 | 0.2375 | 0.4502 | 0.0647 | 14.37% | 52.75% | 0.6658 | **0.0000** | -0.0099 | 0.3464 |
| 19 | 0.3675 | 0.2851 | 0.0824 | 0.3343 | 0.0248 | 7.41% | 24.65% | 0.0076 | 0.7317 | -0.0004 | 0.3300 |
| max according to EA | 0.8229 | 0.7471 | 0.2473 | 0.7848 | 0.0730 | 16.25% | 56.00% | 0.9097 | 0.8063 | 0.0136 | 0.8289 |
| min according to EA | 0.3049 | 0.2085 | 0.0362 | 0.2614 | 0.0113 | 2.03% | 6.52% | 0.0039 | 0.0000 | -0.0099 | 0.2415 |

*Source:* compiled by the authors.

Insignificant numerical differences of both indicators of expense according to different years, essential correlation, and absence of trends are apparent. A principal point is the significant costs of Ukraine's economy compared to others. For example, for the United States, the Frobenius – Perron number in 2000 was 47,69%, in 2015 – 44,15%. The dynamics of the share of GDP in the structure of output (the indicator inverse to costs) for selected countries is shown in Fig. 6.

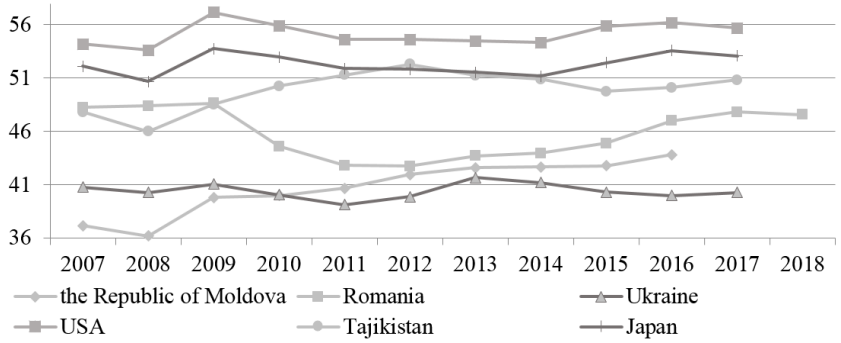


**Fig. 6. GDP (in basic prices) in the structure of output (in basic prices), % (Output = 100%)**

*Source:* compiled by the authors based on data from [24].

**Conclusions and directions of further development**

1. The volatility of the intersectoral structure of flows ("input-output" tables) in relative terms (matrix of direct costs) can be estimated in different ways. Among them: variation, relative variation, selective standard deviation, standard deviation relative to average, historical volatility, and standard error of trends (regression). The article proposes a new vision of volatility, which can be called trend volatility. The authors envisage replenishment of the system of indicators characterizing volatility. For example, historical volatility with fading memory may be helpful. This indicator attributes to the observation a weight that increases over time. That is, the observations of 2017 are more significant for the calculation than the observations of 2000.

2. Calculations show that the volatility of most intersectoral flows in relative terms (elements of the direct cost matrix) in Ukraine is significant. The threshold of significance of the volatility level is the normalization of direct cost ratios, all of them are less than unit. In addition, the Brauer – Solow number, in other words the sum of the coefficients of direct costs per column is less than unit too. For example, the maximum variation for the coefficients of direct costs for EA 10 for all years of observation was 0,3144, for EA 5 – 0,3004, and for EA 18 – 0,2673 (see Fig. 3, Table 2).

3. Aggregates (the Brauer – Solow numbers or relative consumption of EAs, in other words, $\Sigma_i a_{i,j}$) are volatile too. If we turn to the standard deviation relative to average (s/a), the greatest is the value of EA 15. The opposite of volatility is stability. The smaller is s/a, the greater is the EA stability. The most stable in terms of this indicator is EA 1 (2,03%).

4. Despite the volatility of the Brauer – Solow numbers, Ukraine's economy has a significant margin of productivity. The maximum value of $\Sigma_i a_{i,j}(t)$ for all $t = 2000,...,2017;$ $j = 1,...,19$ was 0,8229 (EA 3). In other words, a sufficient Brauer – Solow condition of the performance of the direct cost matrix is guaranteed to be fulfilled for all years of observation.

