DOI 10.52260/2304-7216.2026.3(64).7
UDC 338.45:330.43:330.35
SRSTI 06.71.02

Ye. Zhailauov*, PhD[1]
T. Pritvorova, d.e.s., professor[1]
Zh. Omar, PhD Student[2]
«RATIONAL SOLUTION» LLP,
Astana, Kazakhstan[1]
Esil University, Astana, Kazakhstan[2]
* – main author (corresponding author)
e-mail: zhailauov@rationalsolution.kz

ASSESSING THE COMPLEXITY OF PRODUCTION TRAJECTORIES AND INTERNAL INTEGRATION OF VALUE CHAINS IN THE ECONOMY OF KAZAKHSTAN

This paper proposes a Stochastic Downstream Production Complexity Framework, based on representing the economy as an absorbing Markov chain. Within the proposed approach, the output of each industry is considered as a source of probabilistic downstream trajectories culminating in domestic final demand or exports. To assess the characteristics of production chains, a system of indicators was developed, including the expected downstream depth (EDD), the branching entropy of trajectories (H), the integrated index of downstream trajectory complexity (DTC), the production transformation score (PTS), and the export leakage index (ELI). The methodology was tested using data from a symmetric input-output table for the Republic of Kazakhstan for 2023. The results showed that the chemical industry, metallurgy, and oil refining are characterized by the greatest complexity of downstream trajectories. At the same time, these industries exhibit an increased risk of export leakage, indicating significant untapped potential for deepening domestic processing chains. In contrast, oil and natural gas production are characterized by low complexity downstream trajectories and high levels of export leakage, consistent with a model of commodity export specialization. The research's novelty lies in the development of a probabilistic approach to analyzing production systems that combines tools from inter-industry analysis, absorbing Markov chains, and information entropy. The practical significance of the results lies in the possibility of identifying industries with the greatest potential for deepening processing and increasing domestic added value.

Keywords: *input-output analysis; value chains; downstream trajectories; production complexity; Markov chains; entropy; industrial policy; Kazakhstan.*

Кілт сөздер: *«кіріс-шығыс» талдауы; құндылық тізбектері; жеткізу тізбегі бойынша өнім ағынының траекториялары; өндіріс күрделілігі; Марков тізбектері; энтропия; өнеркәсіптік саясат; Қазақстан.*

Ключевые слова: *анализ «затраты-выпуск»; цепочки создания стоимости; траектории движения продукции по цепочке поставок; сложность производства; цепи Маркова; энтропия; промышленная политика; Казахстан.*

JEL classification: O14, L23

Introduction. In the context of intensifying international competition, it is becoming increasingly important not only for countries to participate in the production and export of goods, but also to retain subsequent stages of value added creation within the domestic economy. Numerous studies show that long-term economic growth is determined not so much by the volume of output or exports, but rather by the structure of production links and the nature of economic participation in value chains [1-2]. This problem is especially relevant for resource-dependent economies, where a significant part of the products is exported at the early stages of processing. In such conditions, economic growth may be accompanied by limited development of domestic production chains, and a significant part of the potential value added is generated outside the country. In the literature, this phenomenon is often considered in the context of resource dependence and limited structural transformation of the economy [3-4].

Traditionally, assessing countries' participation in value chains is based on an analysis of export structures, inter-industry linkages, and the position of industries within production chains. However, simply exporting products does not allow us to determine how fully the potential for their further processing within the national economy has been realized. Exporting products that have already undergone a significant number of production stages is fundamentally different from exporting intermediate goods at early stages of processing. Therefore, to understand the mechanisms of added value formation, it is necessary to consider not only the position of industries within the production system but also the nature of subsequent product processing trajectories.

Despite significant progress in studying value chains, existing methods primarily focus on measuring the strength of inter-industry linkages, the position of industries relative to final demand, or the length of production processes [5-6]. However, significantly less attention has been paid to analyzing the complexity of subsequent production trajectories and the risk of their premature termination due to the export of intermediate products. This raises the research question: which industries have the greatest capacity to form complex production trajectories within the economy, and in which industries does the premature termination of potential value chains occur?

To answer this question, this article proposes the Stochastic Downstream Production Complexity Framework (SDPCF), a methodology based on representing the economy as an absorbing Markov chain. The proposed approach allows assessing the depth of downstream production, the diversity of possible downstream processing routes, and the risk of export leakage of potential production effects.

