MULTIDISCIPLINARY SCIENCE JOURNAL

RESEARCH ARTICLE
Published Online: June 4, 2024
https://doi.org/10.31893/multiscience.2025024

Innovation and investment determinants of the development of the agro-food sector of Ukraine

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Abstract The article develops a methodical approach to substantiate the innovation and investment determinants of the agro-food sector development. It also establishes a functional model for evaluating the innovation potential of subjects based on the innovation environment effectiveness criterion in the agro-food sector. The volume of innovation potential and costs between active enterprise groups in the livestock industry of Ukraine and EU-28 countries is determined. The study also establishes the criteria for implementing the innovation and investment development strategy for enterprises in the livestock industry of Ukraine at the macro level. The interdependence between the investment volume and the efficacy of innovation and investment processes in production is substantiated. The article concludes that the investment volume increases the innovation potential volume of enterprises of the live-stock industry in Ukraine.

Keywords: strategic modernization, agrarian sector, innovation costs, forecast indicators, live-stock industry

1. Introduction

In order to consider the innovation and investment determinants of the agro-food sector development, it is advisable to examine the determinism of processes and phenomena in economic systems. In this article, the authors study economic determinism, which considers the economy or the economic environment as an exclusive, active factor acting as a subject of the innovation and investment process. Spaargaren (2011) developed the most profound principle of economic determinism as a social phenomenon and substantiated its importance for agro-food production. The researcher singled out the objective basis of economic relations that does not depend on the consciousness and will of people but on the level of development of production forces. In other words, the unity of the development of production forces and economic relations represent the objective relations of production development. Economic determinism is closely related to technological determinism, where the leading role in agro-food sector development belongs to labor tools and production techniques (Nambisan, 2017).

The common feature of all types of determinism is the assumption that certain processes or events are mutually determined, i.e., they depend on the influence of certain factors (causes, conditions). Kovryga (2010) interprets determinants in terms of economic phenomena. Thus, according to the researcher, determinants are factors influencing the innovation and investment process, each of its elements, and the economic system of each subject of production. Lopatynskyi and Todoryuk (2015) examine the innovation and investment determinants of sustainable development from two perspectives. According to the first one, these determinants present conditions, causes, and factors on which sustainable development depends. The second perspective assumes innovation and investment determinants are the elements and components of development. However, the common opinion is that determinants establish the course of innovation and investment processes and the phenomena that cause them.

The determinants of production activity are classified into objective and subjective ones. Thus, objective determinants are the conditions and consequences of the production activity. Subjective determinants include the aim of the activity and the knowledge of the subject of agro-food production about the means, methods, and conditions for its achieving. Accordingly, objective and subjective innovation and investment determinants are in a dialectical relationship that establishes the structure, direction, and effectiveness of the activities of the subjects of the agro-food sector (Stupen, 2017; Vinichenko et al., 2020).

Trusova et al. (2022) note investments are essential for developing an effective, competitive innovation-oriented economy under market conditions. Investments are an integral attribute and a catalyst for the necessary economic transformations of agro-food production. Its progress is a guarantee of the economic and intellectual potential growth of industries, which is reflected in "creating something new and valued." The progress also implies subjects of the agro-food

 Received: March 2, 2024 | Accepted: June 14, 2024

sector “spending all the necessary time and energy on this, taking on all the financial, psychological, and social risk, obtaining profit and satisfaction with the achievements” (Mishinina, 2013).

The innovation and investment development of the agro-food sector relies on various tools to assess the resource potential of entities, enabling the exchange of innovations between industries. It acts as an incentive for developing cutting-edge technologies in the industry, which requires significant initial investment capital. With certain support, these technologies can quickly and effectively solve problems, overcome market monopolies, and stimulate the development of competitive products in the economic environment (Alon et al., 2005).

In the agro-food sector, implementing innovative and investment initiatives requires a new approach to accountability for activity results, profit, and innovation effects. Within the framework of this initiative, the agro-food sector acts as the main organizational form of production, which is the basis for the country's economic growth. Furthermore, it makes it possible to ensure an appropriate income level for workers in the industry, adapt to changing business conditions, overcome the unstable nature of the economy, and direct actions towards innovative investment development and long-term efficiency (Trusova et al., 2023).

The authors suggest the following types of agro-food sector development should be distinguished: factor-oriented, investment-oriented, and innovation-oriented development. According to subordination to certain types of management, determinants can be divided into current and strategic ones. Current determinants affect the solution of current management tasks, while the influence of strategic ones is aimed at solving strategic management tasks. This will enable the agro-food production industries to shift towards innovation-oriented development. It will also help identify strategic determinants that are crucial for transitioning the innovation platform of a countryэs economy from the fifth (informational) technological system to the sixth (post-informational) system, which focuses on expanding knowledge-intensive technologies.

The dynamics of innovation and investment development in the agro-food sector highlight the need to expand the channels for applying scientific and technological advancements in the production and processing of agricultural products. Additionally, there is a need to enhance the integration between production, scientific research, and service sectors. However, the priority of this research is to apply a methodical approach to the substantiation of innovation-oriented determinants of the agro-food sector development. This contributes to accelerating technological re-equipment, ensuring progressive changes in the innovation and investment process, and forming clear criteria for implementing the agro-food production strategy.

2. Materials and Methods

In order to form an effective policy in the field of innovation and investment development, it is necessary to focus on industry positions. This approach enables a better analysis of the key drivers of activity in the agro-food sector and allows for evaluating these drivers using indicators and sub-indicators of innovative potential. Such evaluation serves as a resource generator for commercialization opportunities and enhances the effectiveness of regional innovation policy. At the same time, the efficiency of the innovation and investment development of agro-food entities in the region largely depends on the rational innovation potential structure, which, subject to the resource capacity of the latter, allows the introduction, distribution, and commercialization of innovations.

Innovative potential generates a resource base for re-equipping production with technologies, testing and introducing new products, and developing industry innovation and investment infrastructure. However, its full implementation is possible through the collaboration of agro-food sector entities with state research institutes and financial and credit institutions. This collaboration would function as a network organization of a territorially separated group that is interconnected based on technological principles and focused on a common resource product, thereby enhancing group competitiveness in the product market (Kuchynskyi, 2014).

The innovation potential was calculated according to the provided below formulae (from 1 to 20) based on the studies by Fischer (2001) and Korovii and Orekhova (2019). Thus, the influence of external and internal factors on the innovation and investment activity of the entities was examined according to the generalized criterion of innovation effectiveness in the agro-food sector at the level of the functional model.

$$I = I_1 \times I_2 \times I_3 \qquad (1)$$

where I_1 stands for the level of use of the external macroeconomic potential by the subject of the agro-food sector; it is determined by the following formula:

$$I_1 = \sum_{i=1}^{n\Sigma} P_i \times \left[1 - \frac{\sigma(P)}{P_{max}}[]_p\right] \qquad (2)$$

where P_i is the degree to which the *i*-th component of the external macro-innovation operation environment of the subject is used; it includes investment, personnel, IT, technical, technological, research, and marketing potential, etc.;

$\sigma(P)$ is the root mean square deviation of the components of the external macro innovation operation environment of the subject;

P_{max} stands for the maximum possible value of the components of the external macro innovation operation environment of the subject;

$B_p$is the balance of the components of the external macro innovation environment of the subject calculated according to Porter's model;

A is the coefficient of adaptation of the internal innovation environment to the external macro innovation operation environment of the subject.

