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Increasing the Innovative Potential of the Enterprises of the Agro-Industrial Complex of Ukraine: Fundamental Developments

Iryna Petrova[1], Nataliia Sysolina[2], Lesia Kononenko[3], Iryna Sysolina[4], Hryhorii Savelenko[5*]

[1]Professor, D.Sc. in Economics, Department of Marketing and Behavioral Economics, University of Economics and Law "Krok", Kyiv, Ukraine.
E-mail: petrovakrok@gmail.com. ORCID ID: https://orcid.org/0000-0003-4206-5403

[2]Associate Professor, Ph.D. in Economics, Department of Economics, Entrepreneurship and Hotel and Restaurant Business, Central Ukrainian National Technical University, Kropyvnitsky, Ukraine.
E-mail: natlsysol@gmail.com. ORCID ID: https://orcid.org/0000-0003-0101-8854

[3]Associate Professor, Ph.D. in Economics, Department of Entrepreneurship, Accounting and Finance, Kherson State Agrarian and Economic University, Kropyvnitsky, Ukraine.
E-mail: slv2828@ukr.net. ORCID ID: https://orcid.org/0000-0001-5698-5003

[4]Associate Professor, Ph.D. in Technical Sciences, Department of Agricultural Engineering, Central Ukrainian National Technical University, Kropyvnitsky, Ukraine.
E-mail: irinasysln@gmail.com. ORCID ID: https://orcid.org/0000-0002-2168-6553

[5*]Associate Professor, Ph.D. in Technical Sciences, Department of Economics, Entrepreneurship and Hotel and Restaurant Business, Central Ukrainian National Technical University, Kropyvnitsky, Ukraine.
E-mail: grigoriy.savelenko@gmail.com. ORCID ID: https://orcid.org/0000-0001-9310-6223

Abstract
The article aims to analyze the main trends in the development of the innovative potential of enterprises within Ukraine's agro-industrial complex and substantiate approaches to enhancing this potential. A model for utilizing the innovative potential of the agro-industrial regional pool, with the capability for forming various states, has been created. The core advances in innovative processes that improve resource management and productivity are covered in this research. The calculations are performed, and the outcomes are shown. The examination of these advances' industrial uses includes studies of agro-industrial firms that have effectively used advanced technologies to streamline their operations, cut expenses, and enhance the sustainability of agricultural methods. In order to boost growth and efficiency in Ukraine's agro-industrial sector, the study emphasizes the importance of building a robust, innovative environment by linking theoretical ideas with practical applications. To determine the dynamics of the economic object in the future, it is proposed to use the functionality of the MS Excel application package FORECAST for ETS (Exponential, Linear, and Logarithmic dependencies). The introduction of a mechanism to enhance the innovative potential of the agro-industrial complex at each of its levels will ensure an increase in enterprises' investments, competitive advantages, and economic efficiency.

Keywords: Innovation Development, Modelling, Scientific and Technical Platform, Agro-Industrial Complex, Regional Pool, Interregional Alliance, Management, Marketing.

Introduction

The agricultural sector has traditionally been the key sector in Ukraine's national economy. Until 2022, Ukraine had leading positions in the global market for the export of sunflower oil (the 1st place) and wheat grain (the 3rd place) (State Statistics Service of Ukraine, n.d.). The development of the agro-industrial complex is quite uneven across Ukraine's regions. It is significantly hampered by internal causes (poor governance, outdated technologies, inadequate infrastructure) and external threats related to the destruction of land and many enterprises due to the war.

The moderate demand of agricultural enterprises for innovative products was met by imports, leading to deindustrialization, which the war has now exacerbated. However, the strategic prospects for the country's development are promising, as they depend primarily on increasing the innovative potential of agro-industrial enterprises, modernizing production processes, and updating their products.

The study's purpose is to analyze the main trends in the development of the innovative potential of enterprises in Ukraine's agro-industrial complex and to substantiate approaches to improving it.

Theoretical Framework

Foreign and Ukrainian scientists are actively studying the problems of creating and efficiently using the innovative potential of enterprises. Studies by Lavrenenko et al. (2021), and Stræte et al. (2022) are devoted to the development of the innovative potential of the enterprise based on the resource theory, and the works of Savytskyi (2019), Hryhoruk et al. (2020), Piletska & Tkachenko (2020), Saunila (2020), and Shvets & Dubiei (2021) are aimed at studying methods for assessing the innovation potential of enterprises. Integration of innovations is considered as the main factor in increasing the competitiveness of enterprises. This approach is reflected in both classical and modern works (Schumpeter, 1912; Thompson, 1965; Ansoff, 1989; Harkema, 2003; Heiets, 2009; Ferreira et al., 2020; Puzyrova, 2020; Akhtar, 2023). The work of Faivishenko et al. (2020) is devoted to the study of the impact of innovations on increasing enterprise profits. Moreover, the research that evaluated the impact of innovation on the competitiveness of enterprises in various sectors of the economy, in particular, industrial enterprises studied was developed by Cherep et al. (2021) and food industry enterprises – by Hlubish (2021).

Ukrainian scholars Andriichuk (2013), Balanovska et al. (2021), Sabluk (2008), Skotsyk (2017), Smulka (2020), and Ragazou et al. (2022) have studied the issues of economic development, innovation, and the innovative potential of agricultural enterprises. In the work of Trusova et al. (2020), agribusiness subjects' innovation development and competitiveness in the system of ensuring the economic security of the regions of Ukraine are investigated. The study of Ulyanchenko et al. (2021) reveals the role of strategic management of resource potential, in particular innovation, as a basis for increasing the competitiveness of agricultural enterprises.

The academic search for directions for optimizing innovative processes by improving the enterprise management system is essential. Blikhar et al. (2022) studied the managerial and legal aspects of the economic security of enterprises in the innovation process; Kychko et al. (2021) substantiated the need to develop managers' managerial competencies to enhance the company's innovation activities. Showing the organizational aspects of innovation, Lis et al. (2021) established links between geographical and virtual proximity in cluster structures. Groups of researchers led by Hrosul et al. (2021) investigated ways to create clusters in the agro-industrial complex, and the ones led by Kovalyov et al. (2022) studied the development of viticulture and winemaking clustering.

The rural economy of Ukraine plays a significant role in the state's socio-economic development and its positioning in world markets. It has faced considerable challenges and new threats associated with a full-scale war in the country. The preservation of the existing potential of agro-industrial enterprises, the restoration of destroyed resources, and the further development of this priority industry for the national economy are possible based on the creation and use of innovations.

Innovations in agriculture involve the systematic introduction of new technologies and other research results into production, which cause positive quantitative and qualitative changes in the interaction between the biosphere and the technosphere and improve the environment (Karnaushenko et al., 2023). Innovations in the agro-industrial complex cover biological, technical, technological, chemical, economic, social, managerial, and marketing areas. All types of innovations result from the effective realization of the innovative potential of agro-industrial enterprises.

The specialized scientific literature has taken various approaches to defining "innovation potential." In most cases, it is understood as the unused, hidden capabilities of accumulated resources that can be used to achieve the goals of economic entities (Shulhina et al., 2011) and the degree of an economic entity's ability and willingness to carry out innovative activities (Mykytiuk, 2015).

Harbar (2021) rightly believes that the innovative potential of an enterprise is a complex dynamic system of generating, accumulating, and transforming scientific and managerial ideas and scientific, technical, marketing, and other results of the enterprise's activities into innovative products based on a continuous management process. The innovative potential of agricultural enterprises is characterized by significant sectoral, functional, technical,

and organizational specifics, as well as regional peculiarities. The formation of the innovative potential of enterprises of the agro-industrial complex is a continuous and dynamic process that creates new commercial opportunities and the basis for stable development and reproduction in future periods (Goodman, D., & Wilkinson, 2023).

Current political and economic factors have significantly reduced enterprises' innovation potential in Ukraine's agro-industrial complex. In addition, several significant problems negatively affect the innovative development of agro-industrial enterprises, namely: lack of funds, disruption of logistics and price parity in the agricultural segment, focus on the secondary market, low competitiveness of products, loss of sales markets, imperfect state and regional governance in the field of agro-industrial enterprises and lack of actual conditions for the production and implementation of innovative technologies and products in the agro-industrial complex, destruction of infrastructure and enterprises as a result of missile strikes (Ministry of Agrarian Policy and Food of Ukraine, 2022b).

The issue of increasing the innovation potential of agricultural enterprises, taking into account the specifics of individual regions, still needs to be researched more. In addition, the limited resources, on the one hand, and the emergence of new technologies and digitalization of the economy, on the other, require the development of new forms of organizational interaction of enterprises at the regional and interregional levels, which would contribute to more efficient use of the innovative potential of the agro-industrial complex (Kyrylov et al., 2024).