5. Among 361 (19x19) coefficients $a_{ij}$ ($i$, $j$ = 1, … ,19), time trends were recorded for 166. Among them, 91 have an upward trend, and 65 – a downward trend. To fix the presence of the trend, the probability of rejecting the hypothesis about the significance of the linear

dependence $a_{ij}(t) = m_{ij}t + n_{ij}$ (significance of F or p in Table 3) was used. If p < 0,05, it was assumed that the trend exists.

6. For the Brauer – Solow aggregates $\Sigma_i a_{ij}(t)$ ($j = 1,...,19$), the most stable trends were in EAs 4, 6, and 8 ($p < 0,0001$, coefficients of determination $R^2$ are respectively 0,8996, 0,8994, and 0,9097). According to the criterion $p < 0,05$, EAs 1, 2, 7, 9, 10, 12, 13, and 18 had the trends too. Among the Brauer – Solow aggregates with a trend, an increasing trend was recorded for six EAs.

7. Other types of trends of direct cost coefficients and their aggregates are possible. The choice of the linear was due to simplicity, readability and limited history of observations. Undoubtedly, in further developments an attempt will be made to use other trend dependencies.

8. The aggregation of 42 EAs to 19 was associated with the need to obtain a dynamic series of a matrix of direct cost ratios for the period from 2000 to 2017. Any aggregation changes the vision of the "input – output" scheme. Different visions are also useful for analysis. For example, in the United States, "input – output" tables are developed for the levels of detail from 17 to 402 industries. Usually aggregation reduces volatility (standard deviations), which is a consequence of the law of large numbers. The calculations can be interpreted as a lower estimate of volatility.

With an accumulated database with a "longer" history for a more detailed "input – output" table, similar calculations and a proper comparative analysis are possible.

9. The general economic problem of Ukraine is the high costs of the economy. The ratio of intermediate consumption to total output ranges from about 56% to 60 %. This is much higher than in developed countries (see [14, 31, 32]). According to this indicator, Ukraine is inferior to Romania and the Republic of Moldova. Reducing expenses would be a significant resource for Ukraine's economic growth. This resource can only be realized through the latest technologies created by innovators who need a proper institutional environment and funding.

10. The calculations give grounds to consider the matrix of direct costs of the intersectoral balance ("input-output" tables) of Ukraine as random and an opportunity to experimentally (simulation using the Monte Carlo method) to determine the probability distribution of the matrix in different scenarios [14]. Simulation of a random matrix of direct costs will be used to build a "chessboard", a map of intersectoral flows of uncertainty, information (see [14]), and risks according to the concepts of VaR, and CvaR "[33].

11. It is worth noting a more detailed analysis of the dynamics of consumption on foreign trade, in particular, on agriculture (EA 1), which shows a much greater stability of consumption indicators.

12. Taking into account the tradition of intersectoral research and the fact that Ukraine has gathered a certain experience in preparing "input – output" tables (they are compiled by the State Statistics Committee), it would be useful to take the initiative to create a National Report "The structure of Ukraine's Economy".

### *References*

1. Leontief, W. et al (1958). Studies of the structure of the American economy. Theoretical and empirical analysis of the input-output scheme. Moscow: State Statistical Publishing House [in Russian].

2. Glushkov, V.M. (1980). Dysplan is a new planning technology. *Upravljajushie sistemy i mashiny – Control systems and machines*, 6, 5-10 [in Russian].

3. Karpec, Je.P., Glushkova, V.V. (2017). On the possibility of using the DISPLAN system for balanced management of the economy. In Kravchuk A.V. (ed.) *Cybernetics and democratic economic governance* (p. 45-58). Kiev: Center for Social and Labor Studies [in Russian].