The aim of the study is to develop and test a methodology for assessing the complexity of downstream trajectories and the structural incompleteness of production chains based on input-output data. The empirical validation of the methodology was conducted using data from a symmetric input-output table for the Republic of Kazakhstan for 2023. The scientific novelty of the study lies in the development of a probabilistic approach to the analysis of production systems that combines the tools of inter-industry analysis, Markov processes, and information entropy to assess the complexity of downstream trajectories and the risk of their premature termination.

Literature review. The informational basis for analyzing production relationships is the input-output table, first proposed by V. Leontief [7]. His approach allows us to view the economy as a system of interdependent industries linked by flows of intermediate products. Subsequently, the tools of inter-industry analysis were significantly expanded and systematized in the works of Miller and Blair [8], including production multipliers, forward and backward linkages, and various indicators of the structural impact of industries on the economy.

Despite its widespread use, classical input-output analysis primarily focuses on measuring the strength of inter-industry interactions. High multiplier values indicate the presence of significant production relationships, but do not allow us to determine how an industry's output is used in further production processes or the diversity of possible downstream processing options.

The next stage in the development of the literature was the emergence of upstream and downstream indicators. Upstreamness reflects the average distance of an industry from final demand and allows one to determine its position in the production system. Subsequently, Miller and Temurshoev proposed a distinction between output upstream and input downstream, allowing for a more complete account of the role of industries in the structure of production flows. These indicators significantly expanded the possibilities for analyzing production chains; however, they primarily characterize the average position of an industry relative to final demand, leaving open the question of the diversity of possible further uses of its products and the complexity of subsequent production continuations.

A related area of research concerns measuring the length of production chains. Dietzenbacher and Romero proposed the Average Propagation Length indicator, which allows for estimating the average number of steps in the propagation of production effects between industries. Unlike traditional multipliers, this indicator takes into account not only the presence of inter-industry links but also the distance between industries within the production structure.

Wang et al. [9] made a significant contribution to global value chain research by developing a system of indicators for the length of production and the international distribution of value creation stages. Similar issues are addressed in the works of Koopman et al. and Baldwin and Lopez-Gonzalez [10]. These studies demonstrate that not only a country's participation in global value chains but also its ability to retain deeper stages of processing within the national economy is an important development factor. However, existing indicators of production chain length primarily characterize the depth of product flow and do not take into account the diversity of possible further production continuations. Another area of research is the analysis of the complexity of economic systems. Hidalgo and Hausmann [11] demonstrated that the structure of a country's production capabilities is associated with its long-term economic development. This concept was further developed through studies of product space and related diversification opportunities.

In parallel, network approaches to economic analysis have developed. For example, studies by Acemoglu et al. [12] and Carvalho [13] demonstrated that the structure of production networks has a significant impact on the propagation of shocks and macroeconomic dynamics. Interest in applying information theory and entropy methods to the analysis of economic systems has also grown in recent years.

Of particular interest are studies examining inter-industry systems as stochastic networks and Markov processes [14]. These studies demonstrate the potential of probabilistic representations of production systems; however, they are primarily focused on analyzing the structure of the economy as a whole and are rarely used to study the subsequent production trajectories of individual industries.

Thus, existing approaches allow us to assess the strength of inter-industry linkages, the position of industries in the production system, the length of production chains, and the overall complexity of the economy. However, the literature is virtually lacking tools that simultaneously account for the depth of downstream production, the branching of possible production continuations, and the risk of premature termination of trajectories due to the export of intermediate products. Therefore, in this study, we propose an approach combining tools from inter-industry analysis, absorbing Markov chains, and information entropy to address this gap in the literature.

Main part. The proposed Stochastic Downstream Production Complexity Framework methodology is based on conceptualizing the economy as a system of probabilistic production trajectories. Unlike traditional inter-industry analysis, which focuses primarily on the strength of inter-industry linkages, this study focuses on the possible subsequent uses of products after their production.

It is assumed that the output of each industry can follow several alternative trajectories: used by other industries as an intermediate resource, exported, or supplied to final demand. Consequently, the production system can be interpreted as a network of sequential product transitions between processing stages.

To formalize this process, the framework of absorbing Markov chains is used. Within this model, economic sectors are considered intermediate states of the system, while domestic final demand and exports act as absorption states. This approach allows us to analyze not only the sector's position in the production structure but also the depth, branching, and direction of further propagation of production effects.

The initial data for the study are symmetric input-output tables.

Let:

$Z=[Z_{ij}]$ – intermediate consumption matrix;

FD_i – domestic final demand for the output of sector i;

E_i – export of the output of sector i.