$I_2$is the level of use of the external micro innovation environment by the subject of the agro-food sector, as it is seen on the following formula:

$$I_2 = \sum_{j=1}^{m\Sigma} P_j \times \left[1 - \frac{\sigma(P)}{P_{max}}[]_m\right] \qquad (3)$$

where P_j is the degree to which the *j*-component of the external micro innovation operation environment of the subject; it includes investment, personnel, IT, technical, technological, research, and marketing potential, etc.;

$\sigma(P)$ stands for the root mean square deviation of the components of the external micro innovation operation environment of the subject;

P_{max} represents the maximum possible value of the components of the external micro innovation operation environment of the subject;

B_m is the balance of the components of the external micro economic innovation environment calculated according to Matchett's model;

M means the coefficient of adaptation of the internal innovation environment to the external micro innovation operation environment of the subject.

$I_3$is the level of use of the internal micro innovation environment by the subject of the agro-food sector, calculated by the following formula:

$$I_3 = \sum_{k=1}^{i\Sigma\left[\left(\frac{D_p - D_f}{D_f}/\Delta D\right)\right]} P_k \times \left[1 - \frac{\sigma(P)}{P_{max}}[]_{nk}\right] \qquad (4)$$

where P_k is the degree to which the *k*-component of the internal micro innovation environment of the subject of the agro-food sector is used; it includes investment, personnel, IT, technical, technological, research, and marketing potential, etc.;

$\sigma(P)$ stands for the root mean square deviation of the internal micro innovation environment of the subject of the agro-food sector;

P_{max} is the maximum possible value of the internal micro innovation environment of the subject of the agro-food sector;
B_{nk} represents the balance of the components of the internal micro innovation environment of the subject of the agro-food sector calculated according to the model by Norton and Kaplan;

L stands for the general indicator of the financial and economic condition of the subject of the agro-food sector;

K is the coefficient of adaptation of the internal components of the micro innovation environment of the agro-food sector subject to the external components;

D_p presents the potential of innovation and investment development of the subject of the agro-food sector;

$D_f$is the actually achieved level of innovation and investment development of the subject of the agro-food sector;

ΔD is the degree to which the potential of innovation and investment development of the subject of the agro-food sector is used for the year.

The described methodological approach assesses the effectiveness of the use of the innovative environment by the agro-food sector subject according to its components. This approach considers the level of innovation and investment activity involved in supplying resources from the country's integrated economic system to the global market. At the same time, the indicators fully take into account the following features: high level of labor and capital intensity in the industry; increased level of environmental friendliness and resource efficiency of agro-food production; over-borrowing of technical and technological innovations; the specifics of the life cycle of agro-food sector subjects in the context of the innovation process. It is possible to design a general

system of indicators for evaluating the innovative potential environment for the agro-food sector and supplement them with sub-indicators (I_1...I_{23}), which, in turn, are divided into two main groups.

The internal innovative resources include the following sub-indicators:

Q_4 is an indicator of profitability of assets (R_{oa}) that characterizes the efficiency of assets used by the subject of the agro-food sector and is calculated according to the following formula:

$$R_{oa} = \frac{Np}{Av} \times 100\% \quad or \quad R_{oa} = \frac{Op}{Av} \times 100\% \qquad (5)$$

where R_{oa} is a profitability of assets;

Np stands for a net profit;

Av is a value of assets;

Op is an operating profit.

If the "operating profit" indicator, also known as the earnings before interest and taxes (EBIT) is used, it helps to exclude the impact of taxation and the enterprise's capital structure. Therefore, formula (5) is more universal and allows for comparing enterprises of different sectors and countries.

Q_6 is an indicator of the profitability of expenses (R_{ocs}) that characterizes the payback, the marginal values of which are differentiated by sectors and spheres of the economy, as shown in the following formula:

$$R_{ocs} = \frac{P_s}{C+C_e+M_c} \times 100\% \qquad (6)$$

where $R_{ocs}$is the cost effectiveness;

P_s is a profit on sales;

C means cost price;

C_e stands for commercial expenses;

M_c present management costs.

Q_7 is the staff qualification level that characterizes the ability of employees to use new equipment and technologies; it is calculated according to the following formula:

$$Q_p = (P_1 \times V_1 + P_2 \times V_2 + P_3 \times V_3)/(V_1 + V_2 + V_3) \qquad (7)$$

where V_1, V_2, V_3 stand for the number of employees of high, medium, and low qualifications, respectively;

$P_1, P_2, P_3$are the weighting factors for each group of employees (the recommended value is as follows: $P_1 = 3, P_2 = 2, P_3 = 1$).

Q_9 stands for the share of the latest technology and equipment, calculated according to the following formula:

$$S_{lte} = (P_1 \times T_1 + P_2 \times T_2 + P_3 \times T_3 + P_4 \times T_4 + P_5 \times T_5) +/(T_1 + T_2 + T_3 + T_4 + T_5) \qquad (8)$$

where T_1, T_2, T_3, T_4, T_5 represent the number of equipment of different levels, including advanced world, general world, advanced domestic, general domestic, etc.;

P_1, P_2, P_3, P_4, P_5 are the weighting factors of equipment quality (the recommended values are as follows:$P_1 = 1, P_2 = 0.8, P_3 = 0.6, P_4 = 0.4, P_5 = 0.2$).

Q_{10} is the share of innovation costs in gross profit, calculated by the following formula:

$$S_{icgs} = \frac{C_{dii}}{G_p} \qquad (9)$$

where S_{icgs} is the share of innovation costs in gross profit;

C_{dii} presents the costs for the development and implementation of innovations;

G_p is a gross profit.

Q_{11} is the share of innovative investments in income, calculated as follows:

$$S_{iii} = \frac{I_c}{G_p} \quad (10)$$

where S_{iii} is the share of innovative investments in income;

I_c stands for the innovation costs;

G_p is a gross profit.

Q_{12} is the expenditure rate for the research and development, calculated according to the following formula:

$$R_{srd} = (C_1 - C_0)/C_0 \quad (11)$$

where R_{srd} is the rate of growth of spending on research and development;

C_0 represent the expenditures for the research and development at the beginning of the period;

C_1 represent the expenditures for the research and development at the end of the period.

