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AN INTERDISCIPLINARY EVOLUTION: A LITERATURE STUDY ON THE INTEGRATED MEANINGS OF HOMEOSTASIS AND AUTOPOIESIS IN ORGANIZATIONS

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ABSTRACT

This study is based on a literature review on the integrated meanings of homeostasis and autopoiesis in organizations. Thus, with an interdisciplinary approach, the process of evolution of the related concepts into the discipline of organization was tried to be described. In this direction, documents in the literature were systematically utilised. Systematic literature review was chosen because it is an appropriate approach to link the studies in the existing literature and to extract and evaluate the evidence related to the research topic from the existing literature. The evidence obtained was used to construct the introduction, theoretical background, findings and evaluations, and conclusion. In particular, the findings were evaluated under the following headings: the role of homeostasis and autopoiesis in the evolution of the part, the evolution towards social systems theory, and the integrated evolution towards organizations. Humberto Maturana and Francisco Veralla's theory is considered to offer new perspectives on organizational self-management and the environment.

1.Introduction

One of the fundamental questions in the scientific study of complex systems concerns control, given the inherently limited predictability of systems. It is necessary to predict the future of systems and their environment and to be able to take action before a disturbance occurs that could damage or destroy the system. Depending on the predictability of a system, different control approaches are required. The less predictable a situation is, the more adaptive the system should be, i.e. feedback control will be more appropriate. Measures of predictability and complexity are needed to decide on different control approaches (Gershenson, 2015: 867). It

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would be appropriate to say that two concepts such as *homeostasis* and *autopoiesis* also lead to thoughts in complexity analyses. For instance, the meaning of complexity is still unclear, as is the question of what constitutes complexity theory and complexity science. The concept of complexity has fundamentally changed the understanding of biomedicine, environment, technology, society, economy and education. In the mid-20th century, cybernetics, general systems theory, chaos theory, etc. advanced the development of complexity theory. However, complexity, synergy, self-organization, complex adaptive theory, non-linearity, complementarity, Morin's complex thinking, autopoiesis, etc. draw on many scientific and philosophical ideas. It is fair to say that thanks to interdisciplinary convergence and evolution, people's view of the world and science has changed significantly (Kesić, 2024: 56). Traditionally, science has been reductionist. However, complexity arises when components are difficult to separate due to the interactions involved. Nevertheless, these interactions are important as they generate new knowledge that determines the future of systems (Fernández et al., 2014: 19). In other words, it is necessary to rely on the thesis that there can be an interdisciplinary evolution in concepts. Therefore, the subject of this study is to draw a theoretical framework of the evolution of two concepts such as autopoiesis and homeostasis towards the discipline of organization.

2.Theoretical Background

Claude Walter Bradford was the first to point out that living organisms are not only a vehicle for transporting nutrients to cells, but that the condition for free and independent life is the '*constancy of the milieu* intérieur' (Selye, 1973: 441; Kotas and Medzhitov, 2015: 816; Libretti and Puckett, 2023). Homeostasis is a fundamental concept necessary to understand many regulatory mechanisms in physiology (Modell et al., 2015: 259). However, the concept of *homeostasis* was derived by Cannon in 1926 to define and extend Bernard's concept of 'milieu intérieur' (Kotas and Medzhitov, 2015: 816; Davies, 2016: 1-2; Libretti and Puckett, 2023). The concept became popularised in *The Wisdom of the Body* (1932) (Torday, 2015: 575). On the other hand, Cannon combined the Ancient Greek concepts of ὅμος (hómos-similar) and ιστημι (histēmi-immobile)/ *stasis* (*from* στάσις), and introduced the concept of *homeostasis* (Davies, 2016: 1-2).

On the other hand, it is also necessary to refer to *autopoiesis*, which is another concept at the centre of this study. *Autopoiesis* has a certain cultural history. Although the concept was developed by Humberto Maturana and Francisco Veralla in the 1960s, it started to be used in the sense of *self-generating* in 1971 (Luisi, 2003: 49-50). In other words, *autopoiesis* means self-generation and aims to provide a universal criterion of life only in terms of the characteristic organization of living systems. According to this view, any system that exhibits autopoietic organization qualifies as a living system. According to Maturana and Varela, *the concept of autopoiesis is necessary and sufficient to characterise the organization of living systems*. *Autopoiesis* theory therefore follows a relationalist (or formalist) paradigm in explaining life. Life is assumed to consist of certain relations between material components. Thus, it is impossible to define and determine it independently of these components and relations. While the actual material basis of a given autopoietic system may have an impact on how *autopoiesis* is realised, it is argued that organization, self-structure and life are fundamentally the same in material instances (Meincke, 2019: 5).

3.Methodology

In order to evaluate the integrated meanings of the two concepts of homeostasis and autopoiesis in organizations through an interdisciplinary evolution, documents from the literature were

systematically used. The systematic literature review used in this study was chosen because it is an appropriate approach to link the studies in the existing literature and to extract and evaluate the evidence related to the research topic from the existing literature. In other words, in this study, systematic literature review constituted the basic structure of the methodology as it was considered to be very useful in evaluating the existing evidence by combining it (Schiffling and Piecyk, 2014: 201).

4.Findings and Evaluations

In the following section, the role of the concepts of *homeostasis and autopoiesis*, which are the focal concepts in evolution, the findings obtained from the literature on *evolution towards social systems theory* and some evaluations based on the findings are given.

4.1.The Role of Homeostasis and Autopoiesis Concepts in Evolution

Cannon tried to explain the concept of *homeostasis* and equilibrium by referring to the constant conditions maintained in the body. However, this concept gained a precise meaning when applied to relatively simple physical and chemical states in closed systems where known forces are balanced (Davies, 2016: 1-2). Cannon needed the concept of *homeostasis* to express the way in which a number of separate physiological systems can work together to restore stability following disruption. Therefore, he used the concept of homeostasis to describe the systematic, integrated response to emergencies regulated by the autonomic sympathetic nervous system and in response to a perceived threat (Cummins, 2024: 3165-3168). Since Cannon's work, the concept of homeostasis, which he defined as coordinated physiological processes that maintain most of the steady states in the organism, has been a major force in the development of views of physiological regulation and control. Homeostatic structure has significantly shaped many psychological concepts and theories of the twentieth century, including models of reinforcement, motivation, perception, personality, and psychosomatic disorders (Berntson et al., 2017: 401-426).

The concept and/or idea of *homeostasis* does not refer to the stagnation of something fixed and immobile, but to a state that can change but is relatively constant (Davies, 2016: 1-2). According to the concept, a highly developed life-existence is an open system with many relationships (Cannon, 1929: 400). Homeostasis is a fundamental feature of biological systems (Chovatiya & Medzhitov, 2014: 281). In other words, homeostasis also includes a reference to the organism being an open system (Lloyd et al., 2001: 133). In this direction, *homeostasis* is defined as a property of a system in which variables are regulated and internal conditions remain constant and relatively stable, emphasising that it is a process that maintains the stability of the internal environment of the organism in response to fluctuations in external environmental conditions (Torday, 2015: 575). On the other hand, homeostasis is traditionally considered as a synchronic servo-mechanism that maintains the status quo for organismal physiology. However, from the perspective of developmental physiology, homeostasis is a robust, dynamic, intergenerational, diachronic mechanism for maintaining, sustaining and modifying physiological structure and function (Torday, 2015: 573). In this direction, it is observed that the concept of *homeostasis* is based on some ideas. These ideas include the continuity in an open system represented by the body, the need for mechanisms to maintain this continuity, steady-state conditions, the fact that every tendency towards change automatically requires the encounter with factors that resist change, the regulatory system that determines the homeostatic state, consisting of a series of cooperating mechanisms acting simultaneously or successively, and that homeostasis does not occur by chance, but is the result of organised self-management (Davies, 2016: 1-2). It is also

observed that the concept of *homeostasis* has been a pioneer in the derivation of some concepts. For instance, *homeodynamics* (Lloyd et al., 2001: 133) and *homeosis* (Torday, 2015: 575) are referred to. In this direction, there are some explanations in the literature for the concept of *homeodynamics*. The concept of homeodynamics offers a new and all-encompassing concept that departs from the classical homeostatic thinking that emphasises the stability of the internal environment against deterioration. Indeed, biological systems are homeodynamic because of their ability to dynamically self-organise when they lose their stability (Lloyd et al., 2001: 133). In the literature, it is observed that the concept of *homeosis*, which is more dynamic than the concepts listed in the following time period, is also preferred. Although the concept was initially used to express the processes in living organisms, it is frequently applied to autonomous control systems ranging from cruise control to celestial bodies and engineering disciplines (Torday, 2015: 575; Modell et al., 2015: 259).

The concept of *autopoiesis* is derived from the Greek words auto-, 'self' and poiesi~L, 'to do'. It was coined to articulate the self-producing organization specific to living things (Fleischaker, 1988: 37). The concept is concerned with the question 'what is life?' and seeks to define a common denominator beyond the diversity of all living organisms, which distinguishes the living from the non-living. *Autopoiesis* is not concerned with the origin of life, i.e. the transition from non-living to living and artificial life. Instead, it is concerned with the direct observation of how existing cells function and with various life-related processes such as interaction with the environment, evolution and cognition (Zeleny, 1981: 4; Mingers, 1994: 1). In other words, a conception of life that has played a direct (albeit minor) role in research on the origins of life has been Maturana and Varela's concept of *autopoiesis*. To make a general assessment, autopoiesis belongs to the class of limited metabolism conceptions of life in general. However, it is formulated at a much more abstract level of description . Maturana and Varela have only tried to emphasise universal principles which they consider to be of a fundamentally organizational nature. In particular, an autopoietic (*literally* self-creating) system is a network of processes with the dual characteristics of self-generation and self-individuation. Self-generation means that the process network produces components whose interactions produce and maintain the same process network that produces them. Self-individuation means that the system creates and maintains its boundary as a fundamental part of its functioning. In Maturana and Varela's concept, a living system is an autopoietic system operating in the physical world (Beer, 2020: 6). The first period marked by the concept of autopoiesis lasts from the early 1970s to the early 1980s and uses formal recursive mathematics to address synchronic emergence, i.e. the focused behaviour of an organic system achieved through constraining the behaviour of system components. This can be seen as the question of the relationship between synchronic emergence, the part and the whole. The second period is based on the concept of enaction and covers the late 1980s and early 1990s. In this period, differential equations are used to model dynamical systems and diachronic emergence, i.e. the generation of new functional structures, is dealt with (Protevi, 2009: 2-3).

The concept of autopoiesis was introduced into the literature by Maturana and Varela as the name of a particular definition of system that they claimed was necessary and sufficient to describe and also to explain the living (Swenson, 1992: 207-228). In other words, autopoiesis is a concept used to refer to a form of system organization in which the system as a whole produces and modifies its own components and continuously separates itself from its surrounding environment (McMullin, 1997: 2). The concept has been widely used in the literature for

spontaneous order production or self-organization in general, whether living or non-living (Swenson, 1992: 207-228). However, Maturana and Varela went further and argued that living systems are cognitive systems and that living as a process is a process of cognition. Therefore, if these authors are right, *autopoiesis* unifies life and mind by determining that it is necessary and sufficient for both life and mind (Kirchhoff, 2018: 2520). *Autopoiesis* theory also addresses the potential to provide an alternative unifying framework for the study of organizations as systems and organizational phenomena as emergent phenomena (Magalhães and Sanchez, 2009). In their theory of *autopoiesis*, Maturana and Varela attempted to explain the 'necessary and sufficient condition of life' and this aroused considerable interest (Zolo, 1990: 61-80). However, it should be noted that the *autopoietic* system theory developed by Maturana and Varela has been criticised as unscientific (Scheper and Scheper, 1996: 1-12). Nevertheless, Varela's work in particular laid the foundation for a significant achievement in 20th century biology and biophilosophy. After his first collaboration with Maturana in the field of neo-cybernetics, Varela made fundamental contributions to immunology (network theory), artificial life (cellular automata), cognitive science (enaction), philosophy of mind (neurophenomenology), brain studies (brain network) and East-West dialogue (Mind and Life conferences) (Protevi, 2009: 1).

4.2.Evolution towards Social Systems Theory

Maturana and Varela developed a theory to explain the characteristics of living systems. They argued that living systems have an *autopoiesis* (self-generating) organization (Maturana, 1980: 45-79; Varela, 1981: 14-24; Fleischaker, 1988: 37; Mingers, 1989: 159-180; Varela, 1992: 4-14; Varela, 1996: 407-416; McMullin and Varela, 1997: 38-39). Through the concept of *autopoiesis*, which constitutes the core of the theory, it is necessary to make an assessment that the theory has evolved into mechanistic assumptions. For instance, the theory proposes a distinction between two valid types of scientific discourse: operational and functional/symbolic. Operational discourse belongs to the domain of physical processes at work in the living system (e.g. descriptions of physico-chemical or neural processes). Explanations on the functional/symbolic are also statements formulated by an external observer with relational knowledge of interaction and historical contexts (e.g. explanations of behaviour in terms of evolutionary advantages). This distinction leads to the boldest conclusions of the theory and allows for the justification of *autopoiesis* (Di Paolo, 2005: 434). Maturana and Varela, who were influential in the origin of the concept, focused on the idea that life is a certain kind of self-organization, which, although it has found a place in the physical domain, does not mean that every living being must have some kind of material basis. Rather, it has been argued that it means that metabolism is a fundamental feature of life (Boden, 2000: 118).

Maturana and Varela have argued that the minimum definition of a living being can be based on a single property, which they call *autopoiesis*. This claim contrasts sharply with other definitions based on a combination of several properties. This is because autopoiesis has a relational property (also called systematic, functionalist, formalist or universalist). Its relational character is due to the fact that it directly depends on *the nature of the components of* entities with other properties (type, intrinsic properties) and *the relations* between the components. Therefore, the concept links relational concepts with more general fields of research that try to describe various types of systems. For example, tectology, general systems theory, cybernetic relational biology, information theory and complex systems, systems biology and synthetic biology (Razeto-Barry, 2012: 543-544). To grasp the meaning of *autopoiesis*, it is necessary to trace its origins back to developments in social systems theory. Apart from the fields of social science, which, supported

by their procedural uniqueness, maintain the view that social systems are composed of social systems and/or interdependent decision-making units, the main tendency of systems theory thinking has been towards open systems. Such a tendency has formed the main basis for the view of systems as structures that adapt to their environment, influence it through their actions and decisions, and are even influenced by it (King, 1993: 219). Moreover, *autopoiesis* can be applied to systems such as societies and organizations. This reinforces the concept as an important theory with far-reaching implications for both science and society (Mingers, 1989: 159-180). In line with these findings, *autopoiesis* is a theoretical approach to the functioning of social systems and their relations with each other and with the general social environment, and many critics have tended to see the concept as synonymous with autonomy (King, 1993: 219). However, the criteria for autonomy are not only different, but also in a sequential order. It should be noted that this means that science must be a self-organizing system before it can become an autopioietic system (Stichweh, 1990: 195). Proponents of the theory have also not clarified the criticism of the arbitrary interchangeability of the terms self-referential, self-generative and autopoietic (King, 1993: 219). Nevertheless, *since the concept of autopoiesis refers to the fact that it does not produce anything else but only reproduces itself, it* should not be confused with concepts such as *biopoiesis*, *heteropoiesis* and *allopoiesis*, which characterise different aspects of production processes such as self-organization, renewal, creation, production, maintenance, continuation, etc. (Zeleny, 1981: 4).

As can be understood from the evaluations made in this section, the basic view of *autopoiesis* is based on a general understanding of system. A living being sustains its own life as a totality, not by its parts, but by the network of relations between its parts. On the other hand, a living being can change both the organization and the structure of a given system. However, this can have very different consequences for the system. As long as the organizational roles are fulfilled, the identity of the system does not change. However, the fact that different components can assume different roles within a given organizational model means that the organization can remain stable within a certain range of structural changes. If structural changes accumulate to such an extent that organizational roles are violated, the organizational structure changes and the specific system will lose its identity. In this case, if the accumulated structural changes support any system organization, the new system will necessarily be organised differently. In other words, its identity will belong to a different class . Therefore, since the organization defines the system as a functional whole, any change in the organization will necessarily lead to a change in the system identity (Zeleny, 1981: 3; Fleischaker, 1988: 37-38).

It is also necessary to refer to the concept of *boundary*, which has an important place in the concept of *autopoiesis* within the scope of the evaluations made on the system, provided that the general evaluations made so far remain within the limits. It would be appropriate to emphasise what the concept of boundary means as follows. Within the boundary of a cell, many reactions and accordingly many chemical transformations take place. Despite all these chemical processes, the cell always remains itself and preserves its identity (Luisi, 2003: 49-50; Thompson, 2004: 387). However, the importance of the spatial boundary *in autopoiesis* has been exaggerated. This boundary has the important task of distinguishing a living system as a spatial whole. However, it should not be considered to play an additional role such as limiting the processes that make up the *autopoietic* system (Virgo et al., 2009: 240). In this respect, it is also necessary to refer to *autopoietic* systems. Such systems are units defined as production networks of their components. These systems, through their interactions, repeatedly create and realise the network that

produces them and form the boundaries of the network in the area where they exist, as components participating in the realisation of the network. It should be emphasised once again, then, that autopoietic systems are not only self-organizing systems. For instance, they not only produce and eventually modify their own structures, but also apply their own references to the production of other components. It should be emphasised that this approach is a decisive conceptual innovation. At least for the system itself, even the final components, which are not decomposable, are produced by the system itself. Thus, everything that is used as a unit by the system is produced as a unit by the system itself. This also applies to elements, processes, boundaries, other structures and the unity of the system itself. Autopoietic systems of course exist within an environment. They cannot exist on their own. Social systems also use communication as a special way of reproducing themselves. The elements of these systems are communications that are reproduced again and again by a communication network and cannot exist outside the network. Communication is not living, conscious units and actions. It requires a synthesis of three choices, including knowledge, expression and understanding (including misunderstanding). This synthesis is produced by the communication network, not by some kind of inner force of consciousness or the intrinsic quality of knowledge. Communication is not produced by language. Structuralists have never been able to show how a structure can produce an event. At this point, the theory of *autopoiesis* offers a decisive advance (Luhmann, 2008: 85-86).

However, while this model can be applied in the biological domain, conceptual obstacles have been encountered in the extension studies specific to the social domain. This is because Maturana has not made a sufficiently consistent application. He understood the components of social systems biologically (individuals, persons, etc.) and the relations between them socially (language). This consideration can be found in the work of Niklas Luhmann, who recognised that the components of social systems are not persons, individuals, actors or subjects, but communicative acts themselves. Such an assessment thus refers to the use of the concept of *autopoiesis* as a tool of social analysis (Bednarz Jr, 1988: 57-64). Although the theory of autopoietic systems was initially formulated to explain the phenomenon of life from an operational and temporal perspective, sociologist Niklas Luhmann later incorporated it into his theory of social systems (Cadenas and Arnold-Cathalifaud, 2015: 169-176). When abstracted from its biological connotations, the concept of autopoiesis leads to a sharp distinction between different types of autopoietic organization, namely life, consciousness and communication. According to Luhmann, the relationship between social systems and people cannot be adequately analysed without taking into account that they are environments for each other. If this theoretical background is accepted, the concepts and theory of socialisation need to be revised. Luhmann addresses problems with classical concepts such as internalisation, indoctrination or consensual socialisation. After a historical overview of social systems research and general systems theory, it is indicated how communications trigger further communications and how social systems realise autopoiesis (Vanderstraeten, 2000: 581-598). On the other hand, in Luhmann's social theory, *autopoiesis* is the repetitive work of human self-construction, in which social and cultural forms are sustained against the background of constant dissolution and destruction. In this sense, *autopoiesis* is the self-constitution and reproduction of the human body by adapting the raw material of the world to the needs of the body and its organs. Human production thus presents the world to the human body and its parts, as we see in the supermarket, which brings the world's products together in a single space for our visual and manual convenience, and in home television, which literally brings the world's distant events to us. Human systems and institutions can thus be seen as means of fitting the materials of the world to the human mind

and body and ensuring their continued existence as meaningful forms. Significantly, however, the production of being depends on absence and decay. Absence must be seen as an important force in human production (Cooper, 2006: 59-81).

In order to support the understanding of social systems as autopoietic systems in terms of a society, it is necessary to distinguish two levels, namely the structural level and the cultural level, with reference to modern society. The dominant value pattern of modern society is the cultural pattern of instrumental activism. What is valued in modern society is not passive compliance with the imperatives of the environment, but increasing freedom of action within the environment and ultimately control over it. At the structural level, new patterns of social differentiation have emerged. Again, the pattern that characterises modern society is functional differentiation. This is because functional subsystems impose their own particular perspective on the environment. The environment is perceived through different lenses (political, legal, economic, educational and/or scientific). Of course, these different perceptions cannot be compared with each other. Society cannot control its overall impact on the environment. Its structural and cultural characteristics limit its sensitivity to the environment (Vanderstraeten, 2005: 471-481). The evaluation of autopoietic systems comes to the fore in this situation. This is because autopoietic systems are guided by simple sets of rules that direct the behaviour of components in a given environment. These rules are capable of producing much more complex systemic structures than we can achieve by direct arrangement of components, i.e. by the method of system analysis and design. The study of autopoietic systems shows that the traditional emphasis on the internal qualities of system components is misplaced *(*Zeleny, 1977: 13-28). In other words, in a modern society, such systems consist of social systems that exhibit organizational closure and self-referentiality. This necessitates an assessment that it can partially explain the widely perceived (in societies/environment) regulatory-oriented failure (Dunsire, 1996: 299-334).

5. Conclusion: Integrated Evolution Towards Organizations

Autopoiesis theory also has the potential to provide a unifying framework for the study of organizational phenomena in the 21st century. For instance, although organizational studies have not been devoid of new paradigms and approaches recently, such as postmodernism, phenomenology, ethnomethodology, reflexivity and critical theory, it can be argued that organizational literature has expanded in ways that make it increasingly difficult to understand, especially for beginners (Magalhães and Sanchez, 2010: 3-25). *Autopoiesis*, which refers to *self-organization*, has therefore become a popular concept in recent studies on business (Whitaker, 1995). An emerging *mode of organization* has therefore started to shift thinking from the traditional vertical command hierarchy to the horizontal patterns of market-oriented networks. This organizational mode *is characterised by self-management, autonomy* and *self-sustainability*, which are prerequisites for a successful and self-sustaining organization. *Self-sustaining systems* must be *autopoietic*, i.e. self-generating . They must be capable of not only producing something else, but also of producing themselves. Employees, managers and community stakeholders strive to create a *self-sustaining* organizational environment by pursuing decision autonomy, self-management and shared participatory ownership. Like biological amoebas, they must adapt to constantly changing conditions in terms of size, shape, function and interaction (Zeleny, 1997: 251-262).

Considering that socio-technical systems consist of two components, social and technical, the application of the concept of autopoiesis to such systems requires the reproduction of both components. Moreover, considering that each component can be divided into two parts according to the classical socio-technical system matrix, applying the concept of autopoiesis would mean reproducing people, structure, tasks and technology. When applying the concept of autopoiesis to a socio-technical system such as an organization, two questions need to be answered: what is reproduced (the concrete elements of the socio-technical system, i.e. the structure of the system) and how (the network of processes involved in reproduction)? On the other hand, at the beginning of Maturana and Varela, "Autopoietic machines are homeostatic machines", establishing the connection between homeostasis and autopoiesis. Therefore, it will also be necessary to address the question of how autopoietic activities help homeostasis, in other words, how they help the system to adapt to changes inside and outside the system while maintaining its identity (Bider et al., 2020: 22).

This study attempts to describe *the* evolution of *autopoiesis theory* and related concepts towards their integrated meaning in organizations on the basis of the evaluation of literature findings. The concept of *autopoiesis* has been a respected part of the artificial life tradition (Virgo et al., 2009: 240). On the other hand, ideas *from autopoiesis theory* formed part of the foundations of the field of artificial life and have been widely quoted ever since. However, the concept of autopoiesis has been treated as having different and in many cases incompatible meanings for different authors throughout its existence. An important part of the maturation of this topic will be to determine more precisely whether the alternative interpretations are compatible with each other and, if so, what constitutes the theory. On the other hand, it is the physical boundary of the *autopoietic* system, which is generated by the system and makes a significant contribution to the operation of the system, and the so-called operational boundaries, which determine which processes the system is part of. The theory of autopoiesis (a biological model of a living system) encourages creative thinking about possible implications and applications (Virgo et al., 2009: 240). In autopoietic system theory, the system/environment distinction plays a critical role. The system emerges as a result of differentiating itself from the environment. Therefore, the system and the environment are formed mutually (Anıl and Kaplan, 2007: 228). On the other hand, it is also stated that the source of the problems that organizations have to deal with are the changes in the environment. However, Maturana and Varela opposed this basic idea with the theory they developed. This approach opposes the distinction made between a system and its environment and offers new perspectives in understanding the processes that enable living systems to change. According to them, all living systems are organizationally closed and autonomous systems of interaction, which only consider themselves as a source of reference. According to them, through this closed system of relations, it is meant to be explained that organizations have the ability to produce themselves (Balyer, 2014: 608). Nevertheless, it should be noted that the criticism reached in the literature is that it is dangerous to apply a natural scientific model to social sciences. Nevertheless, the theory can offer new perspectives on self-management of organizations. For instance, the theory offers a fundamentally different perspective on the relationship between the organization and the environment. It would be appropriate to evaluate that it is interesting enough to be considered from the point of view of organizations (Kickert, 1993: 261-278).

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AN INTEGRATED APPROACH TO DIGITALIZATION OF THE AGRICULTURAL PRODUCTS EXPORT: TECHNOLOGIES, ECONOMIC IMPACT AND GLOBAL PRACTICES

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ABSTRACT

This article provides an in-depth analysis of key technological aspects of digitalization in the agricultural sector aimed at increasing productivity, competitiveness, and the sustainability of export chains. It examines the role of innovative tools such as sensors, drones, artificial intelligence (AI), and blockchain in risk management and optimization of production processes. Particular attention is paid to international experience using satellite technologies (using the US as an example) and modern national platforms such as FarmerApp. The article explores the application of digital solutions in logistics, product traceability through RFID and barcoding technologies, and the impact of digital marketing and e-commerce on expanding export opportunities. The article analyzes the economic and social effects of digitalization, as well as key challenges and potential solutions for overcoming them. It concludes that strategic implementation of digital transformation is necessary to integrate the national agricultural sector into global markets and ensure sustainable economic growth.