Methodology

The methodological foundation of this work employs general scientific methods and scientific research techniques, namely quantitative and qualitative analysis, to characterize the processes and patterns of developing the innovative potential of agribusiness enterprises. Sociological methods are applied to diagnose the current state of agrarian business in the Kirovohrad, Cherkasy, and Ternopil regions of Ukraine and to assess the capabilities and readiness of their enterprises to implement innovations. A systemic approach is utilized to construct a mechanism for increasing the innovative potential of agro-industrial complex enterprises within these regions.

Modeling is employed to develop a model for utilizing the innovative potential of agro-industrial enterprises, and graphic and analytical methods are used for visual illustration of the studied economic phenomena and processes. The abstraction method facilitates the limitation of factors by which the innovative potential of agro-industrial enterprises is evaluated during the study, enabling the prediction and simulation of potential consequences and performance indicators.

New approaches to increasing the innovative potential of agro-industrial complex enterprises are proposed and substantiated, such as creating a scientific and technical platform, interregional alliances, and regional pools within the agro-industrial complex system. A mechanism for enhancing the innovative potential of agro-industrial complex enterprises and an algorithm for calculating its effectiveness have been developed.

Results and Discussion

Ukraine's agro-industrial complex includes agricultural machinery (engineering) enterprises (M), agricultural enterprises (A), processing enterprises (including food industry (F)), intermediary enterprises (traders), etc. We have chosen manufacturing enterprises (agricultural, machine-building, and processing) for the study since the strategic prospects of the country's development depend on the use of their innovation potential. Table 1 shows the analysis of the dynamics of the number of manufacturing enterprises in Ukraine, including the agro-industrial complex, from 2016 to 2022.

Table 1. Analysis of the dynamics of the number of enterprises of the agro-industrial complex of Ukraine in 2016-2022

Enterprises \ Year		2016	2017	2018	2019	2020	2021	2022
Industry, including (M, F)		127069	123876	125859	130324	126337	126386	102500
The agro-industrial	M	529	545	561	591	616	626	-
	F	15272	15119	15544	16275	16222	16206	-
	Share (M, F) in the industry /	12,4/17,6	12,6/17,1	12,8/17,5	12,9/18,4	13,3/19,4	13,3/19,2	-

	Share (M, F) in the agro-industrial complex, %							
	A	73973	75992	75730	74858	70059	70803	53281
	Total the agro-industrial complex (manufacturing sector)	89774	91656	91835	91724	86897	87635	-
Manufacturing enterprises of the total		201042	199868	201589	222048	196396	197189	155781
The share of A%		36,8	38	37,6	33,7	35,7	35,9	34,2

Source: Compiled by the authors based on statistical data (State Statistics Service of Ukraine, n.d.)*

*Note: The represented statistics exclude the activities of budgetary institutions and the territories temporarily occupied by the Russian Federation and provide a comprehensive view of the agro-industrial complex in Ukraine.

The share of M in industry and the agro-industrial complex grew moderately (by an average of 3.4%) from 2016 to 2021, while F and A exhibited fluctuating dynamics over the period under study (F – ranging from - 1% to +4.7%, A – ranging from -24.7% to +2.7%). This data is crucial for understanding the development of the agro-industrial complex in Ukraine.

During the analyzed period, there were significant fluctuations in the number of enterprises of the agro-industrial complex, both regionally and in Ukraine as a whole. In Ukraine, the number of agricultural machinery enterprises increased by 16.45%, processing enterprises by 6.22%, while the number of agricultural enterprises decreased by 5.29%. This uneven development of agricultural enterprises is a common feature in most regions of Ukraine, highlighting the complexity and diversity of the situation. Before the war, from 2016 to 2021, four of Ukraine's 25 regions saw an increase in the number of all types of agricultural enterprises of the agro-industrial complex (Poltava (+4.3%), Sumy (+3.7%), Khmelnytskyi (+62.8%), and Chernihiv (+1.8%)), while two regions (Volyn (-20.1%) and Chernivtsi (-18.3%)) saw a decrease. In most regions (19), the dynamics of the number of agro-industrial enterprises by their type was uneven. This was typical for the Kirovohrad, Ternopil, and Cherkasy regions, which the authors selected for in-depth analysis. Thus, it can be assumed that the trends inherent in these regions are typical for most areas of Ukraine.

During the analyzed period in the Kirovograd region, there was an increase in the number of agricultural engineering enterprises by 30.30%, processing by 0.73% and a decrease in the number of agricultural enterprises by 0.58%. In the Ternopil region, the number of agricultural machinery enterprises increased by 100.00%, the number of food (processing) enterprises decreased by 7.32%, and the number of agricultural enterprises decreased by 10.50%. In the Cherkasy region, the number of agricultural machinery enterprises increased by 3.85%, processing enterprises decreased by 2.33%, and agricultural enterprises decreased by 1.61%. Unstable dynamics of the development of agro-industrial enterprises characterized the period from 2016 to 2021.

As a result of expectations of changes for the better in 2019 (elections were held), new agricultural enterprises began to be created; for illustration, their number increased by 78 agricultural enterprises in the Cherkasy region. However, in 2020, their number decreased by 123 units (State Statistics Service of Ukraine, n.d.).

Figure 1 shows the agro-industrial complex's disproportionate structure in almost all Ukraine regions. In addition, the number of agricultural engineering enterprises, which should be at the forefront of innovation, is insignificant and ranges from 0.18 to 0.87% of the total number of enterprises of the agro-industrial complex in the regions under consideration.

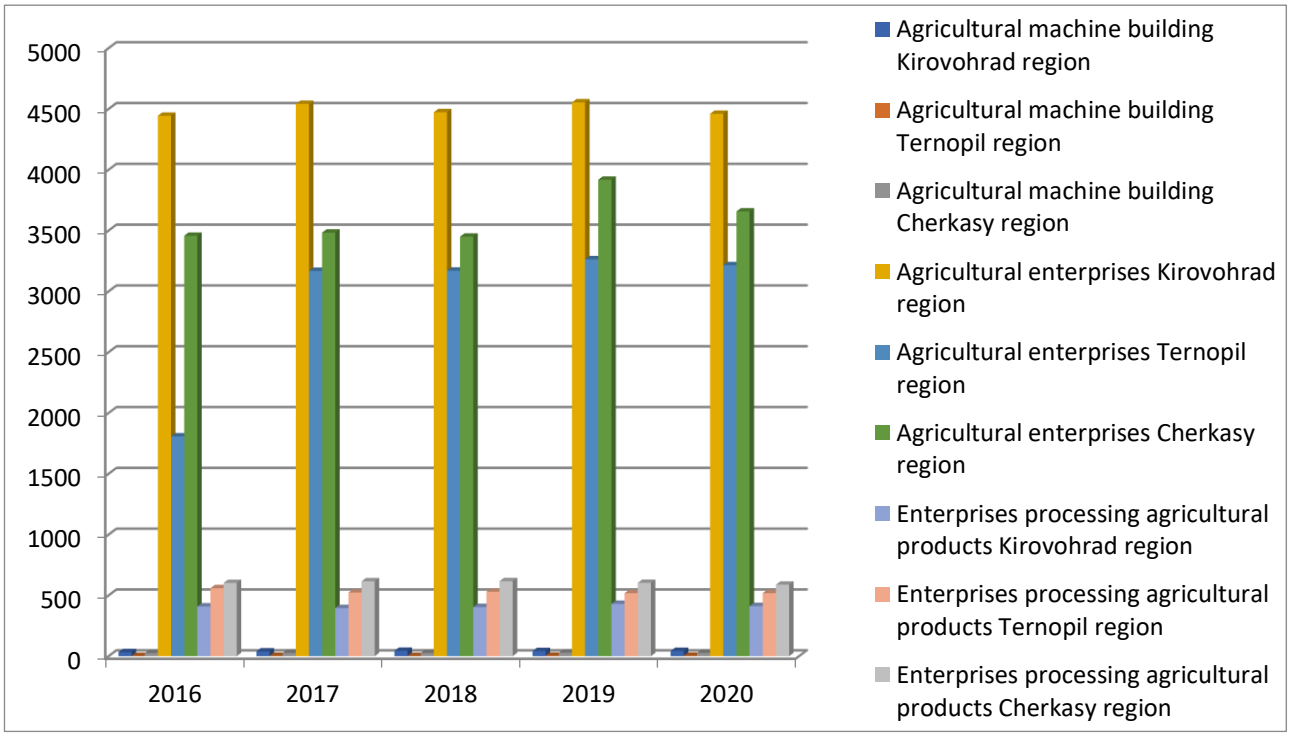

Figure 1. The dynamics of the number of active enterprises of the agro-industrial complex of Kirovohrad, Ternopil, and Cherkasy regions in 2016-2020
Source: Compiled by the authors based on statistical data (State Statistics Service of Ukraine, n.d.)