Q_{14} is the share of the staff involved in the research and development; it is calculated according to the following formula:

$$R_{seisrd} = \frac{N_{eird}}{N_{te}} \quad (12)$$

where N_{eird} is the number of employees involved in the research and development;

N_{te} is the total number of employees.

Q_{15} – the share of costs for staff training and retraining, calculated as follows:

$$R_{\text{секз}} = \frac{A_{estr}}{G_p} \quad (13)$$

where A_{estr} is the annual volume of expenditures on staff training and retraining;

G_p is a gross profit.

Q_{16} is the share of investments in new machinery and equipment, calculated according to the following formula:

$$R_{sin\,me} = \frac{A_{eme}}{G_p} \quad (14)$$

where $R_{sin\,me}$ is the share of investments in new machinery and equipment;

A_{eme} stands for expenses for new machinery and equipment;

G_p is a gross profit.

Q_{17} represents a coefficient of introduction of new technology and equipment and is calculated according to the following formula:

$$R_{int\,e} = \frac{N_{ilte}}{N_{tef}} \quad (15)$$

where $R_{int\,e}$ is a coefficient of introduction of the latest technology and equipment;

N_{ilte} is the number of the introduced latest techniques and equipment;

N_{tef} is the total number of the latest technology and equipment.

Q_{18} stands for the coefficient of introduction of the latest technologies, calculated as follows:

$$R_{ilt} = \frac{N_{iltp}}{N_{tp}} \quad (16)$$

where R_{ilt} is the rate of introduction of the latest technologies;

N_{iltp} represents the number of the introduced latest technologies and processes;

$N_{tp}$is the total number of technologies and processes.

Q_{19} is the share of innovations successfully introduced in the production cycle, calculated by the following formula:

$$R_{isip} = \frac{N_{isip}}{N_{tii}} \quad (17)$$

where R_{isip} is the share of innovations successfully introduced in the production cycle;

N_{isip} is the number of innovations successfully implemented in the production cycle;

N_{tii} stands for the total number of introduced innovations in the production cycle.

Sub-indicators of the external environment of innovation potential include the following:

Q_{21} represents the share of borrowed funds for financing of research and development and is calculated according to the following formula:

$$R_{sbffrd} = \frac{Vlbf}{V_{tardf}} \quad (18)$$

where R_{sbffrd} is the share of borrowed funds for financing of research and development;

$Vlbf$ means the volume of loans and borrowed funds;

V_{tardf} is the total volume of research and development funding.

Q_{22} is the share of state funds for financing research and development, calculated according to the following formula:

$$R_{spffrd} = \frac{A_{pii}}{V_{geb}} \quad (19)$$

where R_{spffrd} is used for the share of state funds for financing research and development;

A_{pii} is the volume of state investments in innovation;

V_{geb} is the total budget expenses.

Q_{23} means the level of sectoral and inter-sectoral cooperation in the field of research and development, calculated according to the following formula:

$$L_{siscrd} = \frac{A_{ijiciipp}}{V_{iepic}} \quad (20)$$

where L_{siscrd} is the level of sectoral and inter-sectoral cooperation in the field of research and development;

$A_{ijiciipp}$ stands for the aggregate investments in joint sectoral and cross-sectoral innovative projects and programs;

V_{iepic} is the aggregate income of subjects of the cluster association participating in innovative cooperation.

When the innovation potential environment of the agro-food sector is assessed according to the given sub-indicators, it corresponds to the variability principles based on statistical and expert methods. Weighting coefficients for partial sub-indicators are determined using formal evaluation for “hard” criteria and expert methods for “soft” criteria. The standardized and actual weighting coefficients ensure the proportionality of the sub-indicators (Spaargaren, 2011).

The multiplicative criterion is used as the objective function to calculate the integral index of the innovative potential of the agro-food sector subject according to the following formula (Alon et al., 2005; Boubezoula et al., 2008):

$$F(x) = \prod_{i=1}^{n} a_i f_i(\overline{x}) \rightarrow max(min) \qquad (21)$$

where a_i is the weighting factor of the *i*-th partial sub-indicator;

f_i is the value of the *i*-th partial sub-indicator;

n is the number of sub-indicators of indicators.

In addition, the entropy method based on studies by Aranchiy et al. (2019), Caserta and Cabo-Nodar (2009), and Maslii (2011) is used to calculate the integral index of the innovative potential of the agro-food sector subject (formulas 22-25). Entropy in the economy involves increasing or decreasing uncertainty due to a change in the information asymmetry of statistical data. The strengths of the entropy method are its relative simplicity and universality; it provides for comparing partial sub-indicators of the innovative potential of subjects in various branches of the agro-food sector. First, the various values of partial sub-indicators are simplified to a single form according to the following formula:

$$N_{ij} = \frac{I_{ij} - min\, I_i}{max\, I_i - min\, I_i} \qquad (22)$$

where $N_{ij}$is the normalized value of the sub-indicator;

I represents the initial value of the sub-indicator;

i means the number of evaluation sub-indicators;

j is the number of subjects under investigation.

The entropy of sub-indicators is determined by the following formula:

$$E_i = 1/LnM \sum_{j=1} LnP_{ij} \qquad (23)$$

where E_i is the entropy value of the partial *i*-th sub-indicator;

P_{ij} is the weighting factor of the *i*-th sub-indicator of the *j*-th subject of the industry;

M is the number of partial sub-indicators.

Thus, the integral index of innovation potential for each subject of the agro-food sector will be determined by the following formula:

$$W_j = \sum_{i=1}^{k} N_{ij} S_i \qquad (24)$$

where N_{ij} is the value of the *i*-th sub-indicator for the *j*-th subject of the agro-food sector;

S_i is the specific weight of the *i*-th sub-indicator, determined by the following formula:

$$S_i = \frac{(1 - \mathrm{E}_i)}{M - \sum_{j=1}^{M} (1 - E_i)} \qquad (25)$$

Thus, the entropy method is substantiated to provide reliable calculations of the integral index of innovation potential and the representativeness of the criteria. These criteria, supported by the mentioned factors, confirm the effectiveness of the financial and budgetary policy, which, in turn, include the following aspects: the limitation of state funds; the need to determine the direction for the activity of state-funded innovative structures in the agro-food sector; exemption from taxes on funds spent by state scientific institutes on research, development, technical equipment, and introduction of high-tech products into the production process. However, the main direction of innovation and investment development in the agro-food sector is intellectual property and private capital investment in the industry through creating an innovative effect for the transparent prolongation of benefits.

3. Results and Discussion

Ukraine's agro-food sector largely relies on systematizing forms of innovation and investment development and corresponding models established in different countries. The following models are suitable for stimulating innovation and investment progress:

1. the model of scientific and technical leadership, which involves implementing large-scale targeted innovation projects oriented toward national security (e.g., USA, Great Britain, France);

2. the model for stimulating innovations by supporting their diffusion and creating a favorable innovation environment (e.g., Germany, Sweden);

3. the model of supporting innovative development through expanding innovation infrastructure, increasing economic adaptability and adaptability to scientific and technical progress, and ensuring cooperation in the scientific and technical sphere (e.g., Japan, South Korea) (European Commission, 2020, 2021).