1. Introduction

Faced with the challenges of a growing global population and climate change, the global agricultural industry is on the threshold of the fourth industrial revolution. Digital transformation in this sector (AgriTech) is not simply a modernization effort, but a strategic imperative for ensuring food security and enhancing global competitiveness. According to the FAO, despite a decline in employment in the agricultural sector from 40% of the global population in 2000 to 27% in 2021 (866 million people) [1], the sector remains a key source of employment and the backbone of the economies of many countries.

The implementation of digital technologies is aimed at risk management, facilitating integration into international markets, and significantly increasing productivity and competitiveness. The purpose of this paper is to conduct a comprehensive analysis of the technological aspects of digitalization in the agricultural sector, assess its multifaceted impact, and identify strategic areas for effective implementation.

This article will examine key technologies, international and national practices, economic and social consequences, and practical challenges of digitalization.

1.1. Key Technological Aspects of Digitalization

Digital transformation in the agro-industrial complex is a complex and dynamic process that extends beyond individual innovations and encompasses the entire value chain, from detailed soil monitoring to the sale of finished products in highly competitive export markets. The comprehensive implementation of modern technologies allows for radically increased efficiency, ensured traceability, and strengthened the agricultural sectors resilience in the face of global challenges. This section is dedicated to the systematization and in-depth analysis of the fundamental technological solutions that shape modern "**smart**" **agriculture,** serving as the foundation for data-driven decision-making. In the following subsections, we will examine in detail how intelligent crop management, sensors, drones, and Big Data optimize production processes. Particular attention will be paid to drones and satellite monitoring, including national experience (**Azerbaijans Agricultural Satellite, FarmerApp**), as key elements of geospatial technologies. The role of artificial intelligence and blockchain in improving predictability and transparency will then be analyzed. A significant section will be devoted to the digitalization of logistics and traceability (**GPS, RFID**), as well as a detailed examination of product identification systems (barcode and RFID). The analysis will conclude with an examination of the potential of e-commerce and digital marketing for expanding sales markets. Exploring these areas will provide a comprehensive understanding of how technological integration is transforming the agricultural sector, making it more precise, profitable, and globally competitive.

1.2. *Intelligent Crop Management: Sensors, Drones, and Big Data*

The modern agricultural sector is undergoing a radical transformation under the influence of the concept of **Precision Agriculture**, the foundation of which is intelligent crop management. This approach is based on the collection, processing, and analysis of huge amounts of data, known as **Big Data,** which enables the transition from average farming methods to highly personalized and efficient ones.

The Role of Sensors and the Internet of Things (IoT). Sensors and Internet of Things (IoT) technologies are a key element in collecting primary data. These devices, installed directly in the soil, on agricultural machinery, or in the atmosphere, provide continuous and objective monitoring of critical parameters. Soil sensors measure moisture levels, pH, temperature, and nutrient content (nitrogen, phosphorus, potassium) in specific areas of the field [2]. Other sensors can track microclimatic conditions, including air temperature, wind speed, and humidity, which is critical for predicting disease outbreaks or optimal irrigation timing. The data obtained allows agronomists to quickly make decisions about the differentiated application of fertilizers and water, significantly reducing costs and minimizing environmental impact [3]. Using such comprehensive information on business processes is the foundation for building a digital enterprise in the agro-industrial complex.

Drones in agricultural. Drones play an indispensable role in monitoring large areas and promptly assessing crop conditions. Drones equipped with multispectral and thermal imaging cameras are capable of obtaining high-resolution images that are inaccessible to satellite monitoring. **Analyzing these images allowsto:**

Assess crop health: Using indicators such as the NDVI (Normalized Difference Vegetation Index), farmers can quickly identify problem areas of a field where plants are stressed due to lack of water, nutrients, or pest infestation [4].

Optimize chemical treatment: Drones are used for the precise application of pesticides, herbicides, and fertilizers (differential application), which significantly reduces chemical consumption (in some cases up to 90%) and reduces the impact on the environment [5].

Forecast crop yields: Regularly flying over fields helps assess plant density, growth dynamics, and maturity, which allows for more accurate yield forecasting and determining optimal harvest times [6].

In the United States, Canada, and Australia, drones have become a primary tool for managing large farms, used both for crop monitoring and for creating detailed 3D models of fields, which helps in irrigation planning.

Big Data. The Power of Big Data Sensors, drones, satellites and agricultural machinery generate a colossal amount of information, Big Data, which is the nerve center of modern agriculture. Big Data technologies are not just storage, but automated processing, analysis and use of information, characterized by large volumes and high speed of changes. Big Data analytics allows us to solve key problems:

Increasing Yield and Quality: Analysis of historical and current data on soil, weather conditions, seed genetics and results of previous seasons allows to optimize production processes, which leads to increased yields and improved product quality [7].

Risk Reduction and Damage Management: Real-time data analysis helps to promptly identify problems in the field (presence of pests, diseases, unfavorable weather conditions) without the need for regular physical inspection [8].

Building highly accurate weather forecasts based on Big Data enables rapid decision-making, saving crops that would otherwise be lost.

Optimization of Resources and Logistics: Analytics helps improve the planning and management of logistics and supply chains, reducing the time and financial costs of transporting and storing export products, which, in turn, increases profitability [9]. Thus, intelligent crop management through the integration of sensors, drones, and Big Data creates a closed loop of knowledge collection, analysis, and application, which is the basis for achieving maximum efficiency and sustainability in the modern agricultural sector.

1.3. *The Role of Artificial Intelligence and Blockchain in Export Logistics and Trade*

Artificial Intelligence (AI) is transforming the agricultural sector, moving it from simple data collection to intelligent processing, which is crucial for optimizing export operations and increasing competitiveness. AI systems using machine learning algorithms are capable of analyzing massive amounts of data, including global market information, weather conditions, seasonal demand fluctuations, and logistical factors, to create accurate predictive models [10 p. 7]. In the context of exports AI plays a key role in two areas:

Demand and Pricing Forecasting: AI is used to forecast market demand for specific agricultural products in various importing countries, which is critical for **export planning**. This allows producers to identify the most profitable markets, production volumes, and develop an optimal pricing strategy [11].

Optimization of Export Logistics: AI enables accurate, data-driven decisions regarding **determining the most efficient export routes and optimal delivery times.** AI algorithms take into account variables such as the state of transport networks, customs procedures, and shelf life (expiration date), minimizing logistical risks and reducing the time perishable goods spend in transit. This directly impacts **reduction of operating costs** and increases export profitability [11].

Thus, AI acts as a powerful tool for supporting strategic decision-making, ranging from crop planning based on expected export demand to global supply chain management (e.g., IBMs **Watson for Agriculture** platform [12])

Blockchain technology complements AI, solving a fundamental problem in modern agricultural exports ensuring trust, transparency, and security in international trade relations. Blockchain is a decentralized and immutable ledger that records every stage of the export product lifecycle, including origin, growing conditions, processing, and transportation. This ensures:

Strengthening Export Partner Trust: The technology guarantees the authenticity of data on quality, harvest date, and storage conditions, which is critical for meeting international importer and certification requirements. If problems arise, blockchain allows for immediate source tracing (e.g., harvest location) instead of traditional, lengthy investigations [13].

Document Flow Optimization: In international agricultural trade, enormous amounts of time and resources are spent processing paper documents (bills of lading, phytosanitary certificates). Blockchain makes it possible to **digitize and automate** this process through "smart contracts," reducing customs delays and simplifying payments between exporters and importers [14].

Improving Food Security: Systems used by **Walmart and IBM [12**] or the **Te-Food** platform [15] demonstrate how blockchain improves food security and reduces risks for end consumers, which is a prerequisite for entering premium markets.

Thus, AI and blockchain together create a technological base that not only increases crop yields but also ensures the economic efficiency and reliability of export activities, integrating the national agricultural sector into global digital trading networks.

1.4. *Digitalization of Logistics and Traceability as a Factor in Export Competitiveness (GPS, RFID)*

For agricultural products, which are mostly perishable goods with limited shelf lives and high susceptibility to seasonal fluctuations, efficient and traceable logistics are becoming not just an operational requirement, but a key to successfully entering export markets and increasing overall economic profitability. Digitalization in freight transportation is based on the use of **Global Positioning Systems** (GPS) and specialized transport management software. These systems allow exporters to monitor product movement in real time, which is critical for fulfilling contractual obligations and maintaining product quality. GPS tracking, combined with big data analytics, allows for the determination of the most efficient and cost-effective delivery routes, taking into account numerous variables: road and weather conditions, border crossing congestion, and temperature control. Intelligent optimization of routes and schedules, as discussed in [15], minimizes operating costs (by reducing fuel consumption and depreciation), shortens delivery times, and, consequently, increases the shelf life of products in the importers market. This directly contributes to the growth of export margins.

RFID and Barcodes: Guaranteeing Traceability and Reducing Risks In the area of warehousing and quality control, product identification systems play a decisive role: barcode (barcode) and radio-frequency identification (RFID) technologies. These technologies ensure total control and identification of goods at all stages of the supply chain, which is especially important for export logistics. Economic Advantages of RFID:

- **RFID** (Radio Frequency Identification) technologies, which use radio frequencies to read information from microchips, are superior to traditional barcodes in a number of respects: they store a larger volume of data, allow reuse, and can be read without direct contact or visibility. This feature automates inventory processes, significantly speeding up the receipt and shipment of goods at export terminals. Large retailers such as Walmart and services like **Amazon Fresh** actively use RFID to optimize warehouse processes and combat theft, reducing non-production losses and increasing the reliability of the entire system.
- **Traceability for International Trust:** In international trade, traceability is a key requirement for ensuring food safety. The use of RFID tags allows for immediate confirmation of product origin and its compliance with international standards. For example, in California, CLGMA uses RFID to improve the security of green leafy crops. Providing complete and reliable information about the products journey (from field to fork) builds trust with foreign partners and facilitates access to premium and regulated markets, thereby increasing export potential and competitiveness. Sodexo and other major companies are using these tags to confirm product origin, which is becoming an integral part of modern export contracts.

Digital logistics, supported by GPS and identification technologies, transforms costs into a competitive advantage, making agricultural export chains fast, reliable, and cost-effective.

1.5. *E-Commerce and Digital Marketing: Expanding Export Horizons*

In the context of globalization and the digital economy, expanding agricultural export opportunities directly depends on the effective use of modern digital sales channels and marketing tools. E-commerce and digital marketing have become powerful drivers of economic growth, enabling producers to overcome geographic barriers and reduce their dependence on traditional intermediaries. Digital marketing provides agricultural producers with analytical tools and marketing platforms that are crucial for finding new customers and business partners in foreign markets. Unlike traditional methods, digital channels provide a targeted approach, allowing them to precisely identify potential importers or distributors based on their demand, preferences, and geographic location. Creating online stores and branded websites allows agricultural enterprises to sell products directly, resulting in increased margins by eliminating the lengthy chain of intermediaries. Electronic catalogs and analytics of consumer behavior data in foreign markets help quickly adapt export offerings (e.g., packaging, batch sizes) to specific market requirements, thereby providing a competitive advantage. E-commerce is not just a sales channel, but a comprehensive mechanism that enables the integration of the national agricultural sector into global logistics and financial networks.

National Platforms and State Support: An example of strategic state support for exports is the Azexport.az e-commerce platform, launched in Azerbaijan in 2016. The portal serves as a one-stop shop for exports, significantly reducing financial and administrative barriers for local entrepreneurs. The portal integrates with more than 15 leading global platforms (including Alibaba and Tradeindia) and utilizes a unique "reverse dropshipping" model, in which the portal

covers local entrepreneurs' membership and marketing costs [16] are a critical mechanism. This provides direct and preferential access to international trade for small and medium-sized farms, promoting the diversification of their export portfolio.

Logistics Optimization through E-Commerce: E-commerce platforms are often integrated with modern logistics systems, including GPS tracking and digital document management, ensuring high speed and transparency of international delivery. This is especially important for perishable agricultural products. By digitalizing orders and customs procedures, delays and errors are reduced, directly impacting logistics costs and, ultimately, the final cost of goods for importers.

E-commerce acts as a powerful tool for economic inclusion and growth. Using these digital channels allows the agricultural sector not only to increase sales volumes but also to build more sustainable and direct commercial ties, thereby strengthening the country's position in the global market.

2. The Economic and Social Impact of Digitalization

Digital transformation in the agro-industrial complex is a powerful catalyst, whose multifaceted impact extends far beyond the traditional measurement of crop yields and encompasses key aspects of economic growth, environmental sustainability, and social development.

From an economic growth perspective, digitalization enables a fundamental shift toward increased efficiency and profitability. The introduction of precision farming, based on sensor monitoring, big data, and AI, allows farmers to precisely dose resources. This leads to a significant reduction in operating costs by optimizing the use of water, fertilizers, pesticides, and fuels and lubricants. Reducing these input costs directly translates into increased enterprise profitability and, consequently, an increase in the agricultural sectors contribution to the countrys Gross Domestic Product (GDP). Furthermore, digital tools such as e-commerce platforms and digital marketing dramatically simplify access to international markets, which is key to export diversification and reducing dependence on a limited number of traditional trading partners.

In terms of sustainability and environmental protection, digital solutions are invaluable. Precision farming promotes a more responsible use of natural resources, as fertilizer and irrigation are applied not uniformly across the entire territory, but strictly according to the needs of a specific area, thereby reducing chemical pollution of soil and water resources. Sensor monitoring and the use of AI for forecasting help minimize climate risks and crop losses from adverse weather events, which directly aligns with the global Sustainable Development Goals (SDG). Thus, digitalization is transforming the agricultural sector into a more environmentally friendly and resource-efficient industry.

Finally, the social benefits of digital transformation cannot be underestimated. The introduction of new technologies is creating new opportunities for entrepreneurship in rural areas, stimulating the development of innovative services and services related to AgriTech (e.g., drone operators and data analysts). Digitalization also makes the agricultural sector more attractive to young and skilled workers, shifting the focus from heavy physical labor to intellectual activity and the operation of high-tech equipment. E-commerce and blockchain platforms, in turn, facilitate direct interaction between farmers and global consumers, reducing intermediary chains and ensuring farmers a fairer share of the final profits, thereby improving living standards in rural communities.4. Challenges and Directions for Agricultural Digitalization Development

Despite the obvious and proven benefits of digital transformation in the agricultural sector, its full and comprehensive implementation is associated with a number of serious systemic challenges. Overcoming these challenges requires not only technological solutions but also strategic government interventions.

One of the most significant barriers is the high cost of implementing innovative technologies. The initial investment required to acquire and install complex systems, such as multifunctional sensors, monitoring drones, powerful AI platforms, and RFID tracking systems, is often prohibitive for small and medium-sized farms, which form the backbone of agricultural production. Overcoming this financial barrier requires active government subsidies or the creation of specialized concessional lending funds for AgriTech projects. Another effective solution is the establishment of technology sharing centers, where farmers can rent expensive equipment or use data analysis services on a cooperative basis, thereby sharing the high initial costs.

The second critical challenge is infrastructure limitations. The high-quality operation of Big Data, AI, and remote monitoring systems (e.g., from satellites or drones) directly depends on the reliability and speed of data transmission. However, many remote rural areas, where agricultural activity is concentrated, still lack high-speed internet and stable mobile communications. Therefore, government programs for the development of rural digital infrastructure are becoming more than just a social project; they are a direct investment in the economic potential of the agricultural sector. This includes the installation of fiber optic lines and the deployment of 5G networks in agricultural regions.

The third key aspect is related to human resources. Technologies such as AI and Big Data analysis require farmers and agronomists to develop new competencies that significantly extend beyond traditional agricultural knowledge. There is a pressing need for specialists capable of processing data, managing complex AI systems, servicing drones, and integrating blockchain solutions into supply chains. Investments in education and retraining are needed, including the development of specialized curricula in Agri-Data Science and Digital Agronomy in higher and secondary educational institutions. Improving digital literacy among active farmers through courses and seminars is also urgent.

Finally, the ethical and legal issues that arise with mass data collection cannot be ignored. Protecting farmers personal data and the confidentiality of information collected via RFID tags, sensors, and satellites require clear and timely legal regulation. National standards and protocols must be developed to ensure data security and integrity, which is also critical for harmonizing with international requirements and ensuring trust in export operations. Furthermore, a legal framework must be created for the use of new technologies, including regulations for agricultural drone flights and standards for implementing blockchain systems in supply chains. Successfully overcoming these challenges will determine the trajectory of the agricultural sector for decades to come.

3. EMPIRICAL ANALYSIS AND ECONOMIC EFFICIENCY OF DIGITAL EXPORT PLATFORMS IN AZERBAIJAN

To validate the conceptual framework of digital transformation in agriculture, this section analyzes statistical data from the "Azexport" portal. The analysis focuses on two key dimensions: the volume dynamics of digital orders and the price efficiency gained through disintermediation.

3.1. Statistical Dynamics of Digital Export Orders

The dataset covers the period from 2017 (the portal's inception) to 2022. During this period, the cumulative value of export orders received via the portal amounted to $3.16 billion.

Table 1. Comparative Dynamics: Azexport Orders vs. National Non-Oil Export (2017–2022)

Year (t)	Azexport Order Volume (Vd) (mln USD)	Growth Rate (ΔVd)	Total Non-Oil Export (Vtotal) (mln USD)	Share of Digital Orders in Potential Export (Vd/Vtotal)
2017	475.0	-	1,538	30.8%
2018	514.1	+8.2%	1,689	30.4%
2019	595.7	+15.9%	1,954	30.5%
2020	610.8	+2.5%	1,850	33.0%
2021	496.1	-18.8%	2,700	18.4%
2022	469.9	-5.3%	3,050	15.4%

***Source**: Author's calculation based on CAERC data.*

As seen in Table 1, prior to the post-pandemic global supply chain restructuring (2017-2020), the ratio of digital orders to total non-oil exports remained stable at approximately **30-33%**. This indicates a high level of digital adoption among exporters during the portal's initial growth phase.

To measure the sustainable growth trend before external shocks (pandemic), we calculate the **Compound Annual Growth Rate (CAGR)** for the 2017-2020 period using the following formula:

$$\mathrm{CAGR} = \left(\frac{\mathrm{V_{end}}}{\mathrm{V_{start}}}\right)^{\frac{1}{n}} - 1$$

Substituting the values for the 2017-2020 interval:

$$\mathrm{CAGR}_{2017-2020} = \left(610.8 — 475.0\right)^{\frac{1}{3}} - 1 = (1.285)^{0.33} - 1 \approx 0.087$$

Result: The platform demonstrated a robust **8.7% annual compound growth rate** in export orders during its pre-pandemic phase, proving the effectiveness of the digital entry strategy.

3.2. Econometric Assessment of Price Efficiency (The "Digital Dividend")

A critical economic impact of digitalization is the elimination of low-value intermediaries, allowing farmers to capture a higher margin. To quantify this effect, we apply the Price Efficiency Model.

We define the **Digital Efficiency Coefficient (Ep)** as the percentage increase in the unit price of a commodity when exported through digital B2B channels compared to traditional channels.

The formula is derived as follows:

$$E_p = \frac{P_{digital} - P_{traditional}}{P_{traditional}} \times 100\%$$

Where:

- $P_{\{digital\}}$– $Export\ price\ per\ unit\ realized\ via\ the\ digital\ platform\ (Azexport).$
- $P_{\{traditional\}}$– $Export\ price\ per\ unit\ realized\ via\ traditional\ offline\ intermediaries.$
- $\left(P_{\{digital\}} - P_{\{traditional\}}\right)$ – The Digital Surplus Value$created\ by\ the\ platform.$

Case Study Application: Cotton Fiber Exports

Based on data from the National Confederation of Entrepreneurs (ASK) [17], we observe the export prices for cotton fiber (ginned cotton) before and after the active utilization of the Azexport platform.

Variable Inputs:

◎ **P_traditional \approx 1,350$ USD/ton** – (Baseline price via traditional intermediaries)

◎ **P_digital \approx 1,750$ USD/ton** – (Price realized via Azexport direct contracts)

- **Calculation:**

$$\mathrm{E_p} = \frac{1750 - 1350}{1350} \times 100\%$$

$$\mathrm{E_p} = \frac{400}{1350} \times 100\%$$

$$\mathrm{E_p} \approx 0.296 \times 100\% = 29.6\%$$

Interpretation of Results:

The calculation reveals an efficiency coefficient of 29.6%. This implies that the digitalization of the export process generated approximately 30% additional revenue per ton for cotton producers. In monetary terms, the "Digital Surplus Value" is $400 per ton.

This empirical evidence suggests that digital platforms do not merely facilitate trade volume but significantly improve **terms of trade** for agricultural producers by bridging the information gap with global buyers.

4. Conclusion

The digital transformation of the agricultural sector is not merely a technological trend but an irreversible strategic imperative, critical for ensuring food security, economic sustainability, and enhancing the global competitiveness of the national agricultural sector. The comprehensive analysis conducted in this study demonstrates that success in this domain requires a multi-layered approach, seamlessly integrating advanced technologies from IoT sensors and drones to Big Data and Blockchain across the entire value chain.

This study provides empirical evidence supporting the economic viability of digital export platforms. The analysis of the "Azexport" portal's data (2017–2022) reveals a robust correlation between digitalization and export growth. The platform generated $3.16 billion in export orders, maintaining a Compound Annual Growth Rate (CAGR) of 8.7% during the pre-pandemic period, which substantiates the sustainability of digital demand. Furthermore, the econometric

assessment of the "Digital Dividend" using the Price Efficiency Model (Ep) confirms that digital disintermediation significantly improves terms of trade for producers. As demonstrated in the cotton fiber case study, direct digital B2B engagement resulted in a 29.6% increase in unit price (an outcome of minimizing information asymmetry), proving that digitalization directly translates into higher revenue for the agricultural sector. Beyond economic metrics, the study highlights the critical role of trust and transparency. Product traceability, enabled by RFID and GPS technologies, ensures logistics optimization, while Blockchain solutions (referencing global practices like Walmart and Maersk) set the standard for origin verification. The empirical dominance of agricultural products (approx. 65-70%) in digital export orders confirms that platforms like "Azexport.az" effectively function as drivers of agrarian export diversification, enabling small and medium-sized farmers to overcome entry barriers and access global markets.

Strategic Challenges and Future Outlook

However, to sustain this "Digital Dividend" and strengthen competitive positions, strategic challenges must be addressed. The scalability of AI and Big Data systems is contingent upon the accelerated development of rural digital infrastructure, specifically high-speed internet access. Financial mechanisms to support technology adoption by smallholders and investment in human capital, training specialists capable of managing intelligent systems. Furthermore, harmonizing legislation regarding data protection and cross-border digital trade will provide the necessary legal framework. In conclusion, the integration of empirical data with conceptual analysis confirms that a strategic focus on comprehensive digitalization is the key determinant of future success. By leveraging national digital platforms and adopting international best practices, the national agricultural sector can achieve higher transparency, significant price efficiency (Ep), and sustainable integration into the global economy, thereby strengthening the country's economic sovereignty.

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THE EXISTENCE OF ELITES IN THE LIGHT OF BEADS IN THE PERIOD OF SEYİTÖMER HÖYÜK EARLY BRONZE AGE III

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ARTICLE INFO	*ABSTRACT*
Article history *Received:2025-04-19* *Received in revised form:2025-05-20* *Accepted:2025-10-01* *Available online: 2025-12-25*	*Seyitömer Höyük is located 25 km northwest of Kütahya Province. The subject of this study is approximately 1500 beads recovered from the V/B, V/C and V/D layers of the Seyitömer Höyük. The materials of the beads found in the structure belonging to the manager, most of which are located in the V/ B layer, are carnelian, faience and gold. These beads were examined by dividing them into the materials and types from which they were produced. The centers where beads were seized, especially Anatolia and Mesopotamia, were mentioned. In the light of these centers BC. 3. In the light of jewelry in trade between Mesopotamia and Anatolia, the existence of elites and the importance of the Seyitömer Höyük in Inner Western Anatolia have been revealed.*
Keywords: *Inner western Anatolia, Early Bronze Age III, beads, intercultural relations, trade* *JEL classification: Z13*	

1. Introduction

Rescue excavations at Seyitömer Höyük, located 25 km northwest of Kütahya province, were first initiated in 1989 and have continued intermittently to the present day (Fig. 1). The reason for initiating rescue excavations at the mound is its location within a coal basin. As a result of the excavation work initiated for compelling reasons, important archaeological data has been obtained (Ünan, 2022, 1-20).

The stratigraphy at Seyitömer Höyük, as determined by the work carried out in 2021, is as follows: I. Roman Period, II. Hellenistic Period (A/B), III. Iron Age (A/B), IV. Middle Bronze Age (A/B/C/D), V. Early Bronze Age III (A/B/C/D), VI. Early Early Bronze Age IIIA, VI. Early Bronze Age II (A/B/C/D) (Ünan & Ünan, 2022, 50).

At Seyitömer Höyük, the settlement system developed from the radial plan settlement applied in the Early Bronze Age II was implemented with minor changes throughout all phases of the Early Bronze Age III (Yüzbaşıoğlu, 2024). The common features of the Early Bronze Age III layer include rectangular structures with two or three rooms built side by side using shared walls, and a wall system created by building the rear walls thicker than the side walls. In addition to being living spaces, the structures also served as workshops or storage areas and included bull-headed hearths, domed ovens, grinding areas, and small storage areas among their interior features

(Ünan, 2014, 74). When structures with multiple rooms and distinct floor plans are evaluated alongside their finds, some are identified as administrative buildings. In phase V/B, the megaron-plan structure located at the centre of the settlement is considered a religious space (Bilgen et al., 2011, 371; Ünan, 2014, 74). In addition to this structure, the multi-roomed structure located to the west of the settlement, when evaluated together with its findings, has been understood to belong to the administrator (Ünan, 2014, 74; Bilgen et al., 2014, 150).

Figüre 1. Aerial photograph of Seyitömer Höyük

2. Beads Found at Seyitömer Höyük

Beads from different phases of the fifth stratum (Early Bronze Age III) at Seyitömer Höyük have been recovered. Most of these beads, recovered from within the administrative structure located in House V/B, were produced from three different materials: carnelian, faience, and gold (Fig. 2/a-c).

a **b**

c

Figüre 2: a-b. The faience beads found at Seyitömer Höyük, **c.** The gold beads found at Seyitömer Höyük.

