UDC 330.34.01:330.341.1:658
JEL Classification: O10, O14, O32
DOI: 10.15587/2706-5448.2025.334782

Viktoriia Prokhorova,
Olexandr Yemelyanov,
Orest Koleshchuk,
Svitlana Shepelenko,
Krystyna Slastianykova

ASSESSMENT OF THE IMPACT OF TECHNOLOGICAL CHANGES ON THE DYNAMICS OF ENTERPRISES' ECONOMIC DEVELOPMENT

The object of this research is the impact of technological changes on the dynamics of economic development of enterprises. The main hypothesis is the assumption of the presence of such an impact for a significant number of companies.

The implementation of this research made it possible to make a certain contribution to the process of solving the problem of finding ways to accelerate the economic development of business entities. At the same time, technological changes were divided into three groups, namely: resource-saving; changes that ensure the improvement of the quality of the enterprise's products; changes that ensure the improvement of management, sales and other processes at enterprises. A methodological approach to assessing the impact of technological changes on the dynamics of economic development of companies was also developed. This approach involves the implementation of two main methods of assessment, namely: establishing the presence or absence of such an impact and determining the magnitude of the impact of technological changes on the dynamics of economic development of enterprises.

The testing of the developed tool on a sample of industrial enterprises showed that the impact of technological changes on the dynamics of their economic development exists and is statistically significant. At the same time, the average impact of technological changes on the growth of financial results of enterprises is quite high. In particular, the average values of the indicator of the impact of technological changes on the net profit of those enterprises that have undergone at least two types of such changes, by type of economic activity, range from 11.25% to 13.32%. Since a significant number of the enterprises studied have not carried out technological changes in recent years, at least some of these enterprises may have significant potential to accelerate their economic development.

The developed toolkit for assessing the impact of technological changes on the dynamics of economic development of enterprises can be used to establish the presence and extent of such an impact both at the level of an individual company and at the industry level. This will allow owners and managers of enterprises to increase the validity of the strategies for technological renewal of these enterprises.

Keywords: *enterprise, technological change, resource saving, economic development, financial and economic result, dynamics, product quality.*

Received: 30.03.2025
Received in revised form: 11.06.2025
Accepted: 02.07.2025
Published: 30.08.2025

How to cite
Prokhorova, V., Yemelyanov, O., Koleshchuk, O., Shepelenko, S., Slastianykova, K. (2025). Assessment of the impact of technological changes on the dynamics of enterprises' economic development. Technology Audit and Production Reserves, 4 (4 (84)), 13–23. https://doi.org/10.15587/2706-5448.2025.334782

1. Introduction

In many countries, there is currently a need to raise social standards. At the same time, such an increase is impossible without ensuring permanent macroeconomic development, first of all, without increasing the national product. In turn, in order to achieve sustainable economic growth at the macro level, it is necessary to ensure economic development at the enterprise level [1, 2]. This is due to the fact that the dynamics of financial and economic results of economic activity received by companies, in particular the increase in the size of their income and profits, ultimately determines the pace of macroeconomic growth [3, 4]. In this case, it is necessary to take into account the fact that the economic development of enterprises is directly related to its other varieties, in particular with technical and technological [5], environmental [6] and resource-saving development [7].

In order to accelerate the economic development of firms, it is necessary, in particular, that the owners and managers of these firms be able to manage at least some of the factors that directly affect the dynamics of such development [8, 9]. However, the ability to exercise such management depends, among other things, on the availability of current and reliable data by enterprise managers on the extent of the impact of certain potentially controllable factors on the dynamics of economic growth of companies [10, 11]. In particular, such factors include the volume of investments [12], the level of innovative activity [13, 14], the competencies available to the personnel of enterprises [15], etc. The specified information may also be of interest to those state bodies and local self-government bodies that develop and implement regulatory policy in the economy of the state and regions [16].

Considering the factors that determine the dynamics of economic development of enterprises, it is impossible not to note the various types of technological changes taking place [17], in particular, changes of a labor-saving [18], energy-saving [19] and other nature. At the same time, taking into account the significance of these changes from the point of view of ensuring economic development, there is an objective need to create effective mechanisms by which owners and managers could manage the process of technological changes at enterprises [20, 21].

ISSN-L 2664-9969; E-ISSN 2706-5448

For this, a preliminary assessment of the impact of technological changes on various aspects of economic activity related to the economic development of enterprises is necessary. In view of this, in [22] a study of the relationships between financial efficiency, technological innovations and the state of the environment was carried out, and the role played in ensuring these relationships by various factors, in particular investments, was also clarified. In [23], ecological technological innovations are considered and the importance of these innovations for ensuring sustainable development is shown. At the same time, in [24], a significant impact is revealed that technological innovations have on the sustainability of companies in the conditions of ecological restoration. This impact was also established by the authors of [25], who conducted an empirical study using data from the economy of the United Kingdom. At the same time, in [26], the achievement of sustainable development goals on the basis of technological progress is considered through the prism of the relationships that exist between social, ecological and environmental factors. In addition, the scientific literature has conducted a study of the impact of technological changes occurring in the economy on the market value of companies. The importance of these studies in the context of assessing the impact of technological changes on the dynamics of economic development of companies is that the growth of the market value of firms is one of the main criteria for such development. At the same time, as noted in [27], the process of modeling the impact of technological changes on the value of enterprises must necessarily take into account the risk factor. At the same time, in [28], technological innovations are considered as an intermediate link that provides an indirect impact that the digital economy has on the value of firms.

The multifaceted consequences of technological change have led to the fact that various researchers have studied the impact of such changes on a number of properties of enterprises, which indirectly determine the dynamics of their economic development. In particular, it is about such properties as environmental efficiency [29], competitiveness [30], the speed of technological innovation [31], financial development [32], employment and corporate investment [33], financial condition [34], etc. It is also necessary to note the presence in the scientific literature of fruitful studies that have studied the direct impact of technological change on economic development. Thus, the presence of such an impact has been revealed according to the economies of the BRICS countries [35], in particular China [36], Tanzania [37], ECOWAS countries [38], etc. [39]. Among other things, the authors of these and other works have convincingly proven the importance of technological change for achieving economic development of companies and countries as a whole. At the same time, it should be noted that in modern scientific literature the issue of developing a formalized toolkit, with the help of which it would be possible to perform a comprehensive assessment of the impact of technological changes on the dynamics of the economic development of enterprises, has not been finally resolved. Therefore, this issue requires further research.

Taking into account the above, *the aim of this research* is to develop and use a toolkit for comprehensively assessing the impact of technological changes occurring at enterprises on the dynamics of their economic development. This will allow owners and managers of enterprises to increase the validity of the strategies for technological renewal of these enterprises. In order to achieve the aim, the following main objectives were solved in the process of the research:

– to build a system of indicators for assessing the level of technological changes occurring at enterprises;

– to develop a methodological approach to assessing the impact of technological changes on the dynamics of the economic development of companies;

– to test the developed toolkit for assessing the impact of technological changes occurring at enterprises on the dynamics of their economic development on a sample of industrial companies.

