Using Probabilistic Dynamics of Innovations to Manage the Recovery and Modernization of Ukrainian Industries

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Abstract

The results of using the apparatus of probabilistic dynamics to manage the development of innovation activity during the recovery and modernization of the Ukrainian economy are presented. Quantitative estimates of the response to innovation proposals depending on the size of enterprises in various industries served as input information. It was established that innovation development in conditions of instability of Ukrainian business relations to new innovative technologies and economically unbalanced ties has a probabilistic-deterministic character. The conceptual model of probabilities of innovation dynamics has been developed, in which simulation and event generation reflect the external environment's influence. Transition matrices and conditional probabilities with different priorities of resource allocation by sectors of the economy have been calculated. Visualization of the system of interrelations of Ukrainian business sectors in graphs of innovative development management during economic recovery is carried out.

Keywords

Markov chains, innovation activity, probabilistic dynamics of innovations, innovation management, dynamic changes in the external environment, innovation technologies

1. Introduction

Innovation activity has always been the basis for the sustainable economic development of any business, as its dynamic development constantly requires the introduction of new technologies and improvements to consumer demands. Only the one that succeeds in developing its production constantly monitors new developments and competitors' experience in achieving exclusive advantages and preferences. Successful enterprises have always had positive dynamics in the development of innovation activity, which requires constant updating of production, personnel training, and improvement of personnel skills in mastering new techniques and technologies. The prospects of success and achieving competitive advantages have always justified the costs of innovation activities.

The legitimate and justified attention to new modern innovative technologies of all links and branches of social production was sharply reduced during the COVID-19 pandemic and the onset of the world economic crisis. The subsequent years have intensified the ambiguous and jumpy nature of the development of innovation activity.

The propensity for innovation growth depends on the size of the business. As the size of firms increases, the likelihood of prioritizing the development and use of innovation as a tool in competition increases. Military actions in Ukraine increase this gap and practically level out the

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possibility of rapid recovery and modernization for micro businesses. Still, at the macro level, it is pretty evident that it is only possible to plan the recovery of Ukrainian business by activating innovation activity. Quantitative estimates of the probabilistic dynamics of innovation to manage the recovery and modernization of Ukrainian industries are presented in Table 1.

Table 1
Quantitative estimates of the response of firm size to innovation proposals of different levels of relevance

Size of enterprises	Types of innovations, %		
	deemed irrelevant	topical with limited applicability	very relevant
Large enterprises	20	42	38
Medium-sized enterprises	27	47	27
Small enterprises	41	46	13
Microenterprises	43	50	8

Source: "Ukrainian Business in a Time of War". Institute for Economic Research and Policy Consulting 2023

Today, such problems of innovation activity development are dominated by an unfavorable political situation and low demand at the level of outdated technologies. Attitudes towards innovation activity for different business sectors are also different (Table 2).

Table 2
Quantitative estimates of response to innovation proposals for different economic sectors

Industries	Types of innovations, %		
	deemed irrelevant	topical with limited applicability	very relevant
Metallurgy	36	27	36
Chemical	35	48	17
Machine building	22	50	28
Woodworking	30	48	22
Building materials production	50	46	4
Food processing	31	53	16
Light industry	44	35	21
Printing	64	27	9

Source: "Ukrainian Business in a Time of War". Institute for Economic Research and Policy Consulting 2023

At the sectoral level, the attitude towards Ukrainian business from the side of new improving innovative solutions is ambiguous. The industry that suffered the most during the war is related to the production of construction materials. Despite the high demand for its products, the industry reveals a shallow and even hostile attitude to new technologies and innovations that are relevant for foreign similar problem companies and that improve the quality of products.

As it follows from Table 2, the gradation of negative attitudes to innovations is headed by the printing industry, which visually represents the state of military operations and operational information about the ongoing changes. The following budget-forming industries also consider innovation activity during the war irrelevant, among them light industry (44%), food industry (33%), metallurgy (36%), and machine building (22%).

Current trends in the development of business under military operations also confirm the instability of business attitudes to new technologies and the imbalance of innovation activity.