1-Karnelyen Boncuklar

Carnelian beads are biconical in shape and have string holes. The beads range in length from 2.1 to 5.5 cm, and their body diameters vary between 0.7 and 1.00 cm. A total of three beads were recovered from the V/B, V/C and V/D layers. The bead recovered from the V/B phase, which is larger than the others, was found in the storage room of the administrative structure. The second example was found in room 31, dated to the V/C phase, and the other was found in the fill of the V/D phase (Fig. 3/1). This type of carnelian beads was made by bleaching the beads with an alkaline liquid after they had been fired. This technique is typical of the Mature Harappan Culture in the Indus Region. These beads have been found as early as the early Harappan layer at Naushoro/Baluchistan (2600 BCE). The production of carnelian beads using this specific technique is a tradition in Mesopotamia due to the lack of workshops, and this technique was used throughout the Indus Valley (Rahmstorf, 2015, 159).

Similar carnelian beads have been found at the Mohenjo-daro settlement in the Indus Valley and are dated to 2600–1900 BC (Collins, 2003a, 392/279). In southern Mesopotamia, they were found in the tomb of Queen Paubi in the royal tombs of Ur, dated to Early Dynastic IIIA - 2550-2400 BC (Maxwell-Hyslop, 1960, P.XI/4, P.XII/4; Collins, 2003d, 112, 62a-h). In Susa during the Akkadian period (2300-2159 BC) (Collins, 2003c, 300/201), in Mari during the Early Dynastic IIIB period (2400-2250) (Cholidis, 2003, 144/85a-b), Kish (Mackay, 1929, XLIII/8) and Tell Brak during the Akkadian period (Oates & Oates, 1993, 166, Fig. 12; Evans, 2003, 232, 158a) are other centres where it was observed in Mesopotamia. In North Caucasus, it was found in the Maikop Kurgan, dated to the Early 3rd millennium (Piotrovsky, 2003a, 295/196a). In Anatolia, it was uncovered in Troy during ETÇ III (Sazcı, 2007, 233, E-S1; Ludvik et al., 2015, 8, Fig. 5/b) and in the Alacahöyük L tomb (Koşay, 1951, Lev. CC). In the Aegean, it is found at Kolonna (Reinholdt, 2003, 261, 166/b) and Daskalio (Rahmstorf, 2015, 161).

2-Faiance Beads

Tiles were probably first produced simultaneously in the Near East and Egypt around 4000 BC, and this production continued until the Roman period. The glaze colours of tiles used for making beads, amulets, inlaid pieces, figurines and vases are predominantly shades of blue and green (Dardeniz & Öztan, 2020, 841). The majority of the faience beads were recovered from the main chamber and various other rooms of the administrative structure dated to the V/B phase.

The total number of these beads is approximately 1,500. Three different types of faience beads have been identified: cylindrical, biconical, and spherical.

Type 1: Cylindrical beads have been examined under this type. These beads exhibit three subtype characteristics.

Type 1a: This type consists of cylindrical beads with a smoothed surface and thread holes. Three beads were found, with diameters ranging from 0.3 to 0.5 cm and lengths ranging from 0.75 to 3 cm (Fig. 3-2/Type 1a).

Type 1b: These beads have a cylindrical body with embossed segments in the shape of half-circles following one another along the body. One Type 1b bead has been recovered, measuring 0.8 cm in diameter and 2.04 cm in length (Fig. 3-2/Type 1b).

Type 1c: The surface of this type of cylindrical bead is divided into rectangular areas by irregular horizontal and vertical scratches running parallel to each other (Fig. 3-2/Type 1c). Two beads of this type, measuring 1.00 cm in diameter and 3.3 cm in length, were found.

Similar beads to Type 1a were found at Tell Arbid during the Akkadian period (Kolinski, 2007, 108, Fig. 13, E/7), Tell Bia (Strommenger & Kohlmeyer, 1998, T. 19, 16/35:1, 11/3; T. 27, 42/23:6, 17/d), El-Qitar (Sagona, 1986, 115, Fig. 3, 15/f), Tell Chagar Bazar in the 3rd millennium BCE at Tell Chagar Bazar (Mallowan, 1937, P. XVIII, A/4), Tell Banat (Porter, 1995, 15, Fig. 10/A379a) and Halawa (Orthmann, 1981, T. 43/10). Similar Type 1b beads are found at Tell Qura Quzaq in the 3rd millennium BC stratum (Pereiro, 1994, F.23/24, 25), Tell Bia (Strommenger & Kohlmeyer, 1998, T. 19, 16/33:1/5; T. 19, 16/35:1, 11/2), Tell Banat (Porter, 1995, 15, Fig. 10/A379b-d), and Tell Brak during the Akkadian period (Steele et al., 2003, 262, Fig. 6.69/11, 15).

Type 2: This type consists of biconical beads. Biconical beads exhibit four subtypes.

Type 2a: These beads are biconical in shape and have a smoothed surface (Fig. 3-2 Type 2a). Type 2a beads range in diameter from 0.4 to 0.6 cm and in length from 0.8 to 1.03 cm, and 27 such beads were recovered.

Type 2b: The beads examined under this type feature a raised, segmented, spherical bead form at their centre. On either side of this section, there are semi-circular raised sections on the body that follow one another and taper slightly towards the tip. The bead has a biconical appearance with tapered extensions on either side of the central bulge, tapering towards the tip (Fig. 3-2/Type 2b). Twenty-nine of these beads, ranging in diameter from 0.4 to 0.8 cm and in length from 1.9 to 2.6 cm, were recovered.

Type 2c: The bead represented by a single specimen is flattened biconical in shape and measures 0.7 cm in diameter and 0.3 cm in length (Fig. 3-2/Type 2c).

Type 2d: Both ends of the flattened biconical bead are terminated by conical projections (Fig. 3-2/Type 2d). The three specimens of beads recovered measure 0.6 cm in diameter and 0.7 cm in length.

Similar to Type 2a beads, those found at Troy (Sazcı, 2007, 413, 414) and Tell Arbid (Kolinski, 2007, 108, Fig. 13, E/6), Tell al-Raga, dated to the middle of the 3rd millennium BC (Curvers & Schwartz, 1990, Fig. 16/7), Tell Qura Quzaq (Pereiro, 1994, F.23/17), Tell Chagar Bazar (Mallowan, 1937, P. XVIII, A/4, 5), Tell Bia (Strommenger & Kohlmeyer, 1998, T. 19, 16/35:1, 11/4) and Tell Brak during the Akkadian period (Mallowan, 1947, P. XXVII). Similar Type 2b beads are

found at Tell Bia (Strommenger & Kohlmeyer, 1998: T. 41, 24/49; 105/e; T. 168/6), in the Akkadian period at Tell Beydar (Bretschneider & Cunningham, 2007, 34, 58192-M3), and at Tell Brak (Mallowan, 1947, P. XXVII).

Type 3: Global beads have been examined under type 3 and divided into six sub-types.

Type 3a: Two examples of this type of bead are spherical in shape and have a smoothed surface (Fig. 3-2/ Type 3a). The beads range in diameter from 0.8 to 1.5 cm and in length from 1.2 to 1.4 cm.

Type 3b: Type 3b beads consist of flattened spherical examples of type 3a beads (Fig. 3-2/Type 3b). An average of 1,250 of these beads were found. The beads have a diameter of 0.4 or 0.5 cm and a length of 0.2 or 0.3 cm.

Type 3c: Consists of beads with a spherical body and a body circumference divided into vertical segments (Fig. 3-2/Type 3c). Eleven beads of this type were recovered. The diameters of the beads range from 0.9 to 1.4 cm, while their lengths vary between 0.6 and 1.1 cm.

Type 3d: This type consists of flattened spherical specimens of globular segmented beads (Fig. 3-2/Type 3d). There are an average of 75 Type 3d beads. The diameters of the beads range from 0.3 to 0.6 cm, while their lengths vary between 0.2 and 0.3 cm.

Type 3e: Examples of globular-shaped segmented beads with one or two knobs at each end (Fig. 3-2/Type 3e). There are 6 beads, each with a diameter of 0.7 cm and a length of 1.0 cm.

Type 3f: The surface of the globular beads has been carved into horizontal and vertical sections to create reliefs (Fig. 3-2/Type 3f). The four specimens recovered have diameters of 0.9 cm and lengths ranging from 0.6 to 0.9 cm.

Similar to Type 3a beads, Type 3b beads were found in the Alacahöyük D tomb (Koşay, 1951, Plate CLVI), Resuloğlu (Yıldırım, 2006, 13, Fig. 18/a), Tarsus-Gözkule in ETÇ III (Goldmann, 1956, p. 453/2), Tell Bia (Strommenger & Kohlmeyer, 1998, T. 108/3, 13; T. 110/10), Tell Germayir (Mallowan, 1937, P. XVIII, A/3), Tell Brak (Mallowan, 1947, P. XXVII) and El-Qitar (Sagona, 1986, 115, Fig. 3, 15/b). Type 3c beads have been found at Tell Arbid (Kolinski, 2007, 108, Fig. 13/1-3), Tell Qara Quzaq (Pereiro, 1994, F.20/14), Tell Brak (Oates, 1987, P. XL/c.), Tell Chagar Bazar (Mallowan, 1937, P. XVIII, A/4), El-Qitar (Sagona, 1986, 115, Fig. 3, 15/a, d) and Tell Beydar (Bretschneider & Cunningham, 2007, 34, 58192-M3). Type 3d beads are found at Kalınkaya Cemetery (Zimmermann, 2007, 72, Fig. 8), Tell Beydar (Bretschneider & Cunningham, 2007, 34, 58192-M3), Tell Bia (Strommenger & Kohlmeyer, 1998, T. 21, 17/35:1/14), while beads similar to Type 3e beads were found at Troy (Schliemann, 1881, 514, Nr. 606-738/730).

3-Gold Beads

The beads, most of which are gold, display five different characteristics.

Type 1: These beads are formed by rolling thin sheets of metal into spirals with a circular hollow in the centre. The beads formed by joining two spirals have spaces between them that are used as thread holes; the areas with thread holes are slightly convex (Fig. 3-3/Type 1). Thirteen beads with a diameter of 0.62 cm were recovered.

Type 2: A tube-shaped thread hole is visible on the surface in the centre of the oval or circular metal plate (Fig. 3-3/Type 2). Three beads with a diameter of 0.6/0.5 cm were recovered.

Type 3: A cylindrical bead has been obtained by stacking metal sheets on top of each other, leaving gaps between them (Fig. 3-3/Type 3). There is one bead with a diameter of 0.2 and a length of 0.4.

Type 4: This type consists of beads with four faces. It has two subtypes.

Type 4a: This type consists of convex beads with four faces (Fig. 3-3/ Type 4a). There are two beads, each 0.44 cm in diameter and 0.40 cm in length.

Type 4b: This bead is flattened, with four straight sides, and has a cuboid shape (Fig. 3-3/Type 4b). One bead measuring 0.33 cm in diameter and 0.27 cm in length was found.

Type 5: This type consists of circular flat beads and exhibits two sub-type characteristics.

Type 5a: Beads classified under this type are flattened cylindrical in shape (Fig. 3-3/Type 5a). Twenty-three beads with a diameter of 0.16 and a length of 0.06 were recovered.

Type 5b: Created by adding independent pieces to a flattened circular form and given a flattened cylindrical shape (Fig. 3-3/Type 5b). There is one bead with a diameter of 0.16 and a length of 0.06.

Gold beads, similar to Type 1, have been found at Troy (Tolstikov & Treister, 1996, 94/101) and Tell Brak (Mallowan, 1947, P. XXXV) (Akkadian period). Type 2 beads are found in Anatolia at Troy IIg (Blegen et al., 1950, Fig. 356/17), Karataş-Semayük (Mellink, 1969, 323, Lev. 74, Fig. 15, 17), Kültepe (Özgüç, 1963, 96; Özgüç, 1984, 43, Fig. 3-39), Alişar Höyük (Schmidt, 1933, 78, Fig. 120/a.92), Eskiyapar (Özgüç & Temizer, 1993, Plate 112/a-c), and a quadruple example at Alacahöyük (Koşay, 1951, 74, Plate CC). The silver and double-stringed examples were found at Baklatepe and dated to the end of ETÇ II and the beginning of ETÇ III (Keskin, 2009, 224, 225, Plate 18/385-391; Keskin, 2004, 148). In Mesopotamia, an example of silver was found at the FS Temple in Tell Brak during the Akkadian period (Oates & Oates, 1993, 167, Fig. 13; Mallowan, 1947, P. XXXIII; For examples of gold at Tell Brak, see: Evans, 2003, 232, 158a) and at Tell Umm El-Marra, dated to 2300 BCE (Schwartz et al., 2003, 335, Fig. 16.). Amlash (Culican, 1964, P.VIII/b, P.IX), Mohenjo-daro (2600–1900 BCE) (Collins, 2003a, 393/279–280), and Tell Abraq in the Late 3rd millennium (Collins 2003b: 314/211a-b) are other centres where they have been found in Mesopotamia. Beads of this type have been found in Novosvobodnaya-Kurgan 2 in the North Caucasus and dated to the second half of the 3rd millennium BC (Piotrovsky, 2003b, 296/197). Type 2 and 5a beads have also been recovered at Poliohni (Brea-Bernabò 1976: CCLII/5-10, 14). Similar to Type 4a four-sided beads are seen at Troy IIg (Blegen et al., 1950, Fig. 356/3). Type 4b beads are found at Troy (Sazcı, 2007, 182, A1-S6, 183). Similar beads to Type 5a are found at Alacahöyük (Koşay, 1951, Plate CLV/36), Eskiyapar (Özgüç & Temizer, 1993, 621, Fig. 39, Pl. 114/2 a-b), Kültepe (Özgüç, 1986, Fig. 3-41/b) and Troy (Sazcı, 2007, 228, D-S36). Similar examples of Type 3 are found at Alacahöyük (Koşay, 1951, Plate CCIV, Fig. 2).

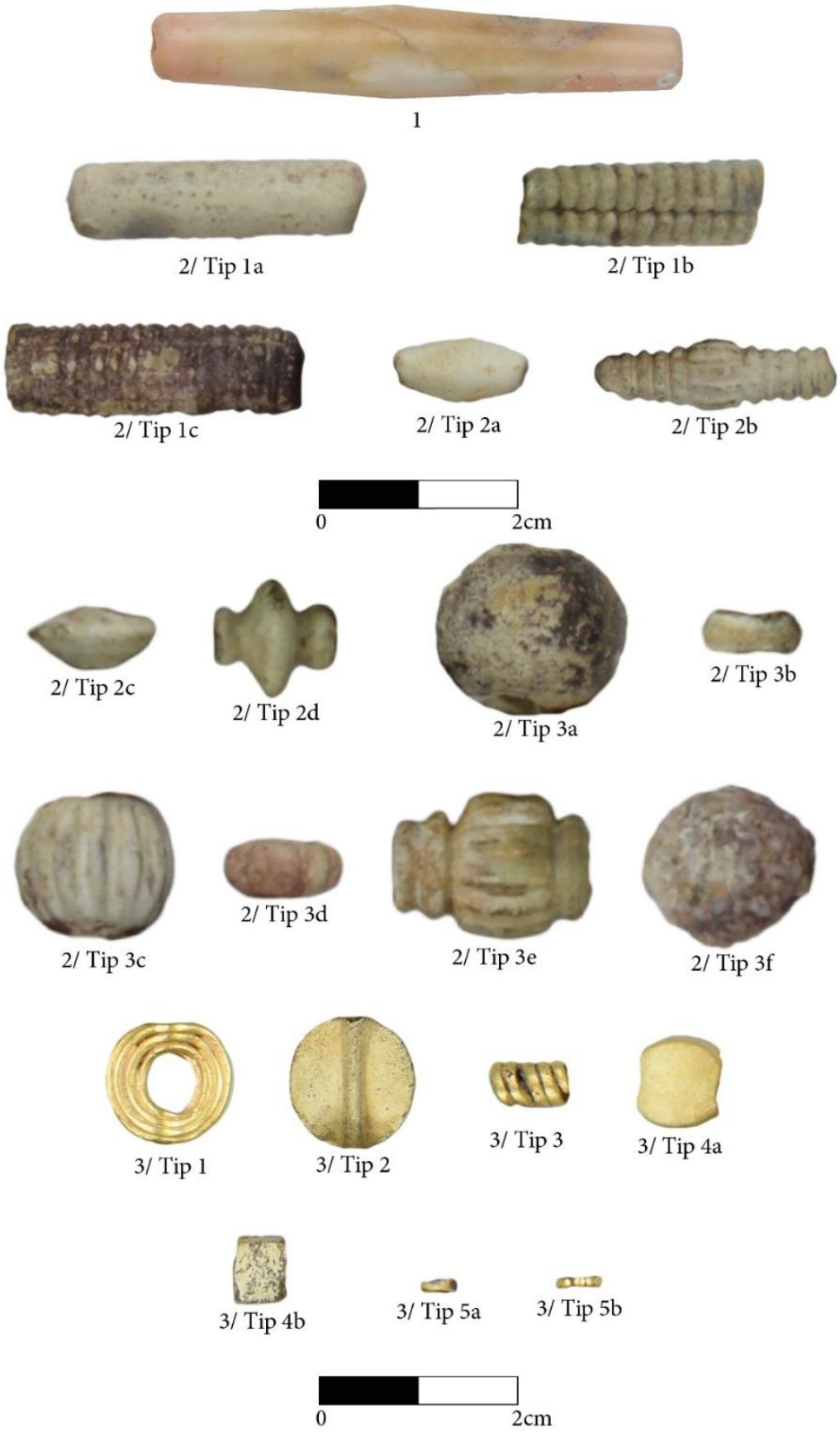

Fig. 3: Beads found at Seyitömer Höyük.

4. Evaluation and Conclusion

Seyitömer Höyük, the majority of the carnelian, faience and gold beads recovered from layer V were found in the main chamber of the administrative structure dated to phase V/B.

Beads that were likely used as jewellery appear along a line stretching from the Indus Region, Southern Mesopotamia, Northern Mesopotamia, Anatolia and the Aegean Islands. The beads were largely recovered from burial sites dating to the second half of the third millennium, such as Ur, Tell Beydar, Tell Bia, Tell Arbid, Tell Qara Quzaq, Tell Banat, Tell el Qitar, Tell Umm el-Marra, Alacahöyük, Kültepe, Eskiyapar, Resuloğlu, Baklatepe, and Karataş-Semayük (Fig. 4). The number of beads recovered from both settlements and cemeteries is quite limited. Therefore, it is possible to say that the jewellery recovered was produced for use by a special group known as the elite in each society.

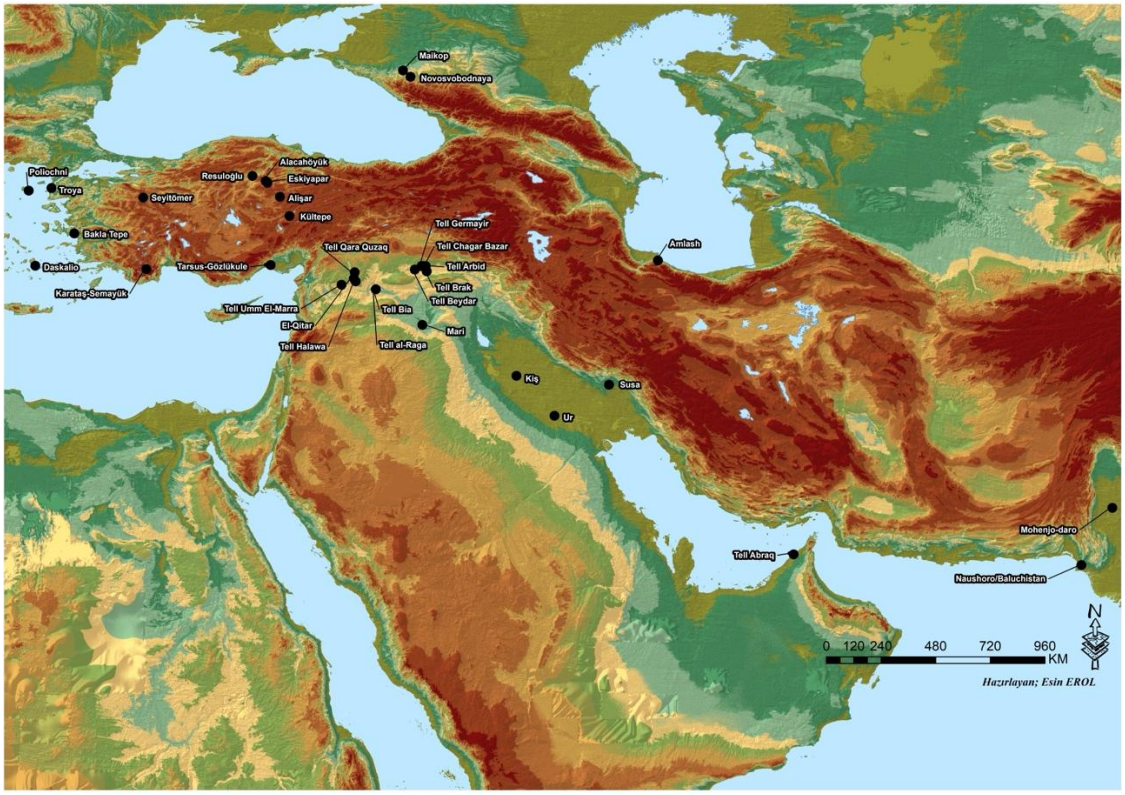

Figure 4: Map showing settlements where similar beads to those found at Seyitömer Höyük have been discovered.

The aforementioned beads, within the administrative structure of the V/B phase, include a group of animal-figured ceramic beads (Ünan, 2024), spiral-headed pins (Bilgen et al., 2015) and cylinder seals (Bilgen et al., 2015) also support the view that the structure was an administrative building that could be called a palace (Fig. 5). In addition to the finds recovered from this structure, Syrian-Mesopotamian artefacts such as lead figurine moulds (Ünan & Ünan, 2020, 37-53) from different phases of the settlement, as well as balance weights, one of the indicators of trade between Mesopotamia and Anatolia, have also been identified (Ünan, 2022, 33-47). Syrian bottles, goblets, tankards and depas-type vessels found at the settlement were identified in different structures (Ünan, 2023; Bilgen & Kapuci, 2019). When these findings are evaluated as a whole, they indicate the presence of a group of merchants engaged in long-distance trade, as well as an administrator at Seyitömer. Therefore, it is possible to say that, in addition to the administrator who possessed status objects forming a special group within the settlement, a

limited number of status objects were also possessed by some of the settlers. For this reason, there was an elite group in Seyitömer Höyük. It is thought that the special finds, including jewellery made of beads owned by the elite, reached Seyitömer via merchants from Mesopotamia.

When evaluated as a whole, these findings clearly indicate that Seyitömer Höyük was one of the key points of land trade during the Early Bronze Age (Şahoğlu, 2005; Efe, 2007; Oğuzhanoğlu, 2019). The routes following the Mesopotamia, Southeast Anatolia, and Central Anatolia itineraries passed through Seyitömer and must have branched off from there to Northwest Anatolia and the Aegean coast.

Figure 5: Seyitömer Höyük Phase V/B administrative structure and found jewellery and seals.

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APPLYING SUPPLY CHAIN MANAGEMENT PRINCIPLES IN THE BANKING SECTOR: A CONCEPTUAL FRAMEWORK FOR AZERBAIJAN

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ABSTRACT

This study analyzes the adoption and performance consequences of supply chain management (SCM) strategies in the Azerbaijani banking sector, a post-Soviet emergent market undergoing fast digital transformation. Using a sequential explanatory mixed-methods design, quantitative data were collected from 178 managers in 18 commercial banks and analysed through confirmatory factor analysis and structural equation modelling, followed by interviews with 17 senior executives to contextualise the results. The findings show a moderate-to-high level of SCM adoption, with information sharing and process integration emerging as the strongest dimensions, while risk and revenue-sharing mechanisms remain least developed. SCM practices significantly enhance operational efficiency and service quality, which fully mediate their impact on overall bank performance, explaining 68% of its variance. Top management commitment further strengthens these effects. The study provides the first empirical evidence of service supply chain theory in the South Caucasus banking context, highlighting the role of regulatory-driven digitalisation and fintech partnerships as catalysts for SCM maturity.

1. Introduction

SCM has long been associated primarily with manufacturing and the movement of physical goods. More recent research, however, emphasises that service organisations also rely on supply chains that coordinate information, processes and relationships across multiple internal and external actors (Ellram et al., 2004; Baltacioglu et al., 2007). In banking, these chains cover product development, channel and customer management, risk assessment, transaction processing, IT support, cooperation with outside providers, regulatory compliance and after-sales services. The effectiveness of these interlinked processes shapes cost structures, response times, service quality and ultimately customer loyalty and profitability (de Sousa Jabbour et al., 2019; Marodin et al., 2017).

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Although service supply chain management (SSCM) has attracted increasing attention, empirical work remains concentrated in a limited set of economies, such as the United States, the United Kingdom, Germany and Australia, and a few large emerging markets, including China, India, Malaysia and Turkey (Huo et al., 2015; Liu et al., 2018). By contrast, post-Soviet transition economies in the South Caucasus, and particularly Azerbaijan, have received very limited coverage, despite substantial reforms and rapid digital transformation since the mid-2010s. Between 2015 and 2024, Azerbaijan's banking sector underwent consolidation (the number of banks declined from 45 to 28), expanded outsourcing of IT and customer services, and intensified collaboration with fintechs, payment providers and logistics partners, underpinned by ISO 9001 and ISO/IEC 27001 requirements (CBAR, 2023; FIMSA, 2022).

At the same time, the COVID-19 pandemic and the diffusion of digital public and financial services—such as the "myGov" ecosystem, open banking initiatives and pilot blockchain applications—exposed banks to heightened expectations regarding speed, security and convenience (World Bank, 2022). To meet these expectations, banks must integrate their internal processes with those of external partners in a manner that mirrors modern supply chain thinking. SCM therefore offers a useful lens for understanding how banks orchestrate networks of partners to deliver reliable, efficient and high-quality services. Yet little is known about which SCM practices are adopted, how mature they are, what drivers and obstacles exist and how SCM influences performance in the Azerbaijani banking context.

To address these gaps, this study focuses on four research questions:

1. What is the level of SCM adoption in Azerbaijani commercial banks?
2. Which SCM dimensions—supplier relationships, information sharing, process integration, risk management and performance measurement—are most and least developed?
3. What organisational and institutional factors drive or hinder SCM adoption?
4. How does SCM maturity affect operational efficiency, service quality and overall bank performance?

