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A Decision Support Model Proposal for the Employment Decisions of Mechanical Design Engineers

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Abstract

The quality of human resources is directly linked to a business's success or failure in the market. Consequently, the selection and effective utilization of human resources remain significant areas of research. Selecting the right personnel—particularly for roles within Research and Development (R&D) departments—presents a complex decision-making problem involving multiple criteria. This study focuses on the selection of a mechanical design engineer for an R&D department and proposes a decision-support model based on the Fuzzy Analytic Hierarchy Process (Fuzzy AHP). First, five main dimensions and eighteen criteria are identified through a systematic literature review. These dimensions and criteria are evaluated via pairwise comparisons by three R&D managers who are subject-matter experts and key decision-makers regarding R&D personnel recruitment. The resulting matrices are then weighted using the Fuzzy AHP method, thereby enabling the modeling of the uncertainty and subjectivity inherent in the selection process. The study reveals that technical competence (0.371) is the most critical dimension in selecting a mechanical design engineer, followed by creativity and innovation (0.190). By employing the Fuzzy AHP approach, the study establishes a systematic evaluation framework for R&D personnel selection, offering an objective and consistent tool for managers.

Keywords: Fuzzy AHP, R&D, Mechanical Design Engineer Selection, Multi-Criteria Decision Making

1.İntroduction

Numerous internal and external factors influence the success or failure of business enterprises. In this regard, human resources constitute one of the most critical factors affecting a firm's market position and future (Barney, 1991, p. 99; Wolfson & Mathieu, 2021, p. 435; Wright, Dunford, & Snell, 2001, p. 701). Particularly within research and development departments, human resources play a pivotal role in a firm's long-term success or failure by influencing strategic variables such as product development and the speed of market introduction (Cohen & Levinthal, 1990, pp. 138-146; Kleiner-Schäfer & Liefner, 2021, pp. 976-980). Consequently, the proper selection of mechanical design engineers for research and development departments is of decisive importance for the firm to achieve its strategic objectives (Chinowsky & Byrd,

2001, p. 34; Erkarslan et al., 2011, p. 140; Yang et al., 2005, p. 155).

Selecting personnel involves a decision-making problem that requires taking multiple criteria into account. While some of these criteria can be measured objectively, others entail subjectivity and uncertainty. Moreover, traditional methods often overlook criteria characterized by subjectivity and uncertainty, proving inadequate in the candidate selection and evaluation processes (Aksakal et al., 2013, p. 68; Lievens et al., 2002, p. 580).

It is critical to support decision-making and evaluation processes regarding human resource selection through a framework that comprehensively addresses both objective criteria (such as education level and years of experience in the relevant field) and subjective ones (such as creativity and problem-solving skills) (Ijadi Maghsoodi et al., 2020; Jereb et al., 2005). It is possible to overcome these and similar limitations by developing a decision-support model based on the Fuzzy Analytic Hierarchy Process (Fuzzy AHP), a multi-criteria decision-making method. By synthesizing fuzzy set theory with the Analytic Hierarchy Process, the Fuzzy AHP method enables the numerical modeling of preferences expressed qualitatively by decision-makers; this yields more realistic results in areas—such as candidate selection—that involve a combination of tangible and intangible evaluation factors (Schmidt & Hunter, 1998, p. 267; Güngör et al., 2009, p. 641; Varmazyar & Nouri, 2013, p. 27).

This study aims to develop a decision-support model using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) for the selection of design engineers for an R&D department and to determine the weights of the dimensions and criteria constituting this model. In the study, dimensions and criteria are identified systematically based on existing literature regarding Fuzzy AHP and candidate selection, and these dimensions and criteria are expressed in terms of their degrees of importance derived from pairwise comparisons made by experts.

2. Purpose of the study and research questions

The recruitment process encompasses the identification, evaluation, and hiring of candidates suited to an organization's operational needs and plays a pivotal role in enabling the organization to achieve its strategic objectives (Gurbuz & Mert, 2011, pp. 1803, 1815-1818; Kim & Ployhart, 2018, pp. 46-47; Selase, 2018, pp. 284-285). Selecting the right candidate and ensuring they begin their role in the appropriate position impacts employee performance as well as the long-term performance of both the specific department and the organization as a whole. In this context, performance is not solely a matter of individual competence; it also depends on a multitude of factors that must be considered holistically—such as organizational culture, team dynamics, and the professional development opportunities offered to the employee (Jacobs & Washington, 2003, pp. 343-347; López-Cabarcos et al., 2022, pp. 361-367; Shahzad, 2014, pp. 222-225).

To ensure the healthy continuation of business operations, every department and employee carries out specific tasks, and the knowledge, skills, and competencies of the workforce vary according to their respective areas of expertise. In this context, R&D department employees engage in activities that require a high level of technical knowledge and skill. R&D mechanical design engineers—who determine the products brought to market and directly influence time-to-market—play a pivotal role in a company's competitive standing; they possess qualities such as the ability to generate new ideas, select optimal solutions by evaluating engineering and customer criteria against alternatives, and adapt to and integrate innovations into work processes. Consequently, the selection of a mechanical design engineer is critical: choosing the right person can lead to project success and the realization of the company's product goals, whereas selecting the wrong engineer can result in increased workforce turnover and project failure (Gurbuz & Mert, 2011, pp. 1813-1816; Kim & Ployhart, 2018, pp. 58-60; Selase, 2018, pp. 285, 287).

In light of the information provided, the aim of this study is to present a consistent, systematic, and objective evaluation model to decision-makers involved in the selection of mechanical design engineer candidates for an R&D department. This evaluation model is based on the Fuzzy Analytic Hierarchy

Process. Accordingly, the study aims to identify the dimensions and criteria to be considered in the selection of mechanical design engineers through a systematic literature review; to calculate the relative importance of these dimensions and criteria using pairwise comparisons involving three R&D managers responsible for hiring decisions; and, finally, to discuss the contributions of the proposed model to the candidate selection process.

In line with these objectives, the primary research questions addressed within the scope of the study are outlined below:

- What are the dimensions and/or criteria that can be evaluated for the selection of mechanical design engineers for R&D departments?
- How can the selection criteria for mechanical design engineers to be employed in R&D departments be categorized?

2.Methodology

The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method forms the basis of the model proposed in this study for the selection of mechanical design engineers for R&D departments. As a multi-criteria decision-making method, Fuzzy AHP is preferred for the systematic and objective resolution of complex selection problems encountered when evaluating candidates for mechanical design engineering positions in R&D departments (Güngör et al., 2009, pp. 642–643; Liang & Wang, 1994, pp. 23–25; Kabak et al., 2012, pp. 3516–3517). This approach makes it possible to overcome limitations such as the uncertainty and ambiguity inherent in human evaluations. By synthesizing fuzzy set theory with AHP, Fuzzy AHP enables the numerical modeling of decision-makers' qualitative expressions. Consequently, it facilitates the achievement of more realistic results in areas heavily reliant on subjective and qualitative assessments—such as mechanical design engineer selection—while minimizing errors in observation and evaluation, as well as reducing uncertainties specific to the R&D department's evaluation processes (Huang et al., 2008, pp. 1041–1043; Dursun & Karsak, 2010, pp. 4325–4326; Hsu et al., 2003, pp. 540–542).

2.1. Process of determining dimensions and criteria

The set of dimensions and criteria for the study was derived in two stages. In the initial stage of determining these dimensions and criteria, the current literature regarding personnel selection—specifically concerning the performance evaluation of R&D department employees and the selection of design engineers—was reviewed. Additionally, studies focusing on the evaluation of candidates using the Fuzzy AHP method were taken into account. Through this process, a list of potential dimensions and criteria was established.

In the second stage of the process for determining dimensions and criteria, the compilation of dimensions and criteria obtained in the first stage underwent a preliminary evaluation by experts. Through this preliminary assessment, R&D managers—who are experts and decision-makers in personnel recruitment—evaluated the dimensions and criteria within the context of mechanical design engineering and adapted them to the research field. Criteria from the literature deemed unsuitable were eliminated, and the adaptation process was finalized by rephrasing the dimensions and criteria into terms clearly understood within the R&D department. As shown in Table 1, the final set of dimensions and criteria—consisting of five dimensions and eighteen criteria—aligns with previous studies in the literature.

Table 1. *Dimensions, criteria, and necessary definitions for mechanical design engineer selection*

Dimension	Criteria	Definition	References
Technical Competence (TY)	TY1: CAD/CAM/CAE Knowledge	Proficiency in computer-aided design, manufacturing, and engineering tools	Erkarslan vd., 2011, s. 138-139; Kovačić vd., 2018, s. 2-4; Zdorova vd., 2020, s. 2-5

	TY2: Knowledge of Materials	Knowledge of the properties and selection criteria of engineering materials	Deng & Edwards, 2007, s. 294-296; Ashby, 1989, s. 509-511; Krucken vd., 2017, s. 5-8
	TY3: Analysis and Simulation Skills	Ability to use simulation tools such as finite element analysis, fluid dynamics, etc.	Deng & Edwards, 2007, s. 300; Kovačić vd., 2018, s. 8-10
	TY4: Competence in Design Tools	Proficiency in current design software and platforms	Erkarslan vd., 2011, s. 139; Zdorova vd., 2020, s. 3-6; Kovačić vd., 2018, s. 4-6
Creativity and Innovation (YI)	YI1: Generating New Ideas (Concepts)	The ability to develop unique and innovative design concepts	Cropley, 2015, s. 163-164; Kobe & Goller, 2009, s. 133-135
	YI2: Improving Existing Designs	Ability to improve and optimize existing products/designs	Snider vd., 2016, s. 170-173; Cropley, 2015, s. 162
	YI3: Providing Innovative Solutions	The ability to come up with unconventional and creative solutions to complex problems	Snider vd., 2016, s. 180-182; Cropley, 2015, s. 164-165
	YI4: Adapting to New Technologies	The ability to adapt quickly to technological changes and a desire to learn new technologies	Petty, 1983, s. 9-12; Cropley, 2015, s. 168-169
Problem-Solving Skills (PC)	PC1: Analytical Skills	Ability to systematically analyze complex engineering problems	Ramadi vd., 2015, s. 40-42; Nilsson, 2010, s. 407-409; Yazdani vd., 2018, s. 3-5
	PC2: Research Skills	Access to technical information, the ability to conduct literature reviews and research	Igarashi vd., 2004, s. 1-3; Edvardsson Stiwne & Jungert, 2010, s. 535-537
	PC3: Planning (/Organizing) Skills	Planning the resolution process, organizing resources, and setting priorities	Güngör vd., 2009, s. 642-643; Çelikbilek & Tüysüz, 2018, s. 13-15
Teamwork and Communication (TC)	TC1:Interdisciplinary Practice	Ability to collaborate with different engineering disciplines	Ford & Riley, 2003, s. 184-186; Ramadi vd., 2015, s. 42-44; Gider & Urbančič, 2010, s. 268-270

	TC2: Verbal Communication	Presenting ideas effectively, active participation in technical meetings	Ramadi vd., 2015, s. 43-44; Ford & Riley, 2003, s. 187-189; Schulz vd., 1999, s. 385-387
	TC3: Written Communication	Technical reporting, documentation, and written communication skills	Ford & Riley, 2003, s. 188-190; Ramadi vd., 2015, s. 43-44; Palma vd., 2014, s. 3-5
	TC4: Interpersonal Skills	Team cohesion, empathy, and collaboration skills	Khusainova vd., 2020, s. 6-10; Schulz vd., 1999, s. 387-389
Project and Time Management (PY)	PY1: Project Management Skills	Project planning, monitoring, and control skills	Çelikbilek & Tüysüz, 2018, s. 14-16; Palma vd., 2014, s. 4-7; Gider & Urbančič, 2010, s. 269-271
	PY2: Time Management	Meeting deadlines, prioritization, and effective time management	Ramadi vd., 2015, s. 43-45; Kovačić vd., 2009, s. 705-707; Edvardsson Stiwne & Jungert, 2010, s. 540-541
	PY3: Use of Resources	The ability to efficiently manage budgets, equipment, and human resources	Güngör vd., 2009, s. 642-643; Gider & Urbančič, 2010, s. 269-270; Palma vd., 2014, s. 5-7

2.2.Fuzzy AHP method

The study utilizes the fuzzy AHP method to quantitatively evaluate the dimensions and criteria to be presented to experts. The classical AHP method is not preferred because it is difficult to compare dimensions and criteria—particularly in the context of human resource selection—using precise numerical expressions. Furthermore, the classical AHP method cannot fully reflect uncertainties in the conversion of evaluations to precise numbers in accordance with qualitative expressions. Consequently, it is not possible to obtain satisfactory results using this method within the scope of this study (Aly & Vrána, 2008, p. 530; Bozbura et al., 2007, p. 1111). The Fuzzy AHP method combines fuzzy set theory with the AHP methodology to compare dimensions and criteria in human resource selection (Bozbura et al., 2007, p. 1103; Güngör et al., 2009, p. 642; Kahraman et al., 2003, p. 386). This makes it possible to provide a more realistic basis for evaluating qualitative statements that are difficult to express through precise numerical assessments (Dursun & Karsak, 2010, pp. 4324–4325; Güngör et al., 2009, p. 642). In this study, using triangular fuzzy numbers, three parameters—pessimistic, probable, and optimistic values—are defined for the evaluation of dimensions and criteria (Aly & Vrána, 2008, p. 531; Bozbura et al., 2007, p. 1104; Dursun & Karsak, 2010, p. 4325; Kahraman et al., 2003, p. 385). Thus, these three values enable the decision-maker to express uncertainty (Aly & Vrána, 2008, p. 531; Güngör et al., 2009, p. 642).

This study aims to present a model using the fuzzy AHP method and is based on expert opinions. Fuzzy AHP analysis based on expert opinions does not require a large sample size due to concerns about statistical generalizability (Chan et al., 2019, p. 1; Kubler et al., 2016, pp. 399–401; Morgan, 2014, p. 7179; Saaty & Özdemir, 2014, pp. 359–361). However, the research population consists of design experts in senior leadership/managerial positions at engineering firms operating in R&D departments—where at least five people work in the R&D department—who have directly influenced or made personnel hiring decisions at least once. The researchers comprising the sample for this study were selected using purposive sampling. Purposive sampling is a sampling method in which experts intentionally select participants who can contribute most to the research objectives, rather than selecting them based on probability. This approach

makes it possible to include participants who are experienced and competent in their respective fields and to evaluate the contributions they provide within the study (Saaty & Özdemir, 2014, pp. 366–368). In this context, the following criteria are considered when identifying and selecting potential participants for the study:

- The participant must work in the R&D department of a company,
- The participant must carry out their activities in an R&D department with at least five employees,
- The participant must have, at least once in the past, directly influenced the hiring decision or made that decision independently during the hiring process for candidates for positions in the R&D department,
- The participant must have had the authority, at least once in the past, to directly influence or make the hiring decision independently regarding candidates for positions in the R&D department,
- The participant must have at least 6 years of experience in design engineering within the R&D department,
- If the participant agrees to voluntarily participate in the study, they will be eligible to be included in the study,
- The participant must be informed about the study prior to participating.

Prior to administering the paired comparison survey designed to collect data for the study, information regarding the study's purpose, methodology, and scale was provided to ensure the research was conducted in accordance with ethical standards. Furthermore, it was clearly explained that no personal data would be recorded or requested. The study proceeded with three experts who voluntarily consented to participate and met the criteria.

In this study, the 1–9 scale proposed by Saaty (1980) is used; however, during the evaluation phase, calculations are performed using the Fuzzy AHP rather than the classical AHP. In this respect, the data collection approach is the same as that of the classical AHP. The following steps were carried out to calculate the comparison data obtained using the Fuzzy AHP method:

- Most likely value, m: To calculate the most likely value, the values of the comparisons provided by the three experts are first calculated using the geometric mean. This allows the common trend among the three experts to be represented.
- The most optimistic value (u) and the least optimistic value (l): These values—which can also be expressed as the highest (u) and lowest (l)—ensure that a range is determined for each comparison. For example, if one of three experts assigns a value of 3 for a comparison and the other two assign a value of 4, the lowest value (l) is determined to be 3. For the same example, the highest value is determined to be 4. Here, the most likely value is the geometric mean, which is 3.634. Therefore, for the triangular fuzzy number, (l, m, u) is determined to be (3, 3.634, 4).
- Fuzzy AHP calculation method: The steps for fuzzy AHP calculations are based on Buckley's (1985, pp. 233–247) analysis method. The reason Buckley's calculation method is preferred over Chang's (1996, pp. 649–655) Fuzzy AHP calculation method is that information is transferred directly to the analysis via geometric means, without being summarized or interpreted. Thus, rather than comparing probabilities, the trend of participant evaluations and the tolerance range of this calculation are directly revealed (Buckley, 1985, pp. 233–247; Cebeci & Ruan, 2007, pp. 191–207; Buckley et al., 2001, pp. 48–64).

2.3.Fuzzy AHP analysis and findings

The pairwise comparison survey values obtained with the participation of experts are first calculated

using Buckley's (2001) analytical approach to derive the most likely values by taking geometric means (Buckley et al., 2001, pp. 48–64; Ramík & Korviny, 2010, pp. 1604–1613; Zhang, 2017, pp. 1083–1095). The experts' pairwise comparison values and the geometric means of these evaluations are detailed in Table 2. In the next step, the Fuzzy AHP Matrix of Dimensions, as shown in Table 3, is derived by including the most probable values along with the highest and lowest values.

Table 2. *Fuzzy AHP calculation table for dimensions*

Comparison No	Criterion on the Left (A)	Criterion on the Right (B)	Expert 1 U1	Expert 2 U2	Expert 3 U3	Geometric Mean Value
1	TY	YI	4,00	3,00	4,00	3,63
2	TY	PC	1,00	5,00	3,00	2,47
3	TY	TC	3,00	3,00	2,00	2,62
4	TY	PY	1,00	2,00	5,00	2,15
5	YI	PC	2,00	3,00	1,00	1,82
6	YI	TÇ	0, 50	3,00	0,20	0,67
7	YI	PY	3,00	5,00	2,00	3,11
8	PC	TC	2,00	5,00	0,50	1,71
9	PC	PY	1,00	1,00	1,00	1,00
10	TC	PY	3,00	1,00	2,00	1,82

Table 3. *Fuzzy AHP calculation table for dimensions*

Criteri as	TY-l	TY-m	TY-u	YI-l	YI-m	YI-u	PC-l	PC-m	PC-u	TC-l	TC-m	TC-u	PY-l	PY-m	PY-u
TY	1,000	1,000	1,000	3,000	3,630	4,000	1,000	2,470	5,000	2,000	2,620	3,000	1,000	2,150	5,000
YI	0,250	0,280	0,330	1,000	1,000	1,000	1,000	1,820	3,000	0,200	0,670	3,000	2,000	3,110	5,000
PC	0,200	0,400	1,000	0,330	0,550	0,550	1,000	1,000	1,000	0,500	1,710	5,000	1,000	1,000	1,000
TC	0,330	0,380	0,500	0,330	1,490	5,000	0,200	0,580	2,000	1,000	1,000	1,000	1,000	1,820	3,000
PY	0,200	1,470	1,000	0,200	0,320	0,500	1,000	1,000	1,000	0,330	0,550	1,000	1,000	1,000	1,000

In the next step, the geometric mean of the l, m, and u values in this matrix must be calculated for each row. This yields the geometric l, m, and u values for the dimensions. These geometric l, m, and u values are presented in Table 4 as Geo-l, Geo-m, and Geo-u. The sum of the Geo-l, Geo-m, and Geo-u values is subsequently required for the weight calculation process.

Table 4. *Geometric means and column sums*

Geo-l	Geo-m	Geo-u
1,431	2,191	3,129
0,631	1,012	1,715
0,505	0,822	1,380
0,465	0,902	1,719
0,421	0,607	0,871
Total Geo-l = 3,453	**Total Geo-m = 5,535**	**Total Geo-u = 8,814**

Fuzzy weights are derived by dividing the Geo-l, Geo-m, and Geo-u values in each row of the resulting table by the Total Geo-l, Total Geo-m, and Total Geo-u values, yielding the weight values W-l, W-m, and W-u. The row averages of these values represent the net weight values. Final weights are obtained by dividing the net weights by the sum of the net weight column. The sum of the final weight values equals 1. Thus, the final (or normalized) weight value for each dimension is determined. These values are presented in Table 5.