4. Matveev, M.T., Arhangel'skij, Ju.S., Rybal'chenko, V.P. et al (1988). Models of the automated system of planned calculations of Gosplan of the republic. Kiev: Naukova dumka [in Russian].
5. Economic modeling and forecasting - Ukraine: a guide to building a model (n.d.). The Conference Board of Canada. RC/Project 439/Z11109 Commitment 221460 – 2003 [in Ukrainian].
6. Pavel, F., Burakovsky, I., Selitska, N., Movchan, V. (2004). Economic Impact of Ukraine's WTO Accession. First results from a Computable General Equilibrium Model. *The Institute for Economic Research and Police Consalting Working Paper*, 43. Retrieved from http://www.ier.com.ua/en/publications/working_paper? pid=1547
7. Mihalevich, M.V., Sergienko, I.V. (2005).Modeling of transition economy: models, methods, information technologies. Kiev: Naukova dumka [in Russian].
8. Dovhyj, S.O., Bidiuk, P.I., Trofymchuk, O.M. (2014). Decision support systems based on statistical-probabilistic methods. Kyiv: Lohos [in Ukrainian].
9. Information and analytical support of the budget process (2013). NAS of Ukraine, Institute for Economics and Forecasting, V.M. Glushkov Institute of Cybernetics, Institute of Telecommunications and Global Information Space. Kyiv: Informatsijni systemy [in Ukrainian].
10. Arhangel'skij, Ju.S. (1999). Forecasting production volumes based on mac-roeconomic models and intersectoral balance for the coming year. *Ekonomika Ukrainy – Economy of Ukraine*, 6, 20-31 [in Ukrainian].
11. Paskhaver, B.J. (2018).Agro-food complex of Ukraine in intersectoral pro-portions: state and dynamics. *Ekon. prognozuvannâ – Economy and forecasting*, 2, 151-159 [in Ukrainian].
12. Kudin, V.I., Onyshchenko, A.M. (2016). Modelling of technological changes in "input-output" balance model in terms of the Paris agreement. *Ekonomichnyj analiz – Economic analysis*, 25: 1, 37-44 [in Ukrainian].
13. Kudin, G.I., Kudin, V.I., Onyshchenko, A.M. (2014). Analysis of the mesoeconomic structure of production in terms of reducing greenhouse gas emissions. VII International School-Seminar "Decision Theory" (September 29 - October 4, 2014). Uzhhorod [in Ukrainian].
14. Yastremskii, O.I. (2019). Input-output chessboard of uncertainty and its application: forecasting, economic policy, fiscal risk, general equilibrium. *Kibernetyka i systemnyj analiz – Cybernetics and systems analysis*, 55: 3, 28-36. https://doi.org/10.1007/s10559-019-00143-6 [in Ukrainian].
15. Mirzoakhmedov, F., Nazrizoda, S., Yastremskii, O. (2017). Uncertainty estimations in input-output scheme of Republic of Tajikistan. *Ekonomichnyj prostir – Economic space*, 126, 15-23 [in Ukrainian].
16. Yastremskii, O.I. (2017). Uncertainty in input-output scheme: comparative inter-country analysis. *Naukovi pratsi NDFI – RFI Scientific Paper*, 3, 21-35. https://doi.org/10.33763/npndfi2017.03.021 [in Ukrainian].
17. Gurgul, H. (2007). Stochastic input-output modeling. *Ekonomia Menedzerska*, 2, 57-70.
18. Temurshoev, U. Uncertainty treatment in input-output analysis. Department of Economics Universidad Loyola Andalucía. Retrieved from http://www.loyolaandnews.es/loyolaecon/wp-content/uploads/2016/01/an--lisis-input-y-output.pdf
19. Ermol'ev, Ju.M., Jastremskij, A.I. (1979). Stochastic models and methods in economic planning. Moscow: Nauka [in Russian].
20. Yastremskii, O.I. (1992). Economic risk modeling. Kyiv: Lybid' [in Ukrainian].
21. Knopov, P.S., Sergienko, I.V. (2011). On scientific results of Yu.M. Ermoliev and his school in the modern stochastic optimization theory. *Cybernetics and System Analysis*, 47: 6, 835-853. https://doi.org/10.1007/s10559-011-9363-x
22. Table "input - output" of Ukraine for 2017 in basic prices (2019). State Statistics Service of Ukraine. Kyiv. Retrieved from www.ukrstat.gov.ua [in Ukrainian].
23. Methodological provisions for the organization of state statistical observation Table "input - output". State Statistics Service of Ukraine. Retrieved from www.ukrstat.gov.ua [in Ukrainian].