Ukraine is included in several international ratings for innovation and investment development. The most important ones are the Global Innovation Index, Bloomberg Innovation Index, Global Talent Competitiveness Index, and Frontier Technologies Readiness Index. The last index measures the readiness of countries to adopt, use, and adapt advanced technologies. The Global Innovation Index (GII) is a "tool for action" for countries that include it in their innovation and investment programs. The index rates the innovative potential and innovative activity outcomes. It measures criteria such as innovation introduction into existing institutions, human capital and research, infrastructure, loans, investments, and connections. Additionally, it evaluates the creation, assimilation, and dissemination of knowledge and creative results. The index is composed of two subindexes, such as the subindex of the introduction of innovations and the subindex of the release of innovations.

Thus, the world leaders in terms of innovation and investment development are mainly the countries of Europe and the USA, as well as two countries from the East Asian region. The USA, the Netherlands, Singapore, and Germany improved their rating in 2022 compared to 2021. The group of backward countries mainly includes the countries of the African region of the Sahara. This region is the least developed in the world in terms of innovation. However, the leading countries of the Sahara region occupy middle positions in the world ranking (for example, South Africa – 61 place).

Ukraine as a European country should follow the examples of regional and world leaders, such as Switzerland, Sweden, and Great Britain. Unfortunately, Ukraine's position does not allow it to build ambitious plans to become a leader shortly. According to the 2022 index calculations, Ukraine occupies 57th place in the rating. Its position worsened compared to 2021 (the country occupied 49th place).

Ukraine significantly worsened innovation activity outcomes and decreased its position from 37th place to 48th place in 2022. However, Ukraine's economy has average indicators that fall within the group of lower-middle-income countries. The rating of the strengths and weaknesses of the economy of Ukraine from the standpoint of innovation and investment development data is given in Figure 1.

The war in Ukraine has become a challenge for all national branches of the economy, including the dairy sector; it suffers from the occupation, destruction of farms and livestock, disruption of production and logistics infrastructure, mined fields, looting of farms by the occupiers, population migration, price fluctuations, blocked ports, etc.

The war affected about 800 industrial dairy farms, while a hundred of them were destroyed or damaged significantly. Blocking the fodder export (corn, soybeans, meal, and other crops) from Ukraine to the global agro-food sector by the Russian occupiers forces dairy producers to look for other suppliers. Meanwhile, the scale of demining 5 million hectares of agricultural land can take from 30 to 70 years and currently requires EUR 1.5 billion. Despite the losses and destruction, dairy farmers do not stop working to preserve (restore) and develop the industry. In 2022, the number of cows in the livestock sector and milk production decreased by 9% and 7%, respectively (FAO, 2022c; Global Innovation Index, 2022; Bloomberg Innovation Index, 2022; Global Talent Competitiveness Index, 2022; Frontier Technology Readiness Index, 2023).

During the war, milk producers have taken on a special responsibility to stabilize the economic platform of territorial communities. This period forced them to re-suggest their innovation and investment processes and optimize the effectiveness of innovative solutions. Several factors favored farmers in 2021. The profitable period allowed for innovative and investment activities in the livestock industry despite the war impact in the first six months. Initiatives such as organizing a sowing company, paying wages, and acquiring production resources were undertaken. Additionally, grain surpluses were invested in milk and meat production during the blockade of Black Sea ports. Collaboration with the processing industry helped maintain purchase prices and resolve industry challenges. Furthermore, the European Parliament's decision to abolish import tariffs for agro-food products exported to EU countries provided further support. The latter helped largely to prevent the economic crisis in Ukraine, caused by the decreased domestic consumption of dairy products. Furthermore, the opening of European borders for exporting dairy products allowed processing enterprises to maintain the purchase price; later, these enterprises managed to increase them, which became decisive for the country's economy. Thus, the profitability of milk production was 17% in 2022. The volume of exports of milk and dairy products increased by 36.8%, while imports decreased by 47% (FAO, 2022c; Global Innovation Index, 2022; Bloomberg Innovation Index, 2022; Global Talent Competitiveness Index, 2022; Frontier Technology Readiness Index, 2023).

During wartime, the agro-food sector, including animal husbandry, in Ukraine relies on cycles of technological capability restoration in innovation and investment processes. These cycles aim to unify and activate the efforts of stakeholders to revive competitiveness in both domestic and foreign markets. When innovation and investment processes are actively implemented in the livestock industry, it helps boost labor productivity and resource conservation, reduce costs, and increase production

volumes and efficiency. This impacts the level of external investments attracted to enhance the innovation potential of livestock industry entities, preventing economic system crises through scientific and innovative initiatives.