Kirovohrad, Ternopil, and Cherkasy regions together account for 13.5% of the total area of grains and legumes, 15.4% of production, and 16% of the agricultural sector of Ukraine in 2020 (State Statistics Service of Ukraine). These regions are focused mainly on crop production, namely the cultivation of grain and industrial crops.

However, the quantitative analysis of enterprises of the agro-industrial complex needs to allow for a comprehensive characterization of the innovation potential of regional enterprises. Qualitative indicators of the development of enterprises of the agro-industrial complex are related to their innovation activity. At the same time, the innovation activity of agricultural machinery enterprises is 15.7% on average in Ukraine, which is less than in industry (approximately 20%) (State Statistics Service of Ukraine). Thus, today, they cannot meet the demand of agricultural producers for innovative products.

In the processing sector of the agro-industrial complex, sunflower oil production is developing most rapidly, as the state protects sunflower seeds from export. Exports of sunflower oil are profitable for Ukraine (revenues from its sale in 2021 amounted to 6400000 thsd. USD) (Agronews, 2021) and account for the largest share in the export of processed products. The share of new technological processes introduced into production at processing enterprises in 2019 was 6.8%. The level of innovation activity of agricultural processing companies was 14.7% (State Statistics Service of Ukraine, n.d.). In general, in 2016-2019, the cost of research and development in Ukraine was characterized by positive dynamics (2016 – 11530.7 million UAH, 2017 – 13379.3 million UAH, 2018 – 16773.7 million UAH, 2019 – 17254.6 million UAH), but already in 2020 there was a decrease (2020 – 17022.4 million UAH) (Tomashuk, 2023).

The author's analysis of the innovative potential of agro-industrial enterprises has revealed the following problems of their development:

a) Most of the machine-building and processing enterprises of the agro-industrial complex of Ukraine do not meet the current level of innovative development, balancing on the verge of bankruptcy;

b) Tillage, sowing and fertilizer machines, for the most part, cannot compete for markets with products from developed countries. Since Ukraine's independence, its production has decreased by almost 30-50 times (Ministry of Agrarian Policy and Food of Ukraine, 2022a);

c) The vast majority of agricultural machinery produced belongs to the 1-2 generation, has a low level of technological efficiency, and is single-operated (Ministry of Agrarian Policy and Food of Ukraine, 2022a);

d) Some enterprises have been liquidated altogether (for example, Ternopil Harvester Plant JSC, which produced beet harvesters, went bankrupt); some have been cut up for scrap metal (agricultural processing plants (sugar, canning, etc.));
e) Ukrainian enterprises mainly manufacture products in single copies or small batches. For example, Elworthy JSC (Kropyvnytskyi (Kirovohrad), Kirovohrad region) produces seeders, cultivators, and disk harrows in small series.

Thus, in the pre-war period, both agricultural machinery and agricultural processing enterprises declined due to the loss of their production potential. The situation in the agro-industrial complex is deteriorating due to the hostilities. Positive changes in the agricultural sector are possible by promoting the development of production and innovation potential, ensuring the production of high-quality modern products, including agricultural machinery. This requires, first of all, its radical renewal. A significant factor in the intensification of innovation in the agro-industrial complex is the readiness of agricultural producers to apply innovations.

In 2019-2023, the authors interviewed agricultural enterprises in Kirovohrad, Ternopil, and Cherkasy regions with a representative sample of 7%. The interviewed respondents had the relevant properties that are characteristic of the entire general base. The survey considered agricultural enterprises of different sizes (Table 2).

Table 2. Distribution of agricultural enterprises of Kirovograd, Ternopil and Cherkasy regions by size, %

Size	Regions		
	Kirovograd	Ternopil	Cherkasy
Large	0,96	0,87	1,23
Medium	6,41	4,35	5,35
Small	92,72	94,78	93,42

Source: Compiled by the authors based on the interview data

According to the study, small agricultural businesses dominate in Kirovohrad, Ternopil, and Cherkasy regions, aligning with the nationwide distribution (Figure 2).

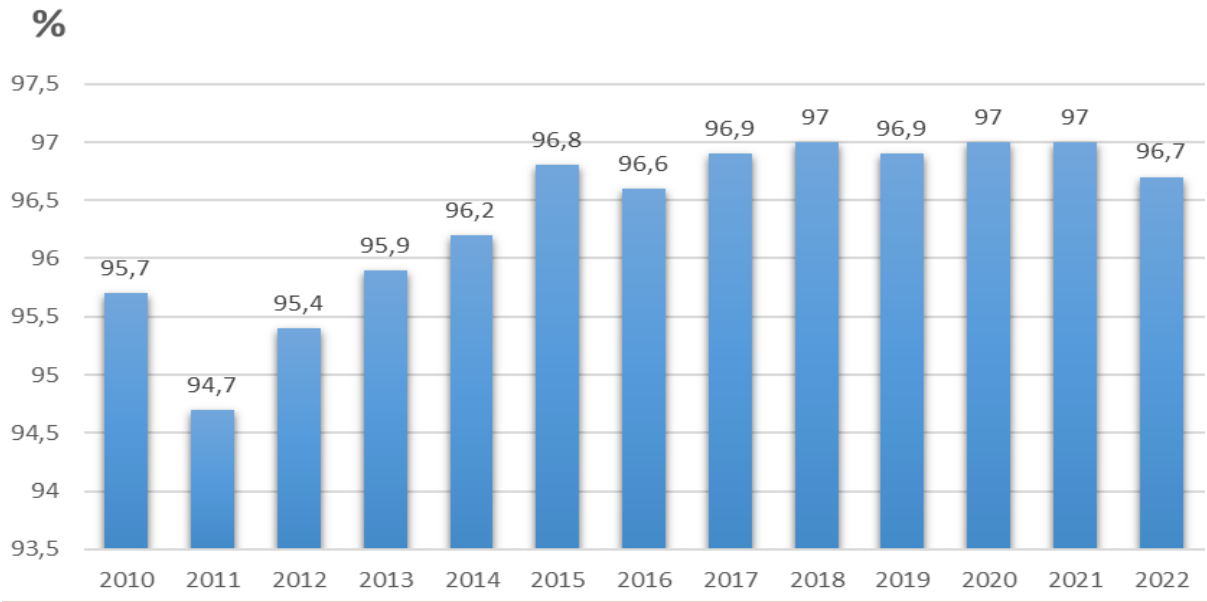

Figure 2. Dynamics of the number of active subjects of small and micro enterprises of agriculture, forestry and fisheries in 2010-2022
Source: Compiled by the authors based on statistical data (State Statistics Service of Ukraine, n.d.)

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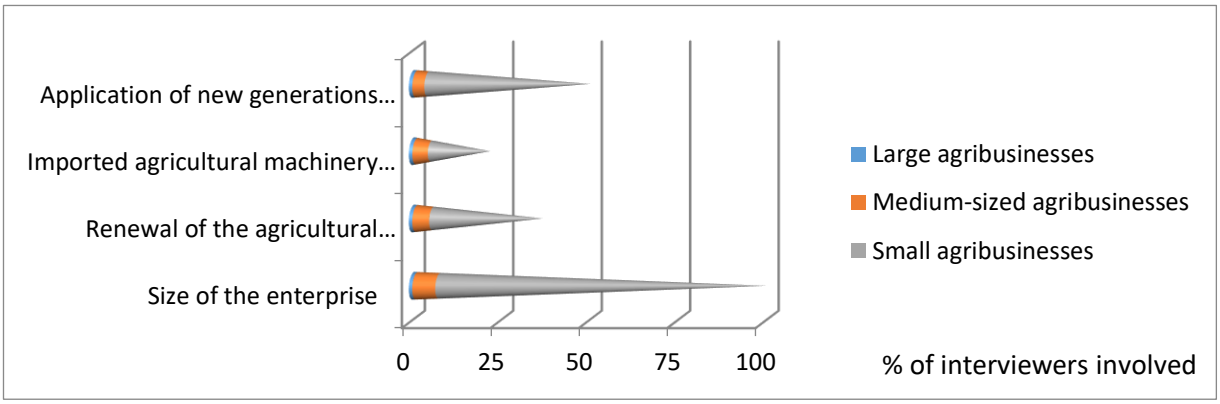
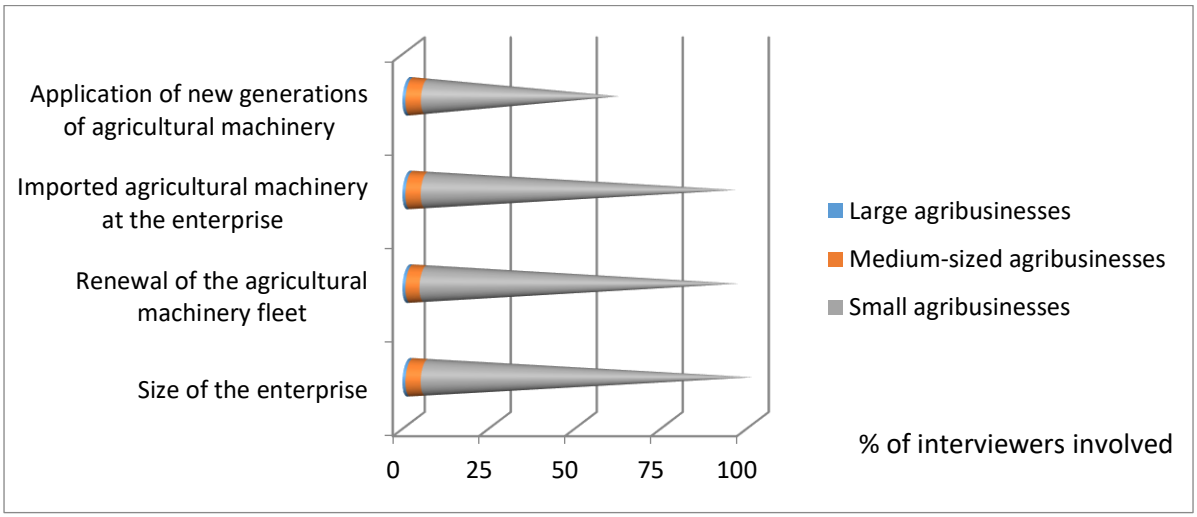
Over the past thirteen years, small agricultural enterprises have made up the “lion's share” of agricultural enterprises in Ukraine (on average, 96.4% for 2010-2022). During the study, we developed a questionnaire (see Appendix 1) and conducted interviews, the results of which are summarized and represented in Figures 3 (parts a, b, c) and Table 3.