Table 5. *Fuzzy weight values, net weight values, and final weights*

W (l)	W (m)	W (u)	Net-Weight Values	Final Weights (Normalized Weight)
0,162	0,396	0,906	0,488	0,371
0.072	0,183	0,497	0,250	0,190
0,057	0,149	0,400	0,202	0.154
0,053	0,163	0,498	0,238	0,181
0,048	0,110	0,252	0,137	0,104
		Total	1,315	1,000

Once the global weights of the dimensions have been determined, the same procedures are applied to calculate the weights of the criteria contained within each dimension. After determining the normalized weights of the criteria, global weight values are obtained by multiplying each criterion's weight by the normalized weight of its respective dimension. Normalized weights indicate the relative importance of the criteria within their specific groups, whereas global weights express the importance of the criteria within the entire set of criteria. Tables 6 and 7 present the values obtained from the calculations for the dimensions and criteria.

Table 6. *Order of importance of dimensions*

Main Dimensions	Abbreviation	Fuzzy Weight (l, m, u)	Final Weights (Normalized Weight)	Priority
Technical Competence	TY	(0,162, 0,396, 0,906)	0,371	1
Creativity and Innovation	YI	(0,072, 0,183, 0,497)	0,190	2
Teamwork and Communication	TC	(0,053, 0,163, 0,498)	0,181	3
Problem-Solving Skills	PC	(0,057, 0,149, 0,400)	0,154	4
Project & Time Management	PY	(0,048, 0,110, 0,252)	0,104	5

Table 7. *Ranking of criteria by global weights*

Rank	Criteria	Code	Dimension	Global Weight
1	Knowledge of Materials	TY2	Technical Competence	0,199
2	Analysis and Simulation Skills	TY3	Technical Competence	0,092
3	Improving Existing Designs	YI2	Creativity and Innovation	0,075
4	Interdisciplinary Practice	TC1	Teamwork and Communication	0,074
5	Generating New Ideas (Concepts)	YI1	Creativity and Innovation	0,065
6	Research Skills	PC2	Problem-Solving Skills	0,063
7	Project Management Skills	PY1	Project and Time Management	0,058
8	Analytical Skills	PC1	Problem-Solving Skills	0,051
9	Verbal Communication	TC2	Teamwork and Communication	0,05
10	CAD/CAM/CAE Knowledge	TY1	Technical Competence	0,047

11	Interpersonal Skills	TC4	Teamwork and Communication	0,043
12	Planning (/Organizing) Skills	PC3	Problem-Solving Skills	0,04
13	Competence in Design Tool	TY4	Technical Competence	0,033
14	Providing Innovative Solutions	YI3	Creativity and Innovation	0,027
15	Time Management	PY2	Project and Time Management	0,027
16	Adapting to New Technologies	YI4	Creativity and Innovation	0,024
17	Use of Resources	PY3	Project and Time Management	0,019
18	Written Communication	TC3	Teamwork and Communication	0,013
				Toplam = 1,000

Subsequently, a sensitivity analysis is conducted to test the extent to which potential changes in the preferences expressed by participants alter the results—or, in other words, how a potential shift in responses affects the importance weights and, consequently, the degree of fragility or robustness of the study's findings. This makes it possible to assess the reliability of the model (Erkut & Tarımcılar, 1991, pp. 62–63; Triantaphyllou & Sánchez, 1997, pp. 152–153).

As part of the study, the sensitivity analysis observes how the ranking of the dimensions' importance changes in response to a ±20% variation in their weights. This approach makes it possible to identify the dimensions to which the model is sensitive (Triantaphyllou & Sánchez, 1997, pp. 156-158; Kaymak & van Nauta Lemke, 1998, pp. 171-173) and to determine whether such sensitivity significantly impacts the model's results (Erkut & Tarımcılar, 1991, pp. 72-75). Furthermore, it allows for the determination of the percentage range of variation within which the model remains valid for use (Buckley et al., 2001, pp. 49-52; Triantaphyllou & Sánchez, 1997, pp. 158-160).

In the sensitivity analysis, for a ±u% change scenario regarding a criterion weight v, if the current weight g_v is expressed in terms of the new weight variable g'_v, the formula is as follows:

$$g'\_v = g\_k * (1+u)$$

For other criteria, the calculation is performed according to the formula below, provided that "v" and "i" represent distinct criteria:

$$g'\_i = g\_i * [(1-g'\_v) / (1-g\_v)]$$

Thus, new weights are obtained and can be compared with the existing importance ranking based on the original weights. The new weights, along with the rates of change, are presented in Table 8.

Table 8. *Sensitivity analysis table, ±20% change scenario, and new weight values*

Change Scenario	Changed Dimension	Rate of Change	New TY	New YI Value	New TC Value	New PC Value	New PY Value

0	-	%0	0,371	0,19	0,181	0,154	0,104
1	TY	+%20	0,445	0,168	0,16	0,136	0,092
2	TY	-%20	0,297	0,211	0,202	0,172	0,116
3	YI	+%20	0,355	0,228	0,174	0,148	0,1
4	YI	-%20	0,388	0,152	0,189	0,161	0,109
5	TC	+%20	0,362	0,185	0,217	0,15	0,101
6	TC	-%20	0,38	0,195	0,145	0,158	0,107
7	PC	+%20	0,363	0,186	0,177	0,185	0,102
8	PC	-%20	0,38	0,195	0,185	0,123	0,106
9	PY	+%20	0,365	0,187	0,178	0,151	0,125
10	PY	-%20	0,378	0,193	0,184	0,157	0,083

By comparing the newly obtained weight values across the change scenarios, it is necessary to check whether there are any shifts in the ranking of the dimensions. This comparison of importance rankings is conducted between the ranking prior to the application of change scenarios and the ranking after their application. In this context, a shift in ranking between CI (Creativity and Innovation) and TW (Teamwork) is observed only for Change Scenario 3 and Change Scenario 5.

An examination of the state of these two weight values prior to the modification reveals a difference of 0.009 between them. Consequently, a 20% variation can lead to a change in their relative ranking in these two scenarios. This results in Table 9, the "Dimension Importance Ranking Table Based on Change Scenarios," which allows for the observation of changes in rankings. Thus, the sensitivity analysis results demonstrate the model's robustness in the face of 20% variations.

Table 9. *Ranking table of dimension importance based on change scenarios*

Change Scenario	**Changing Dimension**	**Difference %**	**1. Row**	**2. Row**	**3. Row**	**4. Row**	**5. Row**
0	-	%0	TY	YI	TC	PC	PY
1	TY	+%20	TY	YI	TC	PC	PY
2	TY	-%20	TY	Y	TC	PC	PY
3	YI	+%20	TY	TC	YI	PC	PY

4	YI	-%20	TY	YI	TC	PC	PY
5	TC	+%20	TY	TC	YI	PC	PY
6	TC	-%20	TY	YI	TC	PC	PY
7	PC	+%20	TY	YI	TC	PC	PY
8	PC	-%20	TY	YI	TC	PC	PY
9	PY	+%20	TY	YI	TC	PC	PY
10	PY	-%20	TY	YI	TC	PC	PY

3. Conclusion, discussion, and recommendations

This study presents a model for selecting a mechanical design engineer for the R&D department using Buckley's Fuzzy AHP method, which is based on the geometric mean. This model identifies the dimensions and criteria for selecting mechanical design engineers through pairwise comparisons conducted by experts with experience in personnel selection for the R&D department, as well as knowledge, competence, and experience. In this regard, the resulting model contributes to the literature as a tool that can be used for decision support.

Considering the findings of the study, it is evident that the technical competence dimension ranks first by a wide margin, including in every change scenario analyzed in the sensitivity analysis. This result is to be expected, as it aligns with the primary activities of mechanical design engineers within the organization. Other studies in the literature also support the validity of this finding, indicating that technical competencies hold similarly high importance for R&D positions (Chen, 2009, pp. 5796–5803; Robinson et al., 2005, pp. 123–153). The fact that "materials knowledge" and "analysis skills"—two criteria within the technical competence dimension—have the highest overall weights demonstrates the strategic importance of these two competencies from a professional standpoint in mechanical design engineering. While material knowledge is important in many areas, such as manufacturability and cost, analysis and simulation skills are important in terms of providing insights into the extent to which the specified engineering conditions can meet the expected design outcomes.

The two dimensions ranked second and third—creativity and innovation, and teamwork and communication—carry nearly equal weight based on the values derived from expert opinions and analysis results. The critical issue highlighted by both dimensions is the generation of alternative solutions. Tasks that are sometimes primarily undertaken by mechanical design engineers are resolved through the contribution of the company's institutional memory, while at other times they are resolved through the competencies of mechanical design engineers, as expressed by the creativity and innovation dimension. The fact that these two dimensions have similar values suggests that they cannot be considered independently of one another in the execution of tasks. Indeed, the criteria of the creativity and innovation dimension—such as improving designs and generating new ideas—along with the criteria of the teamwork and communication dimension—such as interdisciplinary collaboration and verbal communication—are considered qualities that cannot be treated separately for the successful completion of today's R&D projects. This aligns with the organizational dual competence theory in the literature.

The criteria included in the study—represented by the last two dimensions in the order of

importance—are also important qualifications for mechanical design engineers working in the R&D department. It can be said that these dimensions and criteria, which appear less important than others in the research findings, reflect the perspectives of experts working at the management level. Accordingly, a mechanical design engineer possessing technical competence and creativity should naturally also possess problem-solving skills. For this reason, these dimensions and criteria may have been assigned a lower weight (Robinson et al., 2005, pp. 131–132; Valentine et al., 2017, pp. 1309–1310). On the other hand, the reason the project and time management dimension and criteria are considered less important than other dimensions and criteria may stem from the fact that these are seen as qualities that can be acquired over time. At this stage, it should be noted that team leaders and managers assume responsibility and support mechanical design engineers in the areas of project and time management (Ortiz-Marcos et al., 2013, p. 89).

When the study's findings are evaluated based on the ranking of importance, the combined weight of the top six criteria reaches fifty percent. This indicates that material knowledge, analysis and simulation capabilities, design improvement, interdisciplinary collaboration, the generation of new ideas, and research skills are the most critical criteria to assess when selecting mechanical design engineer candidates. A common characteristic of these top six criteria—which account for fifty percent of the total weight—is that they are rooted in knowledge and experience and are intrinsic to the individual. The remaining criteria on the list, conversely, are those that can be developed through organizational adaptation and internal company activities. Consequently, this natural fifty-percent split highlights a distinction in the criteria that companies can consider when seeking either experienced mechanical design engineers or hiring recent graduates for the role. Thus, companies can take into account both the specific expectations associated with the position level and the relative weights of the criteria listed here when evaluating candidates for mechanical design engineering roles.

The model developed in this study offers a clear framework for the selection of mechanical design engineer candidates. This systematically constructed framework has the potential to shape approaches regarding the evaluation of the relevant dimensions and criteria. However, as with any study, this one has its limitations. The study does not provide specific tools for enterprises to evaluate the relevant dimensions and criteria. Furthermore, the relative importance assigned to the dimensions and criteria within the framework does not guarantee optimal results for every enterprise seeking to hire a mechanical design engineer. Dynamic internal and external factors that shift during the course of business operations are not addressed within the scope of the model. The model's validity may vary from one enterprise to another, depending on factors such as the evaluators' competence and intent, the specific conditions facing the enterprise, and various other influences. Another limitation is that the model has not been tested within an actual business setting. The research has not been validated through testing in real-world candidate selection processes or through assessments involving long-term performance or employee satisfaction.

Efforts to address these limitations form the basis for future research proposals. Briefly stated, the research proposals involve testing the developed model within business organizations and investigating and testing tools to evaluate the relevant dimensions and criteria.

The model proposed in this study is a decision-support model characterized by a strong academic foundation, a systematic and objective approach, and the ability to address—with a 20% sensitivity rate—the attributes that minimize uncertainties in the recruitment processes for mechanical design engineers. The findings indicate that the model serves as a viable framework for R&D departments when selecting mechanical design engineers. The research contributes to the literature by presenting a decision-support model for selecting mechanical design engineers for R&D departments through a fuzzy AHP analysis utilizing Buckley’s geometric mean approach. This computational approach, which has rarely been employed in the academic literature, offers a methodological contribution. Furthermore, while providing a practical framework for decision-makers during the evaluation phase, the study also enriches the literature on the fuzzy AHP method, a technique used in multi-criteria decision-making.

Author Contributions

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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Environmental Challenges and Agribusiness Transformation Under Climate Change and Military Conflict

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Abstract

This study examines the environmental challenges facing Ukrainian agribusiness and explores directions for its transformation under climate change and military conflict. The current state of suitability of Ukrainian agricultural lands and the level of chemical load on soils in Ukraine are compared with the corresponding indicators of the countries of Central Asia and Europe. It is revealed how ecological transformations in these regions are related to climate change. The nature and scale of damage suffered by the environment and agriculture of Ukraine as a result of the military conflict have been analyzed here. The purpose of the article is to substantiate the directions and mechanisms of transformation of Ukrainian agribusiness, taking into account climatic, environmental, and military challenges, as well as world experience in adapting agriculture to the consequences of climate change. The study is based on a systematic approach that combines monographic, economic-statistical, and abstract-logical methods, content analysis, and comparative analysis of risks and consequences of climate change for agribusiness in different countries. The findings indicate that Ukrainian agriculture still remains chemically intensive, the area of degraded soils is growing, and water resources are becoming increasingly scarce. These problems are compounded by large-scale environmental and economic losses caused by the military conflict. It follows that the transformation of Ukrainian agribusiness cannot be limited to the climate component alone — it must also take into account military-ecological, resource-economic, European integration, and management challenges. The principal contribution of this study is the systematization of the strategic challenges facing agribusiness transformation and the development of the authors' conceptual model, which integrates organizational and managerial, environmental, financial and investment, and risk management mechanisms. It is based on precision farming tools, circular supply chains, ESG standards and reporting, carbon management, satellite monitoring, digitalization of management, environmental certification, and renewable energy.

Keywords: environmental sustainability, agribusiness, climate change, military-environmental challenges, transformation, land resources, digitalization, sustainable development

1. Introduction

The modern development of the agricultural sector is characterized by a significant increase in the impact of climate change, which transforms the conditions for conducting agricultural production and creates new demands for the functioning and transformation of agribusiness. The increase in the average annual air temperature, changes in the precipitation regime, an increase in the frequency and intensity of droughts, extreme weather events, soil degradation, and a reduction in water resources significantly increase the level of uncertainty and risk in the functioning of agricultural enterprises and require a fundamental reconsideration of approaches to the use of natural resource potential. Under these conditions, traditional

management models, primarily focused on short-term financial performance, are becoming increasingly incapable of ensuring production stability and sustaining the long-term competitiveness of agribusiness.

Climate-related challenges and limited natural resource potential in the EU countries have become the main determinants of changing the strategic course of agricultural development towards increasing its adaptability, resource efficiency, environmental sustainability and risk-oriented management. For Ukraine, the issue of finding directions for environmentally oriented transformation of agribusiness is of particular importance in the context of European integration processes and the damage and destruction caused by the consequences of the military conflict, which increased the risks of qualitative and quantitative changes in natural resources. The combination of climatic and military environmental challenges forms fundamentally new conditions for the functioning of the agricultural sector of Ukraine. This necessitates the revision of the conceptual principles of agribusiness management and the development of resilient models capable of ensuring the effective use of natural resources, increasing the sustainability of agricultural production, and creating the prerequisites for its long-term post-war development.

2. Research Aim and Objectives

The purpose of the article is to substantiate the directions of agribusiness transformation in Ukraine, taking into account the challenges of an environmental and military nature and world experience in minimizing the consequences of climate change in agriculture. To achieve this aim, the following objectives were formulated:

- identify key climatic and environmental risks that affect the natural resource potential of agribusiness and assess their consequences;
- analyze the current state of suitability of agricultural lands of Ukraine and the level of chemical load on soils, taking into account the goals of sustainable agricultural development;
- assess the scale and nature of military-environmental challenges that Ukrainian agribusiness faces today;
- systematize climatic, environmental, resource-economic, European integration and management factors that determine the direction of agribusiness transformation;
- substantiate the directions and mechanisms of this transformation, aimed at increasing adaptability, environmental sustainability and long-term competitiveness of agribusiness.

3. Materials and Methods

3.1. Information base

The study was based on analytical data obtained from official statistical and institutional sources, including Eurostat (data on mineral fertilizer consumption, 2024), the Ministry of Environmental Protection and Natural Resources of Ukraine (data on the current state and degree of agricultural land degradation, 2024), the State Statistics Service of Ukraine, the State Ecological Inspectorate of Ukraine, the Food and Agriculture Organization of the United Nations (FAO), the national statistical agencies of Uzbekistan and Kazakhstan, as well as data from relevant scientific publications.

3.2. Research methods

The following research methods were employed: the monographic method for reviewing scientific literature; the abstract-logical method for developing the authors' conceptual model of agribusiness transformation and formulating the study's conclusions; the comparative analysis method for assessing the degree of agricultural land degradation in Ukraine relative to other countries; the economic-statistical method for analyzing the dynamics of chemical inputs in Ukraine and EU countries; and content analysis for examining international experience in developing climate-resilient agribusiness models.

3.3. Validity and limitations

The reliability of the study's findings is supported by the use of official statistical and analytical data obtained from the European Commission, the State Statistics Service of Ukraine, the national statistical agencies of Azerbaijan and Kazakhstan, the Food and Agriculture Organization of the United Nations (FAO), and the relevant Ukrainian ministries and government agencies responsible for environmental protection. These data enabled a comparative assessment of environmental challenges affecting agriculture across the selected countries.

The main limitation of this study is the ongoing military conflict in Ukraine, which restricts the opportunities for empirical validation and practical implementation of the proposed agribusiness transformation model.

4. Results

4.1. Modern Climate Challenges to Agricultural Development

Active human anthropogenic activity, military conflicts, and the intensification of all types of economic activity have led to large-scale climate changes that exert an increasing impact on agriculture and agribusiness. As a result, the consequences of climate change have already caused a higher frequency of natural anomalies, agricultural soil degradation, the destruction of eco-agrosystems, and alarming rates of biodiversity loss. Research findings by Nunes et al. (2025) demonstrate that climate change has altered the biological life cycle of all biological assets and the nature of their response to the economic activities of agricultural producers - ranging from shifts in crop yields and productivity to reduced resilience of biological assets to all chemical agents. Virtually all scientists and intergovernmental organizations reach the shared conclusion that continuing to use traditional agricultural production models and methods poses a significant threat to global food and environmental security, while also presenting challenges to achieving the goals of sustainable societal development (Albert et al., 2023). There is a broad scientific consensus that sustainable agricultural practices involve increased levels of risk, necessitating the development of new mechanisms to mitigate environmental risks. Furthermore, the implementation of environmentally sustainable agricultural practices requires substantial funding and is characterized by significant regional differentiation across the globe. This existing imbalance leads to a substantial gap in farming models and their outcomes - today, climate-resilient and environmentally safe agricultural technologies cover no more than 35% of the world’s agricultural land (Lu, 2024). Financial provision currently stands as one of the key limiting factors on the path toward greener agriculture. Active state financial support for the environmental transformation of agribusiness should serve as one way to resolve this issue (Barbosa, 2024). Mambo et al. (2025) propose consolidating the efforts of governments, businesses, and non-governmental organizations to identify funding sources that support environmental transformations and sustainable solutions in agriculture. As empirical research by Hultgren et al. (2025) has demonstrated, growth in farmers' income enables them to better respond to the impacts of climate change and take measures to prevent them. The overall result of such actions is the minimization of the negative impact of production activities on the natural environment.

Evaluating current environmental problems in agricultural production faced by producers at the regional level, Wang et al. (2026) highlight the following across the post-Soviet economic space: Central Asian countries (Uzbekistan, Kazakhstan) suffer from water resource depletion, soil degradation, and pollution; Eastern European countries (Ukraine) face soil degradation, biodiversity loss, the trend toward monoculture farming, and the environmental consequences of military conflict; while Western and Central European countries experience soil erosion, loss of organic carbon, and high chemical content in the soil. Such climate changes generate strategic risks for the sustainable development of society on a global scale, manifesting in reduced agricultural and food production, risks to the stable development of rural areas and their social component, as well as risks of direct losses of natural and biological resources, which threaten the existence of future generations (Fanzo et al., 2018).