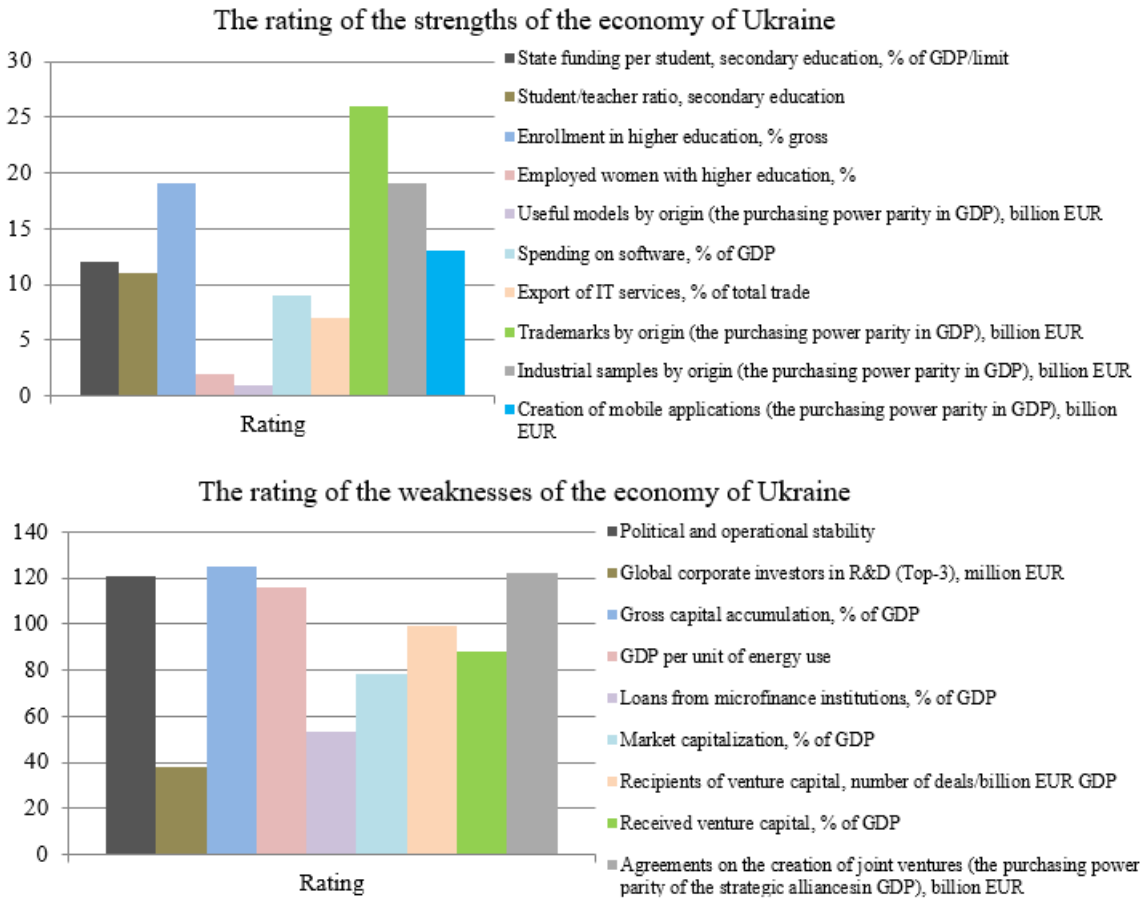


Figure 1 The rating of the economy of Ukraine from the standpoint of innovation and investment development .
Source: built by the authors according to data FAO (2022a, 2022b, 2022c); European Commission (2020); Bloomberg Innovation Index (2022); Global Innovation Index (2022); Global Talent Competitiveness Index (2022); Frontier Technology Readiness Index (2023).

Thus, the period from 2018 to 2022 marked a dynamic change in the structure of the investment distribution for scientific developments and the innovation and investment processes in the livestock industry. The share of state investments in the livestock sector increased from 44.3% to 78.1% in 2022. During the war, the country's higher education sector nearly ceased investing in innovation, with only a 5% share.

The private sector invested almost 37% of its resources in the innovation and investment development of the agro-food sector in 2021, where 15% was allocated by the higher education sector. In 2022, the total investment costs for the implementation of the research work amounted to EUR 350 million and exceeded the level of 2018 by EUR 138.9 million. The fundamental developments were allocated 18.9% of investment resources, while applied developments received 11.2% and scientific and technical (experimental) developments received 36.6%.

Considering how investments in technical re-equipment were distributed among livestock industry businesses from 2018 to 2022, it is evident that a significant portion was allocated to large enterprises focusing on product processing. From 2018 to 2022, the innovative potential with an active investment cycle of large enterprises in the livestock industry accounted for 71% of the total number of innovatively active subjects of agro-food production; on average, 38% of the innovative potential belonged to medium-sized enterprises, and 28% – to small ones. 87.1% of the innovation potential of large enterprises in the livestock industry was used in technological (productive) cycles of re-equipment of production. This share constituted 52.4% in medium-sized enterprises and 29.7% in small-sized enterprises. Figure 2 provides for innovation costs from the total amount of innovative potential for the development of the livestock industry.

The investment determinant on the platform of innovation capabilities of subjects of the livestock industry of Ukraine is a tool for their adaptation to the influence of the innovation environment. Its defining characteristic is the permanent limitation of its resources in the agro-food sector. Therefore, ensuring a successful investment allocation through state institutions should meet the requirements and standards of the strategy of innovation and investment development of the agro-food sector of Ukraine at the macro level.

At the same time, innovative policy in animal husbandry should consider the following: concentration and effective use of investment resources from all sources of their formation; an even investment allocation between regions; acceleration of investment support for the industry development and high level of its profitability; increase in investment volumes in strategically important sub-sectors of animal husbandry; formation of investment sources from the funds of subjects of the agro-food sector; reduction of regulatory influence on investors and attraction of foreign investments (Zabarna et al., 2019).

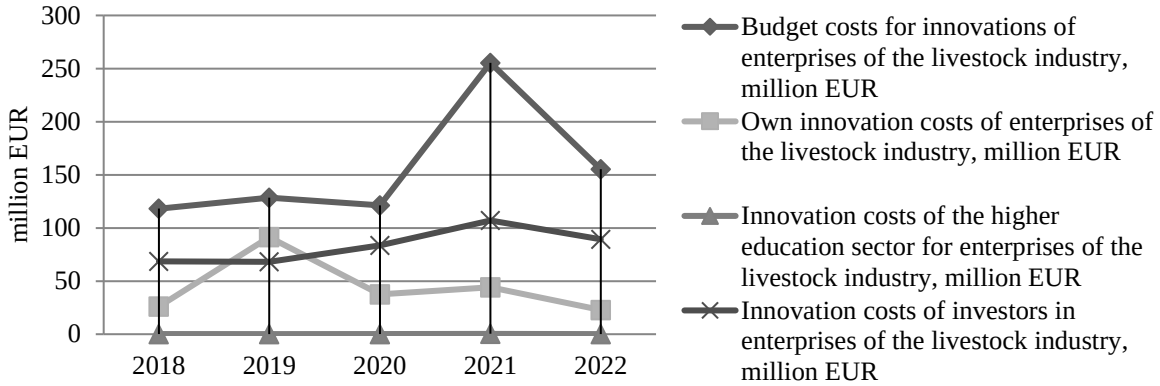


Figure 2 The total amount of innovation costs for the GDR in the technological re-equipment of the livestock industry of Ukraine for 2018-2022, %.

Source: built by the authors according to FAO (2022a, 2022b, 2022c); Bloomberg Innovation Index (2022); Global Innovation Index (2022); Global Talent Competitiveness Index (2022); Frontier Technology Readiness Index (2023).

Therefore, based on scientific approaches to assessing innovation and investment processes in the agro-food sector, the authors present the criteria for implementing the innovation and investment strategy for livestock industry development at the macro level. Additionally, the authors provide a forecast of the innovative potential of subjects for conducting scientific research and development (Figure 3).