2. Problem statement

Innovative activity and modernization of business sectors, in addition to own financing to eliminate stagnation, destruction of production, requires state support in the form of long-term programs, fiscal incentives, support for the training of specialists, external consulting support and establishment of communications with relevant innovators. With limited investment resources, considering which business sectors should be prioritised is particularly acute in the face of uncertainty caused by dynamic changes in the external environment.

Under these conditions, the innovative development of Ukrainian enterprises has a random probabilistic-dynamic character. Markov chains are a convenient tool for describing such phenomena. Since the process of evaluating innovation activity in the conditions of dynamic changes in the external environment starts without taking into account corrections for the current situation, it consists of the sequence of defining states. In this case, only current and future forecast values are considered without considering experience.

The relevance of the work is to develop a methodology for assessing and forecasting the development of innovation activity of individual sectors of Ukrainian business in the context of dynamic changes in the external environment.

The work aims to create an instrumental tool for probabilistic dynamics of management of the development of innovation activity in Ukraine during unpredictable dynamic changes in the environment caused by military actions in Ukraine and the recovery of their consequences.

3. Relative works

Under the conditions of uncertainty of the external environment influence and unpredictability of forthcoming changes, the attitude to innovation activity is different for different industries and sizes of enterprises. The specificity of reactions to innovation proposals in their various manifestations (Table 1, Table 2) requires generalizing the presented information, its ordering and ranking in the form of conditional probabilities for each industry. The experience of using Markov chains to solve various scientific and technical problems is helpful in this case.

The use of information technology to assess the readiness of enterprises for innovative transformation with the help of Markov chains is presented in [1,2]. Models of Markov processes of logical transitions of probabilistic assessments of transitions are presented in [3,4]. In [5], the main methodological constructions of a mixed number of states of Markov processes in discrete time are described. Markov chains in state sequence estimation are given in [6,7], and an information system for water treatment quality assessment is considered in [8]. The relationship between control and human factors of complex control models of Markov processes using Monte Carlo methods is described in [9]. Parametric identification of stochastic state uncertainty in asymptotic choice of alternatives using Markov chains is considered in [10]. In [11], stochastic estimates of transport materials are given. Features of the scenario-optimization model of stochastic processes are described in [12], and intelligent information management [13] and management of resources under an unstable external environment is presented in [14-15]. Mathematical support for eliminating the human factor in navigation equipment systems under uncertainty and risk is given in [16-17], management of development of enterprises in [18], hidden Markov model for lymphatic turor progression in the head and neck in [19]. Practical applications of Markov chains and probabilistic dynamics are vast and diverse in different works: modeling economic impact of COVID-19 epidemic in Kenya using Markov Chains [20], parallel probabilistic swarm guidance by exploiting Kronecker product structures in discrete-time Markov chains [21], innovative activity in Ukraine and other countries [22, 26], Stern assessing the accuracy of record linkages with Markov chain [23], transition distributions of a Markov sequence [24], scarcity exchange model for different processes [25], detecting IoT malware by Markov chains [27], and analysis of changing uncertainty of metro tunnel's long-term settlement via hierarchy Bayesian network [28]. Some fragments and peculiarities of the Markov process methodology have been used in this paper.

4. Materials and Methods

The current state of qualitative assessments of innovation proposals for different industries, obtained based on a large number of statistical data and their forecast expert assessments on of the state and modernization of industries, obtained based on a large number of statistical data, due to innovation activities of technological processes, expressed through conditional probabilities under conditions of uncertainty and risk, were used as research materials. Since the state budget funds are considered a single source of financing innovation activities, the sum of conditional probabilities of different industries in a particular time interval should equal 1.

Markov chains and the peculiarities of their application to the management of recovery and modernization of industries of the Ukrainian economy were used as research methods.

Input information on the probabilistic dynamics of the current state of the industries of Ukraine is presented in Table 3.

Table 3
Current state of probabilities of industry dynamics

№	Industries	Weight ratio	Parameter designation
1	Metallurgy	0.12	v_1
2	Chemical	0.11	v_2
3	Machine building	0.2	v_3
4	Woodworking	0.05	v_4
5	Building materials production	0.17	v_5
6	Food processing	0.13	v_6
7	Light industry	0.07	v_7
8	Printing	0.15	v_8

Source: "Ukrainian Business in a Time of War". Institute for Economic Research and Policy Consulting 2023

5. Methodology

The dynamics of innovations required to manage the recovery and modernization of Ukraine's economic sectors can be described using the following equation:

$$\frac{dx}{dt} = f(x, u, v_1, v_2, \dots, v_n),\ x(t_0) = x_0 \qquad (1)$$

where $x \in E_m$ – vector of phase variables, and E_m - state space at each moment of time t.