The total utilization of the sector's output is defined as:

$$T_i = \sum_{j=1}^{n} z_{ij} + FD_i + E_i \tag{1}$$

Based on this value, the probabilities of product transfer between industries are calculated:

$$q_{ij} = \frac{z_{ij}}{T_i} \tag{2}$$

The probabilities of the transition of products to final demand and export are defined respectively as:

$$r_{i,FD} = \frac{FD_i}{T_i} \tag{3}$$

$$r_{i,E} = \frac{E_i}{T_i} \tag{4}$$

The probabilities obtained from a transition matrix:

$$P = [Q\ R; 0\ I] \tag{5}$$

where:

Q – matrix of transitions between production sectors;

R – matrix of transitions to absorption states;
I – identity matrix.

When using input-output tables, the problem of confusing production transformation processes with distribution circulation arises.

Activities such as trade, transportation and warehousing, financial services, real estate, public administration, and other service industries play an important role in the economy, but they do not create new stages of material processing. Including them in the calculation of production paths artificially lengthens the chains due to service cycles.

To eliminate this effect, the study uses *production-filtered transition matrix.*

The following sectors are considered as generators of downstream trajectories: agriculture; forestry; fisheries; extractive industries; manufacturing industries.

Construction, energy, trade, transportation, financial services, real estate transactions, public administration, and other services remain as actual consumers of products, but do not participate in the generation of subsequent production stages. Thus, a material transformation matrix is formed, reflecting only those transitions associated with further changes in the physical characteristics of products.

To assess the depth of production trajectories, the fundamental matrix of an absorbing Markov chain is used:

$$N = (I - Q)^{-1} \tag{6}$$

The *Expected Downstream Depth (EDD)* indicator is calculated on its basis*:*

$$EDD_i = \sum_{j=1}^{n} N_{ij} \tag{7}$$

This indicator reflects the expected number of production steps an industry's output undergoes before reaching absorption (final demand or export). High EDD values indicate high levels of product integration into subsequent production processes.

Shannon's information entropy [15] is used to estimate the diversity of possible downstream processing directions. The *Local Downstream Branching Entropy* indicator is calculated for each industry*:*

$$H_i = \sum_{j} b_{ij} \log_2 b_{ij} \tag{8}$$

where q_{ij} characterizes the probability of the transition of products from industry *i* to industry *j*.

High entropy values indicate the presence of a large number of alternative downstream processing paths and a more even distribution of production flows between them. Low values are typical of industries with a limited set of downstream processes.

The depth of product flow and the diversity of production processes reflect various aspects of production chain complexity. To combine these, the *Downstream Trajectory Complexity (DTC)* metric is calculated:

$$DTC_i = H_i \times \ln(EDD_i + 1) \tag{9}$$

Using a logarithmic function smooths out the impact of extremely long chains and ensures comparability of results across industries.

High DTC values are typical for industries whose products undergo numerous processing stages and are used in a wide range of subsequent production processes.

To separate actual production processing from service circulation, the *Production Transformation Score (PTS)* is calculated. This metric is defined as the ratio of the production trajectory depth calculated on the filtered transition matrix to the trajectory depth on the full matrix:

$$PTS_i = \frac{EDD_i^{prod}}{EDD_i^{all}} \quad (10)$$

where:
- EDD_i^{prod} – EDD value on the production-filtered matrix;
- EDD_i^{all} – EDD value on the full transition matrix.

High PTS values indicate that the observed chain depth is primarily due to production processing rather than service cycles.

To assess the risk of premature termination of production paths due to the export of intermediate products, the intermediate output orientation coefficient is calculated:

$$IO_i = \frac{\sum_{j=1}^{n} z_{ij}}{\sum_{j=1}^{n} z_{ij} + FD_i} \quad (11)$$

The higher the value of this indicator, the greater the proportion of the industry's output is used in further production processes rather than being sent directly to final consumption.

The *Export Leakage Index (ELI)* is calculated based on this ratio*:*

$$ELI_i = \left(\frac{E_i}{T_i}\right) \cdot IO_i \cdot \frac{1}{ln(EDD_i + 1)} \quad (12)$$

High ELI values are typical for industries whose products are highly intermediate in nature but are exported before undergoing potential domestic processing stages.

Consequently, the indicator reflects the risk of losing potential added value due to the premature withdrawal of products from the domestic production system.

To interpret the results, an industry typology based on a joint analysis of the DTC, PTS, and ELI indicators is used.