Indicator	Reference value	Positive trend of change of the indicator	Critical value	Critical value vector with challenges in mind
The share of the country's research and development expenditures in GDP, %	*3%*	Growth	*Min 1*	Recommendations of the "Lisbon Strategy" for EU countries
The number of patents and copyrights per unit of the country's population	*6.5 units*	Growth	*Min 1*	The average value in the countries of the world - the "Big Seven"
Share of entities implementing technical and technological innovations, %	*44-45 %*	Growth	*Min 1*	Strategy for the development of innovative activities until 2030.
The share of innovative and significantly improved products (works, services) in the total volume of sales, %	*17-18%*	Growth	*Min 1*	
Excess of income over expenses in the field of purchase and sale of intellectual property (licenses, patents, IT systems)	*1.2-1.3*	Growth	*Min 1*	The average value for the ACE countries

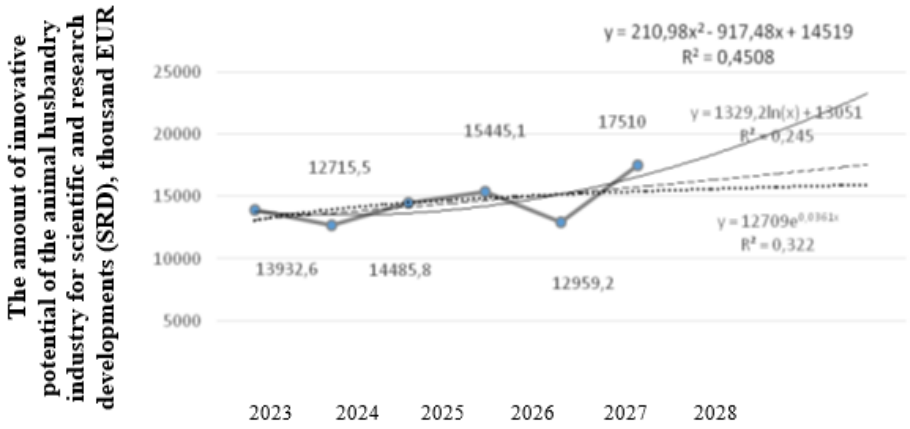
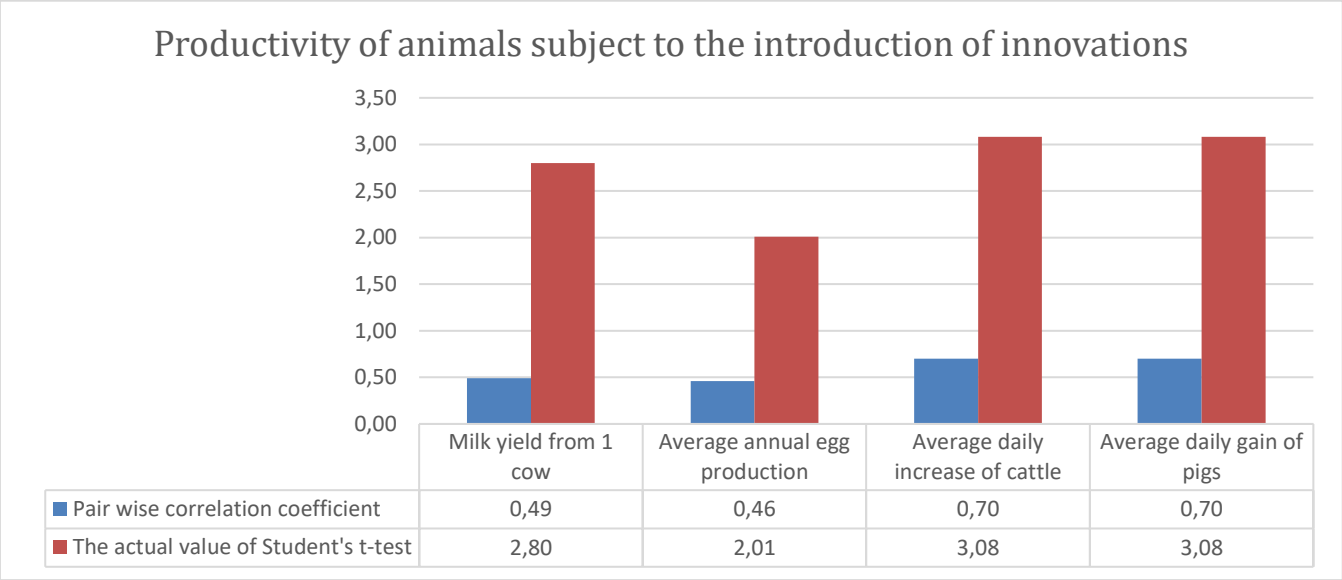


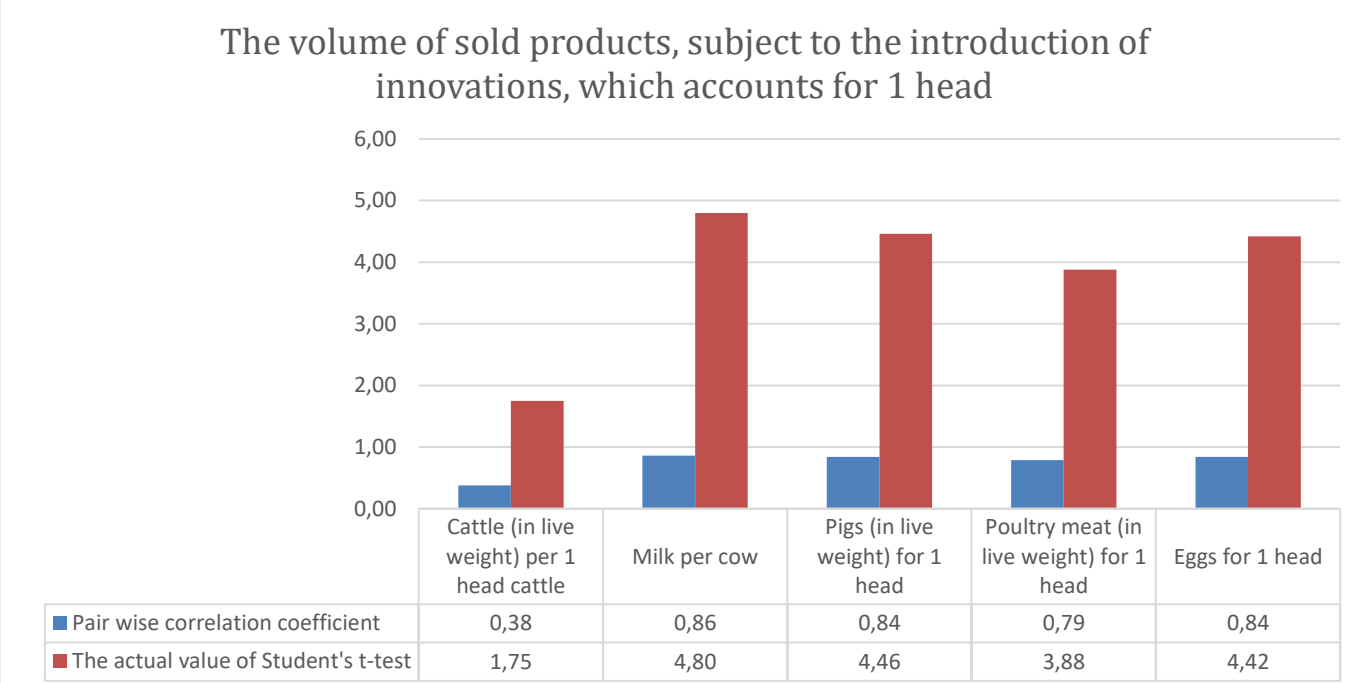
Figure 3 Criteria for implementing the innovation and investment strategy development of the livestock industry of Ukraine at the macro level.