Ukraine is an important participant in global food chains and one of the world's leading exporters of sunflower oil, rapeseed, corn, wheat, honey, and poultry. As one of the European countries, it has joined global initiatives aimed at minimizing the effects of climate change and achieving sustainable development goals. To continuously monitor the results of achieving climate neutrality goals in Ukraine, a digital SDG platform has been created and is operating. Despite certain actions towards achieving climate neutrality, according to the results of the assessment of the Ministry of Environment of Ukraine, numerous problematic aspects in the development of agriculture were identified: soil degradation, reduced crop yields and increased risks of desertification, pollution of water bodies, rapid loss of biodiversity, waste management problems and unpopularity of circular concepts of agri-food production, environmental consequences caused by the military conflict (Environmental problems of Southern Ukraine). The results of climate change are phenological and geographical changes in the location of biological assets, active settlement of their invasive species, increased resistance to drugs used in agricultural production (Ivanyuta et al., 2020); increased intensity of short-term heavy rainfall with simultaneous trends of increasing frequency and intensity of droughts and increasing number and duration of heat waves (Krakovska & Kryshtop, 2024). Tsvihun (2025) adds to the set of these consequences a traditionally high level of intensification of agricultural production, disruption of farming systems, long-term losses of soil fertility, and a shortage of financial resources necessary for technological modernization of agriculture, taking into account the requirements of environmental friendliness and resource conservation.

Ivanov et al. (2024) draw attention to the low growth rates of organic farming in the country. Despite steady demand for organic food products and Ukraine's significant role in the European organic food market, the share of land under organic production does not exceed 1.1%. Further transformation of Ukraine's agriculture toward alignment with the European Green Deal requires addressing several legal issues, among which harmonizing national and European standards, requirements, and taxonomies is currently paramount: introducing requirements for organic production, organic product certification, agroforestry, and land restoration (Obiyukh, 2025). However, according to the authors, the main limiting factor is the slow pace at which agribusiness adopts the values of sustainable development and society understands the need for environmental changes. Traditional management concepts prioritizing short-term financial gain predominate in most Ukrainian agricultural entities (Kryukova et al., 2023). Uncertainty, macroeconomic instability, and war risks heighten the concerns and negative expectations of agribusiness owners, inhibiting the buildup of long-term competitive potential based on greening production. As a result, chemically intensive and resource-heavy production methods oriented toward conventional practices remain the most widespread in Ukrainian agriculture.

The consequences of climate change and intensive agricultural practices manifest in indicators of agricultural soil usability. An assessment of the degree of agricultural land erosion in EU countries showed that the EU average stands at 5.1%, with the highest levels recorded in countries such as Italy (24.4%), Austria (15,3%), Malta (10,6%), and Greece (9,6%) (Eurostat, 2024). Active European initiatives to green the agricultural sector have yielded positive results and a relative stabilization of this indicator—its value decreased over the period 2000–2023.

Assessment of the quality of Ukrainian soils and the degree of their suitability for agricultural production showed that the average indicator fluctuates within 38-69% (Figure 1). Only two administrative-territorial units out of 24 have a high level of agricultural land quality; three regions are characterized by a low level of quality; the rest - by an average level. The maximum deficit of humus, caused by a long-term deficit in the use of organic fertilizers, is 630-810 kg/ha. According to the conclusions of agricultural experts, the highest rates of loss of qualitative soil quality are in territorial units that historically had the highest indicators.

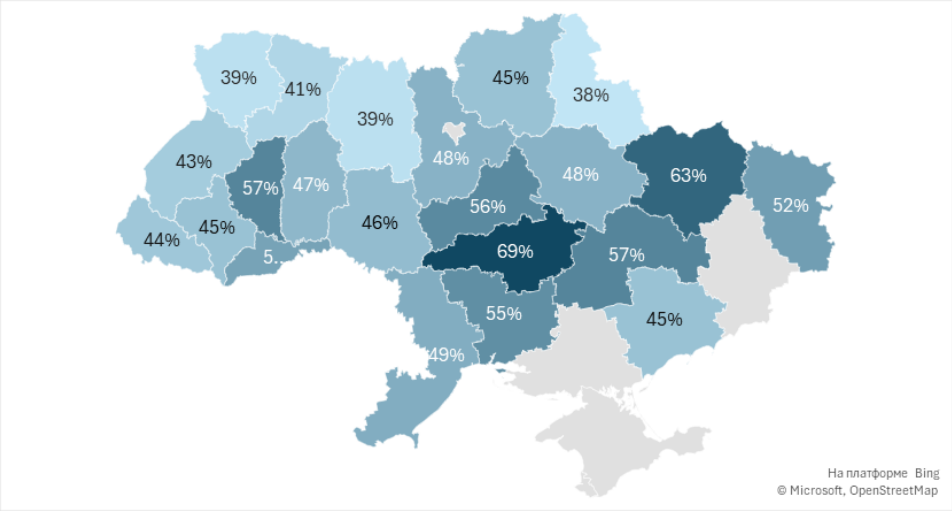

Figure 1. Current state of suitability of agricultural lands in Ukraine, %

Source: constructed by the authors based on data from: Ukraine is catastrophically losing soil fertility (study).

A comparison of actual agricultural land usability indicators with those of selected post-Soviet countries demonstrated that the conservation and restoration of natural land resources is a pressing issue for many nations (Table 1). However, for Ukraine, the rapid acceleration of agricultural land degradation is acquiring an increasingly widespread scale, further compounded by the conditions of military conflict.

Table 1. Comparative assessment of the current state of agricultural land suitability by individual countries

Countries	Main types of agricultural soil degradation	Main indicators
Ukraine	Water and wind erosion, dehumification, heavy metal and explosive contamination, land mining, soil compaction	About 15 million hectares of agricultural land are subject to water erosion; over 6 million hectares are subject to wind erosion; about 20% of Ukraine's territory is at risk of contamination or mining as a result of the war
Kazakhstan	Wind erosion, pasture degradation, desertification, soil salinization	About 70% of the country's territory has experienced land degradation to varying degrees
Uzbekistan	Soil salinization, degradation of irrigated lands, desertification, degradation of pastures	45% of irrigated land is saline; 20% of pastures are degraded; 69% of land has <1% soil organic carbon

Source: Ministry of Environmental Protection and Natural Resources of Ukraine, FAO (2024),
Ecological indicators of environmental monitoring and assessment, FAO SOILS PORTAL, FAO. Uzbekistan

Soil degradation is a consequence of the complex influence of natural and anthropogenic factors, among which erosion processes, depletion of humus state, violation of scientifically substantiated crop rotations, as well as the growing technogenic impact caused by military actions occupy a special place (Tripathi et al, 2020). In order to solve the problem of restoring agricultural lands and minimizing the risks of their degradation, these countries are adopting a complex of policies for the transition to a “green” agroeconomy: “Land Degradation Neutrality” (Uzbekistan), “Climate-Smart Agriculture” (Kazakhstan, Uzbekistan, EU), “Conservation Agriculture”, “National Program for Combating Desertification” (Uzbekistan), RESILAND Central Asia” (Kazakhstan) and others. In Ukraine, to preserve and restore land and resource potential, the National Action Plan to Combat Land Degradation and Desertification, the Strategy for Environmental Security and Adaptation to Climate Change until 2030, and the Strategy for the Development of Agriculture and Rural Areas until 2030 have been adopted.

An important aspect of assessing the environmental sustainability of agricultural production is the level of chemical load on the soil cover, determined by the intensity of mineral fertilizer and plant protection product application. Although the application of mineral fertilizers and plant protection products serves as a key factor in boosting crop productivity, the current agricultural policy of the European Union aims to optimize chemical intensification levels in line with the objectives of the European Green Deal. The European "Farm to Fork" Strategy targets a 50% reduction in the use of chemical pesticides and a minimum

50% reduction in nutrient losses by 2030, which should ensure a decrease in mineral fertilizer application by at least 20% compared to the baseline level (From Farm to Fork). Results of a comparative analysis regarding the impact of chemical input levels on crop yields in EU countries demonstrate that the reduction in mineral nitrogen fertilizer application mandated by EU environmental policy leads to a substantial decline in yield and cannot be implemented through a uniform scenario across all member states. Reducing nitrogen fertilizer use must rely on a differentiated approach that harmonizes the achievement of environmental targets with food security provision (Pacifico et al., 2024). A comparative assessment of chemical input volumes (mineral fertilizers) in EU countries and Ukraine revealed a significantly higher application level in Ukraine. Specifically, the share of land area treated with pesticides during 2020–2024 fluctuates within 93.0–79.6%. At the same time, the chemical load per hectare of cultivated area decreases from 152 kg to 86 kg (Table 2).

Table 2. Indicators of the level of mineral fertilizer application in Ukraine and in EU countries

Indicators	2015	2018	2019	2020	2021	2022	2023	2024
EU countries								
Volume of nitrogen fertilizers applied, thousand tons (average per country)	356,6	346,0	351,5	369,5	359,5	315,8	309,8	327,9
Volume of phosphate fertilizers, million tons (average per country)	38,7	39,8	41,6	43,7	42,0	33,6	31,4	33,8
Ukraine								
Volume of applied mineral fertilizers – total, thousand tons	1415	2151	2142	2489	2584	1832	1400	1298
Share of the crop treated with pesticides (%	81	91	91	93	92	88	87	79,6
Volume of mineral fertilizers, per 1 hectare of area, kg	98	134	131	152	154	144	122	86

Source: calculated by the authors based on data from: Statistical Yearbook of Ukraine (2024), Eurostat (2024)

According to the European Commission, agro-ecological indicators of agriculture during 2023-2024 revealed negative trends, in particular, in terms of increasing the concentration of chemical substances in soils, which creates factors of undesirable pressure on the environment. In Ukraine, increasing the level of applied mineral fertilizers, in particular nitrogen fertilizers, is the main tool for ensuring an increase in the yield of main crops during 2000-2021: the average yield of corn, wheat and sunflower increased by 2.6, 2.3 and 2.0 times, respectively. The increase in the use of phosphorus and potassium fertilizers was also accompanied by a significant increase in yields, with a high coefficient of economic return: increasing the amount of fertilizer application gave a net increase in yields of 3.2 and 1.8 times for winter wheat and 5.8 and 4.2 times for corn (Medinets et al., 2025). Despite the trend of increasing the volume of mineral fertilizers, about 90% of all soils are characterized by a low level of readily hydrolyzable nitrogen. At the same time, the increase in the level of chemical intensification of field production in Ukraine is accompanied by a simultaneous exacerbation of the problem of loss of organic matter and the growing scale of soil erosion. The main causes of soil erosion are the violation of scientifically based norms of the agricultural system, the dominance of commercial monocultures, and the rejection of intercropping, which increases the risks of water and wind erosion (FAO. Ukraine, 2014). The assessment of the quality of agricultural land showed that the loss of humus in Ukrainian black soils occurs on 43% of all areas. In addition, 11% of agricultural land is subject to problems of pollution by chemicals, 4% - problems with salinization and alkalization. The average rate of humus loss in soils is 0.5 t/ha. Based on the results of a comprehensive analysis of the chemical state of agricultural soils in Ukraine, scientists conclude that their current state poses long-term threats to the sustainable development of crop production, the country's ecological security, and global food security (Medinets et al., 2025).

The findings indicate that Ukraine's agricultural sector is undergoing a gradual transformation of its traditional production intensification model. High application levels of agrochemical inputs remain an important factor in maintaining crop productivity; however, the tightening of environmental requirements in line with European Green Deal policies creates the need to optimize their application volumes. The

effectiveness of traditional technologies is also increasingly determined by the impacts of climate change, which are becoming one of the primary factors in agribusiness management. These factors must be taken into account when constructing a modern model of agribusiness transformation, among which the following should be highlighted: accelerated degradation of soil resources in Ukraine, escalating moisture deficits and rising drought risks, declining efficiency of traditional farming technologies, a progressive increase in demands for greening agricultural production according to the country's European integration course, as well as heightened uncertainty and growing operational risks.

4.2. Military challenges and their environmental consequences for Ukrainian agribusiness

The ongoing military conflict in Ukraine has become an additional factor exacerbating existing environmental challenges. Its consequences are large-scale pollution and mining of agricultural lands, soil deterioration, loss of biodiversity, disruption of the water regime, pollution of surface and groundwater, increased risks of erosion processes, ecosystem degradation, and increased greenhouse gas emissions. The combination of these changes leads to a decrease in the productivity of agro-ecosystems, a reduction in agricultural production, a deterioration in the quality of land resources, and requires the implementation of climate-oriented and environmentally sustainable models of agribusiness management. According to the estimates of the State Ecological Inspectorate of Ukraine, the total amount of losses and damage caused to the country's natural environment as of 2025 is estimated at 85.1 billion US dollars, of which about 32% falls on land resources – 24,1 thousand km² of area has been polluted and littered (Figure 2). The scale of damage is determined by the sphere of plant and animal production, the volume of environmental damage of which is estimated at 23,5 billion US dollars.

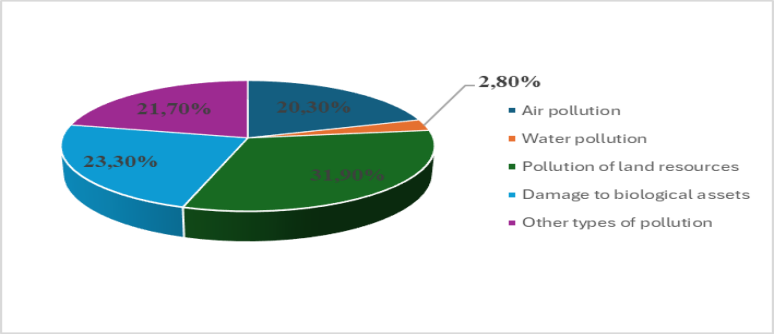

Figure 2. Structure of environmental damage by pollution areas in Ukraine, %

Source: constructed by the authors based on data from: (State Ecological Inspectorate of Ukrainy)

The decline of the Kakhovka HPP was a man-made disaster for the natural environment, which has a direct impact on agriculture. The total area of flooded territories was 612 sq km, which led to the loss of water agro-irrigation potential on the territory of 1,5 million hectares; 64 thousand hectares of forests were flooded. Due to its scale, the volume of biodiversity loss as a result of the Kakhovka disaster has not been finally estimated. The total amount of damage to the environment is estimated at 14 billion US dollars (Kolodezhna & Vasilyuk, 2025). For the sphere of agricultural production, the consequences of the military conflict were manifested both in direct form and in the form of the loss of potential income of agricultural producers. The total amount of economic losses, according to expert estimates, is 80 billion US dollars, of which direct losses account for almost 11% (8.7 billion US dollars). The maximum damage was caused by a decrease in the production of annual crops - over 34.3 billion USD- which caused additional losses due to reduced exports and domestic prices in the amount of 24.1 billion USD. Direct costs in the livestock sector are estimated at 5.6 billion USD (UFRD, 2025).

The military conflict in Ukraine has significantly amplified the negative impact of climate change on the agricultural sector, generating a complex set of interconnected environmental and economic risks. Soil degradation, land and water resource contamination, land mining, destruction of irrigation and drainage infrastructure, biodiversity loss, and disruptions to natural ecosystems reduce the productivity of

agricultural landscapes, elevate production costs, increase investment risks, and limit opportunities for the efficient use of agribusiness resource potential. Under such conditions, environmental losses transform into direct economic damage for agribusiness and heighten its vulnerability to climate change impacts through declining yields, rising production costs, loss of land capital, the need for natural resource restoration, and reduced competitiveness of agricultural entities. In this context, traditional agribusiness transformation models no longer provide an adequate level of resilience, necessitating a transition toward adaptability, climate resilience, environmental safety, and risk-oriented management.

4.3. Directions of agribusiness transformation in the context of climate change and military environmental challenges

Climatic and environmental challenges for Ukrainian agriculture, which have intensified under the conditions of military conflict, have led to an objective understanding of the need for a comprehensive transformation of agribusiness. The findings of this study enabled the systematization of the main strategic climate-related and military-environmental challenges affecting agribusiness and requiring appropriate management responses (Table 3).

Table 3. Strategic challenges of agribusiness transformation in the context of climate change and military-environmental challenges

Strategic challenges	Main content	Implications for agribusiness
Military-environmental challenges	Mining of agricultural lands, contamination of soils, surface and groundwater with explosion products, heavy metals, and fuel and lubricants, destruction of land reclamation and hydraulic infrastructure, damage to natural ecosystems	Withdrawal of land from economic use, loss of part of the resource potential, increase in costs for demining, reclamation and ecological restoration, decrease in the investment attractiveness of agribusiness
Climate challenges	Increase in average annual temperature, change in precipitation patterns, increase in frequency of extreme weather events, water supply shortage	Decrease in agricultural yields and productivity, increased business risk, increased costs for adaptation measures, increased climate risks
Environmental challenges of sustainable nature management	Soil degradation and erosion, reduced soil fertility, reduced biodiversity, limited water resources, excessive anthropogenic load	Decline in natural land productivity, increased costs for maintaining soil fertility and restoring natural and biological resources
European integration environmental challenges	Strengthening EU environmental requirements, implementing the European Green Deal, introducing ESG principles and decarbonizing agricultural production	The need to modernize production, invest in the greening of agribusiness, and increase requirements for the environmental quality of products and competitiveness
Resource and economic challenges	Rising prices for material and technical resources, disruption of logistics chains, shortage of labor and financial resources, high market and macroeconomic uncertainty	Growth in production costs, reduction in the financial stability of enterprises, reduction in investment activity. Growth in economic risks of agribusiness
Management challenges	The simultaneous impact of climatic, military-ecological, environmental and economic factors that change the conditions for the functioning of agribusiness	The need to transition to adaptive, risk-based, climate-resilient and environmentally sustainable management models

Source: compiled by the authors

The totality of these challenges necessitates shifting traditional approaches to agribusiness transformation toward the search for more sustainable environmental models capable of ensuring the long-term competitiveness of Ukrainian agricultural products in both domestic and global markets. Among such models, Chinese scientists propose a conceptual model for ecologically sustainable agribusiness development based on the "Drivers-Pressure-State-Impact-Response" framework, aimed at achieving multi-objective optimization of agricultural activities. Scientists highlight subsidies, carbon trade quotas, preferential "green loans," and other forms of state support as key drivers for its implementation into farmers' practical activities (Wang et al., 2026). As central mechanisms for minimizing climate change impacts within the agribusiness model, Zhang S. et al. emphasize digital finance and supply chains, which

influence final results as well as the economic, environmental, and social sustainability of agriculture through cost management (Zhang, 2025). Ukrainian scholars are likewise working toward identifying effective environmentally oriented models for agribusiness transformation, agreeing that innovation—particularly digital innovation—must serve as their core (Borysiak, 2025). In previous studies, the authors have already demonstrated that without the digitalization of agricultural production, artificial intelligence technologies, and integrated digital platforms, the establishment of climate-resilient agribusiness is hardly feasible (Linde et al., 2024; Zamlynskyi et al., 2024; Shabatura et al., 2025). Food and energy security, rural revitalization, and the building of long-term competitive potential for agribusiness based on sustainable development principles should serve as strategic benchmarks for transformation models (Yermolenko, 2026). Although the authors generally agree on the strategic approaches to agribusiness transformation, they consistently identify limited financial resources as the main barrier to its effective implementation. In the authors' agribusiness transformation model, securing the financial resources required to address environmental challenges involves capital accumulation through funding source diversification, the use of digital financial instruments, and the attraction of green investments and grant programs grounded in ESG-oriented financing. Thus, the proposed model focuses on creating conditions for the inclusive expansion of agricultural enterprises' financial potential. Digitalization serves as the primary tool facilitating such inclusive access for agricultural producers to capital markets and agro-ecological innovations (Figure 3).