Let us denote the general change in the dynamics of the management system for the restoration and modernization of the country's economic sectors as follows $u(t) \in U$, and changes in the dynamics of the control subsystems $v_1(t)$, $v_2(t)$, ..., $v_n(t)$, where $v_i(t) \in V_i$.

Assuming a continuous variation of the control parameter u varying with time, the resulting function will have the form (t), $t \in [t_0, t]$. $u(t) \in U$, will change with the change t. Sets U, v_1, v_2, ... , v_n represent sets of admissible variants of management.

Every managerial step $u(t)$, $t \in [t_0, t]$ allows to define the path of motion of the control system $x(t)$, $t \in [t_0, t]$. The set of endpoints of the trajectories of equation (1) forms the set of reachability, originating from the initial state under all possible program management of the restoration and modernization of the economy $u(t) \in U$, $t \in [t_0, t]$. Each subsequent event depends solely on the previous one and has no dependence on other events. Accordingly, the final control trajectory ends at the point of $x(t)$, achieved by the system at the moment of time t.

Let us represent the initial probability distribution in the form of the following equation:

$$P(x_0 = S) = q_0(S) \ \forall_{S \in E} \qquad (2)$$

where $\forall$ – universality quantum, S – discrete states, q_0 – probability distribution at time $t_0 = 0$.

The elements of the set E are restricted to a finite number of possible states.

$$E = \{e_1, e_1, \ldots, e_n\} \quad (3)$$

Range of values of the random parameter $\{x_n\}$, which defines the characteristics of innovation dynamics for managing the recovery and modernization of Ukrainian economic sectors, is a state space, where the variable n denotes the step number and characterizes the evolution of this parameter in the control system. Probabilities of transition from one state to another are represented by square matrices.

$$P_{ij}(n) = P(x_{n+1} = j \mid x_n = i) \quad (4)$$

$$P = \begin{matrix} & s_1 & s_2 & \cdots & s_n \\ s_1 & p_{11} & p_{12} & \cdots & p_{1n} \\ s_2 & p_{21} & p_{22} & \cdots & p_{2n} \\ . & . & . & \cdots & . \\ s_n & p_{n1} & p_{n2} & \cdots & p_{nn} \end{matrix} \quad (5)$$

Elements, p_{ij} represent transition probabilities from the current state s_i in the following s_j.

Transition probabilities, represented as a matrix, express the probability that the state of the control system at step $n + 1$ is the next state for the current state of the initial system.

$$P(x_{n+1} = S_{n+1} \mid x_n = S_n) = P(S_n, S_{n+1}) \ \forall (S_{n+1}, S_n) \leftarrow E \times E \quad (6)$$

A Markov chain can be considered homogeneous when the transition probability matrix is independent of a particular step number. This can be expressed by the following equation:

$$P_{ij}(n) = P_{ij} \quad (7)$$

In accordance with the Kolmogorov-Chapman equation, the matrix of transition probabilities for the number of steps in a homogeneous Markov chain is expressed as a matrix of states of degree n of transition for one step.

The key characteristics of the Markov chain at any time period are the vector-string of transition probabilities P.

The conceptual model developed in accordance with this approach is shown in Fig. 1.