The method of correlation and regression analysis was used to assess the effectiveness of the implementation of innovation and investment processes in the production cycle of subjects of the livestock industry. The value of investments corresponding to 1 EUR of the volume of innovative potential of the animal husbandry industry was chosen as the factor characteristic (x). The quality and resultative signs of the introduction of innovation and investment processes in production include: labor productivity in animal husbandry under the condition of the introduction of innovations (*y*1), the level of profitability of animal husbandry products, subject to the introduction of innovations (*y*2), the index of the level of profitability of animal husbandry products, subject to the introduction of innovations (*y*3).

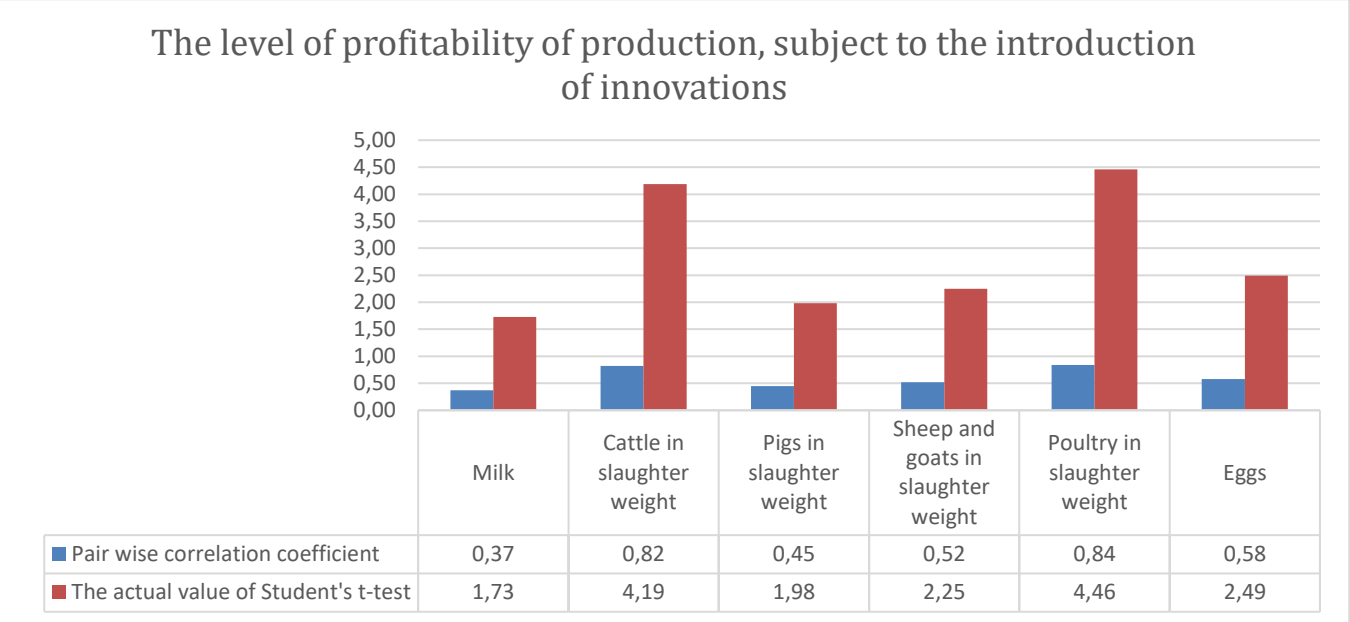
On the priority basis of investment support for the innovation and investment development of the livestock industry in Ukraine and to increase the volume of innovation potential, with the aim of increasing production, the population of highly productive animals was selected as additional quantitative characteristics (cattle – *y*4, cows – *y*5, pigs – *y*6, sheep and goats – *y*7, bird – *y*8). The impact of the amount of investment, which accounts for 1 EUR of the amount of innovative potential of the subjects of the livestock industry, allows us to assess its relationship with the forecast indicators of the introduction of innovation and investment processes in production (Figure 4).



	Milk yield from 1 cow	Average annual egg production	Average daily increase of cattle	Average daily gain of pigs
Pair wise correlation coefficient	0,49	0,46	0,70	0,70
The actual value of Student's t-test	2,80	2,01	3,08	3,08



	Cattle (in live weight) per 1 head cattle	Milk per cow	Pigs (in live weight) for 1 head	Poultry meat (in live weight) for 1 head	Eggs for 1 head
Pair wise correlation coefficient	0,38	0,86	0,84	0,79	0,84
The actual value of Student's t-test	1,75	4,80	4,46	3,88	4,42



	Milk	Cattle in slaughter weight	Pigs in slaughter weight	Sheep and goats in slaughter weight	Poultry in slaughter weight	Eggs
Pair wise correlation coefficient	0,37	0,82	0,45	0,52	0,84	0,58
The actual value of Student's t-test	1,73	4,19	1,98	2,25	4,46	2,49

Figure 4 Relationship between investment and innovation process forecast indicators.

Note: The existence of connection is close linear direct connection. The figure values of the criterion for the level of significance of 0.05 are 1.86 for 0.10 –1.38.

Source: developed by authors

Forecasting the amount of investments to increase the innovative potential of the subjects of the livestock industry in Ukraine was carried out on the basis of a linear trend equation, which has the form $y = 2033.4 + 264.54t$, where, t – time factor The coefficient of determination for this equation is 0.86, which indicates the adequacy of the selected regression model. According to all scenarios, the projected amount of investment to increase the amount of innovation potential is growing steadily. According to forecasts, in 2025, the probable scenario of investing in the innovative potential of the livestock industry in Ukraine will be equal to 88.05 million EUR, in 2026 - 93.69 million EUR, in 2027 - 99.34 million EUR, in 2028 - 124.77 million EUR.

5. Conclusions

Thus, innovation and investment development is a multi-vector process, which includes reproduction at a higher quality level of the product, production forces and relationships between the participants of this process. It is a spiral movement, and each subsequent turn raises production to a higher economic level. The implementation of innovation and investment determinants of the development of the agro-food sector, and in particular in the livestock industry of Ukraine, will help strengthen the food security of territorial communities, strengthen interstate economic ties, and bring the prospect of the country's accession to the European Union closer.

Based on the fact that innovations are manifested in the materialization of scientific ideas and inventions, the final result of the activities of subjects of the agro-food sector, and in particular in the field of animal husbandry, should be a platform of state support programs for the modernization of the economy based on innovations and investments, as well as the creation of a competitive sector of scientific research and development. The reason is its importance in ensuring conditions for its revival and increasing the level of innovation and investment culture.