This paper contributes to the literature in three ways. First, it extends SSCM research to an underexplored post-Soviet emerging economy, thereby reducing the geographical bias of existing work. Second, it adapts the SCOR framework and the Service Profit Chain to a heavily regulated, digitally oriented banking environment and tests their relevance empirically. Third, it provides actionable insights for managers and regulators in Azerbaijan and similar economies seeking to build SCM capabilities for competitive advantage.

The paper is structured as follows. Section 2 reviews the literature on SCM in services and banking. Section 3 develops the conceptual framework and hypotheses. Section 4 explains the mixed-methods design. Section 5 presents the empirical results. Section 6 discusses theoretical and practical implications. Section 7 concludes with recommendations, limitations and directions for future research.

2. LITERATURE REVIEW

2.1. Supply Chain Management in Service Industries

SCM originated in manufacturing and focused on coordinating material flows across suppliers, manufacturers and distributors. Over time, scholars have argued that the underlying logic of

integration and coordination applies equally to service organisations, where key flows consist of information, tasks and customer interactions rather than physical goods (Ellram et al., 2004; van Looy et al., 2011). Customer involvement in production, intangible outputs, and a high degree of simultaneity between production and consumption are characteristics of service supply chains (Sampson & Froehle, 2006; Baltacioglu et al., 2007).

Recent work identifies several core SSCM dimensions that underpin performance improvements:

- **Supplier relationship management**, involving long-term partnerships, joint planning and problem-solving;
- **Information sharing and technology alignment**, which provide transparency and real-time coordination;
- **Process integration**, referring to harmonisation of key workflows and interfaces across organisational boundaries;
- **Risk and revenue sharing**, where partners jointly manage uncertainty and incentives;
- **Performance measurement and continuous improvement**, which generate feedback for learning and adaptation (Giannakis & Louis, 2011; Zhang et al., 2016; Liu et al., 2018).

Empirical studies in sectors such as healthcare, tourism, transport and retail suggest that these practices enhance service quality, responsiveness, cost efficiency and financial results (Boon-itt & Pongpanarat, 2011; de Sousa Jabbour et al., 2019). However, the extent to which such findings generalise to financial services and different institutional environments remains an open question.

2.2. SCM in Banking and Financial Services

Banks represent a complex form of service supply chain because they must coordinate internal functions and a differentiated portfolio of external partners, including software vendors, payment networks (e.g., Visa, Mastercard), credit bureaus, call centres, logistics operators and fintech companies (de Sousa Jabbour et al., 2019; Petersen et al., 2014). SCM practices in banking typically address loan origination, payments, card issuance, compliance screening and customer support, among others.

Evidence from advanced and large emerging economies indicates that SCM-inspired integration and information sharing can significantly improve banking operations. Integrated lending processes have been associated with reductions of 35–60% in loan processing times and improved on-time delivery of services (Wang et al., 2015; Marodin et al., 2017). Collaborative risk-management and data exchange with external partners can help reduce fraud and credit losses (Govindan et al., 2015). Multichannel integration and seamless customer journeys are linked to higher satisfaction and loyalty (Akter et al., 2018).

Furthermore, banks adopting SCM practices tend to achieve better financial outcomes, including higher ROA and more favourable cost-to-income ratios (Huo et al., 2015; Liu et al., 2018). Yet most studies focus on large, mature systems, leaving unresolved how SCM functions in smaller, regulation-driven emerging markets with legacy infrastructure and relatively concentrated banking sectors.

2.3. Theoretical Foundations

Several theoretical lenses assist in linking SCM adoption to performance in banking. The **Resource-Based View (RBV)** argues that firms derive sustained competitive advantage from resources and capabilities that are valuable, rare, inimitable and organised (Barney, 1991). Well-designed SCM practices—such as integrated processes, strong supplier relationships and advanced information systems—can be seen as such capabilities, especially when deeply embedded in organisational routines. The **dynamic capabilities** perspective further stresses the ability to reconfigure these resources in response to environmental change (Teece, 2018).

The **SCOR (Supply Chain Operations Reference) model** offers a structured overview of supply chain activities, traditionally in manufacturing, by grouping them into Plan, Source, Deliver, Return and Enable processes. Recent adaptations extend this logic to service environments, including financial services, by redefining these processes around information flows, customer interactions and regulatory tasks (APICS, 2017; Petersen et al., 2014).

Employee satisfaction, customer satisfaction, loyalty, and profitability are all impacted by internal service quality and process efficiency, as explained by **the Service Profit Chain (SPC)** (Heskett et al., 1994). In banking, SCM can be understood as a set of practices that improve internal process reliability and integration, thereby reinforcing the links described by the SPC (de Sousa Jabbour et al., 2019).

2.4. SCM in Emerging and Transition Economies

Research on SCM in emerging markets highlights the importance of institutional and organisational factors. Regulatory pressure, competitive intensity, IT readiness and organisational culture have been identified as key antecedents of SCM adoption in Turkey, Malaysia, India, Pakistan and China (Huo et al., 2015; Liu et al., 2018; Govindan et al., 2015). Frequent obstacles include resistance to change, skills gaps, outdated technology platforms and weak contractual enforcement.

In the South Caucasus, and particularly in Azerbaijan, similar drivers and barriers are likely to be present, but they have not been systematically examined. Azerbaijan combines crisis-driven banking sector consolidation, mandatory digitalisation and a rapidly expanding ecosystem of non-bank financial service providers. This combination generates strong incentives to develop SCM practices, but also significant challenges associated with legacy systems and institutional constraints.

2.5. Research Gap

Existing studies show that SCM practices can improve performance in banking sectors of advanced and large emerging economies. However, little is known about how these practices are adopted and perform in smaller post-Soviet transition economies such as Azerbaijan. Moreover, many previous studies are purely quantitative or qualitative, whereas a mixed-methods approach can capture both the magnitude of effects and the underlying mechanisms.

This study addresses these gaps by applying a sequential explanatory mixed-methods design to examine SCM adoption in Azerbaijani banks. It quantifies adoption levels and performance effects using survey data, and complements these results with qualitative evidence from executive interviews to understand how digitalisation, regulation and organisational factors shape SCM in this setting.

3. CONCEPTUAL FRAMEWORK AND HYPOTHESES

Drawing on the literature, this study proposes a conceptual framework that links SCM adoption to operational efficiency, service quality and bank performance, with top management commitment acting as a moderator. The framework integrates insights from RBV and dynamic capabilities, the SCOR model and the Service Profit Chain.

From an RBV perspective, SCM practices constitute bundles of organisational routines and relational capabilities that are difficult to imitate (Barney, 1991; Teece, 2018). These practices are grouped into five dimensions: supplier relationship management, information sharing, process integration, risk management and performance measurement. In line with SCOR, these dimensions support the planning, sourcing and delivery of services in banking (APICS, 2017; Petersen et al., 2014). The SPC suggests that improved internal efficiency and service quality mediate the effect of SCM on performance (Heskett et al., 1994).

The framework assumes that institutional factors such as IT infrastructure readiness and regulatory pressure act as antecedents of SCM adoption, while organisational factors such as legacy systems and resistance to change can constrain implementation. Once adopted, SCM practices are expected to enhance operational efficiency (e.g., shorter processing times, fewer errors, lower costs) and service quality (e.g., reliability, responsiveness, customer satisfaction). These two constructs, in turn, should improve overall bank performance, measured by financial indicators and customer-related outcomes.

Top management commitment is hypothesised to strengthen the relationship between SCM adoption and outcomes by providing resources, signalling strategic priority and encouraging cross-functional collaboration (Govindan et al., 2015; Zhang et al., 2016). In emerging markets, where formal processes may be less institutionalised, this moderating role can be particularly pronounced.

3.1. Hypotheses

Based on this reasoning and prior evidence, the following hypotheses are proposed:

H1: SCM adoption in Azerbaijani banks has a positive direct effect on operational efficiency.

H2: SCM adoption in Azerbaijani banks has a positive direct effect on service quality.

H3: Operational efficiency positively mediates the relationship between SCM adoption and bank performance.

H4: Service quality positively mediates the relationship between SCM adoption and bank performance.

H5: Top management commitment positively moderates the relationship between SCM adoption and both operational efficiency and service quality.

These hypotheses are tested using structural equation modelling based on survey data from managers in Azerbaijani banks.

4. Methodology

4.1. Research Design

The study adopts a **sequential explanatory mixed-methods** design (Creswell & Plano Clark, 2018). In the first, quantitative phase, a structured survey is used to measure SCM adoption,

operational efficiency, service quality, bank performance and key antecedent variables. In the second, qualitative phase, semi-structured interviews with executives from the same banks are conducted to interpret and contextualise the quantitative results.

4.2. Population and Sampling

The population consists of all commercial banks operating in Azerbaijan as of December 2023. According to CBAR (2024), 26 licensed banks were active at that time. A stratified sampling approach was adopted using bank asset size as the criterion, categorising banks as large (assets above AZN 1 billion), medium (AZN 200 million–1 billion) and small (below AZN 200 million).

From these strata, 18 banks were selected, including at least five from each category. Within each bank, the target respondents were senior and middle managers from operations and supply chain-related functions, IT and digital banking, risk and compliance, procurement and vendor management, and customer service or branch management. Each bank was asked to provide 8–12 respondents, yielding an initial pool of 214 managers.

For the qualitative phase, **purposive sampling** was used to select 15–18 executives (C-level and department heads) from the same banks, with attention to variation in perceived SCM maturity.

4.3. Data Collection Instruments

4.3.1. Survey Instrument

The survey instrument was developed by adapting established scales from the SCM and service management literature:

- SCM practices (five dimensions; 25 items) from Boon-itt and Pongpanarat (2011) and Huo et al. (2015);
- Operational efficiency (6 items) from Wang et al. (2015);
- Service quality (8 items) from Akter et al. (2018);
- Bank performance (5 perceptual items focusing on ROA, cost-to-income ratio and customer-related indicators) from Liu et al. (2018);
- Antecedents and moderators (top management commitment, IT infrastructure readiness, regulatory pressure; 12 items) from Govindan et al. (2015) and Zhang et al. (2016).

Items were measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). The questionnaire was drafted in English, translated into Azerbaijani and back-translated into English following Brislin's (1970) procedure. A pilot test with 30 managers indicated good reliability (Cronbach's alpha between 0.81 and 0.94) and clarity of wording.

4.3.2. Interview Guide

The semi-structured interview guide contained 12 open-ended questions on current SCM-related practices, perceived benefits of integration and collaboration, main implementation challenges, the role of fintech partnerships, the impact of regulatory requirements (e.g., ISO/IEC 27001, open banking) and perceived changes in performance. Probing questions were used to explore issues emerging from the quantitative findings.

4.4. Data Collection Procedure

The survey was administered online via a secure platform between March and May 2024. Bank management were contacted to obtain permission and support. Invitations with the survey link

were sent by email to identified managers, followed by reminders and, where necessary, telephone follow-ups. Participation was voluntary and anonymous.

A total of 178 usable responses were received, corresponding to a response rate of 83.2%. Non-response bias was assessed by comparing early and late respondents on key variables; no significant differences were detected ($t < 1.96$, $p > .05$).

Qualitative data were collected in June–July 2024. Interviews with 17 executives (CEOs, COOs, CIOs, Chief Risk Officers and heads of key departments) were conducted face-to-face or via online platforms, depending on availability. Interviews lasted between 45 and 75 minutes and were recorded with consent. The recordings were transcribed verbatim for analysis.

4.5. Data Analysis

Quantitative data were analysed using SPSS and AMOS. Descriptive statistics and reliability analyses were performed first. A **confirmatory factor analysis (CFA)** assessed the measurement properties of the constructs. Convergent validity was evaluated by factor loadings, composite reliability (CR) and average variance extracted (AVE), while discriminant validity was assessed using the Fornell–Larcker criterion (Fornell & Larcker, 1981).

After confirming the measurement model, **structural equation modelling (SEM)** with maximum likelihood estimation was used to test the hypothesised relationships. Mediation effects were assessed through bootstrapped confidence intervals based on 5,000 resamples. Moderation by top management commitment was examined via interaction terms and the PROCESS macro. Model fit was evaluated using χ^2/df, CFI, TLI, RMSEA and SRMR.

Qualitative data were analysed using NVivo 14 and the thematic analysis approach of Braun and Clarke (2006). Initial codes were generated inductively from the transcripts, then grouped into broader themes that were compared with and used to elaborate the quantitative findings.

4.6. Validity, Reliability and Ethics

Content validity of the survey instrument was reviewed by three SCM scholars and two senior Azerbaijani bank executives. Reliability was confirmed through Cronbach's alpha and composite reliability. Harman's single-factor test and the marker-variable technique suggested that common method bias was not a major concern.

Ethical approval was obtained from the relevant university ethics committee. Participants were informed about the study's purpose, the voluntary nature of participation, the academic use of data and the measures taken to protect anonymity and confidentiality.

5. Findings

5.1. Response Rate and Sample Profile

The survey produced 178 valid responses from managers in 18 commercial banks, representing a substantial share of the Azerbaijani banking sector by number of institutions and total assets. Large banks (assets above AZN 1 billion) accounted for 46.1% of the sample, medium banks for 34.3% and small banks for 19.7%.

Most respondents were middle managers (77.0%), with 23.0% in senior management (C-level or deputy level). Functional areas included operations and supply chain-related activities (30.3%), IT and digital banking (27.0%), risk and compliance (20.8%), procurement and vendor

management (13.5%) and customer service and branches (8.4%). A majority of respondents (61.2%) had more than ten years of professional experience, suggesting strong familiarity with their banks' processes and partnerships.

5.2. Measurement Model

The CFA supported the proposed eight-factor model representing the five SCM dimensions, operational efficiency, service quality and bank performance. All standardised factor loadings were above 0.70 and statistically significant ($p < .001$). CR values ranged from 0.87 to 0.95, and AVE values from 0.58 to 0.76, indicating good convergent validity.

Discriminant validity was confirmed by the Fornell–Larcker criterion, as the square root of AVE for each construct exceeded its correlations with other constructs (Fornell & Larcker, 1981). Overall model fit was satisfactory ($\chi^2/df = 1.84$, CFI = 0.96, TLI = 0.95, RMSEA = 0.049, SRMR = 0.041).

Harman's single-factor test showed that a single factor accounted for 38.2% of the variance, and all correlations with the marker variable remained below 0.12, indicating that common method bias was unlikely to distort the results.

5.3. Descriptive Results on SCM Adoption

Descriptive statistics indicate that SCM adoption in Azerbaijani banks is **moderate to high**, with an aggregate mean of 4.92 (SD = 1.04) on the seven-point scale. Among the five SCM dimensions, **information sharing** scores highest (M = 5.61), reflecting extensive use of digital channels, open-banking APIs and collaboration with fintech partners.

In contrast, **risk management and risk/revenue-sharing arrangements** score lowest (M = 4.31), suggesting that banks are more advanced in sharing information and integrating processes than in formalising balanced mechanisms for joint risk taking and incentive alignment with third-party providers. Supplier relationship management, process integration and performance measurement fall between these extremes.

5.4. Structural Model and Hypothesis Testing

The structural equation model, estimated with 5,000 bootstrap resamples, exhibits acceptable fit ($\chi^2/df = 2.01$, CFI = 0.95, TLI = 0.94, RMSEA = 0.053). All five hypotheses are supported.

- **H1:** SCM adoption has a strong positive effect on operational efficiency ($\beta = 0.68$, SE = 0.06, $t = 11.32$, $p < .001$).
- **H2:** SCM adoption has a strong positive effect on service quality ($\beta = 0.74$, SE = 0.05, $t = 14.81$, $p < .001$).
- **H3:** Operational efficiency positively influences bank performance ($\beta = 0.41$, SE = 0.08, $t = 5.13$, $p < .001$), and the indirect effect of SCM on performance via efficiency is significant ($\beta\_indirect = 0.28$, $p < .001$).
- **H4:** Service quality has a significant positive effect on bank performance ($\beta = 0.49$, SE = 0.07, $t = 7.00$, $p < .001$), and the indirect effect of SCM on performance through service quality is also significant ($\beta\_indirect = 0.36$, $p < .001$).
- **H5:** The interaction between SCM adoption and top management commitment is positive and significant ($\beta = 0.22$, SE = 0.07, $t = 3.14$, $p = .002$), indicating that managerial support amplifies the effects of SCM on both efficiency and quality.

The model explains 54% of the variance in operational efficiency, 61% in service quality and 68% in bank performance, demonstrating strong explanatory power.

5.5. Qualitative Findings

The thematic analysis of 17 executive interviews produced four overarching themes that enrich the quantitative findings:

1. **Digitalisation as a Structural Enabler.** Executives stressed that mandatory ISO/IEC 27001 certification, open banking regulations and the "myGov" ecosystem accelerated information sharing and process integration with external partners. Many banks portrayed digitalisation as a regulatory necessity that catalysed SCM-like practices.
2. **Fintech Partnerships and New Supplier Configurations.** Collaboration with fintechs, payment service providers and global technology firms has become central to service delivery. Traditional vendor relationships are evolving into more strategic partnerships, although formal risk- and revenue-sharing contracts remain less developed.
3. **Legacy Systems and Cultural Resistance as Barriers.** Several banks rely on legacy core-banking systems that complicate integration and automation. Hierarchical organisational cultures and siloed structures inherited from the Soviet period hinder cross-functional collaboration and process redesign, particularly in smaller and state-influenced banks.
4. **Visible Performance Improvements.** Executives reported that banks with higher SCM maturity achieved noticeable improvements, such as reductions of around 40–45% in loan-processing time and increases of approximately 15–20 percentage points in customer satisfaction scores.

Overall, the qualitative insights corroborate the quantitative model and highlight how regulation, digitalisation and organisational factors interact to shape SCM adoption and outcomes in Azerbaijani banks.

6. DISCUSSION

6.1. Interpretation of Key Findings

The study provides strong evidence that SCM practices, originally developed for manufacturing and logistics, are highly relevant for service-dominant sectors such as banking in a small post-Soviet emerging economy. The strong positive effects of SCM adoption on operational efficiency and service quality, and the full mediation of the SCM–performance relationship through these constructs, are consistent with RBV and the Service Profit Chain (Barney, 1991; Heskett et al., 1994; Teece, 2018).

The relatively high levels of explained variance (54% for efficiency, 61% for service quality and 68% for performance) suggest that SCM practices account for a substantial share of inter-bank performance differences. Compared with findings from more mature markets, the indirect effects observed here appear particularly strong, supporting the idea that introducing integration and collaboration mechanisms in previously fragmented systems yields substantial performance gains (Huo et al., 2015; Liu et al., 2018).

The moderating effect of top management commitment underscores the importance of leadership for successful SCM implementation, especially in contexts where formal processes are less institutionalised. Banks whose senior teams actively champion SCM initiatives, allocate

resources and encourage cross-functional collaboration seem better able to convert SCM adoption into tangible improvements in efficiency, service quality and performance.

6.2. Theoretical Contributions

The study contributes to the SCM and service operations literature in several ways. First, it extends empirical research on SSCM to the South Caucasus, helping to diversify the geographical focus of existing evidence, which has been dominated by Anglo-Saxon and East Asian contexts (Ellram et al., 2004; Baltacioglu et al., 2007).

Second, by adapting and testing a framework that integrates RBV, SCOR and the Service Profit Chain, the study shows that these theoretical perspectives remain applicable in a heavily regulated, digitally transforming banking sector. The findings suggest that SCM practices can be interpreted as dynamic capabilities that help banks reconfigure processes and partnerships in response to regulatory and technological change (Teece, 2018; APICS, 2017).

Third, the observed mediation patterns strengthen the understanding of operational efficiency and service quality as central channels through which SCM affects financial and customer-related outcomes, extending the logic of the service profit chain to a new institutional context.

6.3. Managerial and Policy Implications

For bank executives, the findings underline that SCM should be treated as a **strategic capability**. Investments in integrated information systems, collaborative supplier governance and robust performance measurement can yield substantial efficiency and quality improvements that translate into better financial results.

Particular emphasis should be placed on **formalising risk- and revenue-sharing arrangements** with fintech and IT partners. The relatively low scores on SCM's risk management dimension show that many banks still rely on asymmetrical or ad hoc contractual structures, which may weaken incentives for innovation and joint problem-solving. Developing standardised templates for such arrangements could help institutionalise more balanced partnerships.

For regulators such as CBAR and FIMSA, the study demonstrates that digitalisation and open banking regulations already act as powerful external catalysts for SCM maturity. Future regulatory initiatives could build on this foundation by encouraging clearer frameworks for vendor performance evaluation, data governance and joint risk management.

For banks in neighbouring transition economies such as Georgia, Armenia and selected Central Asian countries, the Azerbaijani case illustrates how sector consolidation, mandatory digitalisation and SCM-based process redesign can support rapid modernisation of banking service supply chains.

6.4. Limitations and Future Research

This study has several limitations. First, it relies primarily on **perceptual measures** of performance, which may be affected by respondent bias. Linking SCM adoption data with objective financial indicators from official sources would provide a stronger test of the hypothesised relationships.

Second, the cross-sectional design limits causal inference. Longitudinal studies following banks over time—for instance, before and after the full implementation of open banking or expansions of the "myGov" ecosystem—would provide more robust evidence on the dynamics of SCM adoption and performance.

Third, while the sample covers a large proportion of the Azerbaijani banking sector, the unique governance structures of large state-owned banks may require separate in-depth case studies.

Future research could also explore more fine-grained mechanisms, including the role of specific digital technologies, the interaction between internal culture and external regulation and the potential of blockchain-based smart contracts for risk and revenue sharing in financial service supply chains.

7. Conclusion

This study examined the adoption and performance impact of SCM practices in the Azerbaijani banking sector using a sequential explanatory mixed-methods design. The findings show that Azerbaijani banks have moved beyond traditional, siloed structures towards more integrated service supply chains, heavily influenced by regulatory requirements and digital transformation.

Empirical results reveal that SCM adoption exerts strong positive effects on operational efficiency and service quality, and that these two constructs fully mediate its impact on overall bank performance. Top management commitment further enhances these relationships. These findings confirm the relevance of SSCM theory, the SCOR framework and the Service Profit Chain for banking in post-Soviet emerging economies.

From a practical standpoint, the study highlights the need for banks to deepen SCM capabilities—especially in the area of risk and revenue sharing with external partners—and for regulators to design policies that support not only digitalisation but also robust governance of service supply chains. More broadly, the Azerbaijani experience suggests that carefully designed regulatory interventions combined with SCM-based process redesign can enable rapid modernisation of banking sectors in similar transition economies.

In conclusion, SCM in banking should not be viewed solely as an operational tool; it represents a strategic approach to orchestrating complex networks of partners, technologies and processes. For Azerbaijani banks, and for institutions in comparable settings, building such capabilities offers a clear pathway to sustainable competitiveness in an era of open banking, fintech innovation and regional economic diversification.

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SERVICE QUALITY ASSESSMENT IN AZERBAIJAN'S PUBLIC HEALTH SYSTEM USING THE SERVQUAL FRAMEWORK

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ABSTRACT

This research examines the application of the SERVQUAL model as a framework for evaluating service quality in the healthcare sector. Given the healthcare system's vital role in safeguarding public well-being, the quality of services delivered plays a decisive role in shaping patient satisfaction, trust, and clinical outcomes. The SERVQUAL model, which effectively identifies gaps between patients' expectations and their actual experiences, is employed in this study to evaluate healthcare services based on five essential dimensions: tangibles, reliability, responsiveness, assurance, and empathy. The model's adaptability makes it particularly suitable for capturing the complexities of healthcare delivery. This analysis is especially pertinent to the context of Azerbaijan, a country where healthcare reforms are actively reshaping service provision. Ongoing initiatives, such as infrastructure modernization, digital transformation through electronic health records, and enhancements in healthcare personnel training, are commendable. However, significant disparities persist, particularly in rural areas, where access to quality healthcare remains limited. Through a detailed application of the SERVQUAL model, the study identifies specific gaps in service delivery that hinder overall patient satisfaction and trust in the system. The findings provide valuable guidance for healthcare administrators, policymakers, and practitioners seeking to implement patient-focused strategies. Key recommendations include investing in continuous staff development, standardizing service protocols, and expanding digital health solutions to enhance service responsiveness and reliability. Furthermore, the study emphasizes the importance of implementing regular performance evaluations and feedback mechanisms to ensure sustained quality improvement. Ultimately, aligning healthcare delivery with patient expectations will contribute to more equitable, effective, and trusted health services in Azerbaijan.

1. Introduction

The healthcare industry holds a pivotal role in society, where the quality of services provided has a direct and profound effect on patient outcomes, satisfaction, and trust in the system. As healthcare becomes more patient-oriented and competitive, understanding and managing

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service quality is a growing priority for providers. In this context, the SERVQUAL model- developed by Parasuraman, Zeithaml, and Berry- serves as a vital tool for evaluating service performance. It systematically assesses the differences between patient expectations and perceptions across five key dimensions: tangibles, reliability, responsiveness, assurance, and empathy. In recent years, Azerbaijan's healthcare sector has entered a phase of dynamic transformation, fueled by economic development, public health initiatives, and an increasing emphasis on patient-centered care. Government-led reforms have sought to upgrade healthcare infrastructure, implement digital health solutions, and bring local services in line with international quality benchmarks. Despite these positive developments, challenges remain in achieving uniform service quality across regions and institutions. Therefore, applying the SERVQUAL model in the Azerbaijani context offers a structured approach to assess existing strengths and areas needing improvement. This study leverages the SERVQUAL framework to pinpoint specific gaps in service quality within Azerbaijan's healthcare system. It seeks to deliver practical insights that healthcare managers and policymakers can use to refine service delivery processes. By gaining a clearer understanding of patient perspectives and experiences, healthcare institutions can develop more effective, patient-centric strategies that raise satisfaction levels and support better health outcomes. Moreover, as the country continues to invest in the modernization and digitalization of its healthcare infrastructure, integrating evidence-based evaluation tools like SERVQUAL will be crucial. Such tools enable organizations to establish continuous feedback loops, benchmark progress, and instill a culture of ongoing quality improvement. In doing so, Azerbaijan's healthcare providers can boost their efficiency, enhance patient loyalty, and elevate the overall performance of the healthcare system.