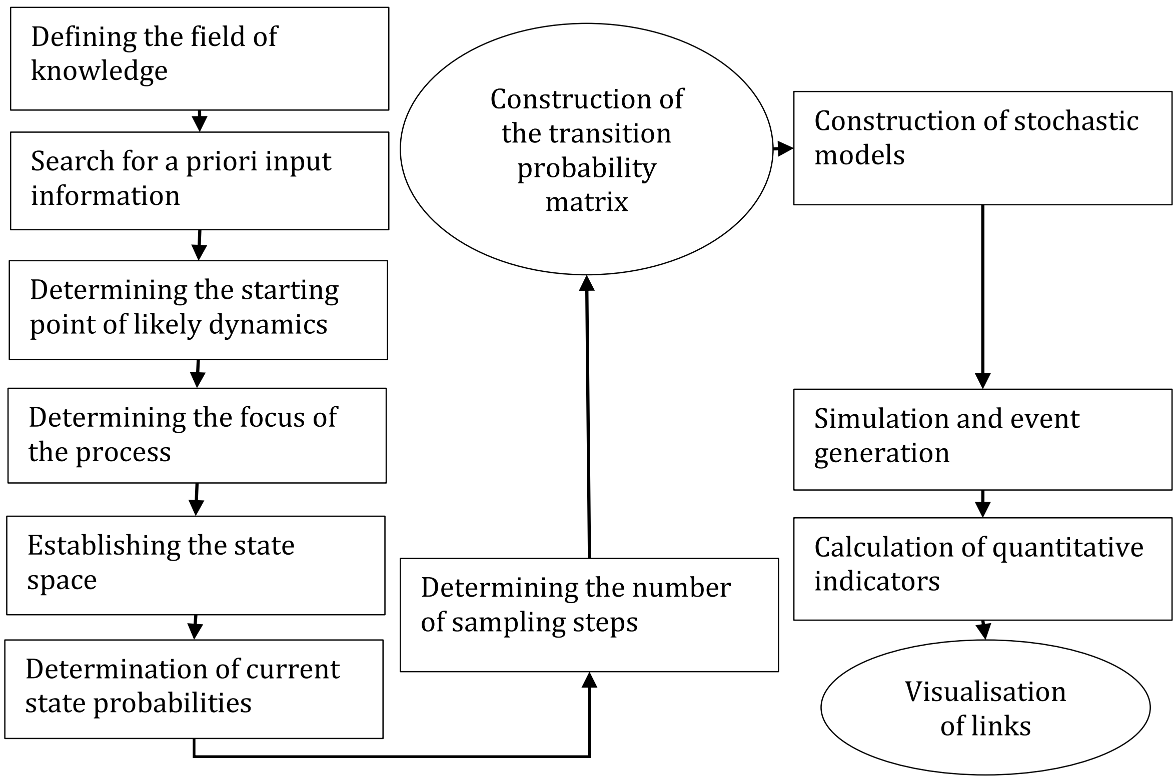

Figure 1: Conceptual model of probabilistic dynamics of innovation

According to the above definitions, the probability distribution in identifying the state of management of rehabilitation and modernization of economic sectors in Ukraine does not depend on time, but is conditioned only by the transitions from the current state to the relevant management operations. By further developing the proposed approach, it is possible to establish a sequence of transitions from the current initial state, forming the necessary basis for management decisions.

The novelty of the presented conceptual model is the transition from discrete time observation of the evolution of probabilistic representations to a continuous sequence of states characterized by intervals of the system being in the equilibrium position of an uncertain situation with varying discretization intervals.

6. Experiment

A specific example of calculating innovation dynamics indicators for managing the recovery and modernization of Ukrainian industries based on Markov chains is considered. The parameters of expert assessment of managerial activity in various country sectors are used as input data. The probability distributions of the current state are presented in Table 3.

Each set of parameters of innovation dynamics indicators for managing the recovery and modernization of industries is assigned a specific probability, which is recorded in a row of the state matrix. The total sum of probabilities in each matrix row always equals one.

The values of conditional probabilities of the parameters of innovation dynamics at different stages of management are presented in Table 4.

Table 4
Conditional probabilities of innovation dynamics indicators for managing the recovery and modernization of Ukrainian industries

Current State / Subsequent condition	Metal-lurgy	Chem.	Mech. eng.	Wood-working	Production of building materials	Food	Light-weight	Print.
Metallurgy	0.12	0.17	0.23	0.06	0.13	0.16	0.08	0.05
Chemical	0.17	0.11	0.07	0.27	0.04	0.10	0.06	0.18
Machine building	0.23	0.07	0.2	0.12	0.06	0.17	0.11	0.04
Woodworking processing	0.06	0.12	0.17	0.05	0.21	0.11	0.17	0.11
Construction materials production	0.14	0.08	0.19	0.11	0.17	0.12	0.10	0.09
Food processing	0.20	0.14	0.05	0.14	0.15	0.13	0.05	0.14
Light industry	0.08	0.09	0.16	0.21	0.07	0.17	0.07	0.15
Printing	0.10	0.13	0.07	0.33	0.02	0.04	0.16	0.15