a)



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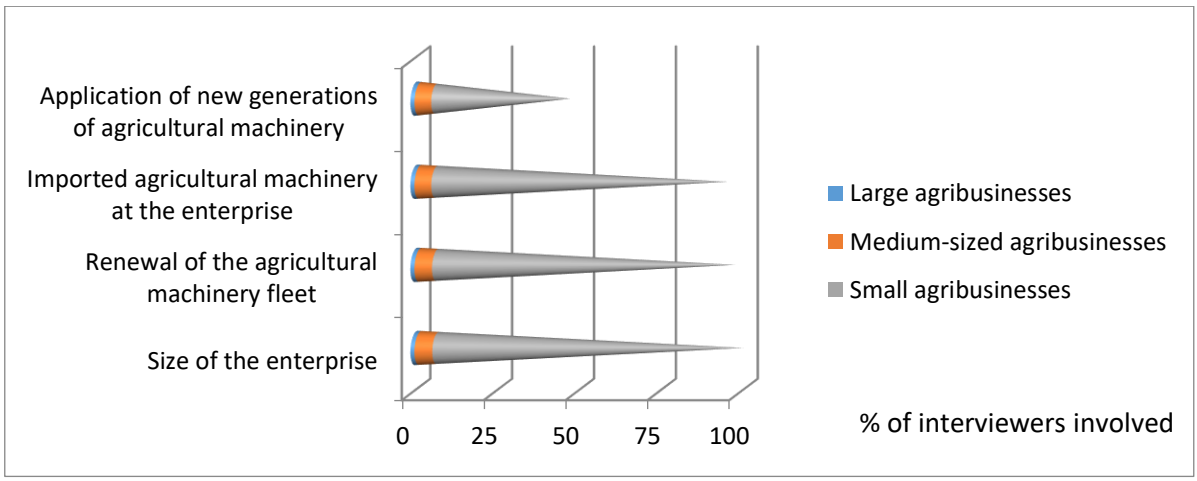


c)

Figure 3. Distribution of agricultural enterprises by types of machinery used, units: a) Kirovohrad region; b) Ternopil region; c) Cherkasy region
Source: Compiled by the authors based on the interview data

According to the results of the study, it was determined that in 2019-2023, the activities of agricultural producers had a particular number of features (Table 3).

Table 3. Comparative characteristics of the use of machinery in the studied regions

Indicators of machinery utilization	Regions		
	Cherkasy	Ternopil	Kirovohrad
1	2	3	4
Agricultural machinery fleet	Updated in the range of 10-30%, mainly due to imported used agricultural machinery	Relatively updated for large and most medium-sized agricultural enterprises, and can practically be considered updated for small ones, but in this case, it is due to imported used agricultural machinery	Not updated at a significant pace (mostly by 5-10%), and there are enterprises where no updates have taken place at all in recent years (Figure 4)
New generations of agricultural machinery	Used by 80% of respondents. At the same time, if small agricultural enterprises are unable to buy certain agricultural machinery, they cooperate	Used by 95% of respondents	Used by 50% of respondents
Agricultural machinery in farms	Imports prevail in percentage terms	All farms use imported multi-profile machinery, as the region is implementing production diversification strategies	The percentage of domestic products is higher

Source: Compiled by the authors based on interview data

The process of updating machinery depends on the size of the enterprise. The best situation is in agricultural holdings, which renew at least 50% of machinery and equipment and have 75% to 100% of modern foreign agricultural machinery. At the same time, this process is slower in the segment of small and medium-sized agricultural enterprises (Figure 4).

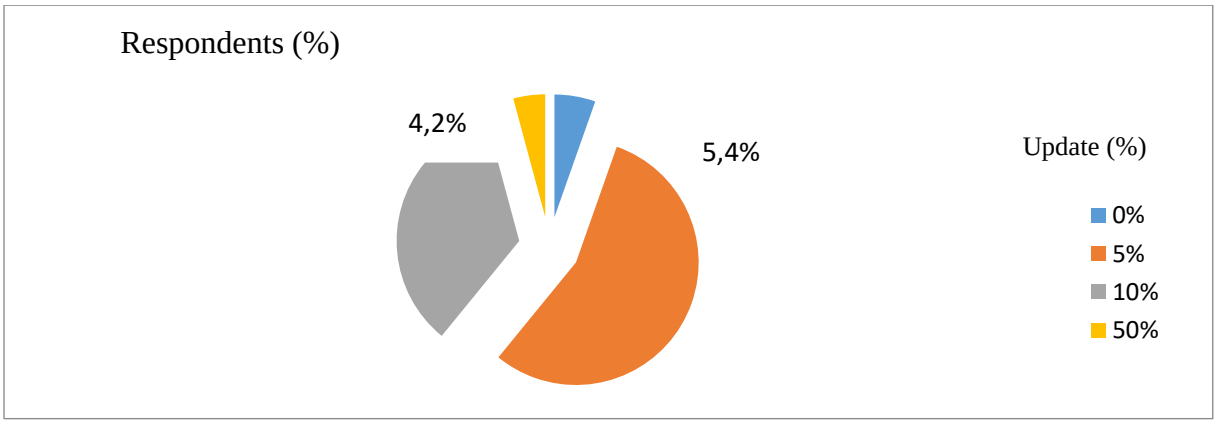


Figure 4. Structure of agricultural machinery fleet renewal by agricultural enterprises in Kirovohrad region
Source: Compiled by the authors based on the interview data

The study revealed that the Kirovohrad region is grappling with the lowest rates of renewal of the agricultural machinery fleet. A staggering 55.5% of the fleet is either updated at a sluggish pace or is practically not updated

at all. The primary reason, as indicated by the interview results, is the financial constraints faced by the respondents, which severely limit their purchasing power.
The survey results lead to the following conclusions:

- The complexity and variety of agricultural machines in farms increase most often (80% of respondents), but financial opportunities prevent them from updating machinery.
- Significant costs do not allow switching to the cultivation of "clean" agricultural products (containing a small amount of unhealthy chemical compounds, without GMOs).
- Enterprises mainly use traditional technology (very rarely no-till, AgroDrones, tractors on autopilots, etc;).
- Almost 100% of enterprises have their own, albeit outdated, machine and tractor fleet and do not use leased agricultural machinery.

The cost of renewal of fixed assets in Ukrainian agriculture in general and in the regions under study is increasing due to the purchase of agricultural machinery at high prices (Table 4).

Table 4. Dynamics of fixed assets in agricultural enterprises of Ukraine in 2019-2021

Year	Agriculture, forestry and fisheries		
	Level of disposal of fixed assets for the year, %	Level of renewal of fixed assets for the year, %	The ratio of the renewal rate to the disposal rate (4=3/2)
1	2	3	4
2019	5,78	22,92	3,96
2020	4,53	15,59	3,44
2021	4,51	21,91	4,86

Source: Compiled by the authors based on statistical data (State Statistics Service of Ukraine, n.d.)