This approach builds upon the authors' previous research, which identified the digital transformation of agricultural production, digital platforms, and artificial intelligence technologies as key tools for enhancing the agricultural sector's adaptation to climate change (Zamlynskyi et al., 2024; Linde et al., 2024; Shabatura et al., 2025). The authors consider digital technologies and solutions as one of the most powerful tools for adapting agriculture to climate change and implementing sustainable methods of agricultural activities. In world practice, digital solutions have strong potential for implementation in all branches of agricultural production (crop production, livestock farming, auxiliary production), work in real time, and contribute to the creation of sustainable agricultural value chains. In the context of adapting agribusiness management to environmental challenges and preventing the consequences of climate change, Finger (2023) divides digital solutions into five main groups: geoinformation technologies, diagnostic tools, applied tools, automated production processes and technological systems, and data networks. Ukraine is characterized by high rates of digitalization of socio-economic relations, in particular, in the field of agricultural production. Similar conclusions regarding the role of digital transformation, the platformization of the agricultural sector, and the application of artificial intelligence technologies in enhancing the adaptability of agribusiness to climate change were reached in the authors' previous studies (Zamlynskyi et al., 2024; Linde et al., 2024; Shabatura et al., 2025). In recent years, in general, an infrastructure for digital transformations of agribusiness has been created, the main elements of which are the digital platform DAR (State Agrarian Register) with relevant analytical modules, the Unified State Platform of Agricultural Knowledge and Innovations AKIS, the unified electronic system "eCrop Production", and the State Register of Environmental Impact Assessment. Local management platforms AgroOnline, Soft.Farm, AgroOffic, Cropio and others are being introduced into the practical activities of agribusiness. These architectural components contribute to the gradual transformation of agribusiness management systems towards increasing the level of climate neutrality and environmental sustainability. The central aspect of the implementation of environmental initiatives of Ukrainian agribusiness remains the financial capacity to ensure environmental transformations. In modern realities, the potential of the Ukrainian financial segment is in a state of stagnation due to geopolitical conflicts and macroeconomic instability. The main financial source of most agricultural structures in Ukraine remains equity. Increasing the level of accessibility and inclusiveness of external financial resources for Ukrainian agricultural producers is currently the leading task of digital infrastructure and a prerequisite for the implementation of climate-oriented solutions in agriculture. In this context, one of the key areas of further development of the country's digital infrastructure should be the

creation of an integrated digital financial system for the agricultural sector and technologically related activities, the key function of which is to ensure inclusive access of agricultural entities to financial capital markets.

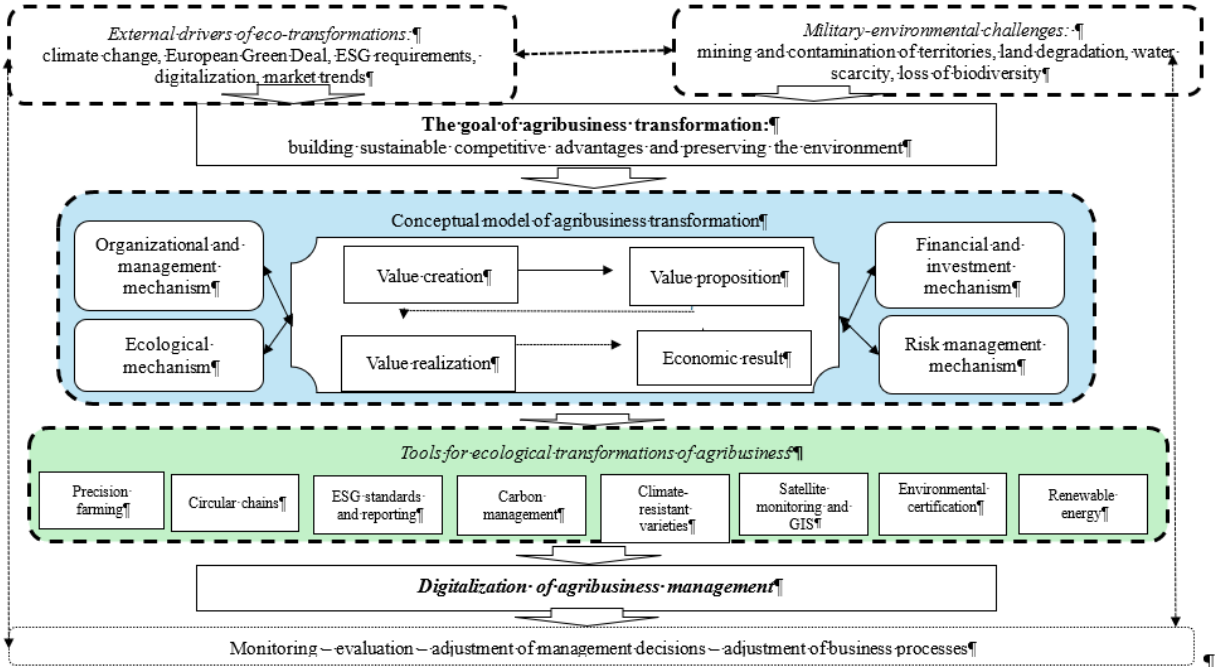

Figure 3. Model of agribusiness transformation in the context of climate change and military environmental challenges
Source: author's development

5. Discussion

A review of global practice in substantiating agribusiness transformation models under climate change has shown that, despite sound methodological approaches, existing models remain limited in terms of transformation scale and national implementation specifics. Most models focus on optimizing management decisions to achieve sustainable development across all its dimensions: environmental, economic, and social sustainability. However, research efforts are predominantly directed toward mitigating (reducing) the impacts of climate change in agribusiness, with less emphasis placed on their prevention. While conceptually agreeing with the sustainable agribusiness development model proposed by Wang et al. (2026), the authors consider the aspects regarding the outcomes and strength of digital finance's influence on climate change impacts to remain open for discussion. Practical agribusiness transformation models based on climate neutrality and sustainable development developed in EU countries often account for small farm sizes, creating limitations for Ukrainian practice where farm sizes are frequently larger (Pret et al., 2025). At the same time, the methods proposed by scholars to build models resilient to environmental challenges remain highly relevant for Ukraine: crop diversification, waste reuse, and the organization of inclusive supply chains within rural areas (De la Parra-Guerra et al., 2026). For Ukraine, the main limitation of these models remains their failure to account for the impact of the military factor, which amplifies environmental challenges and exerts a long-term influence.

6. Conclusions

The findings indicate that Ukrainian agribusiness currently operates under the combined pressure of climate change, degradation of natural resources, the chemical intensification of agricultural production, and the far-reaching consequences of the ongoing military conflict. It is the combination of these factors,

and not any one of them, that forms new business conditions and requires a revision of traditional approaches to management.

Climatic and environmental changes are most noticeably manifested in soil degradation and erosion, loss of humus, reduction of biodiversity, increasing risks of desertification and shortage of water resources, and traditional farming technologies are increasingly failing to cope with their function. A comparison of the state of agricultural lands in Ukraine with Kazakhstan and Uzbekistan shows that this is not a local, but a systemic problem that requires both state and corporate recovery measures.

The intensive use of mineral fertilizers and plant protection products remains a key driver of crop productivity in Ukraine. However, it also increases environmental pressure on soils. In the context of European integration, this requires a shift from maximizing input volumes to the more differentiated, science-based, and environmentally sustainable use of agricultural resources.

The ongoing military conflict has further exacerbated these problems. Mining and land pollution, destruction of land reclamation and hydrotechnical infrastructure, violation of the water regime, loss of biodiversity and damage to ecosystems — all this reduces the resource potential of agribusiness, increases production costs, reduces investment attractiveness and makes the prospects for long-term recovery less certain.

Accordingly, the study systematizes the key groups of challenges shaping agribusiness transformation, including military-environmental, climate-related, environmental, European integration, resource-economic, and management challenges. The findings demonstrate that these challenges can only be effectively addressed through the transition to adaptive, risk-oriented, and climate-resilient management models.

The study develops a conceptual model of agribusiness transformation that integrates organizational and managerial, environmental, financial and investment, and risk management mechanisms. Its practical implementation is based on precision agriculture, satellite monitoring and GIS technologies, circular supply chains, ESG standards and reporting, carbon management, environmental certification, renewable energy and digital management tools.

The practical value of the proposed approach lies primarily in the fact that agricultural enterprises can use it to form their own adaptive management decisions, more effectively use natural resources and access green financing, and therefore strengthen long-term competitiveness. Further research should be directed at developing a system of indicators for assessing the effectiveness of such a transformation and at testing the proposed model directly at the level of agricultural enterprises and regional agri-food systems.

Author Contributions

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript

Conflict of Interest

The authors declare no conflicts of interest

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Neet Youth in The Kyrgyz Republic: Barriers to Labour Market Inclusion for Groups with Low Mobility

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Abstract

The NEET phenomenon (not engaged in labor, study, or vocational training) is one of the most acute socio-economic problems in the Kyrgyz Republic, affecting approximately one-third of young people aged 15–29. The article examines an aspect that has so far received insufficient scientific attention: the structural and spatial barriers that hinder low-mobility populations – including rural youth, young women, persons with disabilities, and internal migrants – from accessing the labor market and educational opportunities. Drawing on data from the National Statistical Committee of the Kyrgyz Republic, the International Labour Organization, and the World Bank, as well as a systematic review of peer-reviewed literature published in 2015–2024, the study reflects the multidimensional nature of exclusion in seven areas. The results show pronounced regional differences: in the southern and remote regions (Batken, Naryn, Jalal-Abad), the NEET rate exceeds 38–43%, while in Bishkek it is 23%. The study identifies six main categories of barriers: physical mobility restrictions, digital access gaps, gender and socio-normative constraints, information asymmetry, legal and institutional barriers, and economic deprivation. Based on the analysis, the article proposes a policy framework focused on digital integration of the labor market, targeted vocational training, inter-agency coordination, and mechanisms to support mobility. The results of the study contribute to the emerging literature on spatially differentiated exclusion of youth from the labor market in Central Asia and offer practical recommendations for policy-makers, NGOs, and international development partners working in the Kyrgyz Republic.

Keywords: NEET youth, Kyrgyz Republic, exclusion from the labor market, groups with low mobility, youth employment, regional differences, social inclusion, Central Asia

1.Introduction

The term NEET—which refers to young people aged 15–29 who are not engaged in work, study, or training—has become one of the main indicators of the social vulnerability of young people in post-Soviet transition economies. In the Kyrgyz Republic, the NEET rate is consistently higher than the global average, reflecting the structural weakness of the labor market, shaped simultaneously by the Soviet institutional legacy, the post-independence economic downturn, large-scale labor emigration, and accelerating digitalization (ILO, 2022; World Bank, 2021).

Although the aggregate national statistics of NEET are documented by the National Statistical Committee of the Kyrgyz Republic (NSC KR) and international organizations, the spatial and group aspects of NEET are comparatively poorly studied. The situation of population groups with low mobility, a category that includes rural youth geographically isolated from economic centers, young women limited by gender norms and domestic responsibilities, persons with disabilities facing physical and institutional exclusion,

as well as internal migrants, whose legal and social status creates additional vulnerability, is particularly poorly studied (Mamytbekov & Dzhaksybekov, 2021; UNICEF, 2020).

This article proceeds from the premise that NEET is not a homogeneous state, but a multidimensionally structured phenomenon in which spatial, gender, and institutional factors interact, generating differentiated forms of exclusion from the labor market. Understanding these interactions is essential for the development of effective, targeted policies that go beyond model youth employment programmes.

Further, the article is structured as follows. Section 1 provides a review of the theoretical and empirical literature on NEET and the exclusion of low mobility groups. Section 2 presents the objectives and methodology of the study. Section 3 analyzes regional data on NEETs. Section 4 identifies and addresses the main categories of barriers. Section 5 offers a policy framework. The report summarizes the main findings and outlines directions for further research.

2. Literature review

First developed in the UK in the late 1990s as an administrative category, NEET has since been adopted by international organizations, including the ILO, OECD and the World Bank, as a composite indicator of youth social exclusion (Quintini & Manfredi, 2009). Its value lies in its ability to capture heterogeneous forms of non-participation that purely employment-oriented indicators miss, including discouraged workers, unpaid caregivers, and those excluded on the grounds of disability (Alfieri et al., 2015).

In the context of Central Asia, the literature on NEET has grown significantly since 2010, thanks in large part to the research programs of the ILO and the World Bank (ILO, 2022; World Bank, 2019). These studies found that the region's NEET populations are characterized by a pronounced gender asymmetry – with a predominance of young women due to early marriage rates and the burden of care – as well as a marked rural-urban divide due to the uneven distribution of educational and economic infrastructure (Djankov & Miner, 2016).

For the Kyrgyz Republic, Mamytbekov and Dzhaksybekov (2021) document the association between rural residence and NEET status, mediated by access to transportation and distance from vocational training institutions. Toktogulova (2019) focuses on gender as a major factor in the status of NEET among young women in southern Kyrgyzstan, arguing that institutional and regulatory barriers to women's participation in the labor market play a more defining role than a lack of skills. Abdyldaeva et al. (2023) extend this analysis to include numerical exclusion as an emerging measure of NEET risk in distant regions.

The notion of low mobility as a structural vulnerability in the labour market has been developed in the wider European literature on disability and employment (Grammenos, 2020) and is increasingly applied to rural youth in developing economies (O'Higgins, 2017). In the Kyrgyz context, low mobility manifests itself in several dimensions: physical (inadequate transport), digital (limited connectivity), informational (lack of awareness of opportunities), and social (gender-based restrictions on independent movement).

A persistent gap in the existing literature is the lack of integrated analyses of how these different dimensions of low mobility interact with NEET status in different regional contexts of the Kyrgyz Republic. This article fills this gap by summarizing the available evidence and offering an analytical framework that addresses multiple barriers.

3. Goals and objectives of the study

The main objective of this study is to identify and analyze the structural barriers that prevent groups of youth with low mobility in the Kyrgyz Republic from accessing employment, education, and vocational training, thereby consolidating the status of NEET.

The study addresses four specific tasks:

1. To display the NEET regional levels for seven regions of the Kyrgyz Republic using available statistical data for the period 2019–2023.
2. To identify and classify the main barriers to inclusion in the labor market for groups of young people with low mobility.
3. To study the interaction between regional location, group vulnerability, and the accumulation of barriers.
4. To offer evidence-based policy recommendations to address identified barriers.

4. Materials and methods

This study uses a mixed methodology combining a systematic literature review, secondary statistical analysis, and thematic synthesis.

5. Data sources

Quantitative data on NEET levels and labour market indicators were obtained from: (1) the National Statistical Committee of the Kyrgyz Republic (NSC KR) Annual Labour Force Survey Reports for 2019–2023; (2) the ILO ILOSTAT database; (3) World Bank World Development Indicators; (4) UNICEF situation analyses for Kyrgyzstan for 2020 and 2022.

6. Literature Review Protocol

A systematic literature review covering 2015–2024 publications in three databases: Google Scholar, Scopus, and ILO repositories was conducted. The search queries used were: "NEET Kyrgyzstan", "NEET Central Asia", "youth employment Kyrgyz Republic", "labour market exclusion disability", "rural youth employment" and "gender labour force participation Kyrgyzstan". After being selected for relevance and methodological quality and relevance, thirty-two sources were included.

7. Analytical framework

Barriers to labour market inclusion were analysed using a six-dimensional framework adapted according to Grammenos (2020) and O'Higgins (2017): (1) physical mobility; (2) digital access; (3) gender and social norms; (4) information access; (5) legal and institutional factors; (6) economic constraints. Each measurement was evaluated by comparing the statistics with the results of the literature reviewed.

8. Results

8.1. Regional NEET Levels in the Kyrgyz Republic (2019–2023)

Table 1 presents the regional levels of NEET among young people aged 15–29 years in seven regions and the city of Bishkek for individual years of the period 2019–2023.

Table 1. NEET Rate (%) by Region, Kyrgyz Republic, 2019–2023

Region	2019	2020	2022	2023
Bishkek (urban)	22,4	28,1	24,7	23,2
Osh region (southern)	34,1	41,3	37,6	35,9
Batken region	38,7	46,2	42,1	39,4
Jalal-Abad region	35,3	43,0	39,8	37,1
Chui region (suburban)	26,8	32,5	28,9	27,3

Issyk-Kul region	29,6	36,4	31,7	30,2
Naryn Oblast (Rural/Remote)	41,2	49,7	45,3	43,0
Talas region	36,8	44,5	40,2	38,7
Average in the Kyrgyz Republic	31,4	38,6	34,9	33,1

Source: compiled by the author based on the NSC of the Kyrgyz Republic (2023); ILO ILOSTAT (2024); World Bank WDI (2024).

The data show that the highest levels of NEETs are consistently recorded in southern and remote areas. In the Naryn region – characterized by high mountains, geographical isolation and limited economic diversification – the NEET rate in 2023 was 43.0%, almost double that of Bishkek (23.2%). In the Batken and Jalal-Abad regions, located in the Fergana Valley and prone to cross-border economic shocks, the rate also exceeded 35%. The temporary spike recorded in all regions in 2020 was due to COVID-19 closures and economic downturns, which disproportionately affected youth in informal employment.

The data also show that the improvements observed in 2020–2023 were uneven, with urban and peri-urban areas recovering faster, while in remote areas, NEET rates remain 10–15 percentage points above the national average, suggesting that the structural factors of rural NEETs are different from the cyclical economic factors prevailing in cities (NSC KR, 2023; ILO, 2022).

8.2. Barriers to Labour Market Inclusion for Groups with Low Mobility

Table 2 presents a framework of multiple barriers applied to NEET subgroups with low mobility in the Kyrgyz Republic.

Table 2. Barriers to Labour Market Inclusion for Youth Groups with Low Mobility

Barrier category	Specific barriers identified	Affected subgroup NEET
Physical mobility	Lack of transport; poor road infrastructure; Distance from urban centers	Rural youth; Youth with disabilities
Digital Access	No internet/devices; low digital literacy; Connection cost	Rural youth; Low-income youth
Gender and Social Norms	Early marriages; the burden of home care; Family mobility restrictions	Young women (especially in the south of the Kyrgyz Republic)
Information barriers	Lack of awareness about vacancies, training programs, public services	Youth from remote areas; Children of migrants
Legal and institutional	Lack of documents; gaps in disability registration; Discrimination	Persons with disabilities; Migrants
Economic	Cost of moving; inability to pay for further education	Young people from low-income families

Source: compiled by the author on the basis of Mamytbekov & Dzhaksybekov (2021); Toktogulova (2019); Abdyldaeva et al. (2023); UNICEF (2020); Grammenos (2020).

9. Discussion

9.1. The Complex Nature of Exclusion in Low Mobility

The results confirm that the status of NEET among youth with low mobility in the Kyrgyz Republic is not due to a single barrier, but to a combination of several mutually reinforcing exclusionary mechanisms. For example, a young woman in the Batken region may simultaneously face: physical distance from vocational training centers; a family environment that restricts independent travel; digital illiteracy, which prevents access to online learning; and lack of information about remote work or government support programs. The interplay of these barriers forms an exclusion profile that is qualitatively different from that of an urban young man who lacks skills but retains mobility, access to information, and social permission to seek employment (Toktogulova, 2019; UNICEF, 2020).

Persons with disabilities are a particularly vulnerable subgroup in the population with low mobility. Grammenos (2020) notes that exclusion from the labor market due to disability is consistently increasing in countries with weak social support infrastructure, a characteristic directly applicable to the Kyrgyz context, where the social protection system remains underfunded and geographically concentrated in Bishkek and regional centers. Abdyldaeva et al. (2023) note that less than 15% of registered persons with disabilities in Kyrgyzstan have access to adapted vocational training.

9.2. The Role of Digitalization: Opportunity and New Exclusion

The rapid expansion of digital labour platforms and online education creates a structural opportunity to partially decouple labour market participation from physical mobility. Remote work, gig economy platforms, and e-learning could theoretically allow low-mobility youth to access opportunities to earn money and develop skills regardless of location. However, data from the Kyrgyz Republic suggest that digitalization is now a source of new exclusion rather than inclusion for the most vulnerable: internet penetration in the Naryn and Batken regions remains below 40%, and digital literacy rates are particularly low among young women and persons with disabilities (World Bank, 2021; Abdyldaeva et al., 2023).

This finding has important policy implications: measures that rely solely on digital channels – including government employment portals, online job systems, and e-learning platforms – risk systematically bypassing the very populations for which they are intended. Therefore, effective digitalization strategies must be accompanied by parallel investments in communication infrastructure and access to devices, as well as digital literacy programs tailored for students with low mobility.

9.3. Gender as a cross-cutting variable

According to the results of the analysis, gender is the most stable predictor of NEET status among young people with low mobility, manifesting itself in all six dimensions of barriers identified in the frame, and reinforcing each of them. Data from the NSC of the Kyrgyz Republic show that the NEET rate among women in 2023 was about 39.7% nationwide, compared to 26.5% among men, with the gender gap increasing in the southern regions, where the norms of early marriage are most common (NSC KR, 2023). Young women in these settings face not only external barriers, but often internalized constraints due to the perception of participation in the labor market as inappropriate or secondary to household responsibilities (Djankov & Miner, 2016).

Measures that do not take into account the gender dimension – for example, through community-based work with families, flexible programming schedules that take into account care responsibilities, and the creation of a female-friendly educational environment – are unlikely to significantly reduce the NEET rate among women, regardless of their quality or funding. This finding is consistent with the broader literature on gender-sensitive active labour market policies in lower-middle-income countries (O'Higgins, 2017).