2. Materials and Methods

The object of research is the impact of technological changes on the dynamics of economic development of enterprises. The main hypothesis of this research is the assumption of the presence of such an impact for a significant number of companies.

The theoretical basis for the implementation of this research was the works devoted to the issues of modeling technological changes occurring at enterprises, implementing measures for technological renewal and ensuring the economic development of business entities.

When conducting empirical analysis, statistical, accounting and management accounting materials of a number of industrial enterprises were collected and processed. In addition to company reporting, the results of a questionnaire survey of enterprise owners and managers were used to obtain input information. These enterprises belong to three industries, namely: woodworking, production of building materials and instrument making.

For each of these three types of economic activity, a preliminary sample of 60 randomly selected companies in the western region of Ukraine was formed. After that, questionnaires were sent to each enterprise, and data from open sources were analyzed. Ultimately, taking into account the completeness of the collected data and the willingness of enterprises to provide them, a final sample of the studied companies was formed, which in total for all three industries consisted of 112 enterprises. These enterprises included: 37 woodworking companies, 41 enterprises that produce building materials, and instrument-making enterprises.

Various methods of scientific knowledge were used in the research process. In particular, when developing a methodological approach to assessing the impact of technological changes on the dynamics of the economic development of enterprises, economic and mathematical modeling was applied. The need for such modeling is due to the complexity of the specified impact, which necessitates the need to formalize the impact of factors that determine the dynamics of the economic development of enterprises.

When building a system of indicators for assessing the level of technological changes occurring at enterprises, grouping and generalization methods were used. The use of these methods made it possible to identify types of technological changes, as well as develop appropriate indicators for assessing their level.

In order to build a model of the impact of technological changes on some types of financial and economic results of economic activity, the method of system analysis was used. The feasibility of using this method is due to the need to systematize the relationships between factors that affect the formation of financial and economic results of enterprises.

When conducting empirical studies of the impact of technological changes on the dynamics of economic development of enterprises, methods of economic analysis and technical and economic calculations were used. To conduct a survey at enterprises, in particular to assess the quality of management, sales and other processes at them, the questionnaire survey method was used.

In order to process the results obtained, methods of mathematical statistics were used, in particular one-factor analysis of variance [40]. In addition, when performing empirical research, the tools developed in this work were used.

To visually display the results obtained in the process of the research, graphical and tabular methods were used.

When discussing the results obtained, as well as for the purpose of their generalization in the process of forming conclusions, an abstract-logical method was used. This made it possible to highlight the most significant results of the conducted research, identify the reasons that determined the specified results, and outline possible directions for further study of the issues considered.

3. Results and Discussion

3.1. Construction of a system of indicators for assessing the level of technological changes at enterprises

Assessing the level of technological changes occurring at enterprises requires the use of appropriate indicators, each of which must correspond to a certain type of the specified changes. At the same time, technological changes, according to the purpose of their implementation, should be divided into three groups, namely:

1) resource-saving technological changes, the purpose of the implementation of which is to reduce the costs of relevant resources per unit of manufactured products. The specified changes should, first of all, include: energy-saving, labor-saving, capital-saving and other technological changes that ensure a decrease in the specific costs of resources;

2) changes that ensure an improvement in the quality of the enterprise's products. These changes, in turn, can be divided into those that ensure an improvement in only one parameter of product quality, and those that ensure an improvement in several parameters of product quality at the same time;

3) changes that ensure an improvement in management, sales and other processes at the enterprise. These changes, in turn, can be divided into the following three groups:

– changes that ensure the improvement of information support for the processes of developing and implementing management decisions. Such changes include, among others, the introduction of artificial intelligence technologies, cloud technologies, big data analysis, blockchain, etc. into the practice of management at enterprises;

– changes that ensure the improvement of the quality of customer service processes. Such changes include, in particular, the introduction of integrated CRM systems, unified platforms for communication, virtual and augmented reality technologies, technologies for using social networks and messengers, etc. into the practice of companies;

– changes that ensure the improvement of the quality of other processes that occur at enterprises, in particular the processes of financing and investing in economic activities. Such changes include, among others, the introduction of modern ERP systems, artificial intelligence, crowdfunding technologies, smart contracts, etc. into the practice of financial and investment activities of companies.

The proposed system of indicators for assessing the level of technological changes at enterprises is presented in Table 1. As follows from the information provided in this table, all the proposed indicators are relative in nature. Their application involves comparing the values of certain parameters of economic processes occurring at enterprises after the implementation of technological changes with the basic (i. e., before such implementation) values of these parameters. At the same time, with regard to changes that ensure the improvement of product quality, it is possible to distinguish two groups of indicators for assessing the level of these changes, namely: direct assessment of quality by the relevant parameters and indirect assessment.

Table 1

System of indicators for assessing the level of various types of technological changes that can occur at enterprises

Groups of types of technological changes	Types of technological changes	Formulas for calculating the level of technological change	Decoding of symbols in formulas for calculating the level of technological changes
1. Resource-saving	1.1. Energy-saving	$I_{11} = i_{111} / i_{110}$	i_{111}, i_{110} – average level of energy efficiency for the enterprise for a given type (types) of energy resources, respectively, as a result of the implementation of technological changes and before such implementation
	1.2. Labor-saving	$I_{12} = i_{121} / i_{120}$	i_{121}, i_{120} – average level of labor productivity for the enterprise, respectively, as a result of the implementation of technological changes and before such implementation
	1.3. Capital-saving	$I_{13} = i_{131} / i_{130}$	i_{131}, i_{130} – average level of return on capital for the enterprise, respectively, as a result of the implementation of technological changes and before such implementation
	1.4. Technological changes that reduce the specific costs of other types of resources	$I_{14} = i_{141} / i_{140}$	i_{141}, i_{140} – average level of efficiency of use of another type of resource, respectively, as a result of the implementation of technological changes and before such implementation
2. Changes that ensure improvement of product quality	2.1. Changes that improve only one parameter of product quality	$I_{21} = i_{211} / i_{210}$	i_{211}, i_{210} – average level of a given product quality parameter, respectively, as a result of the implementation of technological changes and before such implementation
		$I_{22} = i_{221} / i_{220}$	i_{221}, i_{220} – average level of product prices for the enterprise, respectively, due to the implementation of technological changes and before such implementation, provided that these changes provide an improvement in only one quality parameter products
	2.2. Changes that improve several parameters of product quality at the same time	$I_{23} = i_{231} / i_{230}$	i_{231}, i_{230} – average enterprise-wide general level of product quality as a result of technological changes and prior to such changes
		$I_{24} = i_{241} / i_{240}$	i_{241}, i_{240} – average enterprise-wide level of product prices as a result of technological changes and prior to such changes, provided that these changes provide simultaneous improvement of several product quality parameters
3. Changes that ensure improvement of management, sales and other processes at the enterprise	3.1. Changes that improve the information support of the processes of developing and implementing management decisions	$I_{31} = i_{311} / i_{310}$	i_{311}, i_{310} – average enterprise-wide level of information support for the processes of development and implementation of management decisions as a result of technological changes and prior to such changes
	3.2. Changes that improve the quality of customer service	$I_{32} = i_{321} / i_{320}$	i_{321}, i_{320} – average enterprise-wide level of customer service quality as a result of technological changes and prior to such changes
	3.3. Changes that improve the quality of other processes	$I_{33} = i_{331} / i_{330}$	i_{331}, i_{330} – average enterprise-wide level of quality of other processes as a result of technological changes and prior to such changes