7. Result and Discussion

The initial vector of states, according to Table 3, is written in the form:

$$p(0)=(0.12, 0.11, 0.20, 0.05, 0.17, 0.13, 0.07, 0.15) \quad (8)$$

The matrix displaying the current state of probabilities of transitional probabilities of industry development dynamics has the form:

$$A=\begin{vmatrix} 0.12 & 0.17 & 0.23 & 0.06 & 0.13 & 0.16 & 0.08 & 0.05 \\ 0.17 & 0.11 & 0.07 & 0.27 & 0.04 & 0.10 & 0.06 & 0.18 \\ 0.23 & 0.07 & 0.20 & 0.12 & 0.06 & 0.17 & 0.11 & 0.04 \\ 0.06 & 0.12 & 0.17 & 0.05 & 0.21 & 0.11 & 0.17 & 0.11 \\ 0.14 & 0.08 & 0.19 & 0.11 & 0.17 & 0.12 & 0.10 & 0.09 \\ 0.20 & 0.14 & 0.05 & 0.14 & 0.15 & 0.13 & 0.05 & 0.14 \\ 0.08 & 0.09 & 0.16 & 0.21 & 0.07 & 0.17 & 0.07 & 0.15 \\ 0.10 & 0.13 & 0.07 & 0.33 & 0.02 & 0.04 & 0.16 & 0.15 \end{vmatrix} \quad (9)$$

Each of the rows in the presented matrix is characterized by its own probability distribution. Next, it is necessary to determine the probability of influence of innovation dynamics indicators to manage the recovery and modernization of industries of the Ukrainian economy at different stages of their use.

Initial state S_0 is characterized by the fact that the parameters of functioning are stable and do not depend on the influence of environmental factors. The indicators at the initial stage will be determined by the parameters vi presented in Table 2.

The state of innovation dynamics indicators for managing the recovery and modernization of the country's industries at the first stage of management S_1 is defined by the first vector row of the matrix A. Probability of influence of this parameter $p(1)$, describing the dynamics of industry vi innovation in accordance with the Markov chain methodology is as follows:

$$p(1) = (0.12, 0.11, 0.20, 0.05, 0.17, 0.13, 0.07, 0.15) \text{x}$$

$$\text{x} \begin{vmatrix} 0.12 & 0.17 & 0.23 & 0.06 & 0.13 & 0.16 & 0.08 & 0.05 \\ 0.17 & 0.11 & 0.07 & 0.27 & 0.04 & 0.10 & 0.06 & 0.18 \\ 0.23 & 0.07 & 0.20 & 0.12 & 0.06 & 0.17 & 0.11 & 0.04 \\ 0.06 & 0.12 & 0.17 & 0.05 & 0.21 & 0.11 & 0.17 & 0.11 \\ 0.14 & 0.08 & 0.19 & 0.11 & 0.17 & 0.12 & 0.10 & 0.09 \\ 0.20 & 0.14 & 0.05 & 0.14 & 0.15 & 0.13 & 0.05 & 0.14 \\ 0.08 & 0.09 & 0.16 & 0.21 & 0.07 & 0.17 & 0.07 & 0.15 \\ 0.10 & 0.13 & 0.07 & 0.33 & 0.02 & 0.04 & 0.16 & 0.15 \end{vmatrix} = \quad (10)$$

$$= (0.1525, 0.1101, 0.1443, 0.1645, 0.0988, 0.1249, 0.0991, 0.1058)$$

The probability that from the state S1, the indicators of innovation dynamics to manage the recovery of industries of the Ukrainian economy will move to the state of S_2, characterized by unstable, poorly predictable changes in environmental parameters is equal to $p(2)$.