Based on this, the following industry groups are identified:

1. Mature Production Hubs – high DTC, high PTS, and low ELI;
2. Branching but Leaky Sectors – high DTC and high ELI;
3. Raw Export Sectors – low DTC and high ELI;
4. Final-Demand Sectors – low DTC and low ELI;
5. Circulation-Dependent Sectors – high overall depth with low PTS.

This typology allows us not only to identify the most complex production hubs in the economy but also to identify industries where potential value chains are prematurely interrupted.

Using our proposed approach, we analyzed the input-output tables of the Republic of Kazakhstan for 2023, revealing significant differences between industries in their ability to shape downstream production trajectories. To eliminate the influence of distribution and service cycles, calculations were performed using a material transformation matrix, in which trade, transportation, finance, real estate, public administration, and other service industries were considered end-use sectors and were not involved in generating new downstream trajectories.

Calculating the DTC index allowed us to identify industries with the highest potential for building vertical production chains. Table 1 presents the leading industries based on the DTC index.

Table – 1

Leading industries by the Downstream Trajectory Complexity Index

Industry	DTC	ELI
Chemical industry	1,657	0,175
Other mining	1,272	0,286
Forestry and logging	1,269	0,013
Coke production	1,082	0,014
Metallurgy	1,008	0,338
Textile industry	0,922	0,029
Metal ore mining	0,921	0,227
Agriculture	0,775	0,055
Rubber and plastic products manufacturing	0,718	0,101
Petroleum product manufacturing	0,609	0,353

**calculated by the authors*

The highest DTC value is observed in the chemical industry, as chemical products are involved in a wide range of subsequent production processes and are used as intermediate inputs for many industries. In fact, the chemical industry is a key hub for value chains, supporting the further development of petrochemicals, plastics, construction materials, and end-use products.

Relatively high DTC values are also characteristic of metallurgy, coke production, and mining products. This indicates the significant role of these industries in providing the material base for subsequent production processes. Forestry and logging also have relatively high DTC values; their products are used in a wide range of applications, but their share of gross economic output is low.

Overall, the results confirm that the most complex downstream trajectories are formed around industries producing intermediate products capable of being repeatedly recycled and recycled. To assess the risk of premature product withdrawal from the national production system, the Export Leakage Index (ELI) was calculated, reflecting the combination of an industry's export orientation, the intermediate nature of its products, and the limited depth of its domestic production trajectories. Table 2 presents the leading industries according to this index.

Table – 2

Leading industries by the Export Leakage Index

Industry	ELI	DTC
Oil and natural gas production	1,387	0,088
Petroleum product manufacturing	0,353	0,609
Metallurgy	0,338	1,008
Coal mining	0,305	0,432
Other mining	0,286	1,272
Metal ore mining	0,227	0,921
Wood processing	0,175	0,565
Chemical industry	0,175	1,657

**calculated by the authors*

The highest ELI values are found in oil and natural gas production, due to the export of a significant portion of production before potentially undergoing processing within the national economy. As a result, a significant share of potential added value is generated outside the country.

High ELI values are also observed in metallurgy, oil refining, and several extractive industries. However, unlike the oil and gas sector, these industries are also characterized by relatively high complexity of downstream trajectories. This means they possess significant potential for the formation of domestic value chains, which is only partially realized.

The results obtained suggest the existence of not only a problem with raw materials exports, but also a problem with incomplete production chains in certain sectors of the manufacturing industry.

At the same time, industries that combine highly complex downstream trajectories and significant levels of export leakage are of interest. Such industries possess a well-developed system of production linkages, but some of the potential benefits from further processing are transferred outside the national economy (Table 3).

Table – 3

"Branching but Leaky" Industries

Industry	DTC	ELI
Chemical industry	1,657	0,175
Metallurgy	1,008	0,338
Petroleum products production	0,609	0,353

**calculated by the authors*

The industries listed in the table occupy a special position in the structure of Kazakhstan's economy. Unlike primary extraction industries, they already have established downstream links and are capable of generating complex production trajectories. At the same time, a significant portion of their output is exported before the full domestic processing cycle is completed.

From an industrial policy perspective, these industries are of particular interest for stimulating the deepening of production chains and the creation of additional added value within the country.

Based on the ratio of the DTC and ELI indices, several industry types can be identified, characterizing their roles in the national production system (Table 4).

This typology shows that the structural incompleteness of Kazakhstan's economy manifests itself not only in the dominance of raw materials exports but also in the existence of a number of industries with untapped potential for developing domestic value chains. The most promising areas for further development are the chemical industry, metallurgy, and oil refining, where expanding domestic processing could provide the greatest increase in national added value.