24. United Nations (2019). National accounts statistics: Main aggregates and detailed tables, 2018. Part I–V. (ST/ESA/STAT/SER.X/61). Department of Economic and Social Affairs Statistics Division. New York.
25. State classifier DK 009: 2005 "Classification of economic activities" (NACE- 2005). Approved by the order of Derzhspozhyvstandart of Ukraine dated December 26, 2005. № 375 (as amended). Retrieved from http://search.ligazakon.ua/l_doc2.nsf/link1/FIN19567.html [in Ukrainian].
26. Classification of economic activities. Correspondence tables of NACE-2010 – NACE-2005. Retrieved from www.ukrstat.gov.ua [in Ukrainian].
27. Piketty, Thomas (2014). Capital in the Twenty-First Century. Harvard University Press. https://doi.org/10.4159/9780674369542
28. Åslund, Anders. Kremlin aggression in Ukraine: the price tag. Retrieved from http://www.atlanticcouncil.org/images/publications/Cost_of_Kremlin_Aggression_ web.pdf
29. Pustoviit, R.F. (2016). Military expenditure and its impact on the domestic economy. *Finansy Ukrainy – Finance of Ukraine*, 11, 79-93 [in Ukrainian].
30. Nikaido, H. (1968). Convex Structures and Economic Theory. New York, London: Academic Press.
31. Yastremskii, O.I. (2019, February 22). Expert opinion: Working more sparingly is a resource for Ukraine's economic growth. *Voice of America* [in Ukrainian].
32. Kulyk, V.V., Kudin, G.I. (2018). Forecasting changes in intrabranch ties in the input-output model. *Problemy ekonomiky – Problems of the economy*, 3, 45-55 [in Ukrainian].
33. Uriasiev, S. (2017). Risk Management with POE, VaR, CVaR, and bPOE. Optimization Under Uncertainty and Data-Driven Science and Engineering. Duke University.

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***Ястремський О.І.***[3]
***Кулик В.В.***[4]

# ВОЛАТИЛЬНІСТЬ СТРУКТУРИ МІЖГАЛУЗЕВИХ ЗВ'ЯЗКІВ ЕКОНОМІКИ УКРАЇНИ

*Досліджена волатильність міжгалузевих потоків економіки України протягом 2000–2017 рр. Для цього був побудований динамічний матричний ряд коефіцієнтів прямих витрат у зіставній деталізації (19 видів економічної діяльності (ВЕД)); розраховано статистичні характеристики динаміки 361 (19х19) коефіцієнтів прямих витрат міжгалузевого балансу України; проаналізована динаміка показників вит-*

[3] **Ястремський, Олександр Іванович** – д-р екон. наук, професор, головний науковий співробітник, ДННУ "Академія фінансового управління" (вул. О. Гончара, 46/48, м. Київ, 01034), ORCID: 0000-0001-9900-3612, e-mail: yast2005@ukr.net
[4] **Кулик, Володимир Васильович** – канд. екон. наук, старший науковий співробітник, ДННУ "Академія фінансового управління" (вул. О. Гончара, 46/48, м. Київ, 01034),
ORCID: 0000-0002-2226-2795, e-mail: volodymyr_kulyk@ukr.net

*ратності національної економіки України (відношення ВВП до загального випуску, числа Фробеніуса – Перрона) і ВЕД (числа Брауера – Перрона).*

*Побудова історичної серії матриці прямих витрат у зіставній деталізації була досягнута за рахунок агрегування таблиць "витрати – випуск".*

*Волатильність оцінювалася за допомогою показників варіації, відносної варіації, вибіркового стандартного відхилення, стандартного відхилення, віднесеного до середнього, історичної волатильності, стандартної похибки трендів (регресії), тобто трендової волатильності.*

*Волатильність міжгалузевих потоків в Україні є значною. Максимальна варіація для коефіцієнтів прямих витрат для ВЕД "Інформація… " за всі роки спостереження становила 0.3144, для ВЕД "Водопостачання…" – 0.3004, ВЕД "Мистецтво…" – 0.2673.*

*Похідні агрегати (числа Брауера – Солоу, відносна витратність ВЕД) також волатильні. За оцінками стандартного відхилення, віднесеного до середнього, найстійкішим є агросектор, найбільш нестійким – державне управління.*

*Економіка Україна має значний запас продуктивності. Достатня умова Брауера – Солоу продуктивності матриці прямих витрат гарантовано виконується для всіх років спостереження.*

*Серед 361 коефіцієнтів прямих витрат тренди у часі були зафіксовані для 166. Серед них 91 мають зростаючий, 65 – спадний тренд. Для фіксації наявності тренду була використана імовірність відхилення гіпотези про значущість лінійної залежності коефіцієнтів прямих витрат від часу.*

*Загальноекономічною проблемою України є висока витратність економіки. Відношення ВВП до загального випуску в Україні становить приблизно 40%. У розвинених країнах цей показник близький до 60%. Зменшення витратності є значним ресурсом економічного зростання в Україні.*

***Ключові слова:*** *економіка України, таблиці " витрати – випуск" , міжгалузевий баланс, матриця прямих витрат, волатильність, рівень витрат видів економічної діяльності та національної економіки, числа Фробеніуса – Перрона, числа Брауера –Перрона*