ISSN-L 2664-9969; E-ISSN 2706-5448

The second approach to assessment is based on the fact that a higher level of product quality should be reflected in a higher price for it, at which buyers will agree to purchase this product. In other words, this approach involves assessing the quality of products by consumers in the process of setting their prices. It should also be noted that the assessment of changes that ensure the improvement of management, sales and other processes may require the use of ordinal (rank) scales.

For example, the level of information support for the processes of developing and implementing management decisions can be assessed on a five-point scale (from very low (1 point) to very high (5 points)). In this case, such an assessment requires conducting a survey of enterprise personnel, and if necessary, involving additional experts who are specialists in the relevant fields.

The use of the system of indicators given in Table 1 is a necessary condition for further assessment of the impact that various types of technological changes have on certain properties of enterprises, in particular on the dynamics of their economic development.

3.2. Development of a methodological approach to assessing the impact of technological changes on the dynamics of economic development of companies

The impact of technological changes on the growth of financial and economic results of enterprises is generally indirect, that is, it occurs due to the action of intermediate factors. This statement is influenced, in particular, by the model of the impact of technological changes on the growth of net profit and excess profit of the enterprise shown in Fig. 1. At the same time, the second type of financial and economic results of economic activity is calculated as the difference between the growth of the enterprise's net profit and the product of the investments that caused this growth, on their rate of profitability.

In this case, investments are understood as one-time expenses incurred in implementing technological changes at the enterprise. Regarding the rate of return on investments, this rate refers to the minimum ratio acceptable to the owners of the enterprise between the amount of net profit growth and the amount of investment that caused this growth.

Since the impact of technological changes on the dynamics of economic development of enterprises is indirect, it is necessary to develop a special methodological approach to assessing this impact. The specified approach should provide for the implementation of two main methods of assessing the impact of technological changes on the dynamics of economic development of companies, namely:

1. *Establishing the presence or absence of such an impact.* Solving this problem requires creating a sample of enterprises with their subsequent division into groups according to the level of a certain type of technological changes on them.

For example, it is possible to identify enterprises with low, medium and high levels of technological changes that occurred during the studied time period. At the same time, for each such group of enterprises, it is necessary to average the values of the levels of a certain type of technological changes. Then, using the method of one-factor analysis of variance, it is possible to establish the presence of statistically significant differences between these averaged values. If such differences exist, this means that there is a clear impact of technological changes on the dynamics of economic development of the enterprises under study (Fig. 2).

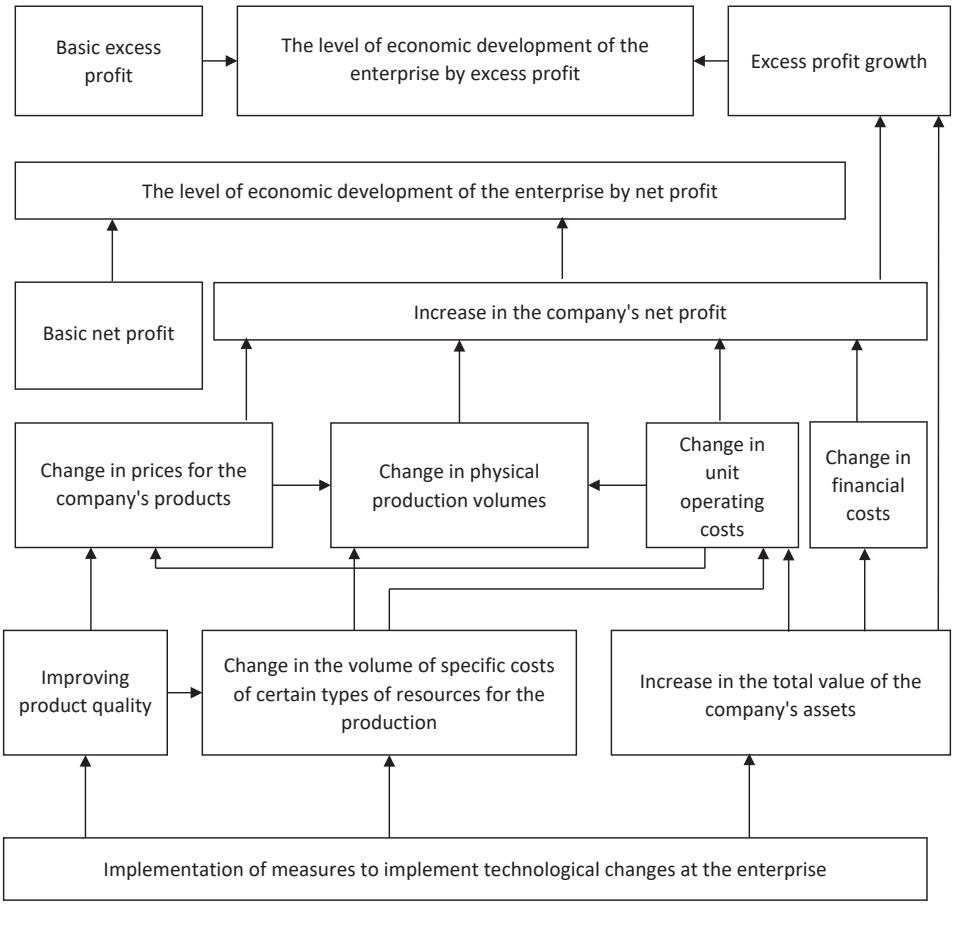

Fig. 1. Model of the impact of technological changes on the dynamics of economic development of an enterprise