Table – 4

Typology of industries based on SDPCF results

Industry Type	Characteristic	Examples
Mature Production Hubs	High DTC, Low ELI	Textile industry, rubber and plastics manufacturing
Branching but Leaky Sectors	High DTC, High ELI	Chemical industry, metallurgy, oil refining
Raw Export Sectors	Low DTC, High ELI	Oil and gas production, coal mining
Final-Demand Sectors	Low DTC, Low ELI	Most service industries
Circulation-Dependent Sectors	High overall depth with a low share of production transformation	Trade, transportation, financial services

**calculated by the authors*

Production system studies traditionally use indicators of inter-industry linkages, production multipliers, and the position of industries in value chains. In particular, upstream and downstream indicators allow us to assess the relative position of an industry vis-à-vis final consumption and other stages of the production. However, these indicators primarily characterize the average position of an industry in the production system and do not allow us to assess the diversity and complexity of subsequent product uses.

Our proposed methodology assumes that industries can differ not only in their position in the production chain but also in the number and diversity of potential extensions of the production process. In this regard, the developed approach is conceptually close to production chain studies based on Average Propagation Length indicators, which take into account not only the strength of inter-industry linkages but also the distance of production effects within the economy. At the same time, the method shifts the emphasis from the analysis of the spread of shocks to the analysis of potential trajectories for further processing of products.

The results show that the chemical, metallurgy, and oil refining industries have the greatest complexity in downstream trajectories. These industries share the common characteristic of producing intermediate products used in a wide range of subsequent production processes. Thus, these industries serve as transformation nodes through which a significant number of potential production trajectories pass.

A group of industries identified as *branching but leaky sectors* deserve special attention. This group includes the chemical industry, metallurgy, and oil refining. Unlike primary extraction industries, these activities are already embedded in relatively complex production chains, but a significant portion of their output is exported before undergoing any subsequent processing stages within the country. This result is particularly interesting from the perspective of global value chain theory. According to Wang et al., the characteristics of production chains are determined not only by the industry's position in the production structure but also by the length of the production processes through which value is created. The results indicate that for Kazakhstan, the problem lies not only in raw material specialization per se, but also in the premature termination of production trajectories in industries that already possess significant potential for further processing.

In this context, the ELI indicator allows for a new interpretation of the problem of commodity dependence. Traditionally, an economy's reliance on raw materials is viewed through a high share of extractive industry exports. However, the study's results show that the mere fact of exporting does not necessarily indicate an economy's structural weakness. A more significant question is at what stage of the production chain the export of products occurs. Exports of products that have already undergone a significant number of processing stages differ fundamentally from exports of intermediate goods at early stages of processing. Consequently, the structural incompleteness of production chains is a more complex phenomenon than simple dependence on commodity exports.

A comparison between the oil and gas sectors and oil refining is particularly revealing. While oil and gas production is characterized by extremely high levels of export leakage and low complexity of downstream trajectories, oil refining exhibits both a relatively high level of DTC and a high ELI. This suggests that further development of petrochemical production and the production of higher-value products could yield a significantly greater impact on the national economy than simply increasing raw material production. Similar conclusions can be drawn regarding the metallurgy sector. Despite a well-developed system of production linkages, a significant portion of metallurgical products are exported as semi-finished and intermediate materials. Accordingly, the expansion of metalworking, mechanical engineering, and other industries that use metallurgical products as intermediate inputs could further deepen domestic value chains.

From a methodological perspective, the study's results confirm the potential of integrating input-output analysis, network analysis, and information theory. The use of entropy characteristics to describe the structure of economic systems has a long history in studies of input-output models. In recent years, approaches that consider inter-industry systems as stochastic networks and Markov processes have develop. Our proposed framework advances this line of research by combining the analysis of production trajectories, Markov transitions, and entropy characteristics within a single methodology.

A number of limitations of the study should also be noted. First, the calculations are based on an aggregated input-output table, which inevitably obscures differences between individual product groups within aggregated industries. Second, the results are partially dependent on the chosen procedure for filtering the industries involved in generating downstream trajectories. Despite the theoretical justification for this approach, alternative classification options may lead to some changes in the industry rankings. Third, the Markov model used is a probabilistic approximation of production processes and does not reflect all the technological features of specific value chains.

Despite these limitations, the study demonstrates that downstream trajectory analysis allows us to identify aspects of the economy's structural development that remain hidden when using traditional inter-industry analysis metrics. Specifically, the proposed approach allows us to distinguish between industries that are the source of complex production trajectories and those that experience premature interruptions of potential value chains. This opens up new opportunities for analyzing the structural incompleteness of the economy and developing industrial policy aimed at deepening domestic processing and increasing national added value.