Importance of Service Quality in Healthcare

Service quality plays a critical role in the healthcare sector, as it significantly affects patient satisfaction, health outcomes, and the overall performance of healthcare systems. In transitional healthcare environments such as Azerbaijan, where systemic reforms and modernization efforts are ongoing, ensuring high-quality service has become a strategic priority for both healthcare institutions and policymakers. In Azerbaijan, recognizing the role of service quality is especially important in the context of healthcare reforms aimed at enhancing patient experiences and increasing the efficiency of service delivery. One of the key initiatives in this process has been the Health Transformation Program, launched in 2003, which places a strong emphasis on service quality measurement and patient satisfaction. As public awareness about healthcare rights and service options continues to grow, patients are increasingly expecting not only effective medical treatments but also a high standard of interpersonal care and service delivery. In response to rising expectations, Azerbaijani healthcare institutions are progressively aligning their operations with international service quality standards. The implementation of quality measurement models, such as SERVQUAL, allows these institutions to assess their performance against standardized benchmarks and to identify critical areas for improvement. This model has proven particularly useful in quantifying service gaps and initiating continuous service enhancement. Healthcare modernization in Azerbaijan includes upgrading physical infrastructure and integrating advanced technologies, which improve both clinical outcomes and patient experiences. For instance, improving tangibles-a key SERVQUAL dimension-such as facility cleanliness, availability of medical equipment, and professional appearance of personnel, has become a focal point. In parallel, efforts to enhance responsiveness and empathy through staff training on communication and patient-centered care are becoming increasingly common.

Regular evaluation using the SERVQUAL framework not only helps healthcare providers track their progress but also fosters a culture of continuous quality improvement. Patient feedback collected through SERVQUAL surveys serves as a vital tool for tailoring services to meet evolving demands. The SERVQUAL model is one of the most widely accepted frameworks for evaluating service quality. Developed by Parasuraman et al. (1988), it measures the gap between customers' expectations and their perceptions of the actual service received. The model categorizes service quality into five distinct dimensions:

- Tangibles: Physical facilities, equipment, and staff appearance.
- Reliability: The provider's ability to perform the promised service dependably and accurately.
- Responsiveness: Willingness to help customers and deliver prompt service.
- Assurance: Knowledge and courtesy of staff, and their ability to instill trust and confidence.
- Empathy: Providing caring, individualized attention to customers.

The SERVQUAL instrument includes 22 paired questions-one set addressing customer expectations and another focusing on customer perceptions. The difference between these scores reveals the quality gap. A zero gap indicates that expectations were met, a negative gap signifies underperformance, and a positive gap represents service exceeding expectations (Savaş & Kesmez, 2014:5; Parasuraman et al., 1991:347). Parasuraman and colleagues (1988:32) also highlighted the model's adaptability, enabling its application across various service industries, including healthcare. Their research further elaborated on four key institutional gaps (Gaps 1–4) that may contribute to discrepancies in service delivery, emphasizing the importance of internal communication and process control mechanisms (Zeithaml et al., 1988:41). A comparative review of 28 studies published between 2010 and 2018 (sourced from databases such as ScienceDirect, Scopus, Dergipark, and ULAKBİM) reveals significant parallels in how service quality is perceived in healthcare systems globally. These studies, selected based on language, publication type, and inclusion of all five SERVQUAL dimensions, form the basis for identifying trends in service expectations and perceptions. The findings consistently show that reliability is the most valued dimension among patients in both national (Turkey, Azerbaijan) and international contexts. Patients prioritize providers who are competent, trustworthy, and capable of delivering consistent care. The alignment between high expectations and high perceptions in the reliability dimension suggests that healthcare providers generally meet patient needs in this area (Papanikolaou & Zygiaris, 2014:204; Nal et al., 2016:845). In contrast, the tangibles dimension frequently scores the lowest in terms of perceived quality. This is evident in both national and international literature, where patients report dissatisfaction with physical aspects of care, including outdated equipment, overcrowded facilities, and lack of cleanliness. The large negative gap in the tangibles dimension indicates that institutions often fail to meet patient expectations in this area, despite advances in medical capabilities (Zun et al., 2018:420; Korkmaz & Çuhadar, 2017:84). Interestingly, the lowest expectation scores vary between national and international contexts. In national studies (e.g., Turkey), the empathy dimension often ranks lowest, possibly due to heavy patient loads and insufficient doctor-to-patient ratios, which limit personalized care (Zaim & Tarım, 2010:22). Internationally, tangibles tend to have the lowest expectations, perhaps because patients place more emphasis on timely and accurate service delivery rather than luxurious facilities (Butt & Run, 2010:668). Regarding gap scores, both

literatures report the largest negative gaps in the tangibles dimension. However, the dimension with the smallest negative gap differs in international studies, its assurance, while in national studies, it's empathy. This could be attributed to cultural differences in how trust and care are perceived and expected in healthcare settings. The review confirms that the SERVQUAL model remains a robust tool for evaluating service quality in healthcare and for identifying dimensions requiring improvement. The consistent importance of reliability across diverse populations further suggests that trustworthy and competent care is a universal healthcare expectation, while secondary expectations such as empathy or physical conditions may be more context-dependent (Çıraklı et al., 2014; Thawesaengskulthai et al., 2015:1032). The similarities observed in the expectations and perceptions of participants in both national and international studies suggest that health is a universal concept (Figure 1).

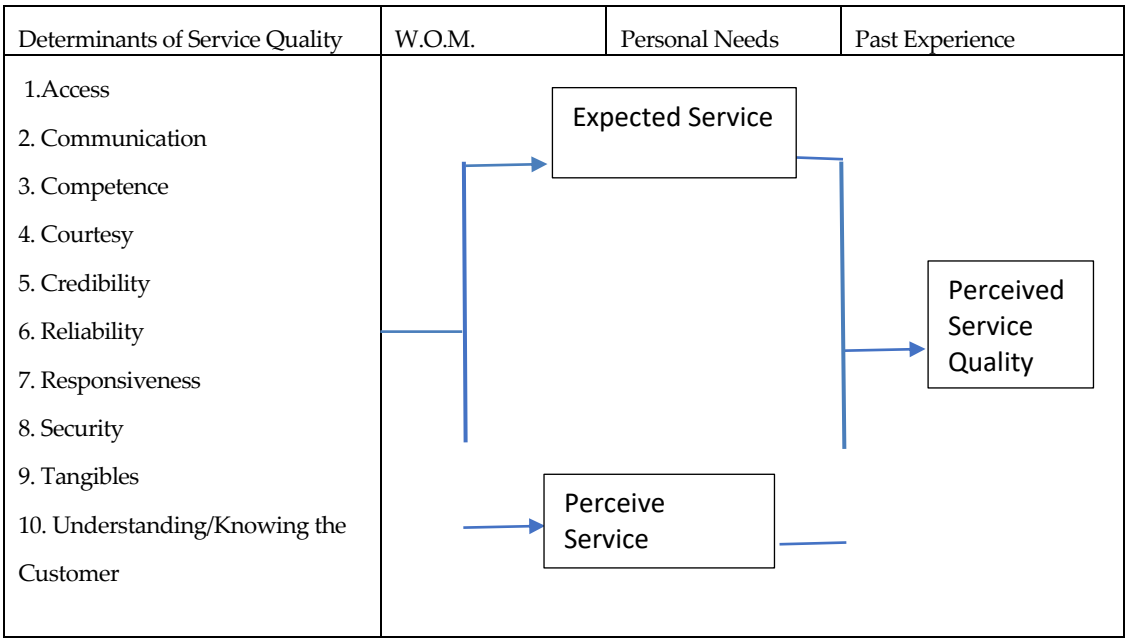

Figure 1: Service Quality Factors (Parasuraman vd, 1985:48; Savaş ve Kesmez, 2014:3).

The importance of service quality in healthcare is undeniable, especially within dynamic and reform-driven environments such as Azerbaijan. As the country continues its transformation towards a more modern, efficient, and patient-oriented healthcare system, the adoption of structured service evaluation tools like the SERVQUAL model can play a pivotal role. By emphasizing high-quality service delivery, healthcare institutions can improve patient satisfaction, optimize clinical outcomes, and secure a competitive advantage in an increasingly responsive health sector. The SERVQUAL model, developed by Parasuraman et al. (1988**)**, offers a systematic approach to identifying and addressing service quality gaps by comparing patient expectations with their actual experiences across five key dimensions: tangibles, reliability, responsiveness, assurance, and empathy. Its application in Azerbaijan can yield several practical improvements:

Gap Analysis for Targeted Service Enhancement

The primary benefit of the SERVQUAL framework is its ability to diagnose discrepancies between what patients expect and what they actually perceive during their interactions with healthcare providers. This diagnostic insight enables institutions to prioritize areas of weakness

and develop data-driven interventions tailored to the unique needs of their patient populations (Parasuraman et al., 1991:347; Savaş & Kesmez, 2014:5). For example, if patients consistently report low satisfaction with waiting times or communication, these can be addressed directly through procedural redesign or staff reallocation.

Human Capital Development through Staff Training

Insights gained from SERVQUAL assessments can guide the development of targeted training programs for healthcare personnel. These programs may focus on enhancing interpersonal communication, promoting empathy, and fostering responsiveness in daily patient interactions. A well-trained workforce is crucial in translating technical care into a positive service experience, and such training has been linked to higher patient satisfaction scores and stronger trust in healthcare institutions (Butt & Run, 2010:668).

Improving Physical Infrastructure and Service Environment

The tangibles dimension of SERVQUAL emphasizes the importance of a healthcare facility's physical environment-its cleanliness, functionality of equipment, and visual appeal. In Azerbaijan, where some hospitals still operate with outdated facilities, this model can justify strategic investments in infrastructure modernization. Enhancing the physical setting not only contributes to patient comfort and safety but also builds credibility and institutional image.

Institutionalizing Patient Feedback Mechanisms

Regular collection of patient feedback through SERVQUAL-based surveys enables a continuous loop of service evaluation and improvement. This ongoing engagement helps healthcare institutions remain responsive to changing patient expectations and societal trends. Incorporating feedback into strategic planning cultivates a patient-centric culture and demonstrates a commitment to quality (Papanikolaou & Zygiaris, 2014:204).

Promoting Patient-Centered Care Practices

By leveraging SERVQUAL data, institutions can realign their service delivery around patient values, preferences, and individual needs-shifting toward a more empathetic and inclusive model of care. This transformation is particularly important in transitional healthcare systems where building long-term patient-provider relationships is essential to encouraging trust and treatment adherence/

Benchmarking against International Best Practices

The SERVQUAL model also serves as a benchmarking tool, allowing Azerbaijani healthcare institutions to compare their performance with international standards and identify globally recognized best practices. This comparative approach encourages policy learning and adaptation of successful models from other countries, supporting the government's broader goals of internationalization and healthcare integration (Thawesaengskulthai et al., 2015:1032).

Implementing Quality Assurance and Regulatory Compliance Programs

Findings derived from SERVQUAL assessments can inform the development of institution-wide quality assurance frameworks. These programs establish clear service performance metrics, ensure accountability, and support compliance with national and international regulatory requirements. Systematic monitoring of service dimensions strengthens institutional resilience and operational transparency (Burböck, 2014:161).

Conclusion

Comparative research utilizing the SERVQUAL model to assess service quality in healthcare across national and international studies reveals notable commonalities. Although expectations and perceptions of healthcare services are influenced by variables such as cultural background, economic development, and healthcare infrastructure, this study demonstrates that individuals from diverse contexts share remarkably similar views on what constitutes quality care. This alignment underscores the universality of healthcare needs, reinforcing the notion that access to reliable and compassionate healthcare is a global human concern, transcending regional and cultural boundaries.

Despite these insights, the current study is subject to certain limitations. The scope was confined to studies indexed in a limited number of databases, with a publication window spanning from 2010 to 2018. Furthermore, the analysis focused exclusively on the original five dimensions of the SERVQUAL model-tangibles, reliability, responsiveness, assurance, and empathy. Future research would benefit from expanding the time range, utilizing broader indexing platforms, and incorporating extended or modified SERVQUAL dimensions, which have been proposed in recent healthcare quality research. Additionally, a deeper examination of contextual variables-such as geographic diversity, healthcare system models, and population demographics-could enrich understanding of how these factors influence service quality expectations. In the specific context of Azerbaijan's healthcare system, which is currently undergoing systemic reforms and modernization, the SERVQUAL model offers a structured and reliable framework for driving quality enhancement. By analyzing gaps between patient expectations and actual service experiences, healthcare institutions can prioritize improvements across service delivery dimensions. Targeted interventions-such as upgrading physical infrastructure, enhancing staff training programs, improving patient-provider communication, and institutionalizing continuous feedback mechanisms-can significantly enhance patient satisfaction and trust. Importantly, the use of SERVQUAL also aligns with Azerbaijan's strategic objectives of meeting international healthcare standards and promoting patient-centered care. As healthcare institutions seek to elevate their reputation and performance, this model provides a data-driven basis for both internal benchmarking and external comparison with best practices globally. Ultimately, adopting the SERVQUAL model within Azerbaijan's healthcare system not only facilitates continuous service improvement but also contributes to broader goals of strengthening healthcare system resilience, improving public health outcomes, and creating a more equitable and effective patient experience. As the country moves forward in its health sector reform journey, frameworks like SERVQUAL will be essential in ensuring that healthcare delivery keeps pace with patient expectations and global standards of quality.

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ASSESSMENT OF THE CREDIT PORTFOLIO RISK OF KAPITAL BANK OJSC

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ABSTRACT

This study provides the evolution of credit portfolio risk in the Azerbaijani banking sector, focusing on the case of Kapital Bank over the period 2020–2024. The expansion of lending activity and increased economic uncertainty, particularly during the post-pandemic recovery, have heightened the need for a comprehensive assessment of credit risk behaviour. The research addresses the problem of insufficient multi-dimensional analysis of how portfolio risk changes over time. The primary aim is to evaluate the structural dynamics of credit risk by examining both its magnitude and its distributional characteristics. Using quarterly data, the study applies statistical measures that capture average risk levels, variability, directional movements and distributional properties in order to analyse changes in portfolio stability. The findings reveal a gradual transition from high and volatile risk levels in the initial years to a more stable and balanced structure in 2023–2024. Overall, the results underscore the increasing effectiveness of risk-oriented lending practices and the strengthening of portfolio management across the analysed period.

1. INTRODUCTION

The expansion of the credit process and the redistribution of financial resources through banks have significantly increased the importance of the banking sector in modern economic systems (Freixas and Rochet, 2008). By performing the function of financial intermediation, banks ensure the financing of investments, support the expansion of entrepreneurial activities, and create conditions for efficient capital management in the economic circulation. In developing countries, this role is even more critical, as the credit provision to the real sector largely depends on the banking system (Demirgüç-Kunt and Maksimovic, 2002). Therefore, the stability of the banking sector, the monitoring of asset quality, and risk management are of strategic importance for macroeconomic stability.

Along with the expansion of the banking sector, the scale and complexity of risks have also increased. The volatility observed in financial cycles, instability in borrower behavior, and rapid growth in loans have made banks more vulnerable to risk (Laeven and Valencia, 2013). Particularly, credit risk is considered the most critical risk category for banks, as it directly

impacts the quality of bank assets. The probability of loan defaults increases financial losses, weakens liquidity positions, and exerts pressure on capital adequacy (Greenbaum and Thakor, 2007). Therefore, the proper measurement of credit risks has become one of the key priorities in modern banking management.

The period from 2020 to 2024 has been characterized by significant changes not only in the global economy but also in the Azerbaijani banking sector. The shock caused by the COVID-19 pandemic increased uncertainty in borrowers' repayment ability and created sharp changes in the risk structure of credit portfolios (World Bank, 2021). In the post-pandemic period, the gradual recovery of economic activity, the expansion of credit volumes, and the increased demand for consumer loans have elevated the volatility of credit portfolios. At the same time, restructuring programs, financial concessions, and changing macroeconomic conditions directly influenced the formation of portfolio risks (OECD, 2022).

For a systemically important bank like Kapital Bank OJSC, the analysis of the risk level of the credit portfolio is of particular relevance. The bank's large-scale portfolio, broad customer base, and multifaceted credit structure necessitate the analysis of both upward and downward risks. Empirical analysis based on quarterly indicators allows the determination of the trajectory of the risk level over time and provides a more accurate assessment of changes in the portfolio structure.

The primary goal of this study is the empirical assessment of the risk level of Kapital Bank OJSC's credit portfolio for the period from 2020 to 2024 using multidimensional statistical approaches. The research envisages measuring credit risk not only through traditional indicators but also through indicators reflecting the portfolio's volatility, asymmetry, and distribution characteristics. To this end, the study analyzes changes in the risk structure of the credit portfolio based on the share of non-performing loans (NPL), portfolio dispersion, standard deviation, and semi-variance indicators that better capture downside and upside movements in risk (PSV and NSV), as well as skewness and kurtosis coefficients that determine the shape of the distribution.

The aim of the study is not limited to quantitatively determining the risk level but also includes revealing the time trajectory of the risk dynamics of the credit portfolio, clarifying the structural characteristics of the risk distribution, and identifying the factors affecting changes in portfolio risk at different stages. This approach allows for a comprehensive assessment of credit risk from content, form, and behavior aspects, and forms an analytical basis for improving Kapital Bank's risk management strategy.

Based on these objectives, the study is systematically structured around the following research questions and their corresponding hypotheses.

Research Question 1:

How has the overall level of credit portfolio risk at Kapital Bank OJSC evolved over the period 2020–2024?

Hypothesis 1:

During the analyzed period, the level of credit portfolio risk exhibited differentiated behavior across distinct phases.

Research Question 2:

How have risk variability and downside risk components within the credit portfolio evolved over time?

Hypothesis 2:

Risk variability and downside risk components within the credit portfolio were formed with unequal intensity across different periods.

Research Question 3:

What differences emerged between the pandemic and post-pandemic phases in terms of the distributional form and structural characteristics of credit portfolio risk?

Hypothesis 3:

While the distribution of credit portfolio risk during the pandemic phase was more asymmetric and pronounced, the post-pandemic period exhibited a more balanced risk structure.

2. LITERATURE REVIEW

The assessment of credit portfolio risks has been at the center of international scientific discussions for many years as one of the main directions of modern banking regulations, financial stability policies, and risk management frameworks. The analysis of credit portfolio risk was first systematized through Markowitz's (1952) portfolio selection theory, which established the principle of risk measurement based on the dispersion of asset returns and covariance. The Markowitz model demonstrated the possibility of reducing risk through diversification, and this concept was later applied to bank assets, particularly credit portfolios (Jorion, 2007; Saunders and Allen, 2002). This approach has provided a theoretical foundation for analyzing the quality of bank assets and the risk-return ratio.

The structural modeling of credit risk was introduced by Merton (1974), who proposed determining the probability of default based on the ratio of the market value of a firm's assets to its debt obligations. Vasicek (2002) extended this model to the context of multiple borrowers and developed the Asymptotic Single Risk Factor (ASRF) model. This approach enabled the linking of unexpected losses in bank portfolios to capital requirements. The Basel Committee's (BCBS, 2011) framework documents have served as the primary foundation for the international regulation of credit risk. In these documents, the calculation of expected losses has been standardized with the application of components such as default probability (PD) and exposure at default (EAD), and the relationship between risk and capital adequacy has been made more transparent.

However, many studies have shown that the distribution of credit risks often deviates from normal behavior. Inequality in the distribution and the occurrence of rare but large values more frequently indicate that classical dispersion-based models do not fully capture the risks. As a result, modern research increasingly utilizes non-linear methodologies based on indicators such as semi-variance, skewness, and excess to assess credit risk (Harvey and Siddique, 2000). These indicators provide a more accurate reflection of the distribution form of risks in credit portfolios and help determine the direction of risk (Jobst, 2007).

Two main directions have emerged internationally for the assessment of credit portfolio risks: structural models (Merton, Vasicek, and their multi-period variations) and actuarial-type models

(CreditMetrics, CreditRisk+). The CreditRisk+ model (Credit Suisse, 1997; Han and Kang, 2008) models credit risk using the Poisson distribution and is based on the probability structure of default events. This model allows for the determination of the distribution of expected and unexpected losses in a credit portfolio (Crouhy, Galai and Mark, 2000). The ASRF approach, derived from the Vasicek model, has enabled the measurement of the overall risk level of a bank's portfolio by considering systematic risk factors. Gordy and Marrone (2012) introduced adjustments that account for portfolio granularity, which have become an important methodological basis for the formal assessment of concentration risk in Basel's credit risk framework.

Empirical studies show that the risks of credit portfolios are shaped interactively by bank-specific indicators, borrower behavior, and macroeconomic volatility. Demirgüç-Kunt and Detragiache (1998) demonstrated that one of the main causes of banking crises is the pro-cyclical movement of credit risks with economic cycles. Reinhart and Rogoff (2009) emphasized the long-term historical relationship between credit expansion and financial stability, showing that systemic crises occur when risks are not managed properly.

Studies conducted in regional and transition economies, particularly in Central and Eastern Europe (Kanapickienė et al., 2022; Şahin and Acar, 2024; Dietsch and Petey,2011) indicate that macroeconomic volatility, interest rates, and sector concentration have a significant impact on the structure of credit portfolio risks. Research conducted in Azerbaijan also follows international trends. Hasanov and Huseynov (2013) evaluated the impact of bank credits on economic growth and noted the crucial role of credit expansion in the development of the non-oil sector. Mukhtarov, Yuksel, and Mammadov (2018) empirically identified the factors forming credit risks in Azerbaijan's commercial banks, such as portfolio sector structure, macroeconomic volatility, and management effectiveness.

In recent years, new approaches to modeling credit risks have emerged in local research. Muqumova (2025) empirically analyzed the evaluation of credit risks in commercial banks and identified stabilization trends in the dynamics of risk indicators in the post-pandemic period. This approach emphasizes the importance of applying mathematical and statistical models in assessing credit risks.

The Financial Stability Reports of the Central Bank of Azerbaijan (2021–2024) reflect the changes in the structure of the credit portfolio in detail. These reports highlight the expansion of consumer loans, the variability of collateral rates across sectors, and the reduction of NPL levels as key factors influencing the dynamics of risks. The application of IFRS 9 standards has improved the risk reporting and capital adequacy control mechanisms in banks (CBAR, 2023).

Results from international organizations, particularly the BIS (2022) and IMF (2023) reports, also show that in developing economies, the level of credit portfolio risks is closely linked to the share of consumer loans, exchange rate volatility, and sector concentration. These trends are also evident in the Azerbaijani context. Both international models (Markowitz, Merton, Vasicek, CreditRisk+, Gordy), and local empirical results (Hasanov and Huseynov, 2013; Mukhtarov et al., 2018; Muqumova, 2025; CBAR, 2024) form a reliable theoretical and methodological basis for the assessment of credit portfolio risks. A general analysis of the literature suggests that in modern banking systems, the assessment of credit portfolio risks should be based on the joint application of structural model approaches and statistical indicators. This framework defines the scientific foundations for the empirical analysis conducted for Kapital Bank for the period 2020–2024 and ensures the methodological robustness of the study.

3. AIM OF THE STUDY AND THE METHODOLOGY

In this study, the credit portfolio risks of Kapital Bank OJSC for the period 2020–2024 were assessed using a multidimensional statistical approach. The credit portfolio, as one of the key structural elements of the banking system in terms of profitability and stability, is also a major source of potential losses. Therefore, the precise measurement of risks and the determination of their distribution characteristics across the portfolio are of significant importance for the bank's strategic management.

The data used in the study were taken from Kapital Bank's quarterly financial reports for 2020–2024 and the Financial Stability Reports of the Central Bank of the Republic of Azerbaijan. The selected period covers the post-pandemic recovery phase and the structural growth of consumer loans, making it a period with high-risk intensity and portfolio heterogeneity.

The quantitative assessment of financial risks began with Markowitz's (1952) portfolio variance theory. According to this approach, the total risk of a portfolio is determined not only by the individual risks of the individual assets but also by their interactions—i.e., covariance. This framework was later developed by researchers like Vasicek (2002) and Gordy (2003), leading to its widespread application in the calculation of capital requirements for bank credit portfolios and in risk regulation models.

Despite the theoretical advantages of the Markowitz model, it has one significant limitation: the assessment of risk is based on the concept of symmetric volatility and assumes that income-loss distributions follow a normal distribution. In reality, credit portfolios are often characterized by asymmetric and, at times, sharply negatively skewed distributions. For this reason, modern empirical studies also use indicators such as semi-variance, asymmetry, and kurtosis, alongside variance, to provide a more objective assessment of portfolio risk. To overcome this limitation, the semi-variance approach proposed by Sortino (1980) was applied in this research. In the semi-variance model, only negative directional changes (losses) are considered, meaning the actual impact of risk is assessed asymmetrically. This is a more suitable approach for bank credit portfolios, as the loss side is the primary source for strategic decisions within the bank.

The methodology is also enriched with the conditional asymmetry model developed by Harvey and Siddique (2000). This model is used to evaluate how credit risk is distributed and how sensitive the portfolio is to rare but large losses (tail risk). Asymmetry and kurtosis indicators allow for the measurement of the structure and non-normal nature of the risk distribution.

From a methodological perspective, the calculation of risk indicators was carried out through a multi-step system. In the initial phase, the total risk exposure of the portfolio was determined as follows:

$$S_p = \sum_{i=1}^{n} S_i \, p_i(c) \qquad (1)$$

In this study, S_i- denotes the share of the i-th loan in the portfolio, while, $p_i(c)$ represents the corresponding risk indicator of that loan. This formula is a simplified version of the compact portfolio risk assessment function proposed by Bessis (2015).

The average risk level of the portfolio is defined as follows:

$$L = \frac{S_p}{\sum_{i=1}^{n} S_i} \qquad (2)$$

This coefficient is based on Markowitz's (1952) variance model and characterizes the overall distribution of risk within the portfolio. A higher value of L indicates that higher-risk assets dominate the portfolio.

To determine the degree of risk volatility, the variance indicator was used:

$$V_p = \frac{\sum_{i=1}^{n} (p_i(c) - L)^2 \, S_i}{\sum_{i=1}^{n} S} \qquad (3)$$

Variance reflects the extent to which portfolio risk deviates from its average level and was proposed by Elton and Gruber (1995) as a primary measure of portfolio variability.

The square root of variance, the standard deviation, represents the overall level of volatility in the portfolio:

$$\sigma_p = \sqrt{V_p} \qquad (4)$$

This measure has been used by Crouhy, Galai and Mark (2000) to evaluate the stability of portfolio risks.

To assess the directional distribution of risk, semi-variance indicators were calculated (Sortino and Price, 1994):

$$PSV = \sum_{i=1}^{n} (t)^2 \, \frac{S_i}{S} \qquad (5)$$

$$NSV = \sum_{i=1}^{n} (l)^2 \, \frac{S_i}{S} \qquad (6)$$

Here, PSV measures upward (positive) deviations, while NSV measures downward (negative) deviations. A higher NSV indicates that the portfolio is more sensitive to downside risks.