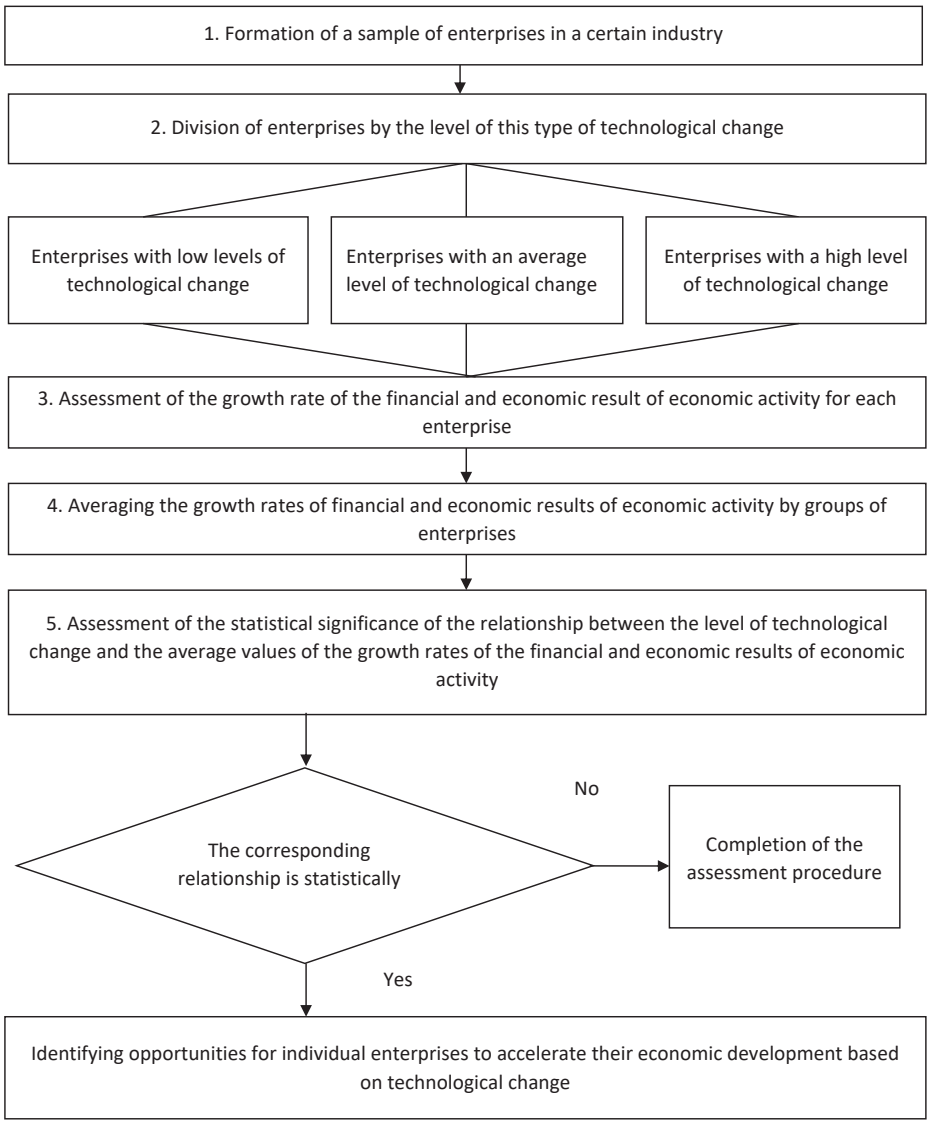

Fig. 2. Sequence of assessing the impact of a certain type of technological change on the dynamics of economic development of enterprises by some financial and economic results of their activities

2. *Establishing the magnitude of the impact of technological changes on the dynamics of economic development of enterprises.* The procedures for such establishment depend on the types of these changes that are considered and on the specific types of financial and economic results. In particular, if to consider energy-saving technological changes, and the growth of net profit and excess profit of the enterprise are chosen as development criteria, then the indicators for assessing the impact of technological changes on the dynamics of economic development of the enterprise will look like this:

$$I_1 = \frac{\Delta P_1 + \Delta P_2}{\Delta P}; \quad (1)$$

$$I_2 = \frac{\Delta P_1 + \Delta P_2 - I \cdot n}{\Delta P_s}, \quad (2)$$

where I_1 – the indicator of the impact of energy-saving technological changes on the net profit of the enterprise; ΔP_1 – the increase in the net profit of the enterprise in the reporting period compared to the base period, due to the increase in net income as a result of the implementation of energy-saving technological changes; ΔP_2 – the increase in the net profit of the enterprise in the reporting period compared to the base period, due to the decrease in costs as a result of the implementation of energy-saving technological changes; ΔP – the total increase in the net profit of the enterprise in the reporting period compared to the base period; I_2 – the indicator of the impact of energy-saving technological changes on the net profit of the enterprise; I – the amount of investment made by the enterprise in implementing these changes, at the expense of its own sources of funds; n – the rate of return on investment in fractions of a unit; ΔP_s – the total increase in the excess profit of the enterprise in the reporting period compared to the base period.

If to consider the entire set of technological changes that have occurred at the enterprise, leaving the same development criteria, then the indicators for assessing the impact of technological changes on the dynamics of the enterprise's economic development will have a form similar to expressions (1) and (2). At the same time, the indicators of net profit growth and investment volumes in this case should be calculated as the sum of their respective values, corresponding to each of the types of technological changes that have occurred at this enterprise during the period under study.

ISSN-L 2664-9969; E-ISSN 2706-5448

3.3. Testing the toolkit for assessing the impact of technological change on the dynamics of economic development of enterprises

The study conducted on a sample of enterprises in three industries showed that for most types of technological changes, the scale of their implementation by the totality of the studied enterprises during 2020–2024 was small. As follows from the data presented in Table 2, only energy-saving technological changes can be considered to be their implementation on a fairly large scale. During the period 2020–2024, such changes were implemented by 43.24% to 50% of the studied enterprises in various types of economic activity. The most common types of technological changes that occurred in the studied companies (although in a much smaller number than energy-saving ones) include two more. This refers to labor-saving technological changes and technological changes that provide improvements in several product quality parameters at the same time. Therefore, in the future, it was these three types of technological changes listed above that were given the main attention.

Using the criteria for dividing the studied enterprises into classes according to the levels of different types of technological changes given in Table 3, these enterprises were divided into their respective classes. In doing so, the corresponding indicators from Table 1 were used. As follows from the data presented in Table 4, for all types of economic activity, the vast majority of the studied enterprises belong to the class of companies with a low level of technological changes.

As for enterprises belonging to the classes of companies with medium and high levels of the corresponding types of technological changes, their number is approximately the same for all these types. At the same time, as follows from the data summarized in Table 5, for enterprises belonging to the class of companies with a low level of technological changes, the average level of these changes is equal to or approaches unity. This means that the majority of such enterprises did not undergo any corresponding technological changes during the studied time period.

Thus, in most of the studied business entities, the level of technological changes during 2020–2024 was extremely low. Therefore, these enterprises may have the potential for economic growth based on the implementation of technological changes in them. At the same time, in order for this potential to really exist, it is first necessary to establish that the impact of technological changes that have already occurred at enterprises on their economic development exists and is sufficiently significant. The presence of such an impact in this case is easiest to verify for energy-saving technological changes, since there are relatively many enterprises that have implemented such changes. As follows from the data presented in Table 6, with an increase in the level of energy-saving technological changes for all types of financial and economic results of economic activity considered, the growth rate of these results increases. Therefore, there is a relationship between an increase in the level of technological changes and the economic development of enterprises. Using the sequence of actions shown above in Fig. 2 made it possible to establish the statistical significance of this relationship. This conclusion was obtained based on the application of one-way analysis of variance, according to which the actual values of the *F*-criterion, given in Table 6, are greater than the critical ones.