Conclusions. This study proposes the Stochastic Downstream Production Complexity Framework, a methodology designed to assess the complexity of downstream product processing trajectories and identify structural incompleteness in production chains based on input-output tables. Unlike traditional inter-industry analysis metrics, which focus on measuring the strength of interdependencies or the position of industries relative to final demand, the proposed approach allows for the analysis of the diversity of possible downstream product processing routes and the risk of premature interruption of production chains.

The methodology is based on representing the economy as an absorbing Markov chain, in which industries are treated as intermediate states, and domestic final demand and exports are considered as absorption states. This allowed us to develop a system of interconnected indicators, including the depth of distribution of production trajectories (EDD), the entropy of their branching (H), the integrated index of downstream trajectory complexity (DTC), the production transformation index (PTS), and the export leakage index (ELI).

Testing the methodology using data from a symmetric input-output table for the Republic of Kazakhstan for 2023 revealed that the chemical industry, metallurgy, and oil refining have the greatest capacity to generate complex production trajectories. At the same time, these industries simultaneously exhibit a relatively high level of export leakage, indicating significant untapped potential for deepening domestic value chains.

The analysis also revealed that the economy's structural incompleteness is not limited to a high share of commodity exports. A significant portion of potential added value may also be lost in manufacturing sectors that already possess a developed system of production linkages but are focused on exporting intermediate goods. As a result, branching-but-leaky sectors were identified, characterized by a combination of highly complex downstream trajectories and a significant risk of export leakage. These sectors are of particular interest from the perspective of industrial policy aimed at deepening processing and expanding domestic production chains.

The theoretical contribution of this study lies in its development of existing approaches to analyzing production systems through the integration of inter-industry analysis, Markov processes, and information theory. Unlike upstream indicators, production multipliers, and traditional measures of economic complexity, the proposed methodology allows us to consider a production system as a set of probabilistic trajectories for the further transformation of products, opening up new possibilities for analyzing the structural characteristics of the economy.

The practical significance of this study lies in the potential for using the proposed methodology to identify industries with the greatest potential for deepening processing, as well as to assess the impact of various industrial policy scenarios. The results obtained can be used in developing industrial development programs aimed at increasing domestic added value and reducing dependence on the export of intermediate products.

This research is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP23490547 "Atlas of Economic Specialization of the Regions of Kazakhstan: Conditions of Formation and Mechanisms of Restructuring").

REFERENCES

1. Hausmann R., Hwang J., Rodrik D. What you export matters // Journal of Economic Growth. – 2007. – №12. – P. 1–25. – DOI: 10.1007/s10887-006-9009-4.

2. Baldwin R., Lopez-Gonzalez, J. Supply-chain trade: A portrait of global patterns and several testable hypotheses // The World Economy. – 2015. – №38(11). – P. 1682–1721. – DOI: 10.1111/twec.12189.

3. Auty R.M. Resource abundance and economic development. Oxford University Press. – 2001. – 340p.

4. Sachs J.D., Warner A.M. The curse of natural resources // European Economic Review. – 2011. – №45(4–6). – P. 827–838. – DOI: 10.1016/S0014-2921(01)00125-8.

5. Antràs P., Chor D., Fally T., Hillberry R. Measuring the upstreamness of production and trade flows // American Economic Review. – 2012. – №102(3). – P. 412–416. – DOI:10.1257/aer.102.3.412.

6. Dietzenbacher E., Romero I. Production chains in an interregional framework: Identification by means of average propagation lengths // International Regional Science Review. – 2007. – №30(4). – P. 362–383. – DOI: 10.1177/0160017607305366.

7. Leontief W.W. Quantitative input and output relations in the economic system of the United States // The Review of Economics and Statistics. – 1936. – №18(3). – P. 105–125. – DOI: 10.2307/1927837.

8. Miller R.E., Blair P.D. Input-output analysis: Foundations and extensions. Cambridge University Press. – 2009. – 750p.

9. Wang Z., Wei S.-J., Yu X., Zhu K. Characterizing global value chains: Production length and upstreamness. NBER Working Paper No. 23261. – 2017. – DOI: 10.3386/w23261.

10. Koopman R., Wang Z., Wei S.-J. Tracing value-added and double counting in gross exports // American Economic Review. – 2014. – №104(2). – P. 459–494. – DOI: 10.1257/aer.104.2.459.