9. 4. Policy recommendations

Based on the analysis, the study proposes a four-component policy framework to reduce the NEET rate among youth with low mobility in the Kyrgyz Republic.

Component I – Digital Infrastructure and Literacy. The government, in partnership with international donors and telecommunications operators, should prioritize the expansion of broadband in remote areas, with a target of 70% internet penetration in Batken, Naryn, and Talas oblasts by 2027. These investments should be accompanied by a national digital literacy program specifically designed for out-of-school youth, with materials tailored for low-level users' literacy, and delivered through community resource centers (Abdyldaeva et al., 2023; World Bank, 2021).

Component II — Accessible training. The Ministry of Labor and Social Development should audit the geographical accessibility of all government vocational training facilities, identifying those that are unattainable in a two-hour trip for the majority of rural youth in each region. Mobile vocational training units – already tested in a limited form in the Jalal-Abad region – should be scaled up throughout the country, giving priority to areas with NEET levels above 35% (ILO, p. 2022).

Component III – Gender-sensitive active labour market policies. Active Labour Market Policy (ALMP) programmes targeting NEET youth should necessarily include gender-sensitive design principles as a condition of public funding. This includes: flexible scheduling that takes into account caregiving responsibilities; female-only groups where community norms require it; community-based components aimed at removing barriers at the family level; and mentoring by working women from similar backgrounds. NGOs with proven experience in gender programs should be involved as implementing partners (Toktogulova, 2019; UNICEF, 2020).

Component IV – Inter-agency coordination and data systems. Effectively reducing the NEET rate among young people with low mobility requires coordination between the ministries responsible for education, labor, social protection, transport and digital development – areas that are currently characterized by institutional fragmentation. A dedicated inter-ministerial working group should be established, supported by a disaggregated NEET monitoring system capable of tracking results on a quarterly basis by region, gender, status, disability, and Migration Status (NSC KR, 2023; Mamytbekov & Dzhaksybekov, 2021).

10. Conclusion

This article examines the structural and spatial barriers to labour market inclusion for groups of youth with low mobility in the Kyrgyz Republic, which contributes to the emerging literature on spatially differentiated NEET in Central Asia. The analysis found that the status of NEET among rural youth, young women, persons with disabilities and internal migrants is the result of cumulative, mutually reinforcing barriers that cannot be overcome by model youth employment measures.

Regional data for 2019–2023 confirm that the highest concentration of NEET is observed in geographically remote and economically marginalized areas, where the structural conditions for the exclusion of young people from the labor market are most severe. The gender gap in the NEET rate – about 13 percentage points nationwide, and even wider in the southern regions – represents the most acute measure of inequalities within the NEET population and requires priority attention from policy.

The study's proposed four-component policy framework – combining investment in digital infrastructure, geographically accessible training, gender-sensitive ALMPs and inter-agency coordination – provides a structured framework for policy-making. Implementing this framework will require not only financial resources, but also sustained political will, the involvement of civil society and international partners, and the development of robust disaggregated monitoring systems.

The main limitation of this study is the reliance on secondary data, which limits the granularity of group analysis. Further research should prioritize the collection of primary qualitative data—including in-depth interviews and focus groups—among NEET youth in identified subgroups and regions, as well as longitudinal tracking of program participants to assess the effectiveness of policies over time.

Author's contribution

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript.

Conflict of Interest

The authors declare no conflicts of interest

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Output Taxation, Productive Investment, and Cost Pass-Through under Cournot Competition

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Abstract

This paper examines the interaction between output taxation, productivity-enhancing investment, and tax pass-through under Cournot competition. A two-stage n-firm model is developed in which firms first choose cost-reducing investment and subsequently compete in quantities under a specific output tax. Investment reduces marginal production costs and involves a convex investment cost, while firms take the strategic effects of investment on subsequent market competition into account. The model derives the symmetric subgame-perfect equilibrium and characterizes the effects of taxation, investment productivity, and market structure on investment, output, effective marginal cost, and equilibrium prices. The results show that an increase in the output tax reduces both equilibrium output and productivity-enhancing investment. The investment response arises indirectly because taxation reduces the equilibrium production scale and therefore lowers the private return to cost reduction. Lower investment subsequently increases firms' effective marginal production costs. The analysis further shows that greater investment productivity increases both investment and output, while greater competition reduces investment per firm but can increase aggregate industry investment under the maintained parameter conditions. Finally, endogenous investment can amplify tax pass-through and generate tax over-shifting when investment productivity is sufficiently high relative to its cost. These results highlight an investment-mediated channel through which output taxation affects productive efficiency and tax incidence under imperfect competition.

Keywords: output taxation; productive investment; cost-reducing investment; Cournot competition; tax pass-through; tax over-shifting; industrial organization

1. Introduction

Taxation can affect firms not only through its direct effect on production costs but also through firms' incentives to invest in productivity-enhancing technologies. This interaction is particularly relevant in imperfectly competitive markets, where firms make strategic production decisions, and the anticipated scale of output affects the private return to cost-reducing investment. The relationship between market structure and investment has long been examined in the industrial-organization literature. Brander and Spencer (1983) show how cost-reducing R&D can have strategic effects in oligopoly, while Fershtman and Judd (1987) emphasize strategic incentives in imperfectly competitive markets. More recent studies examine process R&D and cost-reducing investment under alternative competitive environments. López and Vives

(2019), for example, analyze cost-reducing R&D in an n-firm Cournot setting with ownership structures and R&D spillovers, while Hinloopen and Vandekerckhove (2009) examine process R&D under Cournot andBertrand competition.

A related literature considers government policy jointly with endogenous cost-reducing investment. Kujal and Ruiz (2007) study strategic trade policy when firms undertake cost-reducing R&D before competing in an oligopolistic market. The present paper differs in both the policy instrument and the transmission mechanism. Rather than examining export policy and strategic trade effects, it considers a specific output tax and asks how taxation affects productivity-enhancing investment through equilibrium production. The framework is also related to environmental-economics models of taxation and innovation. Lambertini, Poyago-Theotoky, and Tampieri (2017) analyze environmental taxation and green R&D in an n-firm Cournot model, while Aoyama and Silva (2022) compare emission and output tax incentives for abatement innovation. Unlike these studies, the present analysis focuses on investment that directly reduces ordinary production costs rather than pollution or environmental damage.

The paper also contributes to the literature on tax incidence under imperfect competition. Seade (1985) examines tax shifting in oligopoly, Delipalla and Keen (1992) compare specific and ad valorem taxation under imperfect competition, and Weyl and Fabinger (2013) provide a general framework for pass-through. The present model connects this literature with endogenous productive investment. A specific output tax directly increases the effective cost of production, but it also reduces equilibrium output and thereby lowers the return to cost-reducing investment. Lower investment subsequently raises effective marginal production costs. Thus, taxation can affect prices through both a direct tax channel and an indirect investment-mediated cost channel.

The paper develops a two-stage n-firm Cournot model in which firms first choose productivity-enhancing investment and subsequently compete in quantities. Investment reduces marginal production costs and has a convex cost. The analysis derives the symmetric subgame-perfect equilibrium and examines the effects of output taxation, investment productivity, and market structure on investment, output, effective marginal cost, and tax pass-through.

The model yields four main results. First, higher output taxation reduces equilibrium output. Second, it reduces productivity-enhancing investment even though investment is not directly taxed, because the tax lowers the equilibrium production scale and therefore the return to cost reduction. Third, greater investment productivity increases both investment and output, while greater competition reduces investment per firm but increases aggregate industry investment under the maintained parameter restrictions. Finally, endogenous investment can amplify tax pass-through and generate tax over-shifting when investment is sufficiently productive relative to its cost. The contribution is therefore to identify a specific investment-mediated transmission mechanism through which output taxation affects productive efficiency and tax incidence within a tractable Cournot framework.

2. Literature Review

The relationship between strategic investment and product-market competition is well established in industrial organization. In oligopolistic markets, cost-reducing investment can influence not only a firm's production cost but also its subsequent strategic position. Brander and Spencer (1983) show that R&D investment can serve as a strategic commitment in oligopoly, demonstrating that investment decisions may affect competitive outcomes beyond their direct cost-reduction effect. Subsequent research has examined how process innovation and cost-reducing investment interact with different forms of market competition. Hinloopen and Vandekerckhove (2009), for example, compare process R&D incentives under Cournot and Bertrand competition, while López and Vives (2019) analyze cost-reducing R&D in an n-firm Cournot environment with ownership structures and R&D spillovers. This literature establishes the importance of the production scale and competitive environment for firms' incentives to undertake productivity-enhancing investment.

A closely related strand combines government policy with endogenous cost-reducing investment. Kujal and Ruiz (2007) examine strategic trade policy in a framework where firms undertake cost-reducing R&D before competing in an oligopolistic market. Their analysis is particularly relevant because it demonstrates that government policy and firms' investment decisions can interact strategically. The present paper shares the sequential structure in which investment precedes product-market competition but differs in its policy instrument and economic mechanism. Rather than studying export taxation or subsidization and strategic trade incentives, the present model considers a specific output tax imposed on production. The focus is therefore on how taxation changes the scale of production, how that change affects the return to productive investment, and how the resulting investment response feeds back into firms' marginal costs.

The interaction between taxation and innovation has also received substantial attention in environmental economics. Lambertini, Poyago-Theotoky, and Tampieri (2017) examine green innovation in an n-firm Cournot model with environmental taxation and identify an interaction between competition and firms' incentives to innovate. Aoyama and Silva (2022) compare emission and output tax incentives for abatement innovation in a Cournot oligopoly. These contributions demonstrate that tax policy can affect firms' innovation decisions in addition to its direct regulatory effect. However, their primary concern is environmental innovation and pollution abatement. The present model instead considers productivity-enhancing investment that directly lowers the marginal cost of ordinary production. Consequently, the investment channel in this paper operates through the firm's productive scale rather than through an environmental externality, emissions target, or abatement requirement.

A further literature examines taxation and price pass-through under imperfect competition. Seade (1985) analyzes the shifting of cost increases and taxation in oligopolistic markets, showing that strategic market behavior can affect the extent to which taxes are reflected in prices. Delipalla and Keen (1992) compare specific and ad valorem taxation under imperfect competition and demonstrate that the incidence of alternative tax instruments depends on market structure. More generally, Weyl and Fabinger (2013) develop a framework for analyzing pass-through under imperfect competition and emphasize the role of firms' strategic responses to changes in marginal costs. This literature provides the basis for understanding why the relationship between a statutory per-unit tax and the resulting market price need not be one-to-one and why tax over-shifting can arise under certain market conditions.

The present paper connects these strands through an endogenous productive-investment mechanism. In the standard tax-incidence literature, a tax changes firms' effective marginal costs directly. In the present framework, the tax generates an additional indirect effect. A higher output tax reduces equilibrium production; the lower production scale reduces the private return to cost-reducing investment; and lower investment subsequently raises the firm's effective marginal production cost. The equilibrium price therefore reflects both the direct effect of taxation and the endogenous adjustment of productive efficiency. When investment is sufficiently productive relative to its cost, this additional channel can amplify tax pass-through and generate over-shifting.

The contribution should therefore be understood as a specific extension of existing theoretical mechanisms rather than as a claim that taxation, Cournot competition, or cost-reducing investment has not previously been studied. Existing research has separately established the strategic importance of cost-reducing investment, the interaction between government policy and investment, and the determinants of tax pass-through under imperfect competition. The present paper brings these elements together in a tractable two-stage n-firm Cournot model and isolates the transmission from output taxation to productive investment and subsequently to effective marginal cost and price. In addition, the model distinguishes between firm-level and aggregate investment responses to competition, showing that greater competition can reduce investment per firm while increasing total industry investment. This provides a focused theoretical contribution to the literature on taxation, productive investment, and imperfect competition.

3. Theoretical Model

Consider an industry with $n \geq 2$ identical firms competing in quantities. The model follows the standard Cournot framework, in which firms choose output strategically while taking the quantities of their rivals as given (Cournot, 1838). Firm i chooses output $q_i \geq 0$, while aggregate industry output is

$$Q = \sum_{i=1}^{n} q_i. \quad (1)$$

Market demand is represented by the linear inverse demand function

$$p = A - BQ. \quad (2)$$

where $A>0$ is the demand intercept and $B>0$ measures the sensitivity of price to aggregate output.

Each firm has a constant baseline marginal production cost $c>0$. Before competing in quantities, firms undertake productivity-enhancing investment. Let $I_i \geq 0$ denote the investment of firm i. Investment reduces marginal production cost according to

$$MC_i = c - \alpha I_i, \quad (3)$$

where $\alpha>0$ measures the effectiveness of investment in reducing marginal cost.

Investment has a convex cost

$$C(I_i) = \gamma I_i^2/2, \quad (4)$$

where $\gamma>0$ measures the marginal cost of investment.

The government imposes a specific output tax $\tau \geq 0$ on each unit produced. Firm i's profit is therefore

$$\pi_i = [p - c + \alpha I_i - \tau]q_i - \gamma I_i^2/2. \quad (5)$$

Substituting equation (2) into equation (5) gives

$$\pi_i = [A - BQ - c + \alpha I_i - \tau]q_i - \gamma I_i^2/2. \quad (6)$$

The model focuses on productivity-enhancing investment rather than environmental or pollution-abatement investment. The investment decision is made before product-market competition, so firms take into account the effect of investment on subsequent Cournot outcomes.

3.1 Timing of the Game

The model consists of two stages. In the first stage, firms simultaneously choose their productivity-enhancing investment I_i. In the second stage, after investment decisions have been made, firms simultaneously choose output quantities under Cournot competition. The market price is subsequently determined by aggregate output.

The equilibrium concept is a subgame-perfect Nash equilibrium. The output tax τ is treated as an exogenous policy parameter.

3.2 Cournot Competition

Given the investment profile, firm i chooses q_i to maximize

$$\pi_i = [A - B(q_i + Q_{-i}) - c + \alpha I_i - \tau]q_i - \gamma I_i^2/2, \quad (7)$$

where

$$Q_{-i} = \sum_{j \neq i} q_j$$

is the aggregate output of firm i's rivals.

The first-order condition is

$$\partial \pi_i / \partial q_i = A - c - \tau + \alpha I_i - BQ_{-i} - 2Bq_i = 0. \quad (8)$$

Thus, the quantity best-response function is

$q_i = [A - c - \tau + \alpha I_i - BQ_{-i}]/(2B)$. (9)

Investment increases the firm's optimal output because it reduces effective marginal production cost. At the same time, quantities are strategic substitutes because higher rival output reduces the firm's optimal quantity.

For a given investment profile, solving the system of Cournot first-order conditions gives the second-stage equilibrium quantities. In the symmetric case, where $I_i = I$ and $q_i = q$ for all firms,
$Q = nq$

and

$Q_{-i} = (n - 1)q$.

Substitution into equation (8) yields

$A - c - \tau + \alpha I - B(n + 1)q = 0$.

Hence, conditional on symmetric investment, the second-stage equilibrium output per firm is

$q = [A - c - \tau + \alpha I]/[B(n + 1)]$. (10)

3.3 Productivity-Enhancing Investment

At the first stage, each firm chooses investment while anticipating the strategic consequences for the subsequent Cournot equilibrium.

At the Cournot equilibrium, equation (8) implies

$p - c + \alpha I_i - \tau = Bq_i$.

Consequently, operating profit before investment expenditure can be written as

$\pi_i^O = Bq_i^2$.

Firm i's first-stage problem is therefore

$\max I_i \geq 0\ V_i = B[q_i^*(I_i, I_{-i})]^2 - \gamma I_i^2/2$. (11)

Because investment changes the equilibrium output of both the investing firm and its rivals, the strategic effect of investment must be taken into account.

Differentiating the second-stage Cournot system with respect to I_i gives

$\partial q_i^*/\partial I_i = \alpha n/[B(n + 1)]$. (12)

Therefore, the first-order condition for an interior investment equilibrium is

$2Bq_i^*(\partial q_i^*/\partial I_i) - \gamma I_i = 0$.

Using equation (12),

$[2\alpha n/(n + 1)]q_i^* - \gamma I_i = 0$. (13)

Hence, the optimal investment condition is

$I_i^* = [2\alpha n/(\gamma(n + 1))]q_i^*$. (14)

Equation (14) shows that the incentive to invest depends positively on equilibrium production. Unlike a non-strategic investment problem, however, the return to investment incorporates the strategic effect of investment on the firm's position in the subsequent Cournot market.

The second derivative of the reduced-form investment problem is

$d^2V_i/dI_i^2 = 2\alpha^2n^2/[B(n + 1)^2] - \gamma$. (15)

Thus, the first-stage investment problem is strictly concave when

$2\alpha^2n^2<\gamma B(n + 1)^2$. (16)

This condition is maintained throughout the analysis.

3.4 Symmetric Subgame-Perfect Equilibrium

Under symmetry, equation (14) becomes

$I = [2\alpha n/(\gamma(n + 1))]q$. (17)

Substituting equation (17) into equation (10) gives

$q = [A - c - \tau + 2\alpha^2nq/(\gamma(n + 1))]/[B(n + 1)]$. (18)

Rearranging,

$[B(n + 1) - 2\alpha^2n/(\gamma(n + 1))]q = A - c - \tau$. (19)

Define

$H \equiv \gamma B(n + 1)^2 - 2\alpha^2n$. (20)

Under condition (16), $H>0$. The symmetric equilibrium output per firm is therefore

$q^* = \gamma(n + 1)(A - c - \tau)/H$. (21)

Equilibrium investment per firm is

$I^* = 2\alpha n(A - c - \tau)/H$. (22)

Aggregate industry output is

$Q^* = \gamma n(n + 1)(A - c - \tau)/H$. (23)

Aggregate investment is

$I_t^* = 2\alpha n^2(A - c - \tau)/H$. (24)

where I_t^* denotes total industry investment.

The equilibrium market price is

$p^* = A - BQ^*$. (25)

For an interior equilibrium with positive output and investment, it is sufficient to require

$A - c - \tau>0$ (26)

and

$2\alpha^2n^2<\gamma B(n + 1)^2$. (27)

Proposition 1. Existence and Uniqueness

Under conditions (26) and (27), the model possesses a unique symmetric interior subgame-perfect equilibrium characterized by equations (21)–(25).

Proof. The second-stage quantity problem is strictly concave because
$\partial^2\pi_i/\partial q_i^2 = -2B<0$.

The first-stage reduced-form investment problem is strictly concave under condition (27). Therefore, the first-order conditions characterize the unique symmetric interior equilibrium. Substitution of the investment condition into the second-stage Cournot equilibrium yields equations (21)–(25).

3.5 Taxation and Productive Investment

From equation (22),

$\partial I^*/\partial \tau = -2\alpha n/H < 0$. (28)

Proposition 2. Output Taxation Reduces Productive Investment

An increase in the output tax reduces equilibrium investment by each firm.

Proof. Since $\alpha > 0$, $n > 0$, and $H > 0$, equation (28) is strictly negative.

The mechanism is indirect. A higher output tax reduces equilibrium production and therefore reduces the private return to cost-reducing investment. Thus, productive investment can decline even though investment itself is not directly taxed.

3.6 Taxation and Output

From equation (21),

$\partial q^*/\partial \tau = -\gamma(n + 1)/H < 0$. (29)
Similarly, from equation (23),
$\partial Q^*/\partial \tau = -\gamma n(n + 1)/H < 0$. (30)

Proposition 3. Output Taxation Reduces Production

An increase in the output tax reduces both firm-level and aggregate industry output.

Proof. Equations (29) and (30) are strictly negative because $H > 0$.
The output tax therefore affects production through both its direct effect on firms' effective costs and its indirect effect through lower productivity-enhancing investment.

3.7 Investment Productivity

From equation (22),

$\partial I^*/\partial \alpha = 2n(A - c - \tau)[\gamma B(n + 1)^2 + 2\alpha^2 n]/H^2 > 0$. (31)

Proposition 4. Investment Productivity Increases Investment

An increase in the effectiveness of productivity-enhancing investment increases equilibrium investment.

Proof. Under the maintained interior-equilibrium conditions, all terms in equation (31) are positive. Therefore,
$\partial I^*/\partial \alpha > 0$.
Investment productivity also increases equilibrium output. From equation (21),
$\partial q^*/\partial \alpha = 4\alpha\gamma n(n + 1)(A - c - \tau)/H^2 > 0$. (32)
Thus, more effective productivity-enhancing investment increases both investment and equilibrium output.