Table 2

Distribution of the studied enterprises by types of technological changes that occurred at them during 2020–2024

Types of technological changes	Distribution of enterprises by type of economic activity					
	Woodworking industry		Manufacture of building materials		Instrumentation engineering	
	Number	%	Number	%	Number	%
1.1. Energy-saving	16	43.24	19	46.34	17	50.00
1.2. Labor-saving	4	10.81	3	7.32	5	14.71
1.3. Capital-saving	0	0.00	1	2.44	1	2.94
1.4. Technological changes that reduce the specific costs of other types of resources	1	2.70	2	4.88	1	2.94
2.1. Changes that improve only one parameter of product quality	0	0.00	1	2.44	2	5.88
2.2. Changes that improve several parameters of product quality at the same time	2	5.41	2	4.88	7	20.59
3.1. Changes that improve the information support of the processes of developing and implementing management decisions	1	2.70	1	2.44	1	2.94
3.2. Changes that improve the quality of customer service	1	2.70	1	2.44	2	5.88
3.3. Changes that improve the quality of other processes	0	0.00	0	0.00	1	2.94

Table 3

Criteria for dividing the studied enterprises into classes according to the levels of different types of technological changes

Types of technological changes	Ranges of values of the levels of relevant technological changes, at which the enterprise belongs to a certain class according to these values		
	Enterprises with a low level of technological changes	Enterprises with a medium level of technological changes	Enterprises with a high level of technological changes
1. Energy-saving	Less than 1.05	From 1.05 to 1.15	More than 1.15
2. Labor-saving	Less than 1.05	From 1.05 to 1.15	More than 1.15
3. Changes that improve several product quality parameters at the same time	Less than 1.05	From 1.05 to 1.15	More than 1.15

Table 4

Distribution of the studied enterprises by levels of different types of technological changes

Types of technological changes	Number of enterprises belonging to the relevant classes		
	Enterprises with a low level of technological changes	Enterprises with a medium level of technological changes	Enterprises with a high level of technological changes
1	2	3	4
1. Woodworking industry			
1.1. Energy-saving	21	9	7
1.2. Labor-saving	33	2	2
1.3. Changes that provide simultaneous improvement of several product quality parameters	35	1	1
2. Production of building materials			
2.1. Energy-saving	22	10	9
2.2. Labor-saving	38	2	1
2.3. Changes that provide simultaneous improvement of several product quality parameters	39	1	1
3. Instrument-making			
3.1. Energy-saving	17	8	9
3.2. Labor-saving	29	3	2
3.3. Changes that provide simultaneous improvement of several product quality parameters	27	4	3

Table 5

Indicators of the average level of individual types of technological changes by enterprises

Types of technological changes	Average levels of technological change across enterprises		
	Enterprises with a low level of technological changes	Enterprises with a medium level of technological changes	Enterprises with a high level of technological changes
1. Woodworking industry			
1.1. Energy-saving	1.00	1.09	1.22
1.2. Labor-saving	1.01	1.08	1.24
1.3. Changes that provide simultaneous improvement of several product quality parameters	1.00	1.07	1.18
2. Production of building materials			
2.1. Energy-saving	1.00	1.11	1.19
2.2. Labor-saving	1.00	1.09	1.20
2.3. Changes that provide simultaneous improvement of several product quality parameters	1.00	1.12	1.23
3. Instrument-making			
3.1. Energy-saving	1.00	1.10	1.20
3.2. Labor-saving	1.00	1.07	1.18
3.3. Changes that provide simultaneous improvement of several product quality parameters	1.00	1.11	1.27

Table 6

Indicators of assessing the impact of energy-saving technological changes (ETC) at the studied enterprises on the dynamics of individual indicators of their economic development

Indicator names	Enterprise groups by their ETC level	Growth rates of the values of the relevant indicators in 2024 compared to 2020 by type of economic activity		
		Woodworking industry	Manufacture of building materials	Instrumentation engineering
1. Net income	1.1. Enterprises with a low ETC level during 2020–2024	1.18	1.23	1.09
	1.2. Enterprises with an average ETC level during 2020–2024	1.29	1.36	1.21
	1.3. Enterprises with a high ETC level during 2020–2024	1.37	1.40	1.32
	Estimated value of the F-test	5.98	5.43	6.24
2. Gross profit	2.1. Enterprises with a low ETC level during 2020–2024	1.13	1.16	1.07
	2.2. Enterprises with an average ETC level during 2020–2024	1.38	1.41	1.25
	2.3. Enterprises with a high ETC level during 2020–2024	1.51	1.56	1.38
	Estimated value of the F-test	5.54	6.32	6.76
3. Net profit	3.1. Enterprises with low ETC levels during 2020–2024	1.11	1.13	1.05
	3.2. Enterprises with medium ETC levels during 2020–2024	1.33	1.39	1.23
	3.3. Enterprises with high ETC levels during 2020–2024	1.39	1.46	1.34
	Estimated value of F-test	6.08	7.12	6.55

ISSN-L 2664-9969; E-ISSN 2706-5448

The results of consideration of a more general case, which assumes the possibility of simultaneous influence of a number of types of technological changes on the dynamics of economic development of enterprises, are given in Table 7.

The data given in this table allow to identify some patterns. In particular, the average growth rates of those enterprises in which, in addition to energy-saving changes, at least one other type of technological changes occurred are higher than those in enterprises in which only energy-saving changes occurred. At the same time, the average growth rates of the results of the activities of those enterprises under study in which only energy-saving technological changes occurred are higher than those in companies in which no technological changes occurred at all. Sufficiently high values of the *F*-criterion indicate that this pattern is statistically significant.

Based on the above expressions (1) and (2), the averaged indicators of the impact of technological changes on the growth of net profit and surplus profit of these enterprises were calculated. The corresponding data are given in Table 8.