11. Hidalgo C.A., Hausmann R. The building blocks of economic complexity // Proceedings of the National Academy of Sciences. – 2009. – №106(26). – P. 10570–10575. – DOI: 10.1073/pnas.0900943106.

12. Acemoglu D., Carvalho V.M., Ozdaglar A., Tahbaz-Salehi A. The network origins of aggregate fluctuations // Econometrica. – 2012. – №80(5). – P. 1977–2016. – DOI: 10.3982/ECTA9623.

13. Carvalho V.M. From micro to macro via production networks. Journal of Economic Perspectives. – 2014. – №28(4). – P. 23–48. – DOI: 10.1257/jep.28.4.23.

14. Moosavi V., Isacchini G. A Markovian model of the evolving world input-output network // PLoS ONE. – 2017. – №12. – DOI: 10.1371/journal.pone.0186746.

15. Shannon C.E. A mathematical theory of communication // The Bell System Technical Journal. – 1948. – №27(3). – P. 379–423. – DOI: 10.1002/j.1538-7305.1948.tb01338.x.

REFERENCES

1. Hausmann R., Hwang J., Rodrik D. What you export matters // Journal of Economic Growth. – 2007. – №12. – P. 1–25. – DOI: 10.1007/s10887-006-9009-4.

2. Baldwin R., Lopez-Gonzalez, J. Supply-chain trade: A portrait of global patterns and several testable hypotheses // The World Economy. – 2015. – №38(11). – P. 1682–1721. – DOI: 10.1111/twec.12189.

3. Auty R.M. Resource abundance and economic development. Oxford University Press. – 2001. – 340p.

4. Sachs J.D., Warner A.M. The curse of natural resources // European Economic Review. – 2011. – №45(4–6). – P. 827–838. – DOI: 10.1016/S0014-2921(01)00125-8.

5. Antràs P., Chor D., Fally T., Hillberry R. Measuring the upstreamness of production and trade flows // American Economic Review. – 2012. – №102(3). – P. 412–416. – DOI:10.1257/aer.102.3.412.

6. Dietzenbacher E., Romero I. Production chains in an interregional framework: Identification by means of average propagation lengths // International Regional Science Review. – 2007. – №30(4). – P. 362–383. – DOI: 10.1177/0160017607305366.

7. Leontief W.W. Quantitative input and output relations in the economic system of the United States // The Review of Economics and Statistics. – 1936. – №18(3). – P. 105–125. – DOI: 10.2307/1927837.

8. Miller R.E., Blair P.D. Input-output analysis: Foundations and extensions. Cambridge University Press. – 2009. – 750p.

9. Wang Z., Wei S.-J., Yu X., Zhu K. Characterizing global value chains: Production length and upstreamness. NBER Working Paper No. 23261. – 2017. – DOI: 10.3386/w23261.

10. Koopman R., Wang Z., Wei S.-J. Tracing value-added and double counting in gross exports // American Economic Review. – 2014. – №104(2). – P. 459–494. – DOI: 10.1257/aer.104.2.459.

11. Hidalgo C.A., Hausmann R. The building blocks of economic complexity // Proceedings of the National Academy of Sciences. – 2009. – №106(26). – P. 10570–10575. – DOI: 10.1073/pnas.0900943106.

12. Acemoglu D., Carvalho V.M., Ozdaglar A., Tahbaz-Salehi A. The network origins of aggregate fluctuations // Econometrica. – 2012. – №80(5). – P. 1977–2016. – DOI: 10.3982/ECTA9623.

13. Carvalho V.M. From micro to macro via production networks. Journal of Economic Perspectives. – 2014. – №28(4). – P. 23–48. – DOI: 10.1257/jep.28.4.23.

14. Moosavi V., Isacchini G. A Markovian model of the evolving world input-output network // PLoS ONE. – 2017. – №12. – DOI: 10.1371/journal.pone.0186746.

15. Shannon C.E. A mathematical theory of communication // The Bell System Technical Journal. – 1948. – №27(3). – P. 379–423. – DOI: 10.1002/j.1538-7305.1948.tb01338.x.

Жайлауов Е.Б., Притворова Т.П., Омар Ж.Т.