3.7 Market Structure and Investment

The number of firms affects investment incentives at both the firm and industry levels. From equation (22),

$I^* = 2\alpha n(A - c - \tau)/[\gamma B(n + 1)^2 - 2\alpha^2 n]$. (33)
Treating n as a continuous measure of market structure, differentiation gives
$\partial I^*/\partial n = -2\alpha\gamma B(A - c - \tau)(n^2 - 1)/H^2 < 0$. (34)

Proposition 5. Competition Reduces Investment per Firm

An increase in the number of firms reduces investment by each individual firm.

Proof. For $n \geq 2$, $A - c - \tau > 0$, and $H > 0$, equation (34) is strictly negative.

The intuition is that additional firms reduce the strategic value of investment for an individual firm. As competition becomes more intense, each firm's equilibrium production scale is generally reduced, weakening the private incentive to undertake cost-reducing investment.

The effect on aggregate investment is different. From equation (24),
$I_t^* = 2\alpha n^2(A - c - \tau)/[\gamma B(n + 1)^2 - 2\alpha^2 n]$. (35)
Differentiating with respect to n gives
$\partial I_t^*/\partial n = 4\alpha n(A - c - \tau)[\gamma B(n + 1) - \alpha^2 n]/H^2$. (36)
Therefore,
$\partial I_t^*/\partial n > 0$
when
$\alpha^2 n < \gamma B(n + 1)$. (37)

Proposition 6. Competition Can Increase Aggregate Investment

An increase in the number of firms can reduce investment per firm while increasing aggregate industry investment when condition (37) holds.

The result reflects the distinction between the intensive and extensive margins of investment. More competition reduces investment by each firm, while the larger number of firms can nevertheless increase total investment across the industry.

3.8 Taxation and Effective Production Cost

The firm's equilibrium effective marginal production cost is

$MC^* = c - \alpha I^*$. (38)
Using equation (22),
$MC^* = c - 2\alpha^2 n(A - c - \tau)/H$. (39)
Differentiating with respect to taxation,
$\partial MC^*/\partial \tau = 2\alpha^2 n/H > 0$. (40)

Proposition 7. Taxation Increases Effective Production Costs through Investment

An increase in the output tax increases the firm's effective marginal production cost by reducing productivity-enhancing investment.

The result identifies the central indirect transmission mechanism of the model. Although the government does not directly tax investment, taxation reduces investment and thereby weakens the cost-reducing effect of productive expenditure.

3.9 Tax Pass-Through

Using equations (23) and (25), equilibrium price can be expressed as

$p^* = A - B\gamma n(n + 1)(A - c - \tau)/H$. (41)
Differentiating with respect to the output tax gives
$\partial p^*/\partial \tau = B\gamma n(n + 1)/H > 0$. (42)

Proposition 8. Output Taxation Increases the Market Price

An increase in the output tax raises the equilibrium market price.

Tax over-shifting occurs when the increase in the market price exceeds the statutory tax:
$\partial p^*/\partial \tau > 1$. (43)
Using equation (42), this condition requires
$B\gamma n(n + 1) > H$. (44)
Substituting equation (20),
$B\gamma n(n + 1) > \gamma B(n + 1)^2 - 2\alpha^2 n$.

Therefore,
$2\alpha^2 n > \gamma B(n+1)$, (45)
or equivalently,
$\alpha^2 > \gamma B(n+1)/(2n)$. (46)

Proposition 9. Endogenous Investment Can Amplify Tax Pass-Through

If

$\alpha^2 > \gamma B(n+1)/(2n)$,
the equilibrium market price increases by more than the statutory output tax.

Proof. From equation (42), tax over-shifting requires $B\gamma n(n+1) > H$. Substituting equation (20) and rearranging yields condition (46).

The economic interpretation is that taxation generates two related effects. The direct effect increases firms' effective per-unit costs, while the indirect effect reduces productivity-enhancing investment and consequently increases the underlying marginal production cost. When investment is sufficiently productive relative to its cost, this endogenous investment response amplifies the price effect of taxation.

3.10 Equilibrium Profit

At the Cournot equilibrium, the second-stage first-order condition implies

$p^* - c + \alpha I^* - \tau = Bq^*$. (47)
Operating profit before investment expenditure is therefore
$B(q^*)^2$.
Total equilibrium profit is
$\pi^* = B(q^*)^2 - \gamma(I^*)^2/2$. (48)
Using equation (17),
$\pi^* = [B - 2\alpha^2 n^2/(\gamma(n+1)^2)]q^{*2}$. (49)
Under condition (27),
$\pi^* > 0$.

3.11 Main Theoretical Implications

The model yields four principal results. First, an increase in the output tax reduces both firm-level and aggregate equilibrium output. Second, the output tax reduces productivity-enhancing investment even though investment itself is not directly taxed. This effect arises because taxation reduces the equilibrium scale of production, thereby lowering the private return to cost-reducing investment.

Third, greater competition reduces investment at the firm level but can increase aggregate industry investment under the parameter condition specified in equation (37). This result highlights the distinction between firm-level investment incentives and the overall investment response of the industry.

Fourth, endogenous investment can amplify tax pass-through. When investment is sufficiently productive relative to its cost, the reduction in investment induced by taxation raises firms' effective marginal production costs and can lead to tax over-shifting, whereby the increase in the market price exceeds the statutory tax.

These results identify an investment-mediated transmission mechanism linking taxation to market outcomes. Output taxation reduces production, the lower production scale weakens incentives for productivity-enhancing investment, and the resulting decline in investment increases effective marginal production costs. This endogenous cost response can, in turn, strengthen the effect of taxation on equilibrium prices.

4. Conclusion

This paper developed a two-stage n-firm Cournot model to examine the interaction between output taxation and productivity-enhancing investment. Firms first choose cost-reducing investment and subsequently compete in quantities under a specific output tax.

The results show that higher output taxation reduces both equilibrium output and productive investment. The key mechanism is indirect: taxation reduces the equilibrium scale of production, which lowers the private return to cost-reducing investment. Lower investment subsequently raises firms' effective marginal production costs. The model also shows that greater investment productivity increases both investment and output, while greater competition reduces investment per firm but increases aggregate industry investment under the maintained parameter restrictions.

The analysis further shows that endogenous investment can strengthen tax pass-through. When investment is sufficiently productive relative to its cost, the reduction in investment following taxation raises effective production costs and may generate tax over-shifting. Thus, the incidence of output taxation depends not only on its direct effect on firms' production decisions but also on the endogenous investment response of firms.

The model is deliberately simple and abstracts from firm heterogeneity, investment spillovers, and dynamic adjustment. These limitations provide natural directions for future research. Extensions incorporating heterogeneous firms, technological spillovers, or dynamic investment decisions could provide further insight into how taxation affects productive capacity and tax incidence in imperfectly competitive markets.

Author Contributions

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript

Conflict of Interest

The authors declare no conflicts of interest

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Assessment of the efficiency of production infrastructure in the agricultural sector in Azerbaijan

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Abstract

This article examines the current state of production infrastructure in the agricultural sector in Azerbaijan and its impact on the efficiency of agricultural production. The main objective of the study is to assess the economic efficiency of irrigation systems, transport and communication networks, warehouse and logistics centers, energy supply facilities, and other production infrastructure operating in the agricultural sector. It has also been determined that the uneven level of infrastructure provision in some regions is one of the main factors limiting the competitiveness of agricultural production. As a result of the analyses, recommendations were developed to increase the efficiency of infrastructure projects, introduce innovative technologies, and expand public-private partnership mechanisms.

Keywords: agrarian sector, production infrastructure, efficiency, agriculture, logistics, irrigation systems, regional development, Azerbaijan

1.Introduction

1.1. The essence and role of production infrastructure in the agricultural sector

Agriculture is one of the important sectors of the Azerbaijani economy and plays an important role in providing food to the population, increasing employment, and in the socio-economic development of regions. The sustainable development of the agricultural sector depends not only on land and labor resources, but also on a developed production infrastructure. Production infrastructure is a set of technical, economic, and organizational means necessary for the production, processing, storage, and delivery of agricultural products to consumers. As a result of the reforms implemented in the country's economy, which is currently undergoing a successful development process, it is expected that economic, organizational, technical, and technological sustainable mechanisms will be established that ensure the efficiency of the production process, and individual production sectors will develop further in accordance with market demands. However, under modern market relations, it is not only quantitative indicators that drive the growth of production, but also the formation and development of the necessary production infrastructure elements to implement this process, which requires significant relevance.

In general, the main aspect that makes the topic relevant is that there is increasing attention paid to further increasing the production volume of agricultural products, increasing their productivity, and effectively using existing potential in order to give dynamism to existing trends. This goal requires great

importance to be given to the establishment of processing and service enterprises, packaging and transportation, the adaptation of the material and technical base of agriculture to new economic relations, in short, the further strengthening of the achieved trends.

Agricultural economist Lydia Zepeda notes that infrastructure investments made by the state create the foundation for private investment. In his opinion, without roads, irrigation systems, reservoirs, and marketing infrastructure, it is impossible to introduce technologies and increase productivity. He emphasizes that infrastructure investments accelerate the adoption of technologies and improve market access for agricultural products (Zepeda, 2001, p. 5).

Another economist, Robert Evenson, believes that agricultural production infrastructure also includes agricultural advisory and training services. According to his research, increasing farmers' knowledge and spreading innovations have a significant impact on increasing productivity (Evensonç 1997, p.24).

Production infrastructure is a set of logistical and organizational systems that ensure the uninterrupted and efficient implementation of the agricultural production process.

The production infrastructure in the agricultural sector consists of the following elements:

-irrigation and land reclamation systems;

-agricultural machinery and agro-services;

-transport and logistics networks;

-electricity and communication systems;

-warehouses and refrigeration complexes;

-processing plants;

-agroparks and agricultural clusters;

-information and advisory services.

These infrastructure facilities create conditions for reducing production costs in agriculture, increasing productivity, and minimizing crop losses.

The analysis shows that the production process is characterized as a complex socio-economic and production infrastructure system with its own specific characteristics, encompassing the stages of preparation, sale, supply, processing, and consumption of products. From the perspective of modern economic development, the concept of infrastructure has a deeper and more comprehensive content. However, the issues of using infrastructure factors in the market economy system are at the stage of formation in some areas in terms of efficiency. Although the implementation of economic reforms in the agrarian sector of the country's economy and the application of foreign experiences have led to some economic growth, there are sometimes also cases of tension. The poor development of individual infrastructure elements in the agricultural sector also has a negative impact on overall development.

To overcome this deficiency, it is essential to formalize and develop the production and market infrastructure in a comprehensive manner. First of all, infrastructure, as a complex component of production sectors, acts as a subsystem serving the main production. Of course, the final results of the economy depend not only on the level of development of these sectors. It also depends on the level of development of other regions serving the agricultural sector. At this time, the development of both production infrastructures that ensure large-scale production, transportation, supply and processing of agricultural and food products, as well as infrastructure elements that create conditions for the efficient use of these products, emerges as an equally important matter.

It must be admitted that the agricultural sector in our country lags somewhat behind other sectors of the economy in terms of infrastructure provision. The level of service of the existing infrastructure entities here does not yet meet the necessary market requirements. In the agrarian economy, especially in the production process, it is very important for economic entities operating in the agricultural sector to have sufficient access to various machinery, equipment and facilities, pest control products, water supply, warehouses for the purchase and storage of products, modern and convenient roads, and numerous other factors. The weak development of farm communication services in some farms is also a factor slowing down the development of this sector. The gradual resolution of all these problems is a necessary challenge.

However, a number of problems remain:

- limited water resources;

- the presence of outdated irrigation networks;

- differences in infrastructure provision across regions;

- poor development of storage and logistics capabilities in some regions;

- limited access of small farmers to modern technologies.

The efficiency of irrigation systems in particular is critical for agricultural production. In Azerbaijan, 85–90% of crop production is grown on irrigated land, and the quality of water supply directly affects productivity.

In recent years, state programs implemented in Azerbaijan to develop the agricultural sector, the creation of agroparks, the renovation of land reclamation and irrigation systems, and the establishment of logistics centers have had a positive impact on the development of production infrastructure (State Program, 2026). However, assessing and improving the efficiency of existing infrastructure remains a pressing issue.

2. Evaluation of the efficiency of production infrastructure.

The assessment of infrastructure efficiency is based on several economic and technical indicators. If the productivity indicator increases the volume of output per hectare as a result of infrastructure development, this indicates its efficiency (Mustafaeva, Gambarova, & Abbasova, 2024). Resource utilization level: The economic use of water, energy, fuel, and labor resources is one of the main indicators of the effective functioning of infrastructure. Reducing product losses: Modern storage and refrigeration systems reduce product losses, increasing overall profitability.

Logistics costs, transportation, and road infrastructure have a direct impact on product transportation costs. A decrease in costs indicates an increase in efficiency.

The profitability level, the ratio of profit from production to production costs, determines the economic efficiency of the infrastructure.

The efficiency of using production potential in the agricultural sector should be assessed based on the interaction of land, labor, and technical resources. (Amrahov, 2020, p. 45).

The development of production infrastructure in the agricultural sector in Azerbaijan has had a positive impact on the increase in the production volume of agricultural products.

Table 1. Efficiency of production infrastructure in the agricultural sector

Criterion	Evaluation indicator
productivity	volume of product obtained per hectare
resource efficiency	water, energy, and labor consumption
logistics costs	product transportation and storage costs
level of loss	crop loss and waste volume

profitability	profitability index
market access	product sales speed and export opportunities
level of innovation	application of digital technologies

(Source: prepared by the author.)

It would be advisable to implement the following measures to increase efficiency:

-expansion of drip and sprinkler irrigation technologies;

-increasing the number of agroparks and logistics centers;

-development of cold storage networks;

-application of digital agriculture and smart management systems;

-improving farmers' access to technical and financial resources;

-development of the processing industry and expansion of the added value chain.

By examining the effectiveness of the application of information and communication technologies in the agricultural sector, it is shown that the development of digital infrastructure facilitates farmers' access to information, improves the decision-making process, and makes production management more effective. (Bedirzade, 2021, p. 22).

Although the efficiency of agricultural production infrastructure in Azerbaijan has increased significantly in recent years, there is potential for further development, especially in the areas of irrigation, logistics, and digitalization. Modernization of infrastructure creates conditions for increasing agricultural productivity, reducing production costs, expanding export opportunities, and strengthening the country's food security (Məmmədov, 2025).

Theodore Schultz and Zvi Griliches emphasized the role of education, research, and innovation infrastructure when explaining productivity growth in agriculture. Schultz believed that farmers' education and skills directly affected production efficiency. Griliches has shown that investments in agricultural research and advisory services are an important factor in increasing productivity (Chang & Zepeda, 2001). p. 35).

Assessing the efficiency of production infrastructures in the agricultural sector involves determining the impact of the material and technical base used in agriculture, irrigation systems, transport and logistics networks, warehousing, agroparks, and other infrastructure elements on production results. Efficiency assessment allows us to determine the economic results of investments in these facilities and their impact on productivity and profitability.

Thus, economic efficiency is determined by the ratio of funds invested in infrastructure facilities to the results achieved. The following indicators are used here:

-productivity growth rate;

-reduction in production costs;

-reduction in product cost;

-increase in profits and profitability;

-investment payback period (Amrahov et al.,2022)

For example, the implementation of a modern drip irrigation system can reduce water consumption by 30–50% and labor costs by 20–30%, which increases the economic efficiency of production.

Technical efficiency characterizes the ability to produce maximum output using available resources. Technical efficiency evaluation indicators:

-Production per hectare;

-Technical load factor;

-Efficiency factor of irrigation systems;

-Utilization level of storage facilities;

-Technical equipment service life.

Among foreign scholars, Farrell evaluated technical efficiency as the proximity to the maximum level of production that can be achieved with existing resources. The development of agricultural infrastructure also affects social well-being in rural areas. The main indicators include the following:

-number of new jobs;

-increase in rural incomes;

-reduction in rural-urban migration;

-increase in employment levels;

-improvement in living conditions.

For example, the creation of agroparks creates the conditions for the creation of hundreds of permanent and seasonal jobs. One of the important features of modern agricultural infrastructure is environmental sustainability. The evaluation indicators:

-water saving level;

-reduction of soil salinization;

-reduction of energy consumption;

-reduction of waste;

-protection of soil fertility.

In this regard, drip irrigation systems and energy-saving technologies have the highest environmental efficiency indicators.

3. Current status of agricultural production infrastructure in Azerbaijan

The reforms carried out in the agrarian sector during the period of independence gave impetus to the development of agriculture. The state has adopted a number of programs to support the agricultural sector. Agroparks operating in the country allow for the application of modern technologies in agriculture. Production, processing, packaging, and logistics services in agroparks are organized as a single system.

Important projects have been implemented to develop irrigation systems. As a result of the construction of new reservoirs and the reconstruction of existing land reclamation networks, water supply to thousands of hectares of land has been improved. In addition, the renovation of rural roads and the expansion of logistics infrastructure have enabled faster delivery of products to markets.

Table 2. Main indicators of agricultural infrastructure (as of the end of 2023)

Indicators	Numbers
Irrigated agricultural lands	approximately 1.45 million ha
Length of collector-drainage network	More than 31 thousand km
Main and inter-farm canals	More than 52 thousand km
Number of reservoirs	More than 140
Total capacity of grain storage facilities	More than 1.8 million tons
Cold storage capacity	About 500 thousand tons
Number of agroparks	More than 50

Number of tractors in agricultural machinery parks	About 35 thousand pieces
Number of combines	More than 2 thousand 500

(Source: Statistical compilation "Agriculture of Azerbaijan".)

These indicators indicate that the material and technical base of agricultural production in the country has been expanded in recent years. In particular, irrigation systems, storage facilities, and agroparks are considered key elements of agricultural production infrastructure (Azərbaycanın kənd təsərrüfatı, 2024).

Modernization of production infrastructure in the agricultural sector of Azerbaijan has been one of the main directions of state policy in recent years. Expanding irrigation systems, creating agroparks, strengthening technical support, and developing warehousing serve to increase productivity in agriculture.

Let us try to provide an analysis of the current state of agricultural production infrastructure in Azerbaijan.

1. Irrigation infrastructure. Since Azerbaijan's agriculture operates mainly in arid climates, irrigation infrastructure is a key element of agricultural production. Approximately 1.4–1.5 million hectares of agricultural land are irrigated in the country. In recent years, the application of modern irrigation systems such as drip and sprinkler irrigation has expanded. For example, advanced irrigation systems were installed on 26,000 hectares (73%) of the 35,700 hectares of irrigated area used in agroparks in 2024. The breadth of the irrigation network is an important advantage for the country's food security. However, in some regions, water losses and outdated canals still negatively affect productivity.

2. Agroparks and production complexes. Agroparks in Azerbaijan have become a key component of the industrial-based development model of agriculture. In general, in agroparks in 2024:

1. 42.5 thousand hectares of land were brought into crop rotation;

2. 34.1 thousand tons of wheat;

3. 25.5 thousand tons of barley;

4. 91.8 thousand tons of corn;

5. 49.7 thousand tons of sugar beet were produced;

6. The value of total agricultural products amounted to 150 million manats.

Agroparks play an important role in implementing modern technologies, increasing productivity, and increasing export potential (Niftiyev & Ibadoghlu, 2023).

3. Technical support. According to the State Statistics Committee, thousands of tractors, combine harvesters, and other equipment are used in agriculture. The state is improving the provision of machinery to farmers through preferential leasing mechanisms. The fleet of agricultural machinery is updated and expanded every year. Although the provision of machinery has improved compared to previous years, access to machinery is still limited in some small farms.

4. Storage and logistics infrastructure. A network of cold storage and grain warehouses has been formed in the country for the storage of fruit and vegetable products. These facilities allow for reduced crop losses, mitigate seasonal price volatility, and expand export opportunities. New logistics centers and warehouse complexes have been created within the framework of state programs.

Increased storage capacity allows for uninterrupted product delivery to the market, but in some regions, the availability of logistics services is not fully ensured.

Thus, the agricultural production infrastructure in Azerbaijan has developed significantly over the last decade. Modernization of irrigation systems, creation of agroparks, modernization of agricultural machinery, and construction of logistics facilities have increased the competitiveness of the agricultural

sector. However, efficient use of water resources, reducing regional infrastructure disparities, and improving technical support for small farmers remain key priorities for future development (Atashov, 2017).

4. Conclusion

It would be advisable to implement the proposed measures to increase the efficiency of production infrastructure in the agricultural sector in Azerbaijan. These measures include the following:

-Expanding the application of water-saving technologies;

-Implementation of new land reclamation projects;

-Increasing the number of agroparks;

-Strengthening state support for farmers;

-Development of digital agricultural systems;

-Stimulating the application of innovative technologies in agriculture.