During 2019-2021, the level of fixed assets disposal ranged from 4.5-5.8%, and the level of their renewal ranged from 15.6-22.9%. Importantly, the excess was 3.95 times on average, demonstrating the sector's commitment to modernization and growth. In 2022, the purchase of combines decreased by 2.4 times compared to the previous year, and tractors—by two times (Agravery, 2022, 2023). This is happening at a time when Ukraine (including the agro-industrial complex) is suffering significant losses due to military operations. For example, 84.2 thousand units of machinery and equipment (11% of the available as of February 24, 2022) were destroyed or damaged (Ministry of Agrarian Policy and Food of Ukraine, 2022b). The study considered additional conditions that characterized the attraction of investments and labor resources to increase the potential of agricultural enterprises (Table 5).

Table 5. Dynamics of attracting investments, labor costs and volume of products sold to agricultural enterprises of Ukraine for 2017-2021

Year / Indicators	2017	2018	2019	2020	2021
1	2	3	4	5	6
Capital investments in agriculture, hunting and related services, million UAH.	63400,7	65059,4	58555,4	50189,4	67992,6
Labor costs at agricultural enterprises, million UAH.	20326,75	25234,43	29729,6	29932,5	33616,3
Sales of agricultural, forestry and fishery products, million UAH.	467636,1	540509,3	572748,27	624070,13	943489,35

Source: Compiled by the authors based on statistical data (State Statistics Service of Ukraine, n.d.)
Various indicators influence the volume of products sold, but by analyzing Table 5, we can see the impact of investment growth and labor costs on the final result. Thus, in 2020, capital investment decreased by 14.29% and

labor costs increased by 0.68% (mainly due to an increase in the minimum wage), while the volume of products sold increased by only 8.96%.
In 2021, capital investments increased by 35.47%, and labor costs increased by 12.31%, resulting in a 51.18% increase in product volume. In 2022, the utilization of capital investments in agriculture, forestry, and fisheries in all sectors of the Ukrainian economy amounted to 12.6% (I. Solohub, 2023). To attract investment, it is important to understand the dynamics of an economic entity's future behavior, characterized by indicators of growth rates and growth for the period under consideration. The contribution of the growth rate of production factors to the growth rate of results, taking into account the indicator γ, which characterizes the contribution of innovative development, is determined according to the formula:

$$y(t) = |\alpha(t)k(t)| + |\beta(t)l(t)| + \gamma \quad (1),$$

where y(t), k(t), l(t) are continuous indicators of the results of production, capital and labor; α(t), β(t) are elasticities of production results in terms of capital and labor (Zhebka et al., 2006). Next, it will be considered the dynamics of the economic entity's activity in the future on the example of an average small agricultural enterprise C (Table 6).

Table 6. Performance indicators of the small agricultural enterprise in 2016-2023

Year / Indicators	2016	2017	2018	2019	2020	2021	2022	2023
Enterprise capital, thousand UAH	4930,8	5454,9	6276,5	6751,9	7616,7	9736	15129,1	13549,8
Labor costs, thousand UAH.	429,42	691,5	917,67	908,43	930,2	1090,12	1020,1	1140,3
Net sales revenue, thousand UAH	2688,2	3111,5	4428,5	4166,3	4621,6	7532,7	8968	6861,4
Expenditures on innovative development, thousand UAH.	-	0,9	1,3	1	2	2,9	3,1	3,9

Source: Compiled by the authors based on the data from enterprise C

For data forecasting, based on the following arguments, Microsoft Excel industrial application package as it provides several built-in forecasting functions, including the trend line and FORECAST. These tools allow analysis and forecasting based on available data. Table 6 demonstrates the results of the forecast indicators of the studied small agricultural enterprise for 2024-2027, considering its data for 2016-2023: capital investments (Table 7), labor costs (Table 8), and net income (Table 9).

Table 7. Forecast investments of a small agricultural enterprise for 2024-2027

Year	Capital of the agricultural enterprise, thousand UAH		
	Forecasting using the functionality of the application package MS Excel		
	Exponential dependence	inear dependence	Logarithmic dependence
	Trend line		
	$y = 4432e^{0,1083x}$	y = 628,49x + 4282,3	y = 1322,4ln(x) + 4802,8
	The value of the approximation probability		
	$R^2 = 0,9851$	$R^2 = 0,9893$	$R^2 = 0,9498$
2024	11746,45	9938,71	7708,41
2025	13090,03	10567,20	7847,74

2026	14587,30		11195,69	7973,78
	Forecasting using the functionality of the application package MS Excel: function FORECAST.ETS			
	Accepted	Realistic	Pessimistic	Optimistic
2024	12053,59	15328,85	12053,59	18604,10
2025	13375,95	16752,80	13375,95	20129,65
2026	14700,50	18176,75	14700,50	21653,01
2027	16027,05	19600,71	16027,05	23174,36

Source: Compiled by the authors based on the data from enterprise C

Table 8. Forecast labor costs of a small agricultural enterprise for 2024-2027

Year	Labor costs, thousand UAH		
	Forecasting using the functionality of the application package MS Excel		
	Exponential dependence	Linear dependence	Logarithmic dependence
	Trend line		
	$y = 374,66e^{0,2531x}$	$y = 166,32x + 320,96$	$y = 373,89\ln(x) + 439,69$
	The value of the approximation probability		
	$R^2 = 0,7904$	$R^2 = 0,8715$	$R^2 = 0,955$
2024	3655,25	1817,84	1261,21
2025	4708,00	1984,16	1300,60
2026	6063,96	2150,48	1336,24
	Forecasting using the functionality of the application package MS Excel: function FORECAST.ETS		
	Accepted	Realistic	Pessimistic	Optimistic
2024	1010,27	1223,64	1010,27	1437,01
2025	1021,77	1308,98	1021,77	1596,19
2026	1048,59	1394,32	1048,59	1740,05
2027	1083,87	1479,66	1083,87	1875,46

Source: Compiled by the authors based on the data from enterprise C

Table 9. Forecast net income of a small agricultural enterprise for 2024-2027

Year	Net income, thousand UAH		
	Forecasting using the functionality of the application package MS Excel		
	Exponential dependence	Linear dependence	Logarithmic dependence
	Trend line		
	$y = 2323,1e^{0,1667x}$	$y = 575,13x + 2160,8$	$y = 1255,3\ln(x) + 2601,3$
	The value of the approximation probability		
	$R^2 = 0,759$	$R^2 = 0,7962$	$R^2 = 0,8225$

2024	10414,54	7336,97	5359,48	
2025	12303,73	7912,10	5491,74	
2026	14535,62	8487,23	5611,38	
	Forecasting using the functionality of the application package MS Excel: function FORECAST.ETS			
	Accepted	Realistic	Pessimistic	Optimistic
2024	7253,76	9177,34	7253,76	11100,92
2025	8064,56	9988,14	8064,56	11911,73
2026	8875,34	10798,95	8875,34	12722,55
2027	9686,12	11609,75	9686,12	13533,38

Source: Compiled by the authors based on the data from enterprise C

Tables 7, 8, and 9 show possible developments—pessimistic, realistic, and optimistic scenarios that contribute little to innovation development.
The values of the costs of innovative development γ for 2024-2027 are projected using the familiar and trusted FORECAST function as shown in Table 10.

Table 10. Indicators of production results y(t) of a small agricultural enterprise for 2017-2027

Production results/Years	2017	2018	2019	2020	2021	2022
y(t)	8260,63	18827,00	10620,62	10742,53	26037,46	8233,24
Production results/Years	2023	2024	2025	2026	2027	
y(t)	32767,96	6753,70	23660,32	18946,79	19172,91	

Source: Compiled by the authors based on the data from enterprise C

Figure 5 graphically plots the production function y(t) of a small agricultural enterprise C with actual and forecasted indicators.