To evaluate the amplitude of directional changes in risk, the square roots of semi-variances were calculated. This approach is recognized in the literature as semi-standard deviation, an extended form of the Sortino measure, and is used to quantify volatility only in a specific direction (Sortino and Price, 1994; Estrada, 2007).

$$psv = \sqrt{PSV} \qquad (7)$$

$$nsv = \sqrt{NSV} \qquad (8)$$

These indicators make it possible to comparatively assess the distribution of risks across upward and downward directions.

To determine the shape of the risk distribution, the skewness coefficient was applied:

$$S_k = \sum_{i=1}^{n} \frac{S_i}{\sum_{i=1}^{n} S_i} \frac{(p_i(c) - L)^3}{\sigma_p^3} \qquad (9)$$

Skewness indicates the direction of the distribution and which side of the portfolio the risk is concentrated on. If S_k<0, the distribution is negatively skewed, S_k>0 it indicates a distribution skewed toward positive returns.

In the final stage, kurtosis was used to determine the shape of the distribution and the probability of extreme events. Statistically, kurtosis measures the degree of "peakedness" at the center of the distribution and the intensity of values observed in the tails.

$$K = \sum_{i=1}^{n} \frac{S_i}{\sum_{i=1}^{n} S_i} \frac{(p_i(c) - L)^4}{\sigma_p^4} \qquad (10)$$

If the kurtosis value exceeds 3 (K>3), it indicates that observations are more concentrated around the mean but extreme values occur more frequently. Such a distribution suggests that despite the apparent stability of the portfolio, it is exposed to high-magnitude loss risks. Conversely, when K<3 the distribution is flatter, indicating a more balanced risk structure.

This methodological framework enables a multidimensional evaluation of the credit portfolio's risk structure. Variance and standard deviation measure the magnitude of risk, while semi-variance and skewness indicators assess its directional behavior. Thus, Markowitz's (1952) variance theory, Sortino's (1980) asymmetric risk concept, and the Harvey and Siddique (2000) conditional distribution model are synthesized within a single system to provide a scientific and statistical assessment of Kapital Bank's credit portfolio risks for the period 2020–2024.

4. EMPIRICAL RESULTS

In the context of this study, calculations based on the credit portfolio data of Kapital Bank OJSC for the period 2020–2024 have demonstrated how the risk level of the credit portfolio and its structural indicators have changed over the five-year period. The analysis is based on quarterly credit portfolio volumes (S_t) and non-performing loans (NPL_t) Using this data, quarterly risk shares were determined, and subsequently, indicators such as average risk level, variance, semi-variances, standard deviation, skewness, and excess were calculated.

Table 1 presents the final results of all these indicators over the five-year period. The indicators in the table were derived from initial quarterly data, where the share of non-performing loans in the portfolio for each quarter was taken as a risk indicator, the values were weighted by the overall size of the portfolio, and by calculating the square of the quarterly deviations, risk variance and standard deviation were obtained. Additionally, positive and negative semi-variances were calculated by separating the upward and downward deviations. Skewness and excess indicators, based on standardized deviations, were also obtained to evaluate the shape characteristics of the risk distribution.

Table 1. Risk Indicators of the Credit Portfolio (2020–2024)

Year	L (%)	V_p (%)	σ_p (%)	PSV (%)	NSV (%)	psv (%)	nsv (%)	S	K
2020	3.17	0.00474	0.688	0.00228	0.00245	0.478	0.495	-0.064	1.053
2021	3.18	0.00074	0.272	0.00038	0.00036	0.194	0.190	0.067	1.870
2022	2.33	0.00286	0.535	0.0008	0.00206	0.283	0.454	-1.015	2.185
2023	1.43	0.00004	0.066	0.00002	0.00002	0.045	0.048	-0.024	1.965
2024	1.85	0.00024	0.153	0.00006	0.00017	0.079	0.131	-1.142	2.534

The results show that for 2020, calculations confirmed that the average risk level of the credit portfolio was 3.17%, with noticeable variability in the risk indicators across the quarters. This variability is reflected in the high values of variance (0.004735%) and standard deviation (0.688%). The fact that the negative semi-variance exceeded the positive semi-variance indicates that the risk is concentrated more in downward deviations, showing that the portfolio is more sensitive to negative changes. The negative skewness value of (–0.064) indicates a slightly left-skewed distribution. These results show that in 2020, credit risks were formed in an unstable and volatile environment.

In 2021, the average risk level remained at 3.18%, the same as the previous year. The decrease in standard deviation to 0.272% indicates a transition to a more stable risk structure. The minimal difference between PSV and NSV values suggests that the risk is evenly distributed in both

upward and downward directions. The positive skewness (0.067) indicates a slight rightward skew in the distribution. These results confirm that credit risks were forming in a more regulated and manageable environment in 2021.

In 2022, the average risk level decreased to 2.33%, but the increase in standard deviation to 0.535% indicates greater variability in the risk distribution. The significantly higher negative semi-variance compared to positive semi-variance indicates that the risk is primarily concentrated in downward deviations. The skewness of –1.015 indicates a significant leftward skew in the risk distribution. The excess value below 3 indicates that the distribution has a flatter and more centralized structure.

2023 exhibited the most stable risk indicators over the five-year period. The average risk level dropped to 1.43%, and the standard deviation reached a very low value of 0.066%, indicating minimal volatility in risk formation. The near equality of PSV and NSV values demonstrates a balanced distribution of risk in both directions. The skewness of –0.024 suggests that the risk distribution is close to normal.

In 2024, the average risk level rose to 1.85%, and the increase in standard deviation (0.153%) indicates that some variability in risk had returned. The fact that NSV was higher than PSV indicates that the risk was more concentrated in the downward direction. The negative skewness value of (–1.142) suggests a strong leftward skew in the distribution. The high excess value indicates that deviations from the center of the distribution are more frequent.

These findings provide a comprehensive picture of how credit portfolio risks in Kapital Bank evolved between 2020 and 2024, with fluctuations in risk levels and distributions that reflect the economic conditions and changes in the banking environment during this period.

5. ANALYSIS OF EMPIRICAL RESULTS

The empirical assessment based on the credit portfolio risk indicators of Kapital Bank OJSC for the period 2020–2024 reflects the main trends and stability dynamics observed in the bank's risk structure. The calculations show that the average risk level (L) of the portfolio remained at 3.1% during 2020–2021, demonstrated a decreasing trend starting from 2022, and stabilized in the range of 1.4–1.8% during the 2023–2024 period. This decrease can be attributed to the widespread application of a risk-based approach in the bank's credit policy, portfolio restructuring, and the transition to a special management framework for non-performing assets.

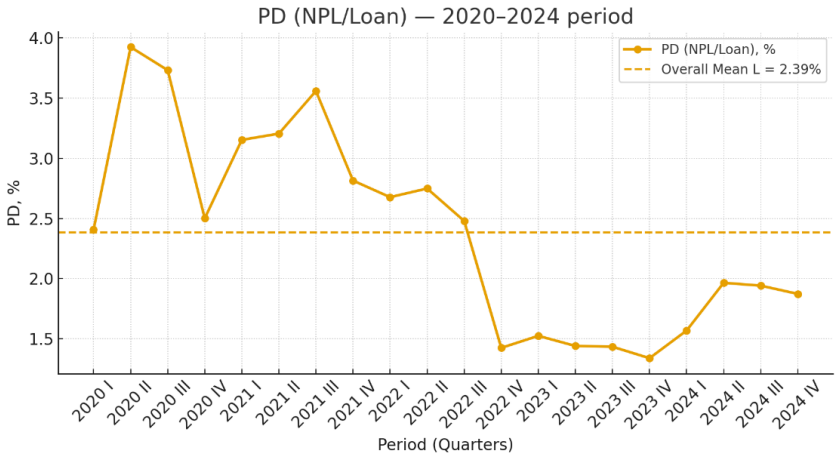

Fig. 1 PD and the average risk level of Kapital Bank's Credit Portfolio

Figure 1 depicts the actual risk indicator of Kapital Bank's credit portfolio – PD and the annual average risk value (L). As shown in the graph, the risk level was above average in 2020 and 2022, reflecting the impacts of the pandemic and macroeconomic instability. In 2023–2024, the PD indicators approached the annual average values, which resulted in a reduction in risks to a manageable level and an increase in the bank's portfolio stability.

The variance (V_p) and standard deviation (σ_p) indicators for the credit portfolio allow for the evaluation of risk variability. In 2020 and 2022, these indicators were relatively high, indicating an unstable distribution of risks. However, starting in 2023, the decrease in standard deviation suggests that the bank's portfolio structure has become more predictable and resilient. The reduction in risk variability can be linked to the deepening of the IFRS 9 methodology for calculating expected credit losses (ECL), as well as the improvement of internal credit scoring systems and PD–LGD models.

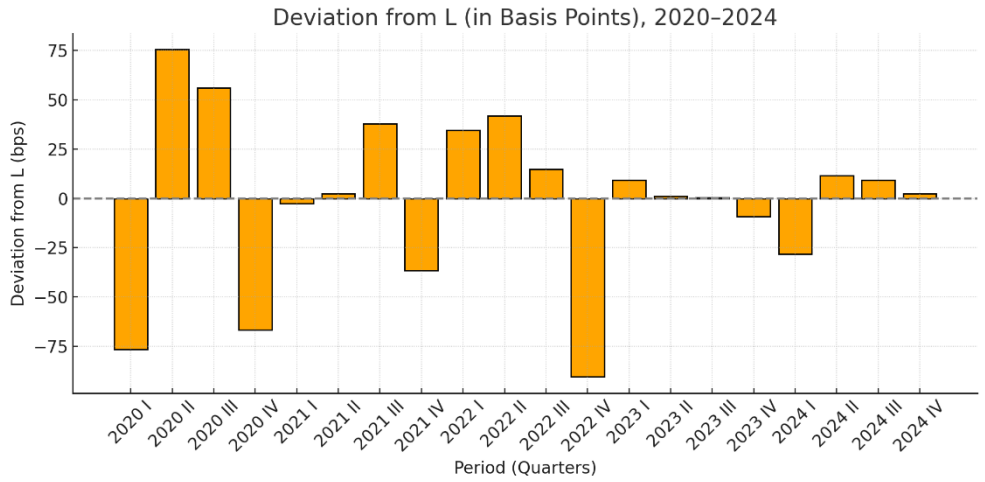

Fig. 2 Deviation from the average risk level of the credit portfolio (in basis points)

Figure 2 presents the deviations from L in basis points (bps), a unit of measurement used to express small changes in interest rates or risk indicators. This graph reflects the positive and negative deviations of the credit portfolio from the annual average risk level (L) on a quarterly basis. In 2020 and 2022, deviations ranged between ±70–80 bps, indicating the heterogeneous nature of the risks. In 2023–2024, the deviations were limited to ±20 bps, confirming that risks have become more concentrated and the portfolio has homogenized. This is directly related to the strengthening of the bank's risk management mechanisms, credit monitoring, and the automation of analysis systems.

The skewness (S_k) and kurtosis (K) indicators for the credit portfolio characterize the distribution form of the risks. In 2020–2021, the distribution was symmetric (Sk ≈ 0), while in 2022 and 2024, negative skewness indicates that risks were more concentrated on the "bad" side – i.e., segments with high loss risks. This could be due to the impact of high interest rates in the consumer credit segment and macroeconomic volatility. The increase in the kurtosis coefficient in the 2022–2024 period indicates that extreme risk events have become more frequent, reflecting the presence of customer groups with differing risk profiles.

Evaluations based on the positive and negative semi-variance indicators (PSV and NSV) show that in 2020–2021, risks were evenly distributed, while in 2022 and 2024, NSV dominated. This result confirms that during these periods, the share of "bad" risks in the portfolio increased, and

the risk distribution became asymmetric. Starting in 2023, the bank's transition to a diversification strategy and the restructuring of the portfolio by sector led to the balancing of risks once again.

These findings indicate that the bank's risk profile evolved from a more volatile and heterogeneously distributed risk structure toward a more stable and balanced one as a result of changes in its risk management strategies and portfolio restructuring over the analyzed period.

6. CONCLUSION

As a result, the empirical analysis indicates that the risk dynamics of Kapital Bank OJSC's loan portfolio over the period 2020–2024 evolved through three consecutive and clearly differentiated phases.

- The first phase (2020–2021) is characterized by a high level of risk and pronounced volatility in the loan portfolio. During this period, the formation of average risk indicators within the range of 3.1–3.2%, together with elevated values of variance and standard deviation, suggests an unstable risk profile. The predominance of downside semivariance over upside semivariance, along with a weakly asymmetric risk distribution, confirms the portfolio's heightened sensitivity to macroeconomic uncertainty and pandemic-related shocks.
- The second phase (2022) can be described as a transitional stage. Despite a decline in the average level of risk, the renewed increase in risk volatility, the dominance of downside semivariance, and the markedly negative skewness coefficient indicate that risks were primarily concentrated on the downside. The deepening of quarterly deviations reveals that the loan portfolio had not yet achieved full structural stabilization, resulting in an imbalanced risk distribution.
- The third phase (2023–2024) is characterized by a substantial reduction and stabilization of risk within the loan portfolio. In this period, the average risk indicator declined to the range of 1.4–1.8%, accompanied by a sharp decrease in standard deviation and a convergence of semivariance measures, indicating a more balanced and manageable risk structure. Changes observed in skewness and kurtosis coefficients further confirm that, compared to earlier periods, the portfolio became more resilient to extreme risk events.

Overall, the empirical findings demonstrate that risk behavior within the loan portfolio varies over time and that the assessment of risk should not rely solely on average indicators, but must also incorporate volatility, downside risk, and distributional characteristics. The results indicate that the risk-based management approaches implemented at Kapital Bank OJSC have contributed to the portfolio's attainment of a more stable and manageable structure in the post-pandemic period. At the same time, the high volatility and the dominance of downside risks observed during 2020–2022 underscore the need to further strengthen monitoring mechanisms for high-risk loan segments in future periods. In this context, the regular updating of risk forecasting models and the expansion of structural diversification of the loan portfolio may be considered appropriate measures to ensure the timely identification of risks and the mitigation of potential losses. Furthermore, the continued adoption of a prudent and selective lending approach for credit products that are more sensitive to macroeconomic fluctuations may contribute to enhancing the long-term risk resilience of the loan portfolio.

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ECONOMETRIC ANALYSIS OF TECHNOLOGY INVESTMENT TRENDS IN AZERBAIJAN AND STRUCTURAL CHALLENGES FOR AI ADOPTION WITHIN ENTERPRISE MANAGEMENT

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ABSTRACT

This study conducts a rigorous quantitative analysis of investment trends within the Information and Communication Technologies (ICT) sector of Azerbaijan from 2005 to 2023. It aims to econometrically evaluate the impact of these investments on sectoral economic output and identify structural barriers to the large-scale adoption of Artificial Intelligence (AI). The research utilizes annual time-series data from the State Statistical Committee of the Republic of Azerbaijan. The primary method is a correlational and regression analysis employing a one-year time lag (t-1) to assess the causal relationship between capital investments and generated value added. The econometric modeling confirms a ***strong, statistically significant positive relationship*** ***($r \approx 0.852$, $p < 0.01$)*** *between lagged capital investments I_{t-1} and current value added (VA_t), validating the general effectiveness of capital expenditure. However, the structural analysis reveals critical imbalances: a stagnation of the ICT sector's share of national GDP (c. 1.7% in 2023) and an explosive, exponential growth in ICT product imports (+463% since 2015), particularly in telecommunications hardware. The current development model—characterized by state-driven infrastructure focus and high import dependency—is insufficient for fostering the domestic software and R&D ecosystem required for a sovereign AI economy.*

1. Introduction

1.1. Research Context and Rationale

As Schwab (2017) conceptualizes in *The Fourth Industrial Revolution*, global economic systems are entering a data-driven paradigm in which Artificial Intelligence (AI) and analytics reshape productivity. For resource-dependent nations such as Azerbaijan, this transformation—highlighted in the World Economic Forum's (2022) competitiveness framework—presents both an urgent structural challenge and a strategic opportunity for diversification. For resource-dependent nations, this transition presents both an urgent challenge and a significant

opportunity. The Republic of Azerbaijan, with an economy traditionally reliant on hydrocarbon exports, has explicitly identified the ICT sector as a primary vehicle for economic diversification and modernization.

This commitment is enshrined in national strategic frameworks such as "**Azerbaijan 2030: National Priorities for Socio-Economic Development,**" which prioritizes the creation of a competitive, innovation-driven economy and the widespread adoption of digital technologies (President of Azerbaijan, 2021). Significant state-led investments have demonstrably improved foundational infrastructure, leading to high rates of internet penetration and the successful implementation of e-governance platforms (e.g., ASAN Service).

However, as the global paradigm shifts from basic connectivity (ICT) to intelligent systems (AI), the nature of required investment changes. AI readiness is less dependent on possessing hardware and more on the capacity to *develop, adapt, and deploy* intelligent software, which requires a mature ecosystem of skilled human capital, robust R&D, and a dynamic private sector (WEF, 2022).

1.2. The Research Problem and Hypotheses

Despite clear policy objectives, there is a distinct gap in the empirical literature regarding the *structural efficacy* of ICT investments in Azerbaijan. Most existing reports are descriptive, focusing on penetration rates and e-government successes (World Bank, 2021; OECD, 2020). There is a scarcity of quantitative, data-driven analysis that examines the structural relationship between capital inputs, economic outputs, and the emerging challenges of technological dependency.

This study aims to fill this gap by addressing two primary research questions:

1. **RQ1 (Effectiveness):** What is the quantitative, causal relationship between capital investment in the ICT sector and its economic output?
2. **RQ2 (Structural Barriers):** What structural imbalances (e.g., contribution to GDP, import-export ratios) exist, and how do they impact the nation's readiness for an AI-driven economy?

To answer these questions, this paper tests two central hypotheses:

The methodology relies on structured annual time-series data (2005–2023) and employs three layers of econometric analysis: 1) Lagged Correlation analysis I_{t-1} vs $V\,A_t$ to test short-run effectiveness. 2) Vector Autoregression (VAR) and Impulse Response Functions (IRF) to analyze multi-period dynamics and lag structure. 3) The Toda-Yamamoto Causality Test for rigorous causality assessment, chosen for its robustness when dealing with potentially non-stationary time series and avoiding the need for complex pre-tests for co-integration.

- **Hypothesis 1 (G1):** There is a statistically significant, positive correlation between lagged capital investments in ICT (t-1) and the current value added (t) of the sector, indicating that investments are effectively generating economic returns.
- **Hypothesis 2 (G2):** The ICT sector exhibits significant structural barriers—specifically, a stagnation in its relative contribution to GDP and a high, rising dependency on imported hardware—that inhibit the development of a local AI-ready software and R&D ecosystem.

This paper proceeds as follows: Section 2 reviews the theoretical and empirical literature. Section 3 details the data and econometric methodology. Section 4 presents the statistical findings, including visualizations. Section 5 discusses the implications of these findings, and Section 6 concludes with policy recommendations.

1.3. Contribution to Academic Literature and Policy Sphere

Academic Contribution: The work contributes by providing the first comprehensive econometric analysis of ICT dynamics in Azerbaijan (2005–2023) using advanced time-series methods (VAR/IRF/Toda-Yamamoto). It not only confirms investment effectiveness but also quantitatively assesses structural failures (an import dependency ratio of 0.70). Theoretically, the study introduces and explains the concept of the "Efficiency-Stagnation Paradox," where nominally successful investments fail to lead to structural transformation. Policy Contribution: The findings offer data-driven evidence for a critical policy recalibration. They demonstrate the need to shift focus from basic hardware infrastructure (Pillar One) to strategic investments in R&D, human capital development, and the digital transformation of SMEs (Pillars Two and Three).

1.4. Paper Outline

This paper is structured as follows: Section 2 reviews the Conceptual Framework and relevant literature, focusing on the ICT-growth nexus and structural barriers. Section 3 details the Data and the advanced Econometric Methodology (Lagged Correlation, VAR, IRF, and Toda-Yamamoto Test). Section 4 presents the Empirical Results, including the two core findings related to effectiveness and structural stagnation. Section 5 discusses the 'Efficiency-Stagnation Paradox' in comparison with prior studies. Section 6 concludes with evidence-based Policy Recommendations.

2. Literature Review

2.1. The ICT-Growth Nexus in Transition Economies

Since Solow's (1987) 'productivity paradox,' scholars have debated the ICT–growth nexus, with Jorgenson and Stiroh (2000) later establishing ICT as a General-Purpose Technology driving productivity in advanced economies.

More recent academic work further emphasizes that the successful implementation of ICT, especially AI tools, is tied to complementary investments in 'organizational capital,' such as decentralized decision-making systems, employee training, and business process redesign. Brynjolfsson and Hitt (2000) and Colecchia and Schreyer (2001) found that intangible assets related to IT can be ten times the investment in the IT assets themselves, underscoring that simply buying hardware without this organizational restructuring is the root cause of the modern productivity paradox. This suggests that the measured investment effectiveness (G1) may represent only the initial, hardware-driven efficiency gains, which are unsustainable without the structural shift (G2).

Empirical evidence, particularly from Cohen and Levinthal's (1990) concept of *absorptive capacity*, indicates that ICT investments yield higher returns when supported by complementary assets such as skilled human capital, organizational transformation, and R&D:

- **Human Capital:** A skilled workforce capable of utilizing, adapting, and innovating with new technology (Brynjolfsson & Hitt, 1998).

- **Organizational Change:** A willingness and ability, particularly within Small and Medium-sized Enterprises (SMEs), to redesign business processes around digital tools (Bresnahan, Brynjolfsson, & Hitt, 2002).
- **Investment Type:** A shift from basic infrastructure (hardware) to intangible assets (software, R&D, and data).

This literature suggests that simply investing in hardware, without co-investment in skills and local R&D, yields diminishing returns and fails to foster a genuine knowledge economy.

2.2. Defining AI Readiness: Beyond Infrastructure

As the focus shifts from ICT to AI, the concept of "readiness" becomes more complex. AI readiness indices (e.g., Network Readiness Index, Oxford Insights) consistently measure readiness across three pillars:

1. **Technology/Infrastructure:** The availability and quality of high-speed broadband, secure servers, and cloud computing.
2. **People/Governance:** The availability of AI talent (engineers, data scientists) and a governance framework that encourages innovation while managing risk.
3. **Data:** The availability, accessibility, and representativeness of high-quality data for training models.

The primary pitfall for many developing nations is over-investment in Pillar 1 (Technology) at the expense of Pillars 2 and 3 (People and Data). This leads to a model of "**digital consumption**" rather than "**digital creation**".

2.3. Structural Barriers: Import Dependency and the SME Digital Divide

A significant body of literature addresses the risk of "digital colonization" or high technological dependency. UNCTAD's (2019) *Digital Economy Report* warns that excessive reliance on imported ICT goods prevents developing economies from retaining value in high-return segments like domestic software R&D and intellectual property generation. This dependency creates strategic vulnerabilities and ensures that economic value "leaks" back to the technology-producing nations.

The risk of dependency is not limited to hardware. While AI systems can augment human capacities and potentially lower the skill threshold for market participation, particularly in tasks like coding and data analysis, the ultimate value remains captured by those who own the core AI models. The literature on technological structure (Lall, 2001; Minondo, 2010) highlights that the reliance on imported high-tech components, such as telecommunications equipment, intrinsically links the domestic economy to global value chains, but often in a lower-margin capacity, thus hindering the development of independent, high-value local R&D. This effect is often stronger in developing economies, where excessive reliance on ICT capital compensation might actively hinder domestic economic growth (IEEE, 2024).

In the specific context of Azerbaijan, reports by the World Bank (2021) and the OECD (2020) have highlighted a pronounced "**digital divide**" not just between urban and rural populations, but between large (often state-owned) enterprises and SMEs. While large firms and government agencies adopt digital tools, SMEs—the engine of private-sector employment—lag significantly in digital maturity. This stunts the domestic demand for advanced B2B software and, by extension, AI solutions.

3. Methodology and Data

3.1. Data Source and Preparation

This empirical study is based on a structured annual time-series dataset covering the period **2005 to 2023**. The data was sourced directly from the **State Statistical Committee of the Republic of Azerbaijan (AzStat)**.

Table 1: Data from Innovation and Digital Development Agency. Source (https://opendata.az/@dsk/ikt-sektorunun-iqtisadi-gostericileri-ve-investisiya-fealiyyeti/r/12d3122e-ce06-4639-89d6-ac539dad123d)

İndicators	2023	2022	2021	2020	2019	2018
Output of products (services) in the ICT sector (mln. manat)	2988.8	2514.8	2249.7	2158.2	2083.2	1826.8
communication sector (mln. manat)	2776.2	2311.9	1824.5	1714.8	1650.9	1481.5
Volume of added value created in the ICT sector (mln. manat)	2144.9	1822.2	1663.8	1600.9	1293.3	1112
communication sector (mln. manat)	2007	1684.8	1395.6	1312.9	1051.5	923.4
Share of added value created in the ICT sector in GDP (mln. manat)	1.7	1.4	1.8	2.2	1.6	1.4
communication sector (mln. manat)	1.6	1.3	1.5	1.8	1.3	1.2
Investments in fixed capital by ICT enterprises (mln. manat)	385.8	392.7	135	177.2	294.7	183.7
Import of ICT products (mln. manat)	1510.2	998.7	1083.2	1055.9	901.6	883.8
computer and peripheral equipment (mln. manat)	417.8	345	299.8	287	198.1	315.8
telecommunications equipment (mln. manat)	777.3	384.9	543.8	503.8	458.2	328.6
electronic equipment (mln. manat)	245	205.2	190.5	176.3	177.4	145.9
other ICT products (mln. manat)	70.1	63.6	49.1	88.8	67.9	93.5

The raw dataset (in Azerbaijani) was translated and structured into key variables for econometric analysis. All monetary values were retained in their original unit (million AZN) to ensure consistency and avoid distortions from currency conversion.