The main measures and mechanisms for the implementation of the Programs should be supported for the accelerated increase in the number of cows to increase their productivity. The stimulation of the competitiveness of dairy farms should be also supported, by means of: own expanded reproduction of the herd; cultivation and sale of breeding stock with high genetic potential; purchase of breeding young heifers obtained from artificial insemination, to expand the main herd; introduction of budget support for the creation of cultural pastures and productive hayfields; expansion of the list of maintenance, fodder production machinery and equipment for livestock farms and complexes, which are subject to partial compensation; preservation of partial compensation for lowering the cost of artificial insemination for households; introduction of budget support for the construction and reconstruction of dairy complexes and farms; introduction of partial compensation of feed production costs to enterprises that harvest 60 centners of feed units per conditional head (provided the cows' productivity exceeds 5,000 kg of milk per year); increasing the effectiveness of attracting investment investments; preservation of partial compensation of the cost of complex technological equipment, at the expense of funds from the state and local budgets; creation of an information space about the most competitive investment objects in the livestock industry; implementation of innovative projects for the development of dairy farming by identifying priority territorial communities for its revival.

In the process of implementing the Program, it is important to provide technical and technological support to the animal husbandry industry based on scientific technologies and new generation equipment of domestic and foreign production. It is essential to offer technical support of livestock complexes by: expanding the list of machinery and equipment, which is subject to partial cost compensation, at the expense of the local budget; purchase of equipment with partial compensation of the cost, at the expense of the state budget (on the terms of operational leasing and attraction of soft loans); restoration or construction of farm service centers (implementation and maintenance of equipment) for animal husbandry and fodder production.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

References

Alon, G., Kroese, D., Raviv, T., & Rubinstein, R. (2005). Application of the cross-entropy method to the buffer allocation problem in a simulation based environment. *Annals of Operations Research, 134*, 137-151. https://doi.org/10.1007/s10479-005-5728-8

Aranchiy, V., Zorya, O., Galinska, T., & Golban, T. (2019). Institutional principles of the formation of investment and innovation clusters in the agricultural sector. *Ukrainian Journal of Applied Economics, 4*(2), 17-23. https://doi.org/10.36887/2415-8453-2019-2-2

Bloomberg Innovation Index. (2022). World Population Review. *https://worldpopulationreview.com/country-rankings/most-innovative-countries* Accessed on December 25, 2023.

Boubezoula, A., Paris, S., & Ouladsinea, M. (2008). Application of the cross entropy method to the GLVQ algorithm. *Pattern Recognition, 41*(10), 3173–3178. https://doi.org/10.1016/j.patcog.2008.03.016

Caserta, M., & Cabo-Nodar, M. (2009). A cross entropy based algorithm for reliability problems. *Journal of Heuristics, 15*(5),479-501. https://doi.org/10.1007/s10732-008-9074-2

European Commission. (2020). *A Strategy for Smart, Sustainable and Inclusive Growth*. COM.

European Commission. (2021). Horizon Europe programmer for 2021-2027. European Commission. *https://cinea.ec.europa.eu/programmes/horizon-europe_en* Accessed on December 25, 2023.

FAO. (2022a). *Food and Commodity Balances 2010-2020 – Global, Regional and Country Trends.* FAO.

FAO. (2022b). *The State of Food Security and Nutrition in the World*. FAO.

FAO. (2022c). *Agricultural Production Statistics 2000-2020.* FAO.

Fischer, M. (2001). Innovation, knowledge creation and systems of innovation. *Annals of Regional Science, 35*, 199-216. https://doi.org/10.1007/s001680000034

Frontier Technology Readiness Index. (2023). UNCTAD. *https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=227701* Accessed on December 25, 2023.

Global Innovation Index. (2022). Global Innovation Index. *https://www.globalinnovationindex.org/Home* Accessed on December 25, 2023.

Global Talent Competitiveness Index. (2022). UNCTAD. *https://www.insead.edu/sites/default/files/assets/dept/fr/gtci/GTCI-2022-report.pdf* Accessed on December 25, 2023.

Korovii, Ya., & Orekhova, T. (2019). *Theoretical and Methodological Foundations of the Research of Innovative Development Strategies of Agro-Industrial Enterprises.* Vasyl Stus Donetsk National University.

Kovryga, S. (2010). Determinants of political space. *Socio-Humanitarian Problems are People, 4*, 164–171. http://dspace.nbuv.gov.ua/bitstream/handle/123456789/27420/16-Kovryha.pdf?sequence=1

Kuchynskyi, V. (2014). Assessment and development of innovative potential enterprises. *Bulletin of NTU "KhPI", 65*, 137-145. https://repository.kpi.kharkov.ua/server/api/core/bitstreams/953c9d24-db4c-4cf7-8449-26b60bfab1b1/content

Lopatynskyi, Y., & Todoryuk, S. (2015). *Determinants of Sustainable Development of Agricultural Enterprises*. Chernivtsi National University.

Maslii, I. (2011). Determinants of the emergence and functioning of the shadow economy. *Actual Problems of the State and Law, 58*, 167–172. http://nbuv.gov.ua/UJRN/apdp_2011_58_28

Mishinina, E. (2013). *Determinants of Socio-Economic Development of Enterprises*. Disa Plus.

Nambisan, S. (2017). Digital entrepreneurship: Toward a digital technology perspective of entrepreneurship. *Entrepreneurship Theory and Practice, 41*(6), 1029-1055. https://doi.org/10.1111/etap.12254

Spaargaren, G. (2011). Theories of practice: Agency, technology and culture: Exploring the relevance of practice theories for the governance of sustainable consumption practices in the new world-order. *Global Environmental Change, 21*(3), 813-822. https://doi.org/10.1016/j.gloenvcha.2011.03.010

Stupen, N. (2017). Theoretical aspects and essence of balanced development of recreational areas. Efficient Economy. *http://www.economy.nayka.com.ua/?op=1&z=5833* Accessed on December 25, 2023.

Trusova, N., Hryvkivska, O., Kukina, N., Kotvytska, N., Makarenko, P., & Pilyavsky, V. (2023). Optimal criteria of investment potential in innovation cycles of the economic system of agro-industrial enterprises. *Economic Affairs, 68*(Special Issue), 869-880. https://doi.org/10.46852/0424-2513.2s.2023.33

Trusova, N., Kotvytska, N., Pikhniak, T., Pavlova, M., Plotnichenko, S., & Sakun, A. (2022). Attracting foreign investment in cyclic imbalances of the economy. *Scientific Horizons, 25*(5), 101-116. https://doi.org/10.48077/scihor.25(5).2022.101-116

Vinichenko, I., Trusova, N., Kurbatska, L., Polenenka, M., & Oleksiuk, V. (2020). Imperatives of quality insuring of the production cycle and effective functioning process of the enterprises of agro-product subcomplex of Ukraine. *Journal of Advanced Research in Law and Economics, 4*(50),1462-1481. https://doi.org/10.14505/jarle.v11.4(50).43

Zabarna, E., Kozakova, O., & Cherednychenko, V. (2019). *The Paradigm of Innovative Development in the Conditions of Market Transformation*. Oldy+.

Figures