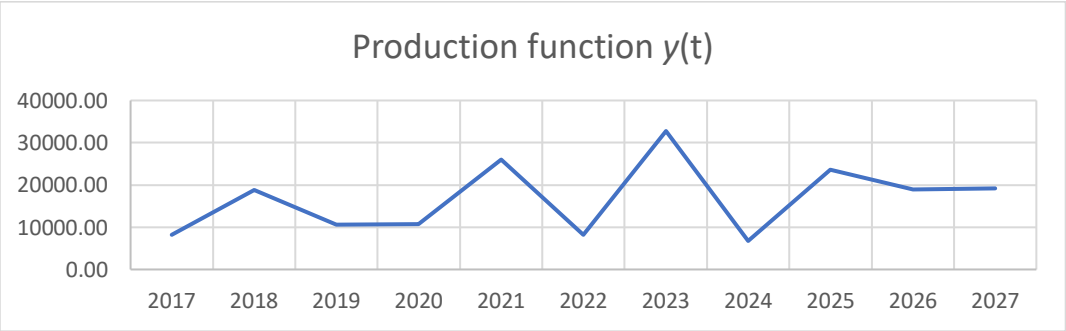


Figure 5. Results for the production function y(t) of a small agricultural enterprise
Source: Compiled by the authors based on the data from enterprise C

Figure 5 shows that the results are unstable, and introducing innovations will allow the enterprise under study to develop more stably. Thus, large and most medium-sized agricultural enterprises have potential and opportunities for development. Even though small enterprises are still struggling to survive, they have not realized hidden potential, including innovation. The introduction of innovative approaches, such as modern technologies, alternative farming methods, or product diversification, can be a way to develop small agricultural producers. This innovation will allow them to increase efficiency, reduce costs, and enter new markets. Therefore, as Kononenko et al. (2022) state supporting the innovation activities of small farms should be a priority to ensure the sustainable development of agriculture in general.
The results of the study (including surveys) conducted in the Kirovoprad, Cherkasy, and Ternopil regions showed that most enterprises of the agro-industrial complex need to attract investment, create new organizational forms,

and optimize management to realize their innovative potential. These trends are also typical for other regions of Ukraine. The regions and Ukrainian enterprises of the agro-industrial complex are facing the following issues: (1) to determine the perspective direction of innovative development; (2) increase spending on innovation and risk mitigation; (3) engage development managers for effective management; (4) create a modern system for managing transformational innovation processes in the agricultural sector; (5) cooperate with agricultural advisory services. In our opinion, to solve these problems, a comprehensive approach to improving the innovation potential, which should consider the regional characteristics of agro-industrial enterprises in Ukraine, is necessary. The modernization of the process of managing the innovation potential of enterprises of the agro-industrial complex should take place at the level of the state, region, associations, and enterprises.

The role of the state in innovation processes should be to provide the necessary institutional and organizational conditions for attracting and protecting investments, develop an appropriate regulatory framework, and implement protectionist tax policies to ensure optimal conditions for the functioning of domestic producers and regional development. In Ukraine, there are state support programs for agricultural producers. Still, they are mainly used by the large agricultural enterprises, in particular rural holdings, which account for only 5-10% of the total number of agricultural enterprises but which, before the war, "monopolized" 70-80% of the national funds for agricultural support measures (NISS, 2023).

On a positive note, the Government of Ukraine has approved a procedure for partial compensation to agricultural enterprises to purchase Ukrainian agricultural machinery. Thus, in 2024, it is planned to allocate 1 billion UAH for a partial compensation program of 25% of the cost of purchased Ukrainian agricultural machinery (Government portal, 2024). However, for most small agricultural enterprises, the compensation procedure is too complicated, making it advisable for them to cooperate with agricultural advisory services.

It is necessary to develop a modern strategy for the innovative development of agricultural enterprises, with appropriate programs and projects to support their innovative potential. Support for small and medium-sized businesses should be an integral part of these programs. The state should promote the development of agricultural universities in regions that impact the training of personnel for agricultural enterprises. Allocating a certain share of the Restoration Fund of Ukraine would be advisable for the revival of the agro-industrial complex, particularly its innovative potential.

A positive direction of action is the development of public-private partnerships, which will contribute to implementing a transparent policy for agricultural producers. At this stage, Ukraine is creating new systems of market participants and new types of partnerships, indicating the decentralization of power. This trend is leading to the transfer of more and more powers to local government structures, where the state, represented by the territorial community, is one of the main subjects. Partnerships between local communities and business structures significantly expand the competence of local authorities. At the regional level, the state should act as a partner to ensure coordination of actions, create orders, and set priorities. For this purpose, new organizational forms should be designed to promote the innovative development of the agro-industrial complex at the state and interregional levels. Given the possibilities of digitalization, a network of independent enterprises can be temporarily, voluntarily, united into a multi-level system to share resources for innovative activities.

The general principles of building an organizational and economic mechanism should ensure the interaction between goals and objectives, their division into small and partial ones, facilitate the correct appointment and selection of responsible executives for the development of the economic potential of regional enterprises, as well as the creation of targeted teams. In the regional aspect, ensuring the principles of division of labor, unity of goals and leadership, and the balance between centralization and decentralization of power is necessary. The following discusses the components of this mechanism. First, a scientific and technical platform for the agro-industrial complex will be created at the state level, combining state management institutions with business and science. The scientific and technical platform can operate through targeted management to prioritize support for specific regions in science and technology development areas.

Territorial communities with the needs and opportunities to intensify innovation will play an important role in the functioning of the science and technical platform. Science and technical platforms will facilitate the self-synchronization of agricultural enterprises, including their cooperation and competition. Agricultural enterprises already have some experience in scientific and technical cooperation. For sample, in 2021, JSC "Elworthy" (Kropyvnytskyi), together with the National Research Center "Institute of Mechanization and Electrification of Agriculture" (Hlevakha, Kyiv region), tested an experimental universal seeder Selena (Adamchuk et al., 2021). The policy for the professional development of agricultural workers also promotes the advancement of the scientific and technical platform. Many farmers in the Kirovohrad, Cherkasy, and Ternopil regions that we studied have received higher agricultural education, which enhances their preparedness for innovative development.

Secondly, creating interregional associations similar to alliances in their organizational and legal form. These are temporary scientific and technical associations of certain agro-industrial regions to attract investment, increase innovation potential, exchange scientific developments, and optimize logistics. In our opinion, such alliances can unite 2 to 5 regions for their interaction to create conditions for innovative development. For example, the unification of Kirovohrad, Ternopil, and Cherkasy regions may be facilitated by their similarity in the following factors: the presence of universities of agro-industrial orientation and scientific schools; preserved production potential of enterprises; approximately the same landscape and soil quality; average or higher than average yields of grain and legumes in Ukraine (authors based on information from the State Statistics Service of Ukraine).
On the other hand, the Western (Ternopil) and Central (Kirovohrad, Cherkasy) regions of Ukraine have unique specifics that will contribute to their complementarity in terms of scientific and technical development, application of innovations, investment attraction, product sales, etc. The potential of the agro-industrial interregional alliance is a dynamic system with direct and reverse links, which takes into account various resource flows, ensures their transformation, and achieves results.
Thirdly, a scientific and technical association at the regional level should be created in the form of a pool. By a pool, we mean a temporary scientific and technical association of certain agro-industrial enterprises in the region, whose profits go to common funds and are distributed according to the results in a predetermined proportion, which combines local community structures with universities and production. A regional pool of agro-industrial enterprises can be created based on a development strategy that includes improving production and business processes. This allows for measures to identify and eliminate additional costs, implement optimal logistics links, and focus on the initial innovation parameters that are critical to the consumer.
In the face of uncertainty, the innovation potential of a pool of enterprises is a probabilistic dynamic system with a set of constituent elements and links between them. The ability to adjust the system's input and output ensures effective management and the achievement of the desired result. The input to the system is a variety of resources that can be used in various combinations (options). The output of the system is a variety of results.
To describe the functioning of the system of transforming resources into results, we proposed a model based on the law of necessary diversity (Ashby's law), according to which system management is effective only when the diversity of results exceeds the diversity of resources used. In order to control what is fed to the system's input, it is necessary to answer the question for each resource: Does this resource exist or not? Depending on the answer at the input, the variety of different states will be equal to 2^n. The optimal combination of various resources (information, intellectual and creative, research, financial and investment, production and technological, material and technical, marketing, organizational and managerial, etc.) enables the system to obtain various outcomes of $2^{(n+1)}$. Such a transformation is possible only through the use of innovations in achieving the regional pool's results.
The model of using the innovative potential of the agro-industrial regional pool of enterprises is complex, so a change in one of its factors leads to a change in another and sometimes to a change in several factors. The system will function if various measures to influence their interaction (including distribution, coordination, information, intellectual and creative, financial and investment, innovation, marketing, logistics, organizational and managerial support of production and technological processes) are used to manage various resources. In addition, this system is open, so to minimize crisis phenomena, it must be dynamic and respond on time to potential changes in the external environment. In the context of decentralization of management, the system increases its diversity in management, corresponding to the law of necessary diversity.

It is possible obtain an innovative result by applying various appropriate measures to ensure innovation processes at agricultural enterprises. The model described for using the innovation potential of the regional pool can be presented as follows (Figure 6).