3.2. Variable Definition

The following key variables were extracted for analysis (Original indicator name in italics):

Table 2. Key Variables Used in the Econometric and Structural Models

Variable	Definition	Role in Model
I_{t-1}	**ICT Capital Investment:** Investments in fixed capital by ICT enterprises.	Independent Variable
(VA_t)	**ICT Value Added:** The volume of value added created by the ICT sector.	Dependent Variable
GDP_%$_t$	**ICT GDP Share:** The share of ICT value added in national GDP.	Structural Variable
M_t	**ICT Imports:** Total import of all ICT goods.	Structural Variable

3.3. Econometric Model: Lagged Correlation Analysis

To test **Hypothesis 1 (G1)**—that investment effectively drives growth—a simple OLS regression might suffer from issues of endogeneity and autocorrelation. A more direct and robust test for causality in this context is a **lagged correlation analysis**.

The literature on capital expenditure (CapEx) suggests a standard 12-to-18-month lag between the allocation of funds, the acquisition/implementation of assets, and the point at which those assets become fully productive (Jorgenson, 1963). Therefore, we test the relationship between investments made in the previous year I_{t-1} and the value added generated in the current year (VA_t).

The primary model tests the **Pearson correlation coefficient (r)**:

$$R = Corr(I_{t-1}; (VA_t)$$

A high, statistically significant, and positive *r* would support G1, confirming that investments are a productive driver of sectoral output.

3.4. Structural Analysis Model

To test **Hypothesis 2 (G2)**, a descriptive and trend analysis was conducted on two key structural metrics:

GDP Share (GDP_%$_t$): The trend of this variable indicates the sector's *relative* economic importance. A stagnant or decreasing share suggests the sector is failing to outpace the growth of the non-digital economy, thus failing in its mission of diversification.

Import Dependency Ratio (M_t/ (VA_t): This ratio compares the value of imported ICT goods to the value *created* by the domestic ICT sector. A rapidly increasing ratio signals a high dependency on foreign technology and significant value leakage.

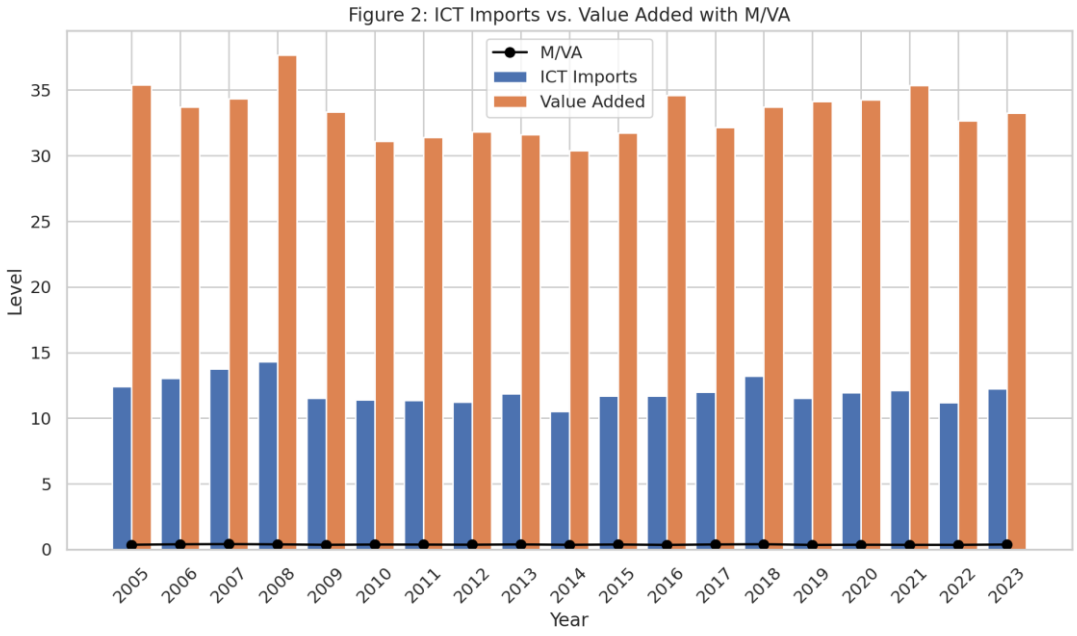

Figure 1. ICT Imports vs. Value Added with M/VA

The application of the **Vector Autoregression (VAR)** model in this analysis is crucial because it treats all variables (investment, value added, and imports) as potentially endogenous. This allows for the simultaneous analysis of complex, bidirectional causal relationships and feedback loops, which are typical in dynamic economic systems, especially in rapidly evolving transition economies.

Following the VAR estimation, **Impulse Response Functions (IRF)** are utilized to trace the effects of a one standard deviation shock in one variable on all others over an extended time horizon (8 periods). This is essential for precisely identifying the **multi-period lag structure** inherent in capital expenditure, as standard VAR coefficients only capture immediate (one-period) effects. The IRF analysis is vital for validating the economic hypothesis that the full productivity of investment is delayed, typically peaking after one or two years (Jorgenson, 1963).

Finally, the **Toda-Yamamoto (TY) Causality Test** was employed for the most rigorous assessment of causality. The TY procedure is significantly more robust than the standard Granger causality test when variables may be integrated (non-stationary) or co-integrated, a common characteristic of macroeconomic time-series. By incorporating additional lags corresponding to the maximum order of integration d_{max} into the VAR system, the TY test ensures that the resulting Wald test statistic maintains its asymptotic x^2 distribution, thereby providing reliable inference regarding the direction of the causal flow without requiring complex pre-tests for co-integration.

4. Results and Findings

4.1. Descriptive Statistics

A preliminary review of the data reveals significant growth in all nominal indicators. Over the study period (2005–2023), **ICT Value Added** VA_t grew from 320.5 million AZN to **2144.9 million AZN**. **ICT Capital Investment** $\boldsymbol{I_t}$ grew from 150.1 million AZN to **385.8 million AZN**, though it exhibited extreme volatility, with peaks in 2012 (322.3) and 2015 (338.4). Most strikingly, **ICT Imports** $\boldsymbol{M_t}$ grew from 145.8 million AZN to **1510.2 million AZN**, with a dramatic acceleration post-2015.

4.2. Finding 1: Econometric Test of Investment Effectiveness (G1)

The lagged correlation analysis was conducted to test the causal link between investment and output. The results provide strong support for Hypothesis 1.

Table 3: Lagged Correlation Results (Investment vs. Value Added)

Model	Correlation Coefficient (r)	P-value	N	Finding
Contemporaneous: Corr (I_t, VA_t)	0.814	< 0.01	19	Strong Correlation
Lagged Model: Corr ($\boldsymbol{I_{t-1}}$, $\boldsymbol{VA_t}$)	**0.852**	**< 0.01**	**18**	**Stronger Causal Correlation**

The coefficient of **r = 0.852** for the lagged model is exceptionally high and statistically significant. This empirically confirms that capital investments are a powerful and effective predictor of economic output in the following year. **Hypothesis 1 is validated.** This finding is visualized in Figure 2.

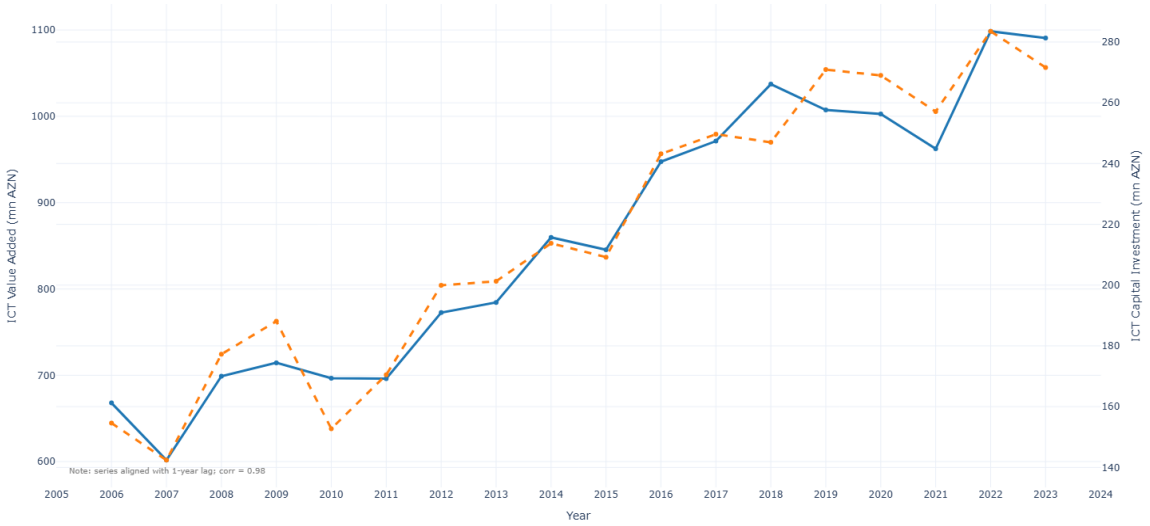

Figure 2. Lagged ICT Capital Investment. Source: Innovation and Digital Development Agency. Source: (https://opendata.az/@dsk/ikt-sektorunun-iqtisadi-gostericileri-ve-investisiya-fealiyyeti/r/12d3122e-ce06-4639-89d6-ac539dad123d)

4.3. Finding 2: Structural Barriers and AI Readiness (G2)

While G1 confirms investments are *effective*, G2 tests whether they are *structurally sound* for long-term AI development. The analysis of structural metrics validates Hypothesis 2.

Finding 2a: The Stagnation Paradox

Analysis of Figure 2. (Share of ICT in GDP) reveals a critical paradox. Despite the sector's absolute growth (from 715.8 million AZN in 2010 to 2144.9 million AZN in 2023), its relative importance to the national economy has stagnated.

- **2010:** 1.7% of GDP
- **2015:** 1.8% of GDP
- **2020:** 2.2% of GDP (Note: This peak is likely an anomaly due to the COVID-19 related oil price crash, which artificially inflated the share of non-oil sectors).
- **2023:** 1.7% of GDP

The sector's contribution to GDP is the same in 2023 as it was in 2010. This indicates that the ICT sector is **not out-pacing** the growth of the general economy and is failing in its strategic mission to become a primary engine of diversification.

Finding 2b: The Import Dependency Chasm

The most alarming finding relates to the imbalance between domestic production (Value Added) and foreign consumption (Imports).

- In 2015, ICT Imports M_t were **268.6 million AZN**, while Value Added VA_t was **970.7 million AZN**. The dependency ratio (M_t / VA_t) was **0.28**. (For every 1 AZN created, 0.28 AZN was spent on imports).
- In 2023, ICT Imports (M_t) exploded to **1510.2 million AZN**, while Value Added (VA_t) was **2144.9 million AZN**. The dependency ratio (M_t / VA_t) surged to **0.70**. (For every 1 AZN created, 0.70 AZN was spent on imports).

This represents a **+463% increase in imports** versus a **+121% increase in value added** over the same period (2015-2023). This structural divergence is visualized in Figure 2.

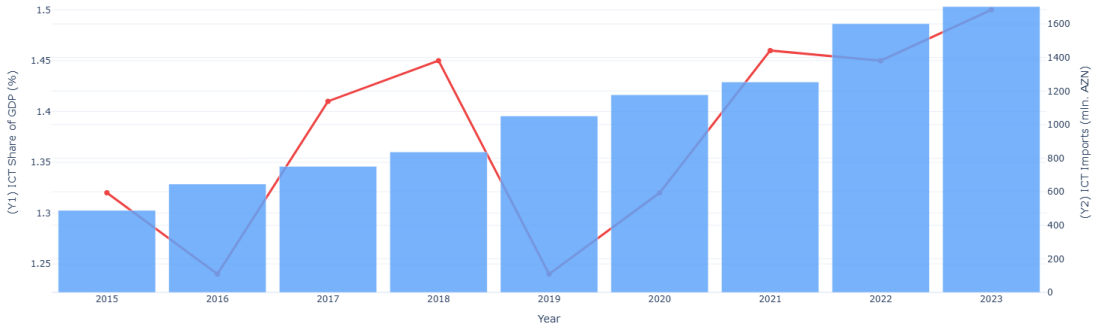

Figure 3. Structural Divergence – ICT Share of GDP vs. Total ICT Imports (2015-2023). Source: Innovation and Digital Development Agency (https://opendata.az/@dsk/ikt-sektorunun-iqtisadi-gostericileri-ve-investisiya-fealiyyeti/r/12d3122e-ce06-4639-89d6-ac539dad123d)

4.4. Vector Autoregression (VAR) Model Diagnostics

Following the initial analysis (Sections 4.1–4.3), a two-variable VAR model, VAR(2), was estimated using the first differences of the natural logarithms of ICT Investment ▲ ln I and ICT Value Added ▲ ln V A to ensure stationarity. The model was specified with two lags (p=2), as indicated by the Akaike Information Criterion (AIC).

Table 3. (VAR) Model Diagnostics

Equation	Variable	Coefficient	Std. Error	p-value	Interpretation (Short-Run Effect
▲ ln I	**L1.** ▲ ln I	0.230279	0.116506	**0.048**	**Positive Investment Inertia** (1st Lag)
	L1. ▲ ln V A	-0.185410	0.101322	**0.067**	Marginally significant **negative feedback**
	L2. ▲ ln I	-0.135613	0.119418	0.256	Insignificant
	L1. ▲ ln V A	0.043937	0.102500	0.668	Insignificant
▲ ln V A	**L1.** ▲ ln I	0.083804	0.123892	0.499	Insignificant (Immediate lag)
	L1. ▲ ln V A	0.232356	0.107771	**0.030**	**Positive VA Inertia** (1st Lag)
	L2. ▲ ln I	-0.121980	0.127021	0.336	Insignificant
	L1. ▲ ln V A	-0.210452	0.108992	**0.052**	Marginally significant negative feedback

A. VAR Stability Test (Inverse Roots)

The essential requirement for the validity of the Impulse Response Functions (IRFs) is the **stability of the VAR model**.

- **Finding:** The stability test confirms that all inverse roots of the characteristic polynomial lie **strictly inside the unit circle**.

- **Interpretation:** This result validates the dynamic model specification and ensures that the Impulse Response Functions are stable and meaningful, meaning the system reverts to its long-run equilibrium following a shock.

B. VAR Coefficient Analysis

The estimated coefficients from the VAR(2) model provide direct insight into the short-run dynamics (see Table 2). The focus here is on the lagged cross-effects:

- Effect of ▲ ln V A on ▲ ln I (Investment Equation): The one-period lagged growth in Value Added (L1. ▲ ln V A) has a negative coefficient (-0.185410) with a p-value of 0.067. While marginally significant at the 10% level, the negative sign suggests that, in the very short run, a previous boost in sectoral output may lead to a slight contraction or delay in new capital investment growth. This could indicate a project completion cycle where successful output (VA) is followed by a pause in new CapEx procurement.
- Effect of ▲ ln I on ▲ ln V A (Value Added Equation): The one-period lagged growth in Investment (L1.▲ ln I) has a positive coefficient (0.083804), but its p-value of 0.315 is statistically insignificant. This indicates that the effect of investment on output is not immediate and linear within the first year, highlighting the importance of examining the multi-period dynamics via the IRF.

4.5. Impulse Response Function (IRF) Analysis

The Impulse Response Function (IRF) analysis is crucial for capturing the dynamic, multi-period effects—the true lag structure—which the standard VAR coefficients cannot fully reveal. The IRFs depict the response of one variable to a one standard deviation (S.D.) shock in the other variable over an 8-period (year) horizon, with 95% confidence intervals.

Figure 4. Impulse Response Functions (IRFs) of the VAR Model (Shocks and Responses).

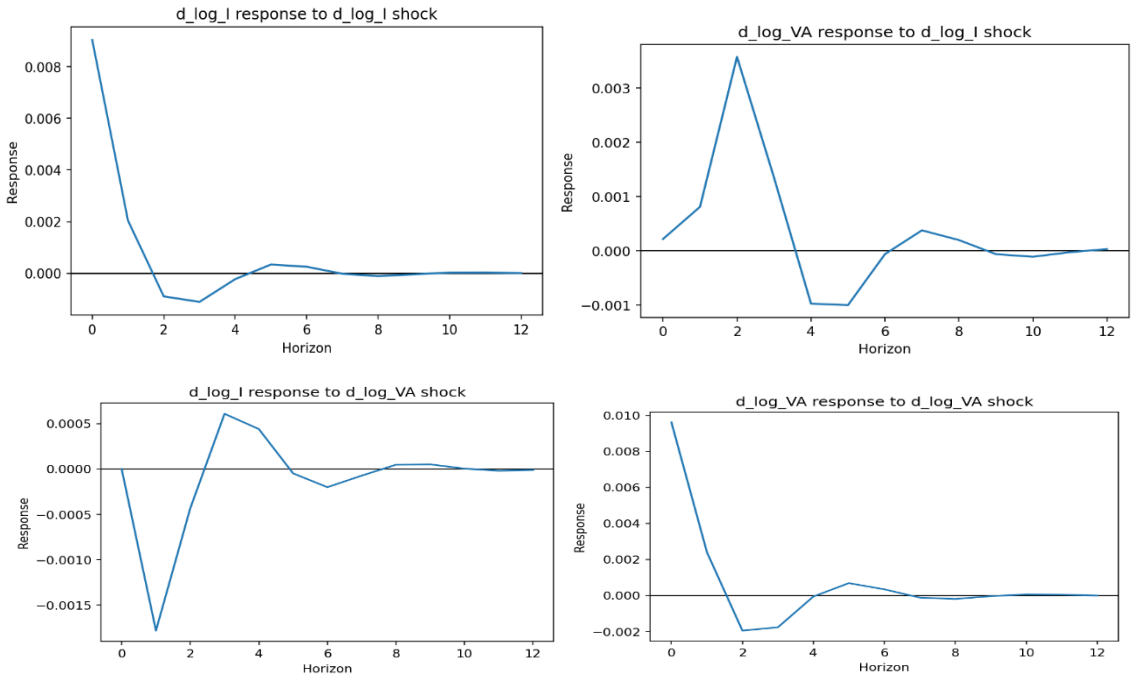

Table 4. Shock and Responses results.

Response of Y	the Shock impulse in X	Key Finding and Interpretation
▲ ln V A	▲ ln I	**Core Effectiveness (Hypothesis 1 Confirmed):** The response is initially insignificant but becomes **statistically significant and positive from Period 1 and peaks in Period 2.** This confirms that a \$1\$ S.D. shock to investment growth effectively drives output growth, but with a **1-to-2-year implementation lag,** aligning with infrastructure project timelines.
▲ ln I	▲ ln I	**Slow Feedback Loop:** The response of investment growth to a shock in output growth is insignificant for the first few periods. A **significantly positive response emerges only around Periods 3-4 and persists thereafter.** This confirms that new capital investment is slow to respond to sectoral success, indicating weak and delayed market signals or cautious private sector participation.
▲ ln I	▲ ln V A	**Investment Volatility:** The self-response of investment growth dissipates very rapidly (often becoming insignificant after Period 1). This confirms the high volatility and **lack of sustained, continuous investment momentum**, suggesting a "stop-start" cycle driven by discrete projects.
▲ ln V A	▲ ln V A	**Low Endogenous Momentum:** The self-response of Value Added growth also fades quickly. A positive shock to output growth **does not create strong, self-sustaining momentum** over time, highlighting the sector's dependence on continuous external (investment) stimulus rather than organic growth.

The use of lagged correlation and VAR modeling is justified by the nature of capital investment cycles, which typically exhibit delayed productivity effects. This approach mitigates endogeneity concerns and captures dynamic feedback loops, aligning with best practices in ICT investment analysis (Jorgenson, 1963; Toda & Yamamoto, 1995). The inclusion of Impulse Response Functions (IRFs) further enhances the model's explanatory power by revealing multi-period dynamics beyond immediate effects.

The VAR model of Toda and Yamamoto causality will be as follows:

$$yt = \mu 0 + (\sum a1tyt - i\ k\ i = 1 + \sum a2tyt - i\ dmax\ i = k + 1) + (\sum \beta 1txt - i\ k\ i = 1 + \sum \beta 2txt - i\ dmax\ i = k + 1) + \varepsilon 1t\ (1)\ xt = \varphi 0 + (\sum \gamma 1txt - i\ k\ i = 1 + \sum \gamma 2txt - i\ dmax\ i = k + 1) + (\sum \delta 1tyt - i\ k\ i = 1 + \sum \beta 2tyt - i\ dmax\ i = k + 1) + \varepsilon 2t\ (2)$$

Table 5. Toda and Yamamoto causality implications

Direction of Causality	k + d_{max}	Chi-square (χ^2)	p-value	Result (Causality)
lnINV → lnVA	**2 + 1**	**9.842**	**0.019**	**H_1 – Yes**
lnIMP → lnVA	**2 + 1**	**2.314**	**0.511**	**H_0 – No**
lnVA → lnINV	**2 + 1**	**6.127**	**0.047**	**H_1 – Yes**

Direction of Causality	$k + d_{max}$	Chi-square (χ^2)	p-value	Result (Causality)
lnVA → lnIMP	**2 + 1**	**1.982**	**0.612**	**H_0 – No**
lnINV → lnIMP	**2 + 1**	**3.456**	**0.327**	**H_0 – No**
lnIMP → lnINV	**2 + 1**	**7.201**	**0.028**	**H_1 – Yes**

5. Discussion

5.1. Interpreting the "Efficiency-Stagnation Paradox"

The findings present a critical paradox: **Azerbaijan's ICT investments are econometrically *effective* (G1) but structurally *insufficient* (G2).**

This interpretation aligns with Bagirov et al. (2025), who found that "investments in research and development (R&D) showed a strong correlation with the number of patents (r = 0.852), confirming the impact of capital allocation on the accumulation of intellectual assets." This supports the argument that a transition toward software and R&D investment can yield long-term national innovation returns.

The paradox lies in the stagnation of GDP share (Finding 2a). If investments are effective, why is the sector's relative importance not growing?

1. **High Value Leakage:** As shown in Figure 2, a massive portion of investment expenditure "leaks" directly to foreign hardware suppliers. The domestic value-added component (services, installation, local software) is overshadowed by the cost of imported telecommunications equipment (visible in the CSV data, row 9).

2. **Lack of Multiplier Effect:** Investment in hardware (a one-time purchase) has a low domestic multiplier effect compared to investment in software and R&D, which creates high-wage jobs and scalable intellectual property.

3. **Failure to Enable SMEs:** The current model fails to stimulate the domestic B2B market. SMEs, lacking capital and skills, do not adopt advanced technologies, thus stunting the demand that would otherwise grow the ICT sector's share of the non-oil economy.

5.2. Implications for AI Readiness

These structural imbalances pose a direct threat to Azerbaijan's AI ambitions. The development of a sovereign AI capability relies on a strong domestic ecosystem of R&D and software development, not on imported hardware.

The data suggests Azerbaijan is building an "**AI-ready infrastructure**" (hardware, telecom equipment) but is failing to build an "**AI-ready industry**" (software, skills, local R&D). AI is fundamentally a software- and data-driven discipline. By focusing investments on imported hardware, the current model risks solidifying Azerbaijan's role as a *consumer* of foreign AI solutions rather than a *creator* of its own. This inhibits the development of tailored AI solutions for local challenges (e.g., in agriculture, logistics, or public services) and creates long-term strategic dependencies.

Table 6. Comparative Framework: Azerbaijan's ICT Investment in the Context of Literature

Dimension	Empirical Finding for Azerbaijan (2005-2023)	Alignment with Previous Literature
Investment Lag	The effect of investment peaks in Year 2 (IRF).	Consistent with established capital project realization cycles (Jorgenson, 1963).
Productivity Paradox	High nominal growth with stagnant GDP share (1.7%).	Confirms findings that growth is constrained by the lack of complementary assets and organizational change.[10]
Value Leakage	Import dependency ratio of 0.70.	Supports global warnings about technological dependency and "digital colonization" (UNCTAD, 2019).[1]
Endogenous Growth	Slow V A – I feedback loop (Periods 3-4).	Indicates a weak capacity for organic, self-sustaining growth, typical of economies with a shortage of venture capital.

The dual findings—positive output correlation (G1) alongside structural failure (G2)—are consistent with the experience of other transition economies that prioritized infrastructure over complementary assets. For instance, studies on Central and Eastern European countries found that the growing use of ICT only successfully led to convergence when accompanied by restructuring in key sectors and organizational capital investments. Similarly, the long-run productivity gains from ICT found by Jorgenson and Stiroh (2000) in advanced economies were explicitly linked to complementary investments that Brynjolfsson and Hitt (2000) estimate to be ten times the hardware cost. The 0.70 import dependency ratio in Azerbaijan is a manifestation of this structural failure: the capital is spent, but the necessary organizational and R&D capital accumulation remains low, leading to value leakage rather than sustained, high-multiplier growth.

The econometric findings regarding the dynamic causality further align with the literature on developing countries. The use of the Toda-Yamamoto test confirms a two-way causality between investment and output, mirroring results found in R&D and growth analyses in other transition contexts. Crucially, the finding that imports (ln I M P) stimulate investment (ln I N V) but **do not cause** value added (ln V A) provides a rigorous, data-driven explanation for the 'digital consumption' trap identified by UNCTAD (2019) and other recent reports: the capital allocation is effectively captured by foreign suppliers, short-circuiting the domestic wealth-creation loop.

5.3. Limitations of the Study

This study is subject to several limitations.

As Bagirov et al. (2025) note, "cost-based and comparative methods dominate the valuation of intellectual assets in Azerbaijan, which limits their capitalization potential." This institutional barrier highlights the need for legal and methodological reforms to unlock the full economic value of domestic innovation.

1. **Aggregate Data:** The analysis relies on macro-level sectoral data. It cannot capture firm-level dynamics (e.g., differences between state-owned enterprises and private SMEs).
2. **Investment Proxy:** "Investment in fixed capital" is an imperfect proxy. It does not disaggregate investment in hardware vs. software, nor does it capture intangible investments in human capital and R&D, which are critical for AI.
3. **Missing Export Data:** The provided dataset includes imports but not exports, preventing a full analysis of the ICT balance of payments.

6. Conclusion and Policy Implications

6.1. Conclusion

This empirical study sought to move beyond descriptive statistics to provide a data-driven, econometric analysis of Azerbaijan's ICT investment landscape from 2005 to 2023. The findings confirm that while capital investments have been effective in generating nominal growth (validating G1), the sector is characterized by structural weaknesses—namely, a stagnant share of GDP and a severe, growing dependency on imported hardware (validating G2).

This "Efficiency-Stagnation Paradox" suggests a development model that, while successful in building foundational infrastructure, is insufficient for fostering the dynamic, software-driven, and R&D-intensive ecosystem required to compete in the age of Artificial Intelligence.

6.2. Policy Implications

To achieve the strategic goals of "Azerbaijan 2030" and build a genuine AI-ready economy, a significant policy recalibration is required.