The development of production infrastructure in the agricultural sector in Azerbaijan plays an important role in the modernization of agriculture. As a result of state programs implemented in recent years, irrigation systems, agroparks, logistics centers, and rural roads have developed significantly. These measures have created conditions for increasing productivity, reducing production costs, and increasing the competitiveness of agricultural products. However, problems such as limited water resources, regional differences, and the obsolescence of some infrastructure facilities still remain. In the future, the introduction of innovative technologies, expansion of digitalization, and strengthening of state support will allow for further increasing the efficiency of production infrastructures in the agricultural sector.

Author Contributions

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript

Conflict of Interest

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The Role of Innovation-Investment Mechanisms in the Commercialization of Scientific Research Results in Azerbaijan

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Abstract
The article examines the role of innovation-investment mechanisms in the commercialization of scientific research results in Azerbaijan. The processes of efficient organization of scientific research and commercialization of their results are analyzed. The importance of developing and implementing new functional mechanisms in an environment of accelerated development of science and technology is substantiated. The advantages of digital transformations were noted. The importance of using artificial intelligence tools was stated. The problems of developing, adopting, and applying innovations in universities were examined. The possibilities of expanding university-state-industry cooperation were considered. The processes taking place in countries of the world related to the application of high technologies were analyzed, and attention was paid to advanced practices. The exceptional role of technoparks in organizing scientific research and applying their results to production processes was noted. The advantages and characteristics of technoparks as multifunctional economic spaces were given. The attractiveness of technoparks in the development of high technologies and in attracting related investments was brought to attention. The work done in the direction of organizing Scientific Research in Azerbaijan was analyzed and evaluated. The steps taken and measures taken to improve the legislation and create an innovation system in the country were presented. The increased interest in the implementation of new educational programs and the creation of innovation centers in universities was reported. The measures taken to improve Azerbaijan's economic development model were noted. The digital economy strategy was approved, and the adoption of an action plan to intensify digital transformation was noted as a positive aspect. The priority of using artificial intelligence tools in the country was noted. The main priorities of state policy towards improving the innovation and investment climate in Azerbaijan were announced. The positive aspects of the application of high technologies, including “smart” technologies, in the liberated territories were given. Recommendations and proposals were made for the most efficient organization of scientific research in Azerbaijan in the near future and the development of mechanisms for the commercialization of its results.

Keywords: Azerbaijan, science and technology, scientific research, universities, industrial entities, innovation, investment, innovation-investment mechanisms, commercialization

1.Introduction

In the context of modern global transformations, the development of science, more efficient organization of scientific research, and application of its results are of exceptional importance. In recent years, serious importance has been attached to the development of science and the intensive application of technologies in Azerbaijan. In this regard, concepts, strategies, and state programs are being adopted. National Priorities have been defined in our country for the period up to 2030 (Azerbaijan 2030: National

Priorities for Socio-Economic Development, 2021). At the same time, the Strategy for the Development of the Digital Economy in the Republic of Azerbaijan for 2026–2029 was approved by the Decree of the President of the Republic of Azerbaijan dated December 10, 2025 (Strategy for the Development of the Digital Economy in the Republic of Azerbaijan for 2026–2029, 2025). In addition, by the Decree of the President of the country dated February 27, 2026, the Action Plan for Accelerating Digital Development in the Republic of Azerbaijan for 2026−2028 was adopted (Action Plan for Accelerating Digital Development in the Republic of Azerbaijan for 2026−2028, 2026). Also, by the Decree of the President of the Republic of Azerbaijan dated March 19, 2025, the Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025–2028 was approved and is being implemented (Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025–2028, 2025). All this shows that successive steps are being taken by the state for the development of science and technology in Azerbaijan.

The Azerbaijani economy is entering a new stage of development. The transition to a high-tech economic development model based on the efficient use of national resources is one of the important tasks (Samadzadeh, Z.A., 2021). For this, large-scale scientific research should be conducted, and its results should be used effectively.

It is extremely important to organize the activities of scientific research institutions in Azerbaijan in accordance with the requirements of the modern era and to demonstrate the unity of science and education, to increase interest in Scientific Research (SR) in scientific research institutions and universities, to conduct fundamental research in the direction of the problems of the era, and to take additional stimulating and motivation-increasing measures in this regard. Currently, the funds allocated for scientific research in our country are very small, and in terms of the capabilities of the funds or relevant organizations in this field, there are not many alternative options for allocating financial resources to scientific research. And those that do exist are capable of ensuring scientific research in a very limited direction.

On the other hand, the level of education in universities, the organization of education based on world experience, the creation of scientific research centers, and the conduct of fundamental scientific research are still at the initial stage. Although these works have become relatively intensive in some universities of the country, it can be said that in most universities, it is very difficult to note the intensification of scientific research work and the development and application of mechanisms for the commercialization of the results of scientific research in this direction. Of course, as a result of the reforms carried out in the country's leading higher education institutions and the Azerbaijan National Academy of Sciences, new conditions have been created. Also, the subordination and structural form of relevant specialized scientific research institutes and institutions in many scientific research areas have been changed, and at the same time, a significant part of such institutions has been transferred to the subordination of the newly established Ministry of Science and Education. As a result, the prospects for a more integrated development of relations between science and research institutions and universities, expansion of relations, and conducting joint research have significantly increased. In this regard, it is necessary to ensure the formation and development of relations, the identification of commercialization problems between the country's scientific research institutions and universities, and the implementation of effective measures to apply the results of scientific research to production and service processes (Silich, V.A. & Silich, M.P., 2011).

In modern Azerbaijan, the role of science is determined by the need for socio-economic development of the state. The qualitative and quantitative increase in the results of intellectual activity, which is expressed in the form of various scientific and technical products, should ensure the development of innovative business and contribute to the increase in its volume. For this, there must be a certain provision of resources. Currently, one of the most important tasks in the provision of resources for scientific research is to expand the participation of business in financing science and increase the specific weight of extra-budgetary funds in the total amount of financing for scientific research and experimental and design work. It is also necessary to gradually increase the budget funds for scientific research and innovation, as well as attract additional

financial resources from the business sector by creating attractive opportunities for joint financing of scientific research and innovation projects. Public-private cooperation should be given priority in this area.

It should be noted that the modern stage of improving the work of industrial enterprises is characterized by the fact that the main productive force of its development is Scientific Research activity. This area of activity of industrial enterprises is currently distinguished by the attraction of a fairly large amount of investment. It is appropriate to divide Scientific Research work into two components: on the one hand, it includes applied research work, and on the other hand, experimental design work. At the same time, applied research work includes work in search of new scientific directions and work of experimental and theoretical planning. They are carried out in industrial enterprises to determine the technical feasibility of creating new types of equipment and technologies within a certain period of time.

Ensuring innovation and investment attractiveness in Azerbaijan is not an easy task. As we have noted, the processes of forming a national innovation system have not yet been completed in the country, or a network of innovation centers and technological centers has not been formed in our country (Cavadov, X.R., 2015). We also believe that very few companies operate in this area, or the appropriate innovation infrastructure has not been formed. Although the economic development processes in the country are proceeding rapidly, there are initiatives related to the transfer of new technologies from abroad (Shekaraliyev, A.Sh. & Shekaraliyev, Q.A., 2016). However, our conclusion is that in terms of investment and innovation attractiveness, problems still remain in Azerbaijan.

2. Research Results

It should be noted that digital mechanisms and artificial intelligence tools play an exceptional role in the efficient organization of scientific research. Digital mechanisms have brought new advantages in the in-depth analysis and objective assessment of problems in these areas (Gasimli, V. et all, 2023). On the other hand, it is necessary to look at these issues in a broader perspective from the point of view of consolidating the activities of the country's scientific research institutions and universities and forming and developing their relations with industrial entities, strengthening ties with relevant investment and innovation funds, expanding cooperation at the international level, and finally, from the point of view of the experience of companies that better organize the processes of commercialization of the application of scientific research works to production processes in terms of world technologies and innovations. The systematization of recent studies and publications made it possible to define the term commercialization of scientific research results as a complex economic and legal category, which expresses the processes of organizing and implementing the transfer of intellectual property objects and scientific research results to the real sector. Despite the large number of publications on the analyzed issues, there is a need to study in depth the mechanism of commercialization of scientific research results in universities and the role of innovative infrastructures in this area.

At the current stage of economic activity, the condition for sustainable innovative development is the preparation and production of competitive innovative products that are the result of scientific and technical development (Shafa Aliyev et all, 2023). The development of scientific and technological achievements and their ability to be applied to production are becoming the main factor in ensuring the competitiveness of the national economy operating in the global environment. In this regard, it is appropriate to present the sphere of scientific and research work as a specific production area that produces a specific product, that is, intellectual property objects. Against the background of global trends, the issues of organizing and conducting high-quality scientific research, increasing the demand for local innovations, obtaining maximum income from the application of technologies, and using effective strategies for the commercialization of local scientific and research work are in the spotlight. The problem may lie in the lack of demand for innovations, in the insufficiently effective supply of the scientific research sector, and in the unreliable processes of transfer and commercialization of scientific research. Commercialization of scientific research can help solve the problem of entering the market with developed innovations. Currently,

one of the main criteria for economic development is the creation of competitive products based on the latest technologies, but the state of the scientific research sector shows that the business sector does not spend enough money on scientific research. This leads to a lag in patenting compared with the leading countries of the world (Karpov, A.V., 2021). We also believe that the scientific results obtained should be useful and their productive use in various sectors of the economy should be ensured.

Considering the characteristics of the domestic market of scientific research, it can be seen that there are a number of problems related to the possibilities of their commercialization. Including the lack of attractiveness of the scientific research market and insufficient skills in the field of investment analysis, marketing, and intellectual property management. One of the current problems is the choice of the method and mechanism for commercialization of scientific research results (Kholiavko, N., 2018). The author is right in a certain sense, since the creation of innovative structures will create favorable conditions for the faster application of important results of scientific research to the economy. In our opinion, the University creates conditions for researchers to realize their creative potential. At the same time, students, masters, and doctoral students are involved in scientific and production activities; they acquire not only theoretical knowledge, but also practical skills. Creating income-generating structures is one of the important conditions for the commercialization of the results of scientific research work of universities. Important steps should be taken to create favorable conditions for the commercialization of the results obtained from scientific research work. Currently, universities often face a number of exogenous and endogenous economic and financial problems in the processes and activities of commercialization of scientific research results.

In order to solve these problems in Azerbaijan, it is important to create a solid base of economic and legal foundations for the commercialization of the results of scientific research of universities and to properly develop tax incentives in this area.

The effectiveness of the application of the mechanism for the commercialization of the results obtained by universities during scientific research requires the identification of potential commercialization objects and their maximum inclusion in commercial circulation (see Table 1).

Table 1. Classification of universities' scientific research results as objects of commercialization

s.s	**Classification group**	**Types**
1.	According to the type of activity it belongs to	1) fundamental research; 2) applied research; 3) research and development; 4) teaching and methodological developments.
2.	For obtaining scientific research results	1) long-term (more than 3 years); 2) medium-term (1-3 years); 3) short-term (up to 1 year); 4) used in current activities.
3	By funding sources	1) external financing (grants from international organizations and funds); 2) state financing (public procurement, targeted programs, state funds); 3) private financing (venture investment, joint ventures, sale of rights, sale of services); 4) mixed financing; 5) creation of endowment funds (investment funds financed by donations (including graduates of higher education institutions as donors).
4.	Depending on the customer	1) at the initiative of the scientist; 2) to meet the internal needs of the higher education institution; 3) by state order; 4) under a contract with the business sector.
5.	Depending on the commercialization method	1) transfer of research results (sale of rights, creation of a small innovative enterprise, transfer of research results to the customer under a contract); 2) internal use (in the educational process, in further research activities, in the provision of services, etc.)

Note: The table was compiled by the author.

We can show the mechanism of commercialization of scientific research results of universities as consisting of five logical stages:

Stage I - taking into account the influence of institutional, scientific-technical, financial and economic factors in commercialization processes; identification of market needs and their adaptation to the profile of scientific research institutions; objective assessment of existing scientific-technical resources and their commercial attractiveness; identification of potential financial sources of scientific research activities;

Stage II - conducting marketing research; preliminary selection of ways to commercialize the results of planned research; preliminary assessment of the commercial potential of the results of planned research; identification of existing financial sources; search for potential customers; organization and implementation of scientific research works;

Stage III - accounting and inventory of scientific research results; technical, economic and commercial audit; financial management; innovativeness, competitiveness, commercial potential and commercialization methods; grouping of scientific research and improvement results according to criteria;

Stage IV - ensuring legal protection of scientific research results; patenting of inventions in national and foreign patent offices; support for the validity of patents;

Stage V - search for ways to transfer rights to scientific research results; commercialization process; obtaining income from the transfer of scientific research results, achieving economic and social impacts.

Taking into account the economic importance of commercialization of scientific research results obtained at universities, it is necessary to make changes to the legislation in this area. We also share this opinion, especially considering the importance of improving the legislation related to innovation activities and the application of scientific research results.

In the modern era, we have provided a block diagram of the main stages and links of the process of commercialization of the results of scientific research activities at universities in Figure 1.

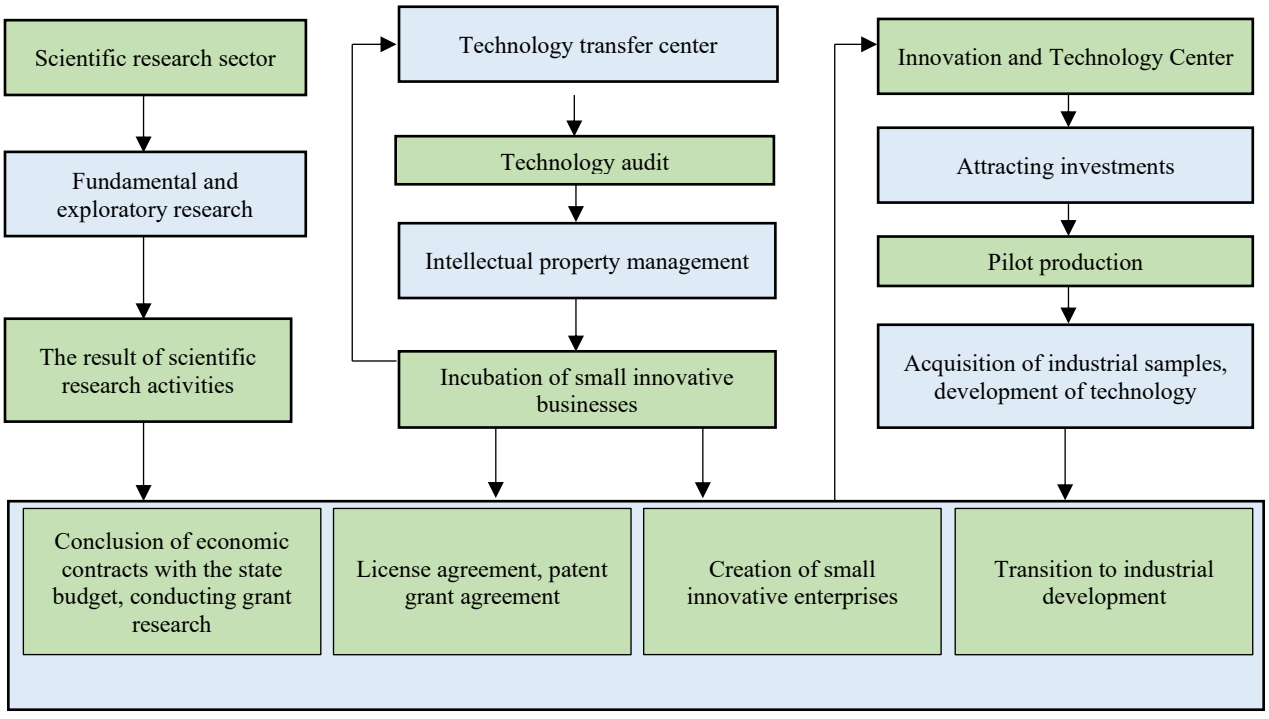

Figure 1. *Block diagram of the main stages and links of the process of commercialization of the results of scientific research activities in universities in the modern era (Source: prepared by the author).*

The organization of the process of commercialization of scientific research results in universities should be considered comprehensively, taking into account factors covering organizational, informational, and

financial-economic aspects. For this purpose, it is proposed to develop a system of organizational and economic support for the process of commercialization of scientific research results, based on the legislation of the country and the interaction of subsystems: organizational and informational support; marketing; financial and economic support; accounting. These subsystems are designed to solve the main tasks in enterprises and organizations engaged in the commercialization of scientific research results, namely: determining the predominant forms of commercialization of specific scientific research results; systematizing financial flows arising in the process of using the results of scientific research and identifying additional sources of income; increasing the efficiency of accounting and evaluation of the results of scientific research at the enterprise; creating conditions for new competitive advantages; increasing the efficiency of legal protection of the results of scientific research (Larin, S.N. & Ostrovsky S.M., 2012). Undoubtedly, strong legal protection of the results of scientific research and the effectiveness of related laws are important conditions.

Currently, a completely different situation is observed in some economic and humanitarian universities of Azerbaijan, where support for these universities is not so obvious. Naturally, scientific developments carried out in such universities are significantly different in nature from high-tech projects developed in technical universities. Orders for Scientific Research within the framework of state-specific programs also have a clear technical and technological focus. Nevertheless, studies show that state and business structures today need developments that can be implemented at a high level by the country's leading economic universities. There is a need to design a mechanism for interaction between the university's scientific community and industrial partners, as well as develop a quality assurance strategy through the creation of such a structure of research centers that would stimulate the activities of employees in higher education institutions.

It should be noted that an important incentive for universities to commercialize Scientific Research may be their desire to obtain the status of research universities, for which it is necessary to increase the share of income from the sale of Scientific Research results. It is difficult for universities with an economic and humanitarian orientation to compete with technical universities or universities with a “mixed” profile, since the scope of their scientific activities is significantly limited (Gorbashko, E.A. et all, 2018). We believe that the researcher is right, since the mentioned services are in sufficient demand. Technoparks are the largest scientific research and production complexes that create the most favorable environment for the development of small and medium-sized innovative companies, mainly engaged in organizing the transformation of Scientific Research results into commercial products and their application in production (Aliyev, Sh.T., 2012). Therefore, in our opinion, there is a need to create a wide network of technoparks. Thus, the work of technoparks should be coordinated with promising innovative business entities, research institutions, or higher education institutions to increase the competitiveness of national products in the field of high technologies.

In order to organize a solid production base of the national economy and expand the production structure in this regard, new economic mechanisms and economic tools are actively used in the country. For these purposes, the processes of creating and accelerating the activities of technoparks, industrial districts, agroparks, as well as special economic zones deserve attention (Aliyev, A.G. & Shahverdiyeva, R.O., 2020). We believe that, taking into account the above, the application of the processes of commercialization of scientific research results in these areas would have a great effect. For this, the cooperation of these infrastructures with universities should be expanded. The technopark is a platform equipped with the necessary industrial and technological infrastructure, which makes it possible to accelerate the implementation of scientific research on its territory and the application of the results of such research to production (Belova, V.V. et all, 2020). We also believe that technoparks allow for the rapid application of modern technologies. On the other hand, a favorable environment is created in the higher education institution that contributes to the development of new technologies and the formation of creative teams of scientists. Technoparks attract students, postgraduates and teachers of educational institutions, and scientific workers of scientific research institutes, who have the ability not only to receive

and impart theoretical knowledge on a scientific-production basis, but also to apply their innovative ideas in practice by demonstrating creative thinking. Ideas and entrepreneurial skills can be tested and applied within the technopark. The creation and development of technoparks in educational institutions serves to increase the prestige of the university and its innovative status in the region. At the same time, the technopark is able to absorb the creative activity of young specialists who can subsequently organize high-tech production in the region. High-tech projects and startups are tested in technoparks, which is possible thanks to preferential taxation. Regions should also be interested in the creation of technoparks. Because their work serves business development and provides additional funds to the budget. In addition, industrial enterprises in the regions should also be able to develop new technologies in their production base, obtain competitive products, and show interest in the activities of technoparks by identifying the demand for this type of product in the market (Mukhamediev, B. & Ilyasova, Zh., 2018). Therefore, technoparks are able to increase the commercial activity of an educational institution by providing a number of services in both the educational and industrial sectors. This is due to the fact that the organization of high-tech production directly creates an opportunity for the training and retraining of personnel for large industrial enterprises in the region. The activities of technology parks ensure the attraction of budget funds to educational institutions through scientific research.