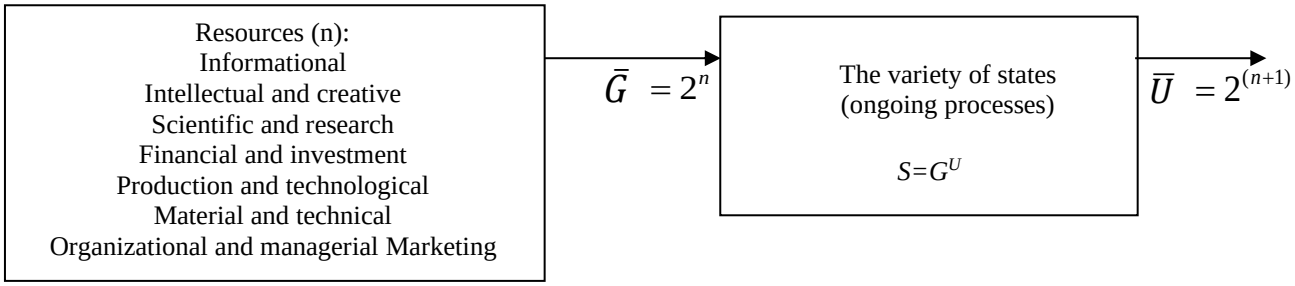


Figure 6. Model of using the innovative potential of the agro-industrial regional pool of enterprises with the possibility of forming various states
Source: Developed by the authors based on the work of Beer (1972)

From the model, $\overline{G}$ – is the input vector to the organizational (production) system; $\overline{U}$ – is the result (final product) vector transformed by the system; S is the number of possible processes that occur to obtain the result; n – is the number of variations of the resources used; (n+1) – is the number of variations of the results obtained. If, according to the given model (n=8), we mathematically calculate the increase in the number of different states, the probability of their outcomes will increase by more than $4703{,}9\times10^{18}$. The model of the innovation potential of an agro-industrial regional pool of enterprises allows us to describe the system's (pool) multiplicity of states in a scenario. The resources involved in the pool, entering into multiple processes of creating new values, are transformed into probabilistically new quality forms, namely innovative results.

Thus, a regional association will help improve the potential for innovative development of its member enterprises by utilizing alternative and optimized resources. An important element is creating conditions for staff creativity. It should be emphasized that restoring the competitiveness of agricultural enterprises requires comprehensive and coordinated actions on the part of state and regional authorities and the enterprises themselves.

Based on the study, we have systematized and structurally identified the elements of a comprehensive mechanism for improving the innovation potential of the main groups of enterprises of the agro-industrial complex (Figure 7).

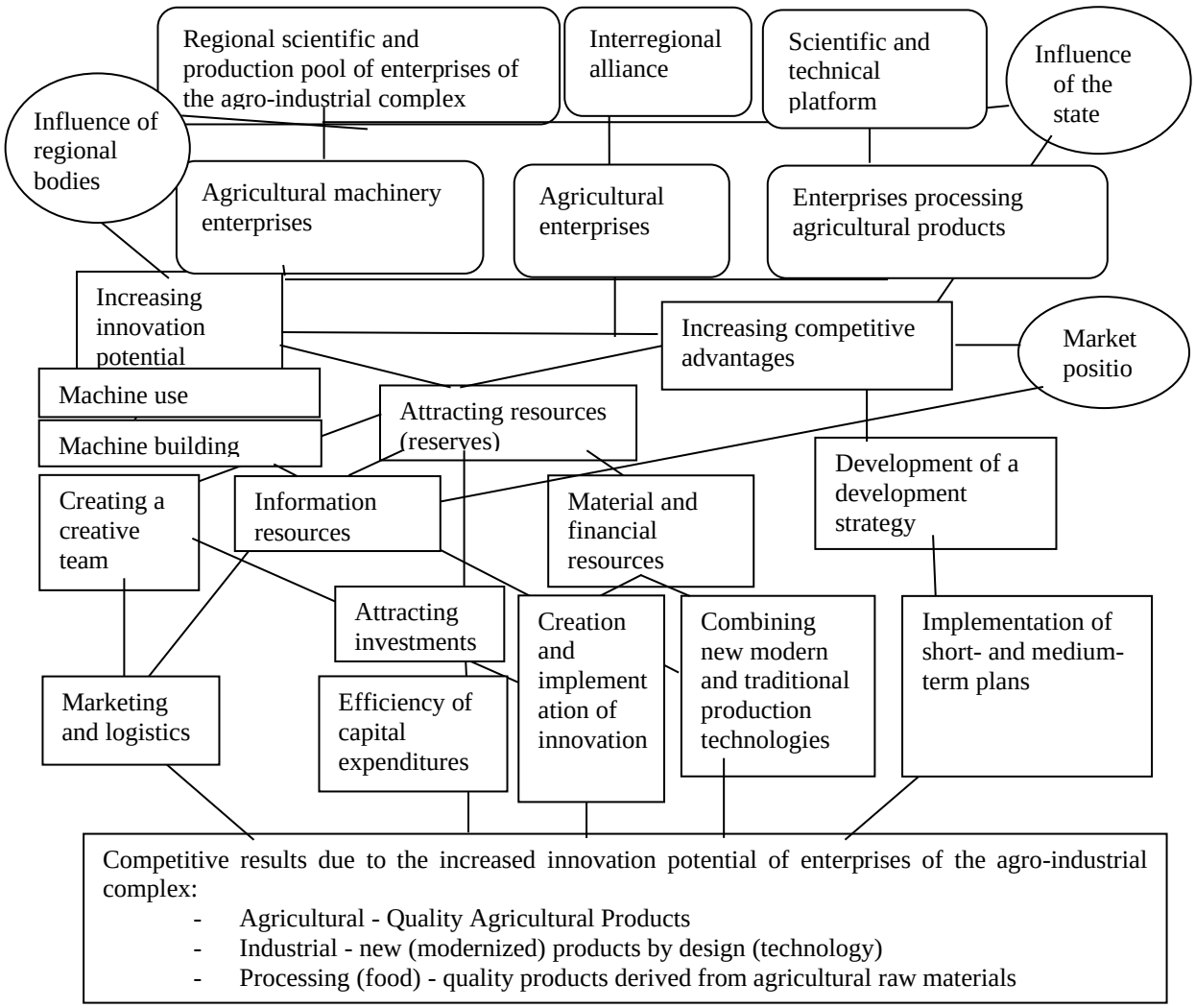


Figure 7. Mechanism for improving the innovation potential of the main groups of agricultural enterprises
Source: Compiled by the authors based considering the work of Sysolina et al. (2018)

In the agro-industrial complex, each enterprise's innovative potential should be effectively used to obtain maximum results and reach a new technological level. The modern development strategy of agro-industrial

enterprises involves focusing on the market and the consumer. Its implementation requires effective marketing, which can increase market share by positioning and promoting high-quality and innovative products.

It is necessary to monitor the results of short- and medium-term plans to reduce risks and attract all resources and reserves to obtain a competitive result. With the optimal use of resources and reinvestment reserves, the possibility of compensating for possible losses increases. In each case, when assessing the system's state, it is necessary to determine the criteria whose optimization will help improve potential opportunities.

Thus, one can consider the proven need to use various means of stimulating human resources to increase the innovation activity of enterprises (Petrova et al., 2010). In managing a pool of agro-industrial enterprises, the emphasis should be placed not on hierarchical subordination in functional units but on the creation of project teams, where the process owner is determined—responsible for the course and result of the entire process, including the work of various functional units involved in the process.

At the enterprises of the agro-industrial complex, it is advisable to create creative teams that include specialists with managerial competencies. In addition, it is indispensable to "grow" own "idea generators." It is important for agricultural, food, and processing enterprises to combine new and traditional technologies with modern machinery.

It should be noted that developing and implementing innovations in agricultural machinery enterprises is a labor-intensive and costly process. Therefore, the first step should be to attract investments to modernize the machinery produced and then to create innovations. To maximize results, it is necessary to model the optimal level of innovation costs for each stage of modernization.

The modernization of the research and production process at agricultural engineering enterprises involves the creation of innovation cycles, which contributes to increasing their innovation potential. The proposed mechanism for increasing the innovation potential of enterprises of the agro-industrial complex will make it possible to attract the necessary investments in the post-war period. Here is a methodology for calculating the economic effect of introducing a mechanism for improving the innovation potential of the main groups of enterprises of agro-industrial complex (Figure 8, part 1, part 2).