$$p(2) = (0.1525, 0.1101, 0.1443, 0.1645, 0.0988, 0.1249, 0.0991, 0.1058) \text{x}$$

$$\text{x} \begin{vmatrix} 0.12 & 0.17 & 0.23 & 0.06 & 0.13 & 0.16 & 0.08 & 0.05 \\ 0.17 & 0.11 & 0.07 & 0.27 & 0.04 & 0.10 & 0.06 & 0.18 \\ 0.23 & 0.07 & 0.20 & 0.12 & 0.06 & 0.17 & 0.11 & 0.04 \\ 0.06 & 0.12 & 0.17 & 0.05 & 0.21 & 0.11 & 0.17 & 0.11 \\ 0.14 & 0.08 & 0.19 & 0.11 & 0.17 & 0.12 & 0.10 & 0.09 \\ 0.20 & 0.14 & 0.05 & 0.14 & 0.15 & 0.13 & 0.05 & 0.14 \\ 0.08 & 0.09 & 0.16 & 0.21 & 0.07 & 0.17 & 0.07 & 0.15 \\ 0.10 & 0.13 & 0.07 & 0.33 & 0.02 & 0.04 & 0.16 & 0.15 \end{vmatrix} = \quad (11)$$

$$= (0.1374, 0.11594, 0.14789, 0.1485, 0.11202, 0.12721, 0.10263, 0.10842)$$

Comparison of values of probability indicators described by vector-string $p(0)$, with corresponding probability distributions of innovation dynamics to manage the recovery and modernization of Ukrainian industries at the first stage of the economy $p(1)$, led to the elaboration of several proposals applicable in practice. Comparison of the same values of the indicators available in equations (8) and (10) showed their increase at the first stage of managing the recovery and modernization of the country's industries, which can be considered satisfactory, except for two parameters "metallurgy" (v_1) and "woodworking industry" (v_4), that have declined. This fact requires a transition to the next stage of calculation of innovation dynamics to manage the recovery and modernization of economic sectors with a probability of $p(2)$.

In the context of unstable functioning due to the influence of external environment impacts, the probability of transition of innovation dynamics indicators for managing the recovery and modernization of Ukrainian industries from the state of S_2 in S_3 denoted as $p(3)$.

At this stage of management, the transition probability of innovation dynamics indicators is determined by the parameter v_3. The probability of impact of this parameter on the transition probability of innovation dynamics indicators, reflecting their controllability, i.e. the ability to correct control actions, is as follows:

$$p(3)= (0.1374, 0.11594, 0.14789, 0.1485, 0.11202, 0.12721, 0.10263, 0.10842)x$$

$$x\begin{vmatrix} 0.12 & 0.17 & 0.23 & 0.06 & 0.13 & 0.16 & 0.08 & 0.05 \\ 0.17 & 0.11 & 0.07 & 0.27 & 0.04 & 0.10 & 0.06 & 0.18 \\ 0.23 & 0.07 & 0.20 & 0.12 & 0.06 & 0.17 & 0.11 & 0.04 \\ 0.06 & 0.12 & 0.17 & 0.05 & 0.21 & 0.11 & 0.17 & 0.11 \\ 0.14 & 0.08 & 0.19 & 0.11 & 0.17 & 0.12 & 0.10 & 0.09 \\ 0.20 & 0.14 & 0.05 & 0.14 & 0.15 & 0.13 & 0.05 & 0.14 \\ 0.08 & 0.09 & 0.16 & 0.21 & 0.07 & 0.17 & 0.07 & 0.15 \\ 0.10 & 0.13 & 0.07 & 0.33 & 0.02 & 0.04 & 0.16 & 0.15 \end{vmatrix} = \qquad (12)$$

$$=(0.1393, 0.11439, 0.1462, 0.15218, 0.11004, 0.12682, 0.10156, 0.10954)$$

Comparison of the same parameters presented in equations (11) and (12) showed an increase for parameters v_2 and v_8 while all other parameters decreased. This was the basis for proceeding to the next stage of calculations. Note that the state *p(0)* describes only the initial state of the system before control. The first stage starts with the step *p(1)*. The transition probability of innovation dynamics indicators at each stage of management should decrease.