When creating a technopark, its direction of activity should be determined individually, taking into account the work profile of the educational institution and the capabilities of the personnel. In general, ensuring the quality of scientific research activities in universities can be viewed from the point of view of the satisfaction of all interested parties. In order to determine the constituent elements of this task, in our opinion, it is necessary, first of all, to organize a monitoring procedure for competitions and grants announced for scientific applied research, and to study the market demand for such developments.

It should also be noted that a significant part of scientific research is an unfinished product (in terms of its subsequent application on the market), and it is necessary to provide a whole complex of measures to ensure that the results of scientific research are competitive. Another way to solve the problem of commercialization of the results of the university's scientific activity may be the organization of an information system, the tasks of which are to inform the market about the potential for possible use of the results of scientific activity.

In terms of increasing the innovation-investment attractiveness of the commercialization of scientific research results, it should be noted that at present, increasing the innovation and investment attractiveness of the processes of commercialization of scientific research results is of great relevance. It is known that before investing, specialized transnational companies and large investment and innovation fund associations, whose potential investors are engaged in investment at the global level, study the problems in this area and factors that hinder the increase in the attractiveness of investments, as well as the level of investment if it is invested; special importance is given to these factors. Therefore, we believe that the commercialization of scientific research results and more active application of their results to production processes are required; additional measures are taken in this regard, including the development of financial mechanisms and the introduction of state support mechanisms and incentive mechanisms. At the same time, by increasing the attractiveness of innovation-investment measures, it is possible to more promptly commercialize and involve scientific research results in production processes in scientific research institutions and universities of the country. In this case, the main goal and approach are to identify the financial mechanisms required for the conversion of scientific research results, and to what extent the proposed mechanisms and economic activity tools can be used and be useful. Intensively directing scientific research results to production processes and at the same time, sufficient financial resources and investments are required for the development of projects, the gradual implementation of innovation adoption and application processes (Aliev, Sh.T. et all, 2021).

In an innovative economy, modern economic reality determines the winner in the competitive struggle of enterprises that are constantly improving the organizational, technical, and technological components of production. This is facilitated, first of all, by the introduction of innovative business processes that are

relevant for the current period and are aimed at changing and modernizing manufactured products. In competitive conditions, many enterprises try to achieve significant results based only on old fixed assets, without ensuring technological improvement, without updating the intellectual component of production. In some cases, despite the presence of design bureaus in their structure, enterprises do not pay attention to the development of innovative products that provide competitive advantages in terms of quality, price, and other parameters. In these conditions, these enterprises should actively participate in innovative activities, and their priority interest should not be the acquisition of added value, but the production process itself, in which the results of Scientific Research are involved. In this case, their activities are accompanied by high productivity.

In modern times, many factors, including material and technical factors, have a special impact on labor productivity of various enterprises (Aliyev, Sh.T., 2010). They include everything that allows for increasing the technical level of production, including the application of innovative business processes. In this case, productivity growth is achieved through the use of achievements of scientific and technical progress, innovative business processes, increasing the efficiency of the use of raw materials, energy sources, increasing the level of mechanization of production and its comprehensive modernization. However, in increasing labor productivity, in addition to intensifying the modernization of fixed assets, their qualitative and technical renewal should also play a key role. Along with all this, the development and expansion of scientific and research services also have a significant impact on increasing productivity. Like any service, a service in the field of Scientific Research has its own characteristics. According to the provisions of services marketing, the following main characteristics are distinguished, which should be inherent in all services in one way or another, distinguishing them from goods. Such features are intangibility, inseparability, instability and non-permanence. The services provided in the field of Scientific Research can also be characterized from another point of view. For example, according to the criterion of participation in the purchase and sale processes, the services provided by scientific research organizations are both market and non-market in nature (Zavyalova, T.A., 2010). The service component of innovation is becoming increasingly important in various fields of activity. An important place in the set of domestic Scientific Research organizations belongs to the academic sector of the scientific research field.

Experimental research is research based on knowledge obtained as a result of scientific research or practical experience, carried out with the aim of protecting people's life and health, creating and improving new production processes, materials, products, devices, and services. Fundamental research is a theoretical and experimental activity aimed at obtaining knowledge about the laws of development of nature, society and people. For example, the study of human behavior patterns in economic decision-making situations can be classified as fundamental. Applied research is an activity aimed at obtaining and using knowledge to solve applied problems arising in the field of human practical activity (Skorev, M.M. et all, 2017). There are various fundamental approaches to improving the education-science-production chain in Azerbaijan. Taking into account the existing human resource potential, material and technical base, and innovation-based development opportunities of Azerbaijan, real conditions are created for the integration of educational institutions of our country with science centers and scientific research institutes. Today, in developed countries, universities are primarily formed as research centers and the educational process is based on scientific innovations. Universities are formed as research and education centers that meet the needs and demands of society. Today, our universities must fulfill such a mission in order to integrate into the globalized world.

Scientific research can be characterized as a set of knowledge about society, nature and the universe, consisting of systematized explanations and predictions that can be directly or indirectly confirmed through scientific experiments, and scientific activity can be characterized as activities aimed at expanding this knowledge. The general drawback of the field of Scientific Research services in Azerbaijan is its weak innovation orientation. Currently, the level of development of high-tech production, innovative development of enterprises, and the state as a whole is the most important element of the future successful development of the country. At the same time, the organization of financing of Scientific Research works

plays an important role. It is precisely effective mechanisms for financing Scientific Research works that allow developing industry and increasing the level of innovative development of companies, regions and the state.

In order to increase interest in Scientific Research and the development of innovations in enterprises, measures should be taken to commercialize the results of Scientific Research and their acceptance by enterprises, and attention should be paid to the mutual efficiency of business processes in this area. Consistent approaches should be provided for the development of innovative mechanisms and new innovations and their application in a scientific research laboratory or elsewhere. First, there should be a concept for the formation and development of an innovation system at the national level, and its development strategies should be determined. Second, measures should be taken for the active application and implementation of Scientific Research results. Then, the necessary analysis and study of innovative business processes in which Scientific Research services are formed should be carried out, a system of indicators should be determined, and a methodology for their assessment should be developed.

Currently, an important feature of the development of the national economy is the formation of a socio-economic system in which innovation activity plays a dominant role as a factor ensuring a higher level of competitive advantages. Both state and private large enterprises actively participate in innovation activity. The state assumes the functions of legislative regulation of innovation activity, implementation of large, fundamental, and socially significant projects, stimulation of private business for the application of innovations, and direct support of innovative enterprises, especially small ones. Thus, the state directs the development of the country's economy in an innovative way. As for the incentives used by the state for the development of innovations, they are quite diverse: tax breaks, provision of preferential loans, subsidies, public procurement, knowledge and technology transfer, accelerated depreciation, and others. Innovation business is stimulated based on the characteristics and state of economic development of a particular country.

In the conditions of uncertainty characteristic of the modern economy, increasing the competitiveness of economic entities is possible only when they develop innovatively (Маркова, Е.В., 2014). This means increasing the volume of innovative research and development in the country, and the introduction and commercialization of technological innovations. Management of innovative activity in the service sector should be associated with certain predictable results, leading both to a serious transformation of the management process within the service-producing enterprise and to significant changes in the external environment. For example, an increase in the requirements for the consumer value of a service may be associated with an increase in effective demand. Such changes lead to the fact that service providers are forced to expand and update their range. Any activity related to the service sector is determined not only by the consumer value characteristics of the services produced, but also by socially significant indicators such as the standard of living and quality of life of the population, health status, and economic entrepreneurship. In fact, the service sector is a system whose elements are aimed, on the one hand, at promoting various activities, and, on the other hand, at satisfying the needs of the population. The role of the service sector in the modern economy is due to the fact that the fundamental factors of economic growth are formed in this sector, namely: new scientific knowledge, intellectual capital, information technologies, financial sector services, consulting (Abbaszadeh, M.T., 2020). It follows from this that large-scale scientific and technical, qualitative and structural changes in service areas, which are of great importance for the further development of the economy and improving the quality of life of the population, are relevant.

The difference between fundamental research and applied research stems from Let's consider some stages of Scientific Research in more detail. It is known that Scientific Research services are based on Scientific Research stages. The implementation of research results, which is the final stage of scientific research, based on innovation processes, is the main factor for increasing its efficiency. Ensuring the efficiency of Scientific Research services is related to the legislation adopted in this field. In recent years, a number of laws, strategies, and priorities have been developed in the direction of expanding the structure

and increasing the volume of Scientific Research services in Azerbaijan. One of these laws is the "On Science" Law that we mentioned at the beginning, and in terms of the main functions and roles of that law, we can distinguish the following: increasing the effectiveness of the influence and role of science in solving socio-economic and cultural problems; optimization and stabilization of activities of scientific, scientific-technical and technological organizations, protection of scientific and scientific-technical potential; creation of necessary organizational and material-technical conditions for scientific-research organizations; provision of social security for employees working in the field of scientific research. On the other hand, that law regulates the processes of financing a group of scientific and technical activities: 1) fundamental research and improvements; 2) projects on the priority directions of science and technology development; 3) nationally important applied scientific developments; and 4) scientific projects in accordance with interstate contracts and agreements (Ahmedova, L.F., 2021). This law is important in terms of stimulating the development of innovative business by influencing the expansion of the structure and volume of scientific research services in Azerbaijan.

The goals set for them. Fundamental research includes activities aimed at identifying the most important regularities of the development of both nature and society, explaining phenomena and processes, gaining a more complete understanding of the object under study, and expanding human knowledge. The use of the results of fundamental research in practice is not immediately set as a task, and no attention is paid to making a profit. These studies form the basis of modern technologies and allow for innovations. When conducting fundamental research, ideas and innovative projects are created. In the innovation process, fundamental research is of great importance because it generates ideas and opens up previously unknown areas of knowledge (Ahmadova, L.F. 2020).

In modern conditions, one of the strategic issues facing universities is to train qualified specialists, as well as to form a wide range of competitive Scientific Research services and introduce them to the knowledge economy market. A multifunctional innovative infrastructure is required for the high-level organization of the Scientific Research services market, and the creation of this infrastructure requires the implementation of targeted and consistent measures. Judging from world experience, it can be noted that innovative approaches are of great importance in expanding scientific research services at universities.

It is also possible to note the formation of conceptual approaches to the problems of expanding Scientific Research services at the university level in Azerbaijan, and targeted measures have already been taken in this direction. In this regard, increasing the role of business processes in the diversification of scientific research services, creating an innovative infrastructure that allows the development and application of innovations, and attracting investments to these areas are important issues at the present time (Aliyev, Sh.T., 2018). In addition to the bachelor's level, higher education institutions operating in the country train personnel at the master's and doctoral levels. Doctoral studies, being the highest level of higher education, ensure the training of scientific and scientific-pedagogical personnel, the improvement of specialties and scientific degrees (Ahmedova, L.F., 2022). It is at this level that the training of future promising scientific researchers and the training of scientific specialists who are quite important in the formation of Scientific Research services takes place. At the same time, taking necessary measures in this direction to regulate the processes of preparing Scientific Research services and introducing them to the knowledge economy markets is an important condition for holding strong scientific events, conferences, planning and coordinating targeted scientific research in the direction of more relevant scientific research services, and achieving the study and application of progressive world experience in the field of science. Another important issue is that measures should be taken to ensure the integrative activities of universities, relevant research institutes of the Azerbaijan National Academy of Sciences, and innovation-oriented production enterprises and business entities (Mehtiyeva, N.Z., 2018). We believe that in order to apply Scientific Research services to production processes in reality, the formation and development of an innovative infrastructure network such as technoparks and industrial clusters should be given special attention.

In recent years, the state has attached great importance to the development of innovative infrastructure in Azerbaijan, and the creation of technoparks, industrial parks, industrial districts, agroparks, and high-tech parks has already begun. Many such science- and innovation-oriented infrastructure facilities and enterprises are already operating. Universities have the potential to actively participate in the formation of Scientific Research services and their introduction to the science and technology markets through integrative relations with such innovative institutions and economic entities. Another important issue is the role and activity of universities in the preparation of scientific research services and the organization of innovative infrastructure in the context of the challenges arising from the new industrial revolution.

It should be noted that the efficient organization of business processes is of particular importance for all areas of activity, including the scientific research field (Fletcher, AC. & Bourne, P.E., 2012). Thus, in order to form scientific research services as a final product, the operational delivery of them to the application processes for their intended purpose and the receipt of the final product, such measures as conducting tests, organizing production processes, studying markets, assessing risks, conducting marketing research, etc., are essential conditions. In general, in countries that are highly developed in terms of science and technology, direct investments are made for these purposes, and large amounts of financial resources are allocated, grants are established, and other large-scale measures are taken. Optimal organization of business processes and systematic measures taken in this regard are essential conditions. This requires taking complex measures and implementing interrelated operations, forming production, scientific, and management staff. At the same time, in the process of applying the results of any Scientific Research activity, it is necessary to go through various stages to organize the business process, formalize resources, provide auxiliary materials, and build and test production facilities (Caulfield, T. et all, 2012).

We would like to note the importance of paying more attention to measures to implement scientific results obtained in universities, research-oriented enterprises and centers through business processes and to increase investment attractiveness in this regard. The main approach here is to create appropriate conditions for researchers to operate productively and apply their scientific results in production and service processes, and to involve professional managers and potential investors in these processes, which ultimately are of decisive importance. Among these measures, we would like to note the most noteworthy: 1) organizing targeted Scientific Research grants and ensuring transparency of related competitions; 2) selecting potential and talented researchers, specializing them in various promising projects and forming professional research groups and teams; 3) holding serious scientific discussions and forums on important and priority problems; 4) taking necessary measures and creating appropriate conditions for testing and preparing research materials for application; 5) strengthening relations with stakeholders, including industrial enterprises, financial and credit institutions and investment associations, holdings, and implementing joint projects, etc. In addition, it is required to put the management circles of business processes into operation, form a control system, assess the level of adaptability of scientific and research results, and significantly and objectively assess the practical contributions they can make (Koltsova, O.V. & Menshchikova, V.I., 2008).

Improving the optimization of business processes and, in this regard, raising investment attractiveness to the required level are characterized as important issues. This can also be considered an indicator of the level of competitiveness of an entrepreneurship or business entity that applies the results of Scientific Research to production processes. In this case, business processes will look more attractive to investors, and the necessary decisions will be made when making investments, and investors will be more interested parties. Modeling the activities of business entities in accordance with new challenges directly depends on their level of competitiveness and maneuverability potential. Along with this, strengthening the infrastructure in Scientific Research institutions, increasing the level of the material and technical base, purchasing necessary equipment, especially laboratory testing devices, and creating appropriate conditions for experiments and tests should be given more priority and should be considered consistently..

A group of business processes related to the organization of the production cycle, which plays a decisive role in the practical application of scientific research results, attracts more attention. For example, if we pay attention to the main business processes, here the income of the enterprise is formed, and purposeful

processes related to the production of goods and the provision of services are carried out. On the other hand, if we look at the characteristics of indirect business processes, we can see that in this case the formation of additional income in the production cycle related to the goods produced and the services provided is more in the spotlight. At the same time, from the point of view of auxiliary business processes, we are witnessing a process that includes the problems of providing the necessary resources, goods, and materials, and issues related to the organization of activities. Along with these, as for the essence of another type of business processes, namely, supporting processes, issues related to strengthening and supporting the production and service infrastructure come to the fore. Development business processes, on the other hand, involve the improvement of goods and services, and the development of technologies. At the heart of entrepreneurial business processes, first of all, are issues of managing the entire cycle of goods and services, and related processes are implemented. Finally, the regulatory business process combines rules and requirements in the cycle of production and services (Burtsev, D.S. et all, 2021). In view of the above, in recent times, the formation of types of business processes based on high technologies, including "smart" technologies, and the emergence of more modern activity models are noteworthy. At the heart of all these processes are the mechanisms of activity related to information and communication technologies, which are predominant.

It can be noted that the state attaches great importance to the development of innovative infrastructure in Azerbaijan, and in recent years, the processes of creating technoparks, industrial parks, industrial districts, agroparks, and high-tech parks can be cited as an example of this; as we have said earlier, there is a need to intensify these processes. Thus, it is precisely at the expense of the potential of that production infrastructure that it is possible to expand the processes of commercialization of scientific and research works. Many science- and innovation-oriented infrastructure facilities and enterprises have already been put into operation, and currently, ensuring the efficient use of using this infrastructure and ensuring that universities and scientific and research institutions benefit more productively from those high-tech-based economic mechanisms remain relevant as important tasks.

In recent years, broad prospects have been formed, and a favorable environment has been created in our country for strengthening the activities of Scientific Research Institutions. Azerbaijan already has 3 communication satellites, and there are real and accessible digital resources for using the capabilities of high technologies. At the same time, the liberation of our lands that have been under occupation for nearly 30 years and the launch of large-scale projects aimed at revitalizing these territories, especially the use of high technologies, including "smart" technologies, and green economy approaches, necessitate the implementation of new Scientific Research. In addition, the newly created Karabakh and East Zangezur economic regions have sufficient underground and surface resources. The establishment of Scientific Research institutions in these economic regions, the formation of temporary and permanent scientific creative teams, and the organization of mobile scientific expeditions, if necessary, have become extremely relevant. We believe that in the near future, the opportunities for expanding Scientific Research and commercializing its results in Azerbaijan will increase significantly.

3. Conclusion

Thus, there is a serious need to maximize the improvement of scientific research and strengthen the stimulating mechanisms in this direction. We have summarized a group of our proposals in this regard:

– Based on modern challenges and digital transformations, there is a need to increase the level of scientific research and intensify measures for the active commercialization of scientific and practical results obtained in these processes, and in this regard, the preparation and implementation of action mechanisms for the activities of scientific research institutions and centers in the country and the active commercialization of scientific research results at universities should be accelerated.

– In order to make the Scientific Research and Innovation environment in Azerbaijan as attractive and efficient as possible, conceptual approaches should be provided at the state level and, in order to strengthen the legislative framework, it is important to adopt a national law "On Innovation Activities". In

addition, legislative acts that include the expansion of the processes of commercialization of Scientific Research results should be developed and actively implemented.

– The state's policy in the field of science and education should take into account the realities of the modern era and, first of all, the systematic consideration and implementation of measures aimed at applying science to production should be reflected in this policy. The state should continuously allocate funds and invest in conducting scientific research. Special attention should be paid to increasing interest in scientific research and regulating the activities of specialized scientific research centers, institutions and structures in this field, and ensuring the effectiveness of state support mechanisms in this regard.

– We believe that there should be a mechanism to motivate the arrival of a new generation, that is, the younger generation, in Scientific Research work; appropriate resources should be allocated, and conditions should be created for the productive conduct of Scientific Research work, the creation of infrastructure, a strong material and technical base, and the experimental testing of research results.

– The issues of commercialization of scientific research should be at the forefront of the legislation of each state and the measures that must be implemented in this regard, and it is important to have perfect mechanisms in this direction. Taking systematic measures to implement scientific research and provide comprehensive support for related work, increasing the interests of scientific research institutions, and identifying favorable scientific research projects that will attract the interest of special funds, scientific and educational funds and investors in this regard should be under the special control of the state, and in this regard, “public-private sector” cooperation should be strengthened in the direction of the activities of specialized scientific research institutions.

– Commercialization of scientific research should be based on clear mechanisms, and in addition to state support mechanisms, it is necessary to ensure that the legislation is functional and that an environment free from bureaucracy is created in the related mechanisms. In order to organize international cooperation in a broader way to strengthen scientific research, the establishment of modern innovative and high-tech universities, scientific research institutions, science and technology centers, and specialized institutions engaged in technology transfer should be given special consideration.

– Mechanisms for the establishment of specialized centers engaged in the commercialization of scientific research results in Azerbaijan should be developed and the establishment of such centers, including in the regions of the country, should be ensured. It would be appropriate to create an information portal reflecting the scientific research methods operating in the country and the scientific research results obtained at universities, as well as proposals, inventions, and discoveries of industrial and commercial importance, and to provide an open database to entrepreneurs, business structures, and interested organizations in this regard.

We can note that in the modern era, the implementation of complex tasks related to the generalization of Scientific Research results, their consideration in practical activity processes, and taking measures for their commercialization is of great importance. In this regard, in the near future, there is a serious need to take complex and systematic measures in Azerbaijan to create mechanisms for the application of high technologies in accordance with international experience and to effectively commercialize Scientific Research results.

Author Contributions

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript

Conflict of Interest

The authors declare no conflicts of interest.

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