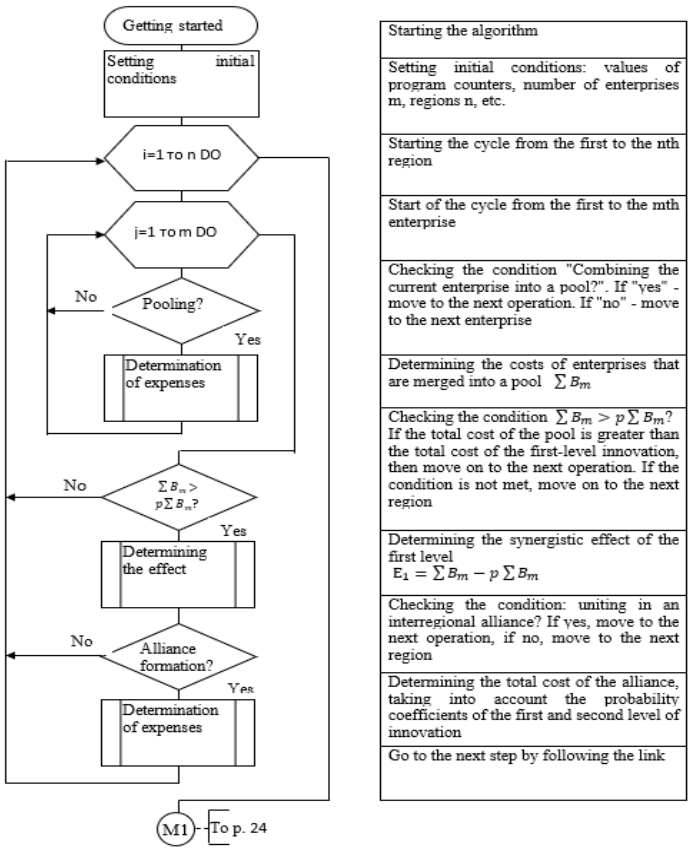
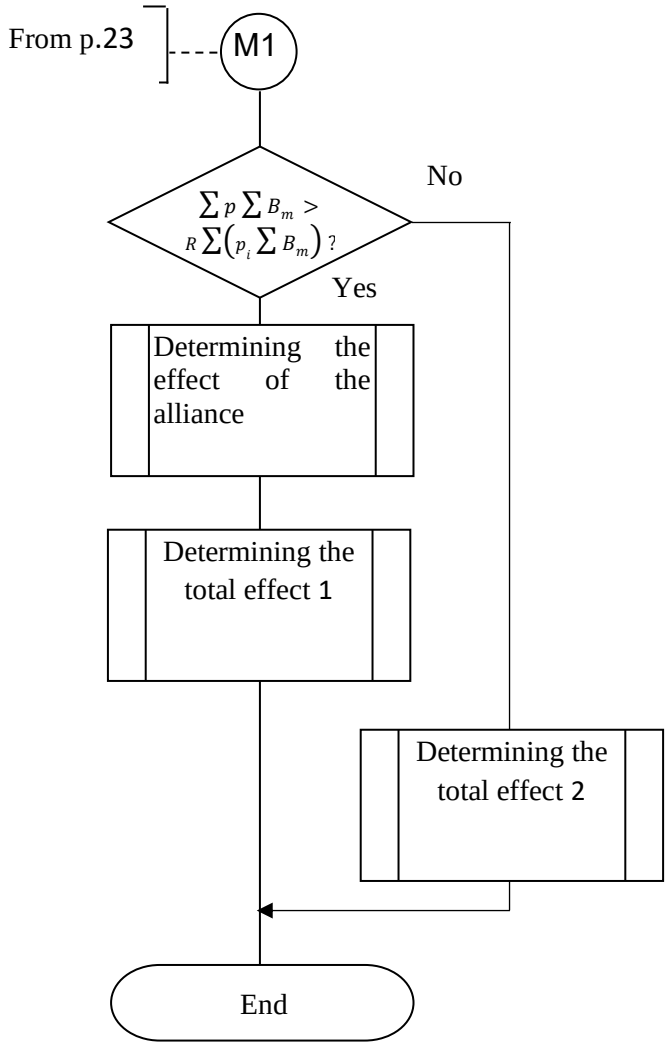


Figure 8. Algorithm for calculating the efficiency of the mechanism for increasing the innovative potential of the main groups of enterprises of the agro-industrial complex (part 1)
Source: Compiled by the authors



Continuation of the algorithm
Checking the condition $\sum p \sum B_m > R\sum(p_i \sum B_m)$? If the total cost of the alliance is greater than the total cost, taking into account the probability coefficients of the first and second level innovation costs, then proceed to the next operation. If the condition is not met, proceed to calculate the total effect
Determining the effect of an interregional alliance $\mathrm{E}_2 = \sum p \sum B_m - R\sum(p_i \sum B_m)$
Determination of the total effect 1 taking into account $\mathrm{E}_{\text{заг}} = \mathrm{E}_1 + \mathrm{E}_2$
Determination of the total effect 2 taking into account $\mathrm{E}_{\text{заг}} = \mathrm{E}_1$
Completion of the algorithm

Figure 8. Algorithm for calculating the efficiency of the mechanism for increasing the innovative potential of the main groups of enterprises of the agro-industrial complex (part 2)
Source: Compiled by the authors

The algorithm for determining the effect of the mechanism has its own preamble; namely, it is crucial to start calculations to increase the innovation potential of agricultural enterprises. That is, each such enterprise must decide whether it wants to merge with others or not. If not, there will be no additional effect ($\mathrm{E}_{01} = 0$). If yes, then together with other enterprises, it can obtain a synergy effect, and due to the merger, costs can be significantly reduced, contributing to innovative development. For example, when purchasing a license for a new technology, etc. To illustrate the calculation, consider three agricultural enterprises in the Kirovograd region, conditionally named 1, 2, and 3. The initial data are given for 2019: the costs of Enterprise 1 amounted to 59948 thousand UAH, enterprises 2 (or C) – to 3028.1 thousand UAH and Enterprises 3 – to 23661 thousand UAH (in total – 86637.1 thousand UAH). Other data and calculations are presented in Table 11.

Table 11. Calculation of the first level synergistic effect

Scenarios / Indicators	Pessimistic			Optimistic	
1	2	3	4	5	6

Coefficient of probabilistic costs of innovation, p	1,1	1,05	1	0,95	0,9
Total expenditures $p\sum B_m$, thousand UAH	95300,81	90968,95	86637,1	82305,24	77973,39
Synergistic effect $E_{11} = (B_1 + B_2 + \cdots + B_m) - p\sum B_m$, thousand UAH	-	-	0	4331,86	8663,71

Source: Compiled by the authors

Since resources are important for innovative developments, the union of regional associations will contribute to the following synergistic effect (the second level). Nevertheless, international experience shows that the more an association expands, the more the costs of coordinating its links with each other increase. That is, on the one hand, the costs are reduced by the merger, and on the other hand, they increase. At the same time, if the result is a significant innovation, the enterprises in the association will improve their innovation potential. The calculation of the second-level synergistic effect is similar to the previous one (Table 11). Still, the coefficient of probability of spending on second-level innovation will decrease by at least two times (R=0.95).

The integration of associations of this level into a state-supported platform is a key step towards securing grants for innovative development. This support from the state can also open up new opportunities, such as the application of circular economy principles in a larger market segment.

At the same time, the state will receive a socio-economic effect by increasing jobs, reducing unemployment benefits, and reducing the cost of implementing environmental protection measures.

Conclusion

The post-war development of Ukraine is a pressing issue that urgently requires significant foreign investments in the region. This is particularly crucial for the production and introduction of innovative technologies and products. The agro-industrial complex, land reclamation, and the revival of production potential on innovative principles are areas that demand immediate attention.

The authors' analysis of the state of agricultural enterprises in Ukraine as a whole and for selected enterprises in Ternopil, Cherkasy, and Kirovohrad regions revealed a low degree of their innovation activity and readiness for innovation. The main problems of their development are the lack of investment and the absence of an effective organizational and managerial mechanism for increasing and using their innovation potential. This study presents an alternative point of view on the formation of associations of enterprises in the agro-industrial complex, in contrast to the position that proposes ways to create clusters in the agro-industrial complex; any association in the agro-industrial complex should aim to optimize all production areas of its activities by increasing the innovative potential of integrated enterprises. Improving the innovation potential of the Ukrainian agro-industrial complex requires a set of measures. There is a need to create a scientific and technical platform at the state level to self-synchronize enterprises of the agro-industrial complex. Next, given the conditions of decentralization at the interregional level, it is recommended to create associations (alliances) that would cover three to five regions. Finally, at the regional level, this study prioritized the creation of a scientific and technical pool that connects territorial communities with universities and industry. All these levels and forms of association should contribute to developing innovative potential and increasing agricultural enterprises' competitiveness.

The research has led to the development of a promising model for utilizing the innovative potential of the agro-industrial regional pool. This model, with its flexibility to adapt to various states, offers the potential to optimize resource use and product placement, thereby enhancing the agro-industrial sector's competitiveness. The authors propose a mechanism for improving the innovation potential of the main groups of enterprises of the agro-industrial complex, which will contribute to improving their management, investment support for their development, and streamlining internal regional logistics. The mechanism for increasing the innovation potential at each management level will bring economic benefits when implemented. Enforcing the proposed approaches to improving the innovation potential of agro-industrial enterprises will require further research focused on building effective models and methods for managing their innovation activities in the context of digital technologies.

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