Probability of change in the dynamics of innovation to manage the recovery and modernization of Ukrainian economic sectors from the state of S_3 in the state of S_4 denoted as $p(4)$.

$$p(4)= (0.1393, 0.11439, 0.1462, 0.15218, 0.11004, 0.12682, 0.10156, 0.10954)x$$

$$x\begin{vmatrix} 0.12 & 0.17 & 0.23 & 0.06 & 0.13 & 0.16 & 0.08 & 0.05 \\ 0.17 & 0.11 & 0.07 & 0.27 & 0.04 & 0.10 & 0.06 & 0.18 \\ 0.23 & 0.07 & 0.20 & 0.12 & 0.06 & 0.17 & 0.11 & 0.04 \\ 0.06 & 0.12 & 0.17 & 0.05 & 0.21 & 0.11 & 0.17 & 0.11 \\ 0.14 & 0.08 & 0.19 & 0.11 & 0.17 & 0.12 & 0.10 & 0.09 \\ 0.20 & 0.14 & 0.05 & 0.14 & 0.15 & 0.13 & 0.05 & 0.14 \\ 0.08 & 0.09 & 0.16 & 0.21 & 0.07 & 0.17 & 0.07 & 0.15 \\ 0.10 & 0.13 & 0.07 & 0.33 & 0.02 & 0.04 & 0.16 & 0.15 \end{vmatrix} = \qquad (13)$$

$$=(0.13877, 0.1147, 0.14632, 0.15173, 0.11044, 0.12666, 0.10194, 0.10947)$$

Comparison of the respective economic sectors presented in (12) and (13) showed a decrease in all parameters except for the v_2, v_5 and v_7. This was the basis for the transition to the next stage of management.

The probability of changing the dynamics of innovations to manage the recovery and modernization of the country's economic sectors from the state of S_4 in the state of S_5 denoted as $p(5)$.

$$p(5)= (0.13877, 0.1147, 0.14632, 0.15173, 0.11044, 0.12666, 0.10194, 0.10947)x$$

$$x\begin{vmatrix} 0.12 & 0.17 & 0.23 & 0.06 & 0.13 & 0.16 & 0.08 & 0.05 \\ 0.17 & 0.11 & 0.07 & 0.27 & 0.04 & 0.10 & 0.06 & 0.18 \\ 0.23 & 0.07 & 0.20 & 0.12 & 0.06 & 0.17 & 0.11 & 0.04 \\ 0.06 & 0.12 & 0.17 & 0.05 & 0.21 & 0.11 & 0.17 & 0.11 \\ 0.14 & 0.08 & 0.19 & 0.11 & 0.17 & 0.12 & 0.10 & 0.09 \\ 0.20 & 0.14 & 0.05 & 0.14 & 0.15 & 0.13 & 0.05 & 0.14 \\ 0.08 & 0.09 & 0.16 & 0.21 & 0.07 & 0.17 & 0.07 & 0.15 \\ 0.10 & 0.13 & 0.07 & 0.33 & 0.02 & 0.04 & 0.16 & 0.15 \end{vmatrix} = \qquad (14)$$

$$=(0.1386, 0.11433, 0.14629, 0.15155, 0.11037, 0.12664, 0.1019, 0.10941)$$

Comparison of similar parameters of change in the dynamics of innovations for managing the recovery and modernization of industries, presented in (13) and (14), showed a decrease in all parameters. This indicates the quality of application of innovations for the management of recovery and modernization by industrial sectors in Ukraine.

Fig. 2 shows an oriented graph of Markov chains for the considered example of distribution of probability indicators of innovation dynamics for managing the restoration and modernization of industries in Ukraine.