Table 7

Indicators of assessment of the impact of various types of technological changes on the enterprises under study on the dynamics of individual financial and economic results of their activities

Names of financial and economic results	Enterprise groups by their ETC level	Growth rates of the values of the relevant indicators in 2024 compared to 2020 by type of economic activity		
		Woodworking industry	Manufacture of building materials	Instrumentation engineering
1. Net income	1.1. Enterprises that did not undergo technological changes during 2020–2024	1.17	1.22	1.09
	1.2. Enterprises that underwent only energy-saving technological changes during 2020–2024	1.32	1.30	1.27
	1.3. Enterprises that underwent at least one other type of technological change in addition to energy-saving technological changes during 2020–2024	1.39	1.38	1.35
	Estimated value of the F-test	5.45	6.57	5.98
2. Gross profit	2.1. Enterprises that did not undergo technological changes during 2020–2024	1.12	1.15	1.07
	2.2. Enterprises that underwent only energy-saving technological changes during 2020–2024	1.41	1.44	1.28
	2.3. Enterprises that underwent in addition to energy-saving technological changes, at least one other type of technological change took place	1.46	1.51	1.36
	Estimated value of the F-test	7.01	6.76	6.08
3. Net profit	3.1. Enterprises in which technological changes did not take place during 2020–2024	1.11	1.12	1.05
	3.2. Enterprises in which only energy-saving technological changes took place during 2020–2024	1.36	1.42	1.27
	3.3. Enterprises in which in addition to energy-saving technological changes, at least one other type of technological change took place during 2020–2024	1.43	1.51	1.39
	Estimated value of the F-test	6.12	5.77	6.32

Table 8

Results of the calculations of the averaged indicators of the impact of technological changes on the growth of net profit and surplus profit of these enterprises

Names of financial and economic results	Names of indicators	Average values of indicators for the relevant groups of enterprises by type of economic activity, %		
		Woodworking industry	Manufacture of building materials	Instrumentation engineering
1. Net profit	1.1. Indicator of the impact of energy-saving technological changes on the net profit of enterprises that underwent only this type of technological change during 2020–2024	7.98	11.14	9.03
	1.2. Indicator of the impact of technological changes on the net profit of enterprises that underwent at least two types of such changes during 2020–2024	12.07	13.32	11.25
2. Excess profit	2.1. Indicator of the impact of energy-saving technological changes on the net profit of enterprises that underwent only this type of technological change during 2020–2024	5.65	8.75	6.24
	2.2. Indicator of the impact of technological changes on the net profit of enterprises that underwent at least two types of such changes during 2020–2024	7.23	10.87	8.60

As follows from the data in Table 8, the average impact of technological changes on the growth of net profit and surplus profit of these enterprises is quite high. In particular, the average values of the indicator of the impact of technological changes on the net profit of enterprises that experienced at least two types of such changes by type of economic activity range from 11.25% to 13.32%. At the same time, the value of such an indicator for surplus profit ranges from 7.23% to 10.87%.

3.4. Discussion of the developed tool for assessing the impact of technological changes on the dynamics of economic development of enterprises

The study showed that assessing the impact of technological changes on the dynamics of economic development of enterprises should be based on the application of the appropriate tool. This tool, in turn, should be based on the system of indicators for assessing the level of technological changes occurring at enterprises, constructed in this work. In this case, three groups of technological changes should be taken into account, namely: resource-saving; changes that ensure the improvement of the quality of the enterprise's products; changes that ensure the improvement of management, sales and other processes at the enterprise. For each type of technological change, a relative indicator was proposed, which involves comparing the values of certain parameters of economic processes that occur at enterprises after the implementation of technological changes with the basic values of these parameters. The use of this system of indicators is a necessary condition for assessing the impact that various types of technological changes have on the dynamics of the economic development of enterprises.

In order to assess the impact of technological changes on the dynamics of the economic development of enterprises, two main methods were developed, namely:

1. *Establishing the presence or absence of the specified impact.* Solving this problem requires creating a sample of enterprises with their further division into groups according to the level of a certain type of technological changes on them. For example, it is possible to distinguish enterprises with low, medium and high levels of technological changes that occurred during the studied time period. In this case, for each such group of enterprises, it is necessary to average the values of the levels of a certain type of technological changes. Then, using the method of one-way analysis of variance, it is possible to establish the presence of statistically significant differences between these averaged values. If such differences exist, this means that there is a clear impact of technological changes on the dynamics of economic development of the enterprises under study.

2. *Establishing the magnitude of the impact of technological changes on the dynamics of economic development of enterprises.* The procedures for such establishment depend on the types of these changes under consideration and on the specific types of financial and economic results. In particular, indicators of the impact of energy-saving technological changes on net profit and excess profit of enterprises were constructed.

The developed toolkit for assessing the impact of technological changes on the dynamics of economic development of enterprises can be used to establish the presence and determine the extent of such impact both at the level of an individual company and at the industry level. This will allow owners and managers of enterprises to increase the validity of the strategies for technological renewal of these enterprises.

The effectiveness of the developed toolkit was established during its testing on a sample of industrial enterprises belonging to three industries. This testing showed, in particular, that there is a statistically significant relationship between the increase in the level of technological changes and the economic development of enterprises. At the same time, a sufficiently high averaged impact of technological changes on the growth of net profit and excess profit of companies was revealed.

The effectiveness of the developed toolkit is due, first of all, to the expansion of the system of indicators for assessing the level of technological changes at enterprises compared to those indicators that are used in particular in works [29–34]. Also, in comparison with the results obtained in the works [35–39], the degree of formalization of the process of assessing the impact of technological changes on the dynamics of economic development of companies was increased. In general, the developed toolkit sufficiently fully covers the issue of assessing the impact of technological changes occurring at enterprises on the dynamics of their economic development. This is achieved due to the fact that the use of such a toolkit makes it possible to perform the specified assessment fully and with due accuracy. Therefore, the information obtained as a result of using the specified toolkit makes it possible to substantiate the ways of realizing the potential of economic development of companies on the basis of implementing technological changes in them.

The specified toolkit will be especially useful after the end of martial law in Ukraine and the beginning of large-scale reconstruction of its economy, since technological renewal should become an important component of such reconstruction. At the present time, martial law and military activity do not allow for the full realization of the potential of such renewal.

At the same time, a limitation of this research is that it does not take into account the existing level of technological development of enterprises at the beginning of the period under study. It is possible that this level was already high enough and some enterprises did not need new technological changes. Also, a certain limitation is the consideration of enterprises of only three types of economic activity. Eliminating these limitations should be directions of further research.

4. Conclusions

In the course of research, a system of indicators for assessing the level of technological changes occurring at enterprises was built, among other things. The specified changes were divided into three groups. The first group includes resource-saving technological changes (energy-saving; labor-saving; capital-saving; technological changes that ensure a decrease in the specific costs of other types of resources). The second group includes technological changes that improve product quality (changes that ensure the improvement of only one parameter of product quality; changes that ensure the improvement of several parameters of product quality at the same time). Finally, the third group includes technological changes that ensure the improvement of management, sales and other processes at the enterprise (changes that ensure the improvement of the quality of: information support for the development and implementation of management decisions, customer service, and other processes).

For each type of technological change, a corresponding relative its application involves comparing the values of certain parameters of economic processes that occur at enterprises after the implementation of technological changes with the base (i. e., before such implementation) values of these parameters.

A methodological approach to assessing the impact of technological changes on the dynamics of economic development of companies was also developed. This approach involves implementing two main methods of such assessment, namely: establishing the presence or absence of the specified impact and establishing the magnitude of the impact of technological changes on the dynamics of economic development of enterprises.