ӨНДІРІСТІК ТРАЕКТОРИЯЛАРДЫҢ КҮРДЕЛІЛІГІН ЖӘНЕ ҚАЗАҚСТАН ЭКОНОМИКАСЫНДАҒЫ ҚОСЫЛҒАН ҚҰН ТІЗБЕКТЕРІНІҢ ІШКІ ИНТЕГРАЦИЯЛАНУЫН БАҒАЛАУ

Аңдатпа

Бұл мақалада экономиканы сіңіргіш Марков тізбегі ретінде көрсетуге негізделген төменгі ағынды өндіріс процестерінің күрделілігі үшін стохастикалық құрылымдық модель ұсынылады. Ұсынылған тәсіл шеңберінде әрбір саланың өнімі ішкі соңғы сұранысқа немесе экспортқа әкелетін ықтимал төменгі ағынды траекториялардың көзі ретінде қарастырылады. Өндіріс тізбектерінің сипаттамаларын бағалау үшін күтілетін төменгі ағынды тереңдік (Expected Downstream Depth), траекторияның тармақталу энтропиясын (H), төменгі ағынды траектория күрделілігінің интегралды индексін (Downstream Trajectory Complexity), өндірісті трансформациялау ұпайын (Production Transformation Score) және экспорттық ағып кету индексін (Export Leakage Index) қамтитын көрсеткіштер жүйесі әзірленді. Әдістеме 2023 жылға арналған Қазақстан Республикасы үшін симметриялы «кіріс-шығыс» кестесіндегі деректерді пайдаланып сыналды. Нәтижелер химия өнеркәсібі, металлургия және мұнай өңдеу төменгі ағынды траекториялардың ең күрделілігімен сипатталатынын көрсетті. Сонымен қатар, бұл салалар экспорттық ағып кету қаупінің жоғарылауын көрсетеді, бұл отандық өңдеу тізбектерін тереңдетудің айтарлықтай пайдаланылмаған әлеуетін көрсетеді. Керісінше, мұнай мен табиғи газ өндірісі тауар экспортының мамандану моделіне сәйкес келетін төменгі ағым траекторияларының төмен күрделілігімен және экспорттың жоғары деңгейдегі ағып кетуімен сипатталады. Бұл зерттеудің ғылыми жаңалығы салааралық талдау құралдарын, сіңіретін Марков тізбектерін және ақпараттық энтропияны біріктіретін өндіріс жүйелерін талдауға ықтималдық тәсілді әзірлеуде жатыр. Нәтижелердің практикалық маңыздылығы өңдеуді тереңдету және отандық қосылған құнды арттыру үшін ең үлкен әлеуеті бар салаларды анықтау мүмкіндігінде жатыр.

Жайлауов Е.Б., Притворова Т.П., Омар Ж.Т.

ОЦЕНКА СЛОЖНОСТИ ПРОИЗВОДСТВЕННЫХ ТРАЕКТОРИЙ И ВНУТРЕННЕЙ ИНТЕГРИРОВАННОСТИ ЦЕПОЧЕК ДОБАВЛЕННОЙ СТОИМОСТИ В ЭКОНОМИКЕ КАЗАХСТАНА

Аннотация

В работе предложена Стохастическая фреймворк-модель сложности нисходящих производственных процессов, основанная на представлении экономики в виде поглощающей марковской цепи. В рамках предложенного подхода выпуск каждой отрасли рассматривается как источник вероятностных нисходящих-траекторий, завершающихся внутренним конечным спросом или экспортом. Для оценки характеристик производственных цепочек разработана система показателей, включающая ожидаемую глубину нисходящего-прохождения продукции (Expected Downstream Depth), энтропию разветвленности траекторий (H), интегральный индекс сложности нисходящих-траекторий (Downstream Trajectory Complexity), показатель производственной трансформации (Production Transformation Score) и индекс экспортной утечки (Export Leakage Index). Апробация методики выполнена на данных симметричной таблицы «затраты-выпуск» Республики Казахстан за 2023 год. Результаты показали, что наибольшей сложностью нисходящих-траекторий характеризуются химическая промышленность, металлургия и нефтепереработка. Одновременно данные отрасли демонстрируют повышенный риск экспортной утечки, что свидетельствует о наличии значительного нереализованного потенциала углубления внутренних цепочек переработки. В отличие от них добыча нефти и природного газа характеризуется низкой сложностью нисходящих-траекторий и высоким уровнем экспортной утечки, что соответствует модели сырьевой экспортной специализации. Научная новизна исследования заключается в разработке вероятностного подхода к анализу производственных систем, объединяющего инструменты межотраслевого анализа, поглощающих марковских цепей и информационной энтропии. Практическая значимость результатов связана с возможностью выявления отраслей, обладающих наибольшим потенциалом углубления переработки и увеличения внутренней добавленной стоимости.