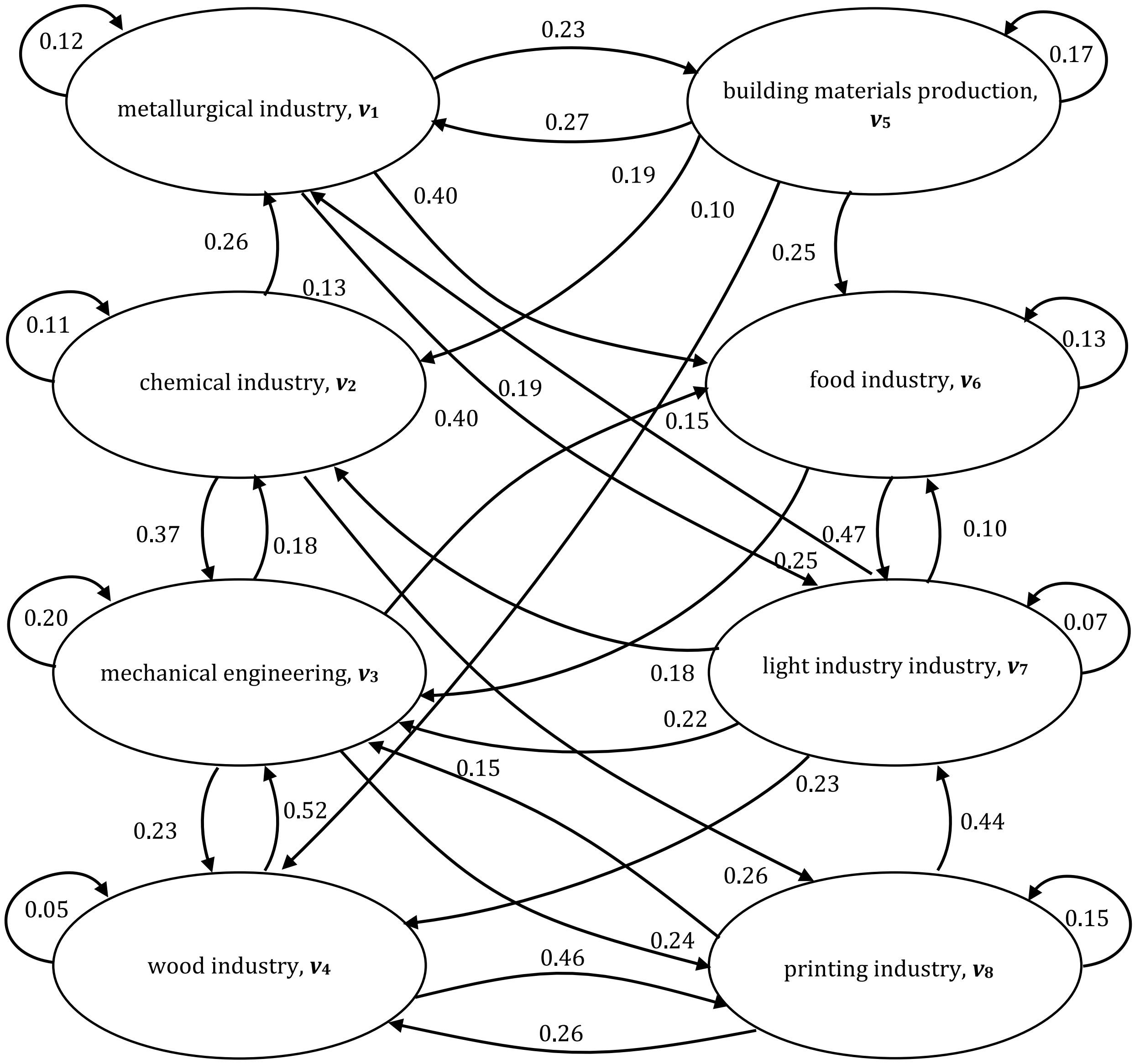

Figure 2: Oriented graph of Markov chains of distribution of probabilistic indicators of innovation dynamics to manage the recovery and modernisation of industries of the Ukrainian economy

Since in the above oriented graph the sum of output probabilities for each of the industries of Ukraine is equal to 1, we can say that the graph corresponds to the calculations performed.

8. Conclusion

1. The solution to one of the situational problems of modern recovery and modernization of industries in Ukraine based on innovation activity is given. There is a sharp decline in interest in innovative technologies for all sectors of Ukrainian business, associated with the consequences of the COVID-19 pandemic, the onset of the global economic crisis, and the military invasion of the Russian Federation in Ukraine.
2. Attitudes toward innovation activity for different sectors of the Ukrainian economy are randomly jumping ambiguously. With limited investment resources, the question of which sectors should be prioritized is particularly acute.
3. A conceptual model of probabilities of innovation dynamics based on Markov chains is developed, in which simulation and generation of events reflect the influence of environmental factors. The novelty of the model is that the argument is not time but a sequence of states of resource interaction and step number reflecting discrediting intervals.
4. Calculations of transition matrices and conditional probabilities of innovation resources by sectors of Ukrainian business are given.
5. The growth of total probabilities with increasing discretization steps is found.
6. The visualization of the priority use of investment resources by different industries in the form of a graph reflecting their mutual probabilities in real-time is made.

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