The testing of the developed toolkit on a sample of industrial enterprises showed, in particular, that with an increase in the level of energy-saving technological changes for all types of financial and economic results of economic activity that were considered, the growth rate of these results increases. Therefore, there is a relationship between the increase in the level of technological changes and the economic development of enterprises. At the same time, this relationship is statistically significant.

ISSN-L 2664-9969; E-ISSN 2706-5448

Similar results were obtained for a more general case, which involves the possibility of the simultaneous impact of a number of types of technological changes on the dynamics of economic development of enterprises. It turned out that the average growth rates of those enterprises in which, in addition to energy-saving changes, at least one other type of change occurred are higher than those in which only energy-saving changes occurred. At the same time, the average growth rates of the results of the activities of those enterprises under study in which only energy-saving technological changes occurred are higher than those in companies in which no technological changes occurred at all. At the same time, the average impact of technological changes on the growth of net profit and surplus profit of these enterprises, averaged across enterprises, is quite high. In particular, the average value of the indicator of the impact of technological changes on net profit of enterprises in which at least two types of such changes occurred, by type of economic activity, ranges from 11.25% to 13.32%. At the same time, the value of such an indicator for surplus profit ranges from 7.23% to 10.87%. Given that a significant number of the enterprises studied have not implemented technological changes in recent years, at least some of these enterprises may have significant potential to accelerate their economic development by implementing such changes.

Conflict of interest

The authors declare that they have no conflict of interest regarding this research, including financial, personal, authorship or other, that could influence the research and its results presented in this article.

Financing

The research was conducted without financial support.

Data availability

The manuscript has no linked data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

References

1. Shabatura, T. S., Kravchuk, A. O., Hnatieva, T. M. (2017). Model of economic development enterprise in the context of European integration. *Scientific Bulletin of Polissia, 2 (3 (11))*, 89–94.
2. Shenderivska, L., Guk, O. (2018). Enterprises development: management model. *Baltic Journal of Economic Studies, 4 (1)*, 334–344. https://doi.org/10.30525/2256-0742/2018-4-1-334-344
3. Smerichevskyi, S. F., Kryvovyazyuk, I. V., Prokhorova, V. V., Usarek, W., Ivashchenko, A. I. (2021). Expediency of symptomatic diagnostics application of enterprise export-import activity in the disruption conditions of world economy sustainable development. *IOP Conference Series: Earth and Environmental Science, 628 (1)*, 012040. https://doi.org/10.1088/1755-1315/628/1/012040
4. Shibaeva, N., Baban, T., Prokhorova, V., Karlova, O., Girzheva, O., Krutko, M. (2019). Methodological bases of estimating the efficiency of organizational and economic mechanism of regulatory policy in agriculture. *Global Journal of Environmental Science and Management, 5*, 160–171. https://doi.org/10.22034/gjesm.2019.05.SI.18
5. Pylypenko, Yu., Prokhorova, V., Halkiv, L., Koleshchuk, O., Dubiei, Yu. (2022). Innovative intellectual capital in the system of factors of technical and technological development. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 6*, 181–186. https://doi.org/10.33271/nvngu/2022-6/181
6. Hyk, V. (2021). Optimization of costs for innovations of industrial enterprises Western Ukraine in ensuring sustainable environmental development. *E3S Web of Conferences, 234*, 00049. https://doi.org/10.1051/e3sconf/202123400049
7. Prokhorova, V., Mrykhina, O., Koleshchuk, O., Slastianykova, K., Harmatiy, M. (2023). The holistic evaluation system of R&D results under the circular economy conditions. *Eastern-European Journal of Enterprise Technologies, 6 (13 (126))*, 15–23. https://doi.org/10.15587/1729-4061.2023.291380
8. Polinkevych, O. (2016). Factors of enterprises' outstripping development in conditions of global economic crisis. *Economic Annals-XXI, 156 (1–2)*, 59–62. https://doi.org/10.21003/ea.v156-0013
9. Cheng, Y., Zhou, X., Li, Y. (2023). The effect of digital transformation on real economy enterprises' total factor productivity. *International Review of Economics & Finance, 85*, 488–501. https://doi.org/10.1016/j.iref.2023.02.007
10. Babenko, V., Baksalova, O., Prokhorova, V., Dykan, V., Ovchynnikova, V., Chobitok, V. (2021). Information and Consulting Service Using in the Organization of Personnel Management. *Studies of Applied Economics, 38 (4)*. https://doi.org/10.25115/eea.v38i4.3999
11. Vysochyn, I., Sytnyk, H., Zhuk, T., Mazur, Y., Shykova, L., Gordeyeva, Y. (2022). Information tools for enterprise management in Economics 4.0. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 3*, 141–145. https://doi.org/10.33271/nvngu/2022-3/141
12. Wang, Q., Fan, Z. (2023). Green finance and investment behavior of renewable energy enterprises: A case study of China. *International review of financial analysis, 87*, 102564. https://doi.org/10.1016/j.irfa.2023.102564
13. Khodakivska, O., Kobets, S., Bachkir, I., Martynova, L., Klochan, V., Klochan, I. et al. (2022). Sustainable development of regions: Modeling the management of economic security of innovative entrepreneurship. *International Journal of Advanced and Applied Sciences, 9 (3)*, 31–38. https://doi.org/10.21833/ijaas.2022.03.004
14. Wang, M., Li, Y., Li, J., Wang, Z. (2021). Green process innovation, green product innovation and its economic performance improvement paths: A survey and structural model. *Journal of Environmental Management, 297*, 113282. https://doi.org/10.1016/j.jenvman.2021.113282
15. Calhau, R. F., Almeida, J. P. A., Kokkula, S., Guizzardi, G. (2024). Modeling competences in enterprise architecture: from knowledge, skills, and attitudes to organizational capabilities. *Software and Systems Modeling, 23 (3)*, 559–598. https://doi.org/10.1007/s10270-024-01151-7
16. Ban, G., Chankoson, T., Wang, Y. (2025). The impact of public policy on enterprise innovation performance: Panel data on financial subsidy policy. *Heliyon, 11 (1)*, e41230, 1–19. https://doi.org/10.1016/j.heliyon.2024.e41230
17. Çalışkan, H. K. (2015). Technological change and economic growth. *Procedia – Social and Behavioral Sciences, 195*, 649–654. https://doi.org/10.1016/j.sbspro.2015.06.174
18. Piva, M., Vivarelli, M. (2018). Technological change and employment: is Europe ready for the challenge? *Eurasian Business Review, 8 (1)*, 13–32. https://doi.org/10.1007/s40821-017-0100-x
19. Prokhorova, V., Budanov, M., Budanov, P. (2024). Devising an integrated methodology for energy safety assessment at an industrial power-generating enterprise. *Eastern-European Journal of Enterprise Technologies, 4 (13 (130))*, 118–131. https://doi.org/10.15587/1729-4061.2024.308056
20. Mohsin, M., Kamran, H. W., Atif Nawaz, M., Sajjad Hussain, M., Dahri, A. S. (2021). Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. *Journal of Environmental Management, 284*, 111999. https://doi.org/10.1016/j.jenvman.2021.111999
21. Prokhorova, V., Protsenko, V., Bezuglaya, Y., Us, J. (2018). The optimization algorithm for the directions of influence of risk factors on the system that manages the potential of machine-building enterprises. *Eastern-European Journal of Enterprise Technologies, 4 (1 (94))*, 6–13. https://doi.org/10.15587/1729-4061.2018.139513
22. Alvarado, R., Tillaguango, B., Toledo, E., Murshed, M., Işık, C. (2024). Links between technological innovation, financial efficiency and environmental quality using quantile regressions: The role of foreign direct investment, institutional quality and natural resources. *Journal of Open Innovation: Technology, Market, and Complexity, 10 (3)*, 100360. https://doi.org/10.1016/j.joitmc.2024.100360
23. Yang, J., Zuo, Z., Li, Y., Guo, H. (2024). Manufacturing enterprises move towards sustainable development: ESG performance, market-based environmental regulation, and green technological innovation. *Journal of Environmental Management, 372*, 123244. https://doi.org/10.1016/j.jenvman.2024.123244
24. Wu, Y., Tham, J. (2023). The impact of environmental regulation, Environment, Social and Government Performance, and technological innovation on enterprise resilience under a green recovery. *Heliyon, 9 (10)*, e20278. https://doi.org/10.1016/j.heliyon.2023.e20278
25. Ahmad, N., Nguyen, D. K., Tian, X.-L. (2024). Assessing the impact of the sharing economy and technological innovation on sustainable development: An empirical investigation of the United Kingdom. *Technological Forecasting and Social Change, 209*, 123743. https://doi.org/10.1016/j.techfore.2024.123743
26. Islam, H. (2025). Nexus of economic, social, and environmental factors on sustainable development goals: The moderating role of technological advancement and green innovation. *Innovation and Green Development, 4 (1)*, 100183. https://doi.org/10.1016/j.igd.2024.100183

27. Yemelyanov, O. Y., Petrushka, T. O., Symak, A. V., Lesyk, L. I., Musiiovska, O. B.; Zaporozhets, A. (Ed.) (2022). Modelling the Impact of Energy-Saving Technological Changes on the Market Capitalization of Companies. *Systems, Decision and Control in Energy III*. Springer: Cham, 89–106. https://doi.org/10.1007/978-3-030-87675-3_5
28. Pan, X., Wang, Y., Zhang, C., Shen, Z., Song, M. (2023). The impact of platform economy on enterprise value mediated by technological innovation. *Journal of Business Research, 165*, 114051. https://doi.org/10.1016/j.jbusres.2023.114051
29. Chen, Y., Jiang, Z. (2024). The Impact of Enterprise Technological Innovation on Environmental Performance – An Industry Perspective. *Sustainability, 16 (15)*, 6457. https://doi.org/10.3390/su16156457
30. Nagdiev, O. (2023). Evaluation of the innovation-investment factor for augmenting the competitiveness of construction enterprises. *Economics of the Transport Complex, 42*, 143. https://doi.org/10.30977/etk.2225-2304.2023.42.143
31. Prokhorova, V. V., Yemelyanov, O. Y., Koleshchuk, O. Y., Petrushka, K. I. (2023). Tools for assessing obstacles in implementation of energy saving measures by enterprises. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 1*, 160–168. https://doi.org/10.33271/nvngu/2023-1/160
32. Andrew, A. A., Adebayo, T. S., Lasisi, T. T., Muoneke, O. B. (2024). Moderating roles of technological innovation and economic complexity in financial development-environmental quality nexus of the BRICS economies. *Technology in Society, 78*, 102581. https://doi.org/10.1016/j.techsoc.2024.102581
33. Liu, Y., Liu, S., Wu, Z., Xiao, Y. (2022). How do technological innovations affect corporate investment and hiring? *The North American Journal of Economics and Finance, 62*, 101759. https://doi.org/10.1016/j.najef.2022.101759
34. Yiu, L. M. D., Yeung, A. C. L., Cheng, T. C. E. (2021). The impact of business intelligence systems on profitability and risks of firms. *International Journal of Production Research, 59 (13)*, 3951–3974. https://doi.org/10.1080/00207543.2020.1756506
35. Anser, M. K., Ali, S., Umair, M., Javid, R., Mirzaliev, S. (2024). Energy consumption, technological innovation, and economic growth in BRICS: A GMM panel VAR framework analysis. *Energy Strategy Reviews, 56*, 101587. https://doi.org/10.1016/j.esr.2024.101587
36. Zhao, J. (2024). How do innovation factor allocation and institutional environment affect high-quality economic development? Evidence from China. *Journal of Innovation Knowledge, 9 (2)*, 100475. https://doi.org/10.1016/j.jik.2024.100475
37. Byaro, M., Rwezaula, A. (2024). How do technological innovation and urbanization drive economic growth in Tanzania and transform societies? Exploring the potential channels. *Journal of Economy and Technology, 2*, 235–246. https://doi.org/10.1016/j.ject.2024.08.001
38. Jammeh, I. Y. (2022). The Effect of Technological Innovation on Economic Growth: Evidence from ECOWAS Countries. *International Journal of Social Sciences Perspectives, 11 (1)*, 1–10. https://doi.org/10.33094/ijssp.v11i1.610
39. Nihal, G., Mounia, C., Hussain, M., Humayun, S., Perveen, N., Yousaf, N. R. et al. (2023). Impact of Innovation on Economic Growth of G8 Countries-Analysis Over 1996-2020. *International Journal of Professional Business Review, 8 (5)*, e01413. https://doi.org/10.26668/businessreview/2023.v8i5.1403
40. Kim, T. K. (2017). Understanding one-way ANOVA using conceptual figures. *Korean Journal of Anesthesiology, 70 (1)*, 22–26. https://doi.org/10.4097/kjae.2017.70.1.22

Viktoriia Prokhorova, *Doctor of Economic Sciences, Professor, Department of Economics and Management, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0003-2552-2131*

✉***Olexandr Yemelyanov,*** *Doctor of Economic Sciences, Professor, Department of Business Economics and Investment, Lviv Polytechnic National University, Lviv, Ukraine, e-mail: oleksandr.y.yemelianov@lpnu.ua, ORCID: https://orcid.org/0000-0002-1743-1646*

Orest Koleshchuk, *Doctor of Economic Sciences, Associate Professor, Department of Business Economics and Investment, Lviv Polytechnic National University, Lviv, Ukraine, ORCID: https://orcid.org/0000-0001-8995-5206*

Svitlana Shepelenko, *Doctor of Economic Sciences, Department of Marketing and Trade Entrepreneurship, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine, ORCID: https://orcid.org/0009-0006-3952-2035*

Krystyna Slastianykova, *Assistant, Department of Economics and Management, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0002-7114-5165*

✉*Corresponding author*