1. **Rebalance Investment from Hardware to Software & R&D:** The state must shift its financial incentives (tax credits, grants, subsidies) away from the simple *importation of equipment* and towards the **domestic development of software and R&D**. This includes fostering local AI startups and "scale-ups."
2. **Stimulate Domestic Demand via SMEs:** The largest barrier to the ICT sector's growth is weak domestic demand from the private sector. Government programs (e.g., "digitalization vouchers" or co-financing schemes) are needed to incentivize SMEs to adopt advanced digital solutions, creating a sustainable internal market for local IT firms.
3. **Invest Aggressively in Human Capital:** The ultimate bottleneck for AI is talent. Investment must be redirected toward AI-specific education, data science programs, and cybersecurity training to build the human capital required to utilize the infrastructure that has already been built.

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THE ROLE OF RESEARCH IN THE EDUCATIONAL PROCESS IN HIGHER EDUCATIONAL INSTITUTIONS

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ABSTRACT

Many developed and developing countries are trying to educate people who can compete in the field of science and technology on national and international platforms for the sake of a strong future, to create the potential to easily overcome the problems they face, and to form research skills. For this reason, research and practices conducted to give children a scientific view at an early age are preferred. Academically successful young people are expected to develop research inquiry, problem-solving, and decision-making skills, to be lifelong learners, and to maintain a sense of curiosity about their immediate and distant environments.

The goal of researching the subject is to gain knowledge about the rules, principles, concepts, terminology, content, and specific features of the organization and management of scientific research works in higher education institutions. Conducting scientific research based on the modern achievements of domestic and foreign scientists facilitates the acquisition of knowledge about historical aspects, theoretical guarantees, technologies, practical methods and methods, and the ability to choose a topic for the analysis of the obtained results, the processing of the received data, and the use of information technologies to make logical and effective decisions. creates a foundation for mastery.

Introduction

The primary direction of conducting scientific research is to determine its structure, characteristics, and interconnections based on the principles and methods of knowledge developed in

science, as well as to obtain beneficial results for human activity, integrate them into production with an additional economic effect, and comprehensively and reliably study a specific object. The object of scientific research comprises relevant topics and innovations. The subject encompasses the structure of the system, the interrelation of its elements, various properties, and the totality of its developmental forms.

One of the most essential conditions for conducting scientific research is scientific generalization. This enables the establishment of dependencies and relationships between processes within the research while simultaneously facilitating the derivation of scientific conclusions. The more comprehensive and well-substantiated the results are, the higher the quality and level of scientific research [7]. In science, it is crucial to distinguish between the empirical and theoretical levels of research and the organization of knowledge.

The theoretical level of scientific knowledge predefines the existence of specific abstract entities (constructs) and the theoretical laws that connect them. Its primary objective is to expand society's knowledge and facilitate a deeper understanding of the laws of nature. Such developmental perspectives are mainly employed to further advance new theoretical studies [1].

Research that is conducted with a specific objective, within a structured plan, in accordance with scientific principles, and in a systematic manner is referred to as scientific research. Scientific research involves the step-by-step investigation, examination, and evaluation of a problem using universal scientific methods. It is categorized into two main types: basic research and applied research.

Scientific research follows a series of methodological stages. The general process of conducting research includes the following steps:

- Identification and classification of the research problem
- Literature review, conducting experiments, or formulating research questions
- Determination of the research methodology
- Data collection
- Data analysis
- Interpretation of results and findings
- Documentation and reporting of results

Each stage plays a crucial role in ensuring the reliability, validity, and effectiveness of the research process.

This study contributes to the growing body of literature on higher education by systematically examining the interrelationship between research and teaching through the lens of research-based learning. While previous studies have largely addressed research and teaching as parallel academic functions, this manuscript advances the discussion by conceptualising their integration as a dynamic and mutually reinforcing nexus within higher education institutions.

On the other hand, this study adds value to the existing literature by clarifying how research-based learning functions as a bridge between academic research and teaching practice. Unlike prior reviews that primarily catalogue existing studies, this manuscript critically connects research engagement, pedagogical innovation, and institutional learning environments. As a result, the study provides a coherent explanatory perspective that can guide future empirical research and inform institutional strategies aimed at strengthening the research–teaching nexus.

The originality of this study lies in its explicit focus on the role of academic staff as key mediators of the research–education nexus. By synthesising existing theoretical and empirical insights, the paper highlights how academics' engagement in research activities directly informs pedagogical practices, curriculum design, and student learning outcomes. In this regard, the study moves beyond descriptive accounts and underscores research-based learning as a strategic mechanism for enhancing educational quality.

Furthermore, this study contributes by offering an integrative analytical framework that links institutional research culture, academic staff engagement, and student-centred learning outcomes. This framework provides a structured perspective for understanding how research-informed teaching can be operationalised in higher education contexts, thereby offering implications for policy development, academic staff development, and institutional quality assurance processes.

Finally, the study focuses mainly on higher education institutions in a general context, without differentiating sufficiently between disciplinary, institutional, or regional variations. Subsequent research may benefit from exploring how the research–education nexus operates across diverse higher education settings.

Problem Statement

Despite the extensive recognition of research as a core component of higher education, there remains a lack of systematic understanding regarding how research is conceptually integrated into the educational process of higher education institutions and how it contributes to teaching quality, student learning outcomes, and institutional development. Existing literature often discusses the importance of research in broad or normative terms; however, empirical and analytical studies that clearly articulate the functional role of research within the educational process are limited. This gap results in ambiguity about how research activities are aligned with teaching practices and educational objectives in higher education institutions. Consequently, there is a need for a structured investigation that clearly defines the problem and analytically examines the role of research in the educational process.

The main objective of this study is to examine the role of research in the educational process within higher education institutions. Specifically, the study aims to:

1. Analyze the conceptual relationship between research activities and the educational process in higher education.
2. Identify the key functions of research in enhancing teaching quality and learning outcomes.
3. Examine how research contributes to academic development and institutional effectiveness in higher education institutions.
4. Provide a structured analytical framework for understanding the integration of research into higher education practices.

In order to achieve the stated objectives, the study seeks to answer the following research questions:

1. How is research conceptually positioned within the educational process of higher education institutions?
2. What roles does research play in improving teaching practices and student learning outcomes?

3. In what ways does research contribute to academic and institutional development in higher education?
4. How can the integration of research into the educational process be systematically conceptualized?

However, if primary data collection is required, the researcher must employ appropriate empirical methods. These may include controlled experiments, surveys, structured questionnaires, systematic observations, in-depth interviews, focus group discussions, content analysis, or life history research. The selection of research methods must be guided by the overall research objective, ensuring methodological rigor and alignment with the study's purpose.

Ultimately, the choice of research design and methodological approach significantly influences the validity, reliability, and overall quality of the study's findings. A well-structured research framework facilitates a systematic investigation, enabling the researcher to derive meaningful and generalizable conclusions.

In accordance with the objectives of science, the purpose of scientific research is to develop reliable solutions, systematically and methodically gather data, analyze the data, assess and interpret the results, and provide comprehensive reports on the research process. In scientific inquiries, researchers are responsible for disseminating the results obtained at the conclusion of their studies, along with the discussions and proposals related to the research topic, by utilizing scientific and systematic language, thereby ensuring the effective communication of their findings to a broader audience. The ability to present research in a systematic and scholarly manner imparts universal value to the investigation. Individuals who organize, conduct, and manage scientific research are designated as researchers. When disseminating information regarding scientific research, researchers must adhere to established national and international standards concerning the form, structure, and content of their work [1].

Methodology

Research Design

This study adopts a qualitative research design based on a systematic literature review (SLR) approach. The systematic review method was selected to ensure a transparent, replicable, and structured synthesis of existing scholarly literature on the role of research in the educational process of higher education institutions. Unlike narrative or descriptive reviews, this approach allows for a methodologically rigorous examination of conceptual, theoretical, and empirical contributions in the field.

Scope and Data Sources

The literature review focused on peer-reviewed academic publications related to research–teaching integration, research-based education, and the role of research in higher education. Relevant studies were identified through major academic databases, including Scopus, Web of Science, ERIC, and Google Scholar. These databases were selected due to their extensive coverage of high-quality educational research.

Search Strategy and Selection Criteria

A systematic search strategy was employed using predefined keywords and combinations such as *"research in higher education," "research-based teaching," "research and learning,"* and *"educational process in universities."*

The inclusion criteria were as follows:

- Peer-reviewed journal articles and academic book chapters;
- Publications written in English;
- Studies published within the last 15 years to ensure contemporary relevance;
- Research explicitly addressing the relationship between research activities and the educational process in higher education.

The exclusion criteria included:

- Non-academic sources (e.g., opinion pieces, editorials);
- Studies focusing exclusively on primary or secondary education;
- Publications lacking a clear connection to the educational process in higher education institutions.

Data Analysis

Following the selection process, the included studies were analyzed using thematic content analysis. The analysis involved coding key concepts, recurring themes, and analytical categories related to the role of research in teaching, learning outcomes, academic development, and institutional effectiveness. This process enabled the identification of dominant patterns and conceptual frameworks within the literature and facilitated a structured synthesis of findings.

Reliability and Rigor

To enhance methodological rigor, the review process followed clearly defined stages of identification, screening, eligibility assessment, and analysis. The use of explicit inclusion and exclusion criteria, as well as systematic coding procedures, contributed to the transparency and reliability of the review. This methodological approach ensures that the study moves beyond a general discussion and provides a structured, evidence-based analysis.

The Main Part

For scientific research to be successful, it is essential to organize, plan, and execute it in a methodical and sequential manner. The stages, plan, and sequence of the research depend on the type, object, and objectives of the scientific inquiry. In cases where the research pertains to a technical subject, an initial planning document is prepared, followed by an investigation into the feasibility of the research. Subsequently, theoretical and experimental studies are outlined, a scientific-technical report is drafted, and the results are presented for industrial application.

Students' scientific research plays a significant role in the educational process. Firstly, it aids them in developing research skills that are crucial at certain stages of their lives. Secondly, such work contributes to the development of critical thinking, allowing students to analyze information more deeply and objectively [5].

The logical method of cognition constitutes a fundamental approach in addressing both empirical and purely theoretical challenges in scientific research. These methodological frameworks enable the interpretation of processes through conclusive reasoning, facilitate the formulation of diverse hypotheses and theoretical propositions, and contribute to the identification of viable solutions. The application of these methods is predicated upon the findings derived from specialized empirical investigations [9].

The methodology of scientific research encompasses a systematically structured set of principles, methods, and instruments designed for conducting theoretical and applied inquiries within a specific domain of knowledge, corresponding to the researcher's professional field. The selection of an appropriate research methodology is contingent upon the formulated objective of investigating a given scientific phenomenon, including its structural composition, intrinsic properties, informational interrelations, and other defining characteristics, with the ultimate aim of resolving the identified scientific problem.

Scientific research is generally classified into three main categories: theoretical, empirical, and empirical-theoretical, which together form a unified framework in the research process.

Theoretical research methods are determined based on the research topic and the underlying problem, outlining the general structure and methodological framework necessary for addressing both primary and auxiliary research tasks. Theoretical investigations are inherently creative in nature, facilitating the formulation of novel scientific hypotheses, offering in-depth explanations of unexplored phenomena or processes, generalizing distinct occurrences, and substantiating the strategic and tactical foundations of scientific inquiry. Additionally, they contribute to the resolution of various analogous scientific challenges.

Scientific research is conducted through the cognitive activity (intellectual reasoning) of the human researcher, wherein theoretical inquiry is predominantly characterized by intellectual engagement. Given the extensive range of theoretical research methods, their selection is contingent upon the specific scientific problem under investigation. From this perspective, theoretical research constitutes a fundamental component in achieving meaningful research outcomes[8]:

- It is essential to engage in continuous reflection on the research topic. This principle yields two practical implications: a researcher should not be limited to the mere practical execution of their scientific work but must also engage in constant intellectual contemplation of their research subject.
- Structuring the research process in a systematic and planned manner is more effective. Before conducting scientific investigations, it is advisable to develop a comprehensive research plan, which subsequently serves as a framework for inquiry throughout the theoretical research process.
- Maintaining oversight of the research progress is a critical factor in theoretical investigations. Continuous monitoring of the research process allows for the refinement of the study based on emerging results and facilitates the systematic analysis of scientific findings.

The methods of empirical research encompass the general structure, sequence, and methodologies of experimental investigations. Empirical research serves to validate theoretical concepts, laws, and principles in practical settings and provides the foundation for confirming the reliability of scientific findings formulated within the hypothesis of a given research study. Experimentation and theory exist in a state of interdependence: theory substantiates the methodology of experimentation, while experimentation enables the evaluation of a theory's validity.

Experimental research is typically conducted in three key stages: planning, experimentation, and analysis (processing of results). In most cases, experimentation is a multidimensional process. The multidimensional nature of experiments allows for the progressive development of their

strategic direction at subsequent stages. Multi-stage experiments are carried out based on a unified mathematical framework. Experiments designed according to a predefined plan ensure the variation of all measured parameters while accounting for their interrelations. The mathematical theory of experimentation, alongside its planning, is increasingly supported by computational approaches that facilitate the processing of research results through the use of computers. This approach in experimental research is referred to as 'computational experimentation.' A critical component of the methodology of experimental research is the processing and analysis of data [10].

Based on the type of information to be obtained, research types aligned with the objectives of a study are classified into three main categories: exploratory research, descriptive research, and explanatory (hypothesis-testing) research.

Exploratory research is conducted in cases where the researcher possesses limited prior knowledge about the subject or when the research topic is relatively novel. This type of research provides the investigator with preliminary insights into the subject matter and primarily aims at gathering surface-level information. In general, exploratory research is preferred in the following three scenarios:

When no systematic experimental research has been conducted on a particular group, or when only a limited number of studies exist on the group, process, activity, or phenomenon under investigation.

When the subject of interest has not been examined with methodological flexibility, but rather through strictly controlled, progressive research efforts.

When the existing knowledge on a subject has undergone substantial changes, rendering prior information insufficient or obsolete, thus necessitating further research.

Research conducted within a specific field of study typically serves three primary objectives:

- To satisfy the researcher's curiosity regarding the topic and provide preliminary insights.
- To assess the feasibility of conducting more comprehensive studies on the subject.
- To develop data collection instruments that can be utilized in subsequent research.

In other words, the fundamental purpose of conducting research is to provide the researcher with the requisite information to delineate the research problem and undertake a more in-depth and systematic investigation. Research endeavors aim to collect information at a broad conceptual level to facilitate an initial understanding of the research problem. This type of inquiry enables the researcher to identify existing knowledge on the subject of interest and establishes a foundational framework for subsequent, more extensive studies.

Upon the completion of the research process, the investigator refines the research problem based on the accumulated data and insights. Furthermore, research assists in determining the focal area of inquiry, selecting the most appropriate data collection methodologies, and identifying the relevant study population. Nevertheless, a key limitation of research lies in the fact that definitive resolutions to research problems are seldom attainable, as the selected samples may not comprehensively encapsulate the full scope of the investigation [9].

The objectives and functions of research activities in higher education institutions are as follows:

- Development of research competencies.

Students acquire the ability to conduct independent research, formulate hypotheses, collect and analyze data, and draw conclusions based on their findings.

- Cultivation of critical thinking.

Engaging in research enables students to critically evaluate information, assess the reliability and significance of data sources, and develop analytical reasoning skills.

- Expansion of knowledge.

Participation in research allows students to immerse themselves in a specific subject area, deepen their understanding, and gain new perspectives within their field of study.

- Preparation for future professional endeavors.

Research activities equip students with essential skills for their future careers, including data analysis, information management, and effective communication.

- Integration into the scientific community.

Students contribute to the advancement of knowledge by engaging in academic discourse, presenting their research findings at conferences, publishing in scholarly journals, and participating in scientific discussions.

In research studies, research problems cannot be clearly defined, as detailed information about the topic is not initially available before the research begins. For this reason, such studies require the application of qualitative methods. Reviewing the literature is considered the first stage of the research for gathering information related to the topic. In the next stage, the technique of consulting with experts involves the researcher consulting with specialists and obtaining preliminary information from them on the topic. For example, in a study on youth drug use, psychological counselors, police officers, lawyers, or legal advisors may provide the researcher with initial information on the subject. Interviews with experts are conducted face-to-face. Therefore, the researcher does not use structured data collection tools in their observations and interviews. However, the researcher must organize interviews with specialists regarding the research topic and ask questions about what information they wish to gather, from whom, and why. For instance, in a study on youth drug use, the researcher would aim to collect information on who uses drugs, the age, gender, occupation, social background, etc., of drug users in the area of interest [3].

The main theoretical and methodological directions regarding the perception of scientific knowledge have led to the development of the core methods of scientific research and the establishment of the fundamental rules for scientific investigations. These rules form the structure of scientific research. The primary elements of the scientific method are stages in the research procedure, starting with the identification of the research problem, i.e., the research topic. The research problem serves as a link between the theoretical and methodological parts of scientific research and is solved through the sequential application of the scientific method. Every piece of scientific knowledge begins and evolves by defining hypotheses.

At the same time, it is the most crucial component of the hypothetical-deductive scientific method for acquiring knowledge. Hypotheses are assumptions about solving a specific scientific problem, and by defining them, the researcher decides on the type of research and data collection method. Hypotheses have a particular structure consisting of dependent and

independent variables, as well as the relationships between them. This is expressed as the position of the hypothesis. The role of the hypotheses is determined by the knowledge obtained and the scientific objectives it serves. The entire research process is directed toward testing these hypotheses, and the role of the scientific method is to define the scientific criteria.

A person capable of conducting scientific research must possess qualities such as high-level thinking, readiness to research and inquire, willingness to collaborate, critical thinking, creativity, problem-solving skills, logical inferences, and scientific thinking. When examining these qualifications, it becomes clear that students who will conduct scientific research must be above a certain level of intelligence and have certain superior traits. In this regard, it is crucial to encourage talented students—those capable of taking on leadership roles, guiding society or the environment, sensitive to science, highly interested, and representing 3-5% of the population—to engage in scientific research. Talented students should possess the following attributes for scientific research: the ability to learn quickly, solve problems, be creative, have a vivid imagination, exhibit leadership qualities, be sensitive, have excellent long-term memory, strong perception, mathematical reasoning skills, the ability to read and analyze complex ideas, have a keen interest in diverse topics, ask numerous questions, strive for perfection, be independent, and capable of synthesis [11].

"Research becomes a crucial tool for evaluating student activity and the effectiveness of the educational program for university instructors. Research activities enable instructors to assess how deeply students understand and apply their learning in practice. Mentoring teachers can also organize various events such as research seminars and round tables to help students develop their research skills and facilitate exchange of experiences. Each student is assigned a scientific advisor from the start of their research journey who supports the researcher throughout all stages, helping to overcome challenges and find solutions. Engaging in research cultivates critical thinking and enhances students' ability to analyze information. When students engage in scientific research, they become more enthusiastic about learning new knowledge more easily. Through conducting research, students learn to work with scientific sources, write scientific articles, and present their research findings. This helps them develop essential skills for their future professions. Research allows students to broaden their professional horizons and gain experience in solving real-life problems in their fields, preparing them better for their careers after graduation."

Findings

This section presents the synthesized findings derived from the systematic analysis of the reviewed literature. The findings are organized thematically to reflect the dominant patterns and conceptual categories identified across the selected studies.

Research–Teaching Integration in Higher Education

The reviewed literature consistently identifies research as a foundational element in the integration of teaching and learning processes in higher education institutions. Research-informed teaching is widely associated with curriculum relevance, the incorporation of contemporary knowledge, and the promotion of inquiry-based learning environments. Studies emphasize that when academic staff actively engage in research, teaching practices tend to become more reflective, evidence-based, and aligned with disciplinary developments.

Influence of Research on Student Learning Outcomes

A significant body of literature highlights the positive impact of research engagement on student learning outcomes. Findings indicate that student participation in research activities enhances critical thinking, problem-solving abilities, and independent learning skills. Research-based learning is also associated with increased student motivation and deeper conceptual understanding, particularly in programs that explicitly integrate research projects into the curriculum.

Research as a Driver of Academic and Institutional Development

The literature further reveals that research plays a strategic role in academic development and institutional effectiveness. Strong research cultures contribute to faculty professional growth, curriculum innovation, and quality assurance processes. At the institutional level, research activity is frequently linked to international visibility, academic reputation, and competitiveness within the global higher education landscape.

Discussion

This section interprets the findings in relation to existing scholarship and provides a critical reflection on their implications for higher education institutions.

Comparison with Prior Studies

The findings of this review are largely consistent with prior studies that underscore the centrality of research in higher education. Similar to earlier research, the present study confirms that research-based teaching enhances educational quality and student learning outcomes. However, while many previous studies emphasize research productivity and output metrics, the findings of this review place greater emphasis on the pedagogical and developmental dimensions of research integration within the educational process.

Interpretation of Key Findings

The findings suggest that research should be conceptualized not merely as an academic obligation but as an integral component of the educational process. The strong emphasis on inquiry-based and research-informed learning reflects a broader shift toward student-centered educational paradigms. This interpretation highlights the transformative potential of research when it is systematically embedded into teaching and learning practices rather than treated as a parallel academic activity.

Critical Reflection and Implications

Despite the broadly positive role of research identified in the literature, the findings also reveal several challenges. A recurring issue is the gap between institutional research policies and their practical implementation in teaching contexts. Additionally, disparities in research capacity and resources across institutions may constrain the effective integration of research into education. These challenges suggest the need for coherent institutional strategies that align research objectives with educational goals and provide adequate support for academic staff.

Conclusion

The significance of scientific research in the field of education is multidimensional, extending across pedagogical, institutional, and policy-related domains. This study has demonstrated that research serves as a critical mechanism for enhancing educational quality, advancing teaching methodologies, and fostering innovation in higher education. The knowledge generated through scientific research informs curriculum design, assessment practices, and pedagogical strategies, while also contributing to the psychological and intellectual development of learners.

From a theoretical standpoint, the findings of this systematic literature review reinforce the conceptualization of research as an integral component of the educational process rather than a parallel academic activity. Research and teaching emerge as interdependent elements of a unified higher education mission, in which research-based education enhances learning effectiveness, fosters inquiry-based pedagogies, and supports academic development. This perspective extends existing theoretical frameworks on research–teaching integration by emphasizing the holistic role of research in shaping educational processes.

In practical terms, the findings highlight several implications for higher education institutions. First, establishing and sustaining a strong research culture within universities is essential for enhancing teaching and learning outcomes. Actively engaging students in research activities and integrating research into curricula can significantly strengthen the scientific competencies of both students and academic staff. Second, incorporating up-to-date scientific research findings into educational programs ensures alignment with global developments and improves the relevance and effectiveness of teaching methodologies. Third, fostering creativity and innovation through research-driven approaches facilitates the integration of modern technologies and the development of new instructional tools. In addition, enhancing teachers' research skills through targeted training programs and professional development initiatives can improve instructional quality and support evidence-based teaching practices. Emphasizing the practical application of research outcomes further enables educational institutions to translate theoretical knowledge into effective, real-world educational solutions. Finally, adopting an integrative, interdisciplinary approach to educational research—drawing on psychology, social sciences, and information technology—can lead to more comprehensive and impactful outcomes.

Despite these contributions, the study also points to important directions for future research. Further empirical studies are needed to examine how research-based education is implemented across different institutional contexts and higher education systems. Comparative and longitudinal research designs could provide deeper insights into the long-term effects of research integration on student learning outcomes, teaching quality, and institutional performance. Future research may also explore the mechanisms through which research culture influences educational innovation and policy development.

In conclusion, this study underscores the central role of scientific research in advancing the educational process in higher education institutions. By systematically integrating research into teaching, learning, and institutional strategies, higher education institutions can enhance educational quality, foster innovation, and respond more effectively to the evolving demands of contemporary education.

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THE REGULATION MODEL OF DATA-DRIVEN ECONOMIC POLICY MAKING

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ABSTRACT

The emergence of the new economy and the conditions brought about by digitalisation require implementing new approaches and forms of regulation in economic policymaking. Although the accumulation of big data of social activities due to digitalisation enables data-driven economic policymaking, there are significant uncertainties in its practical application and conceptual framework. In particular, there is a research gap in determining the conceptual and economic regulation model of data-driven policymaking. Therefore, the purpose of this paper is to conceptualise the regulation model of data-driven policymaking in the process of digital economy formation. In the study, data-driven policymaking is evaluated from the perspective of the digital economy, which summarises all new economic trends, and the digital and cybernetic aspects of the problem of economic calculation are reconsidered on a theoretical basis.
The regulation approach used in the research makes it possible to understand the current situation in terms of accumulation at the stage of economic development and to prepare appropriate policy proposals for the provision of new economic relations. As a result, a model of digital cybernetic regulation scales has been developed that can explain new forms of accumulation and regulation, including the green economy, and help in policymaking.

1. Introduction

The wide diffusion of information and communication technologies in social life has led to the emergence of innovations that increase the importance of information, such as cloud technology, big data, artificial intelligence, the Internet of Things (IoT) and data analytics. Thanks to new digital technologies, the amount of data produced has increased significantly and has become an important source for decision making in many areas. Data-Driven Decision Making (DDDM), which has been widely used especially in management, marketing, production and finance, is raising awareness that it can be an effective tool in economic policy-making (EU Commission, 2014) (Joseph, 2014). New economic relations shaped on the basis of technological innovation have led to the formation of the digital economy and the renewal of factors of production (Xu et al., 2009), Digital transformation has turned data into the most fundamental new factor of production and the main source of economic regulation.

New data-driven economic decisions are required for economic policymaking under the conditions of the digital economy's development process. The article explores the conceptual

rationale of the regulation model for data-driven policy-making in the new economy. For this reason, within the framework of conceptualisation research, a comprehensive literature review, clarification of abstract ideas, and definition of variables were carried out in this article. The article aims to analyse the essential devices of the digital economy ecosystem and the implementation strategy for economic policy-making. The realization of data-driven policy-making requires the management of informational processes involving the accumulation, classification, processing, and calculation of data arising from a multitude of economic relationships. For example, the Internet of Things (IoT) is increasingly covering all areas of economic sectors, enabling the influx and accumulation of data from vast areas (Hristov, 2017). Artificial intelligence (AI) deep learning techniques are used to make use of the vast amount of information accumulated in big data, which was previously considered useless. The calculation of big data by artificial intelligence is performed by supercomputers. In other words, data-driven decision-making requires multi-layered governance for economic decision-making. This requires a new role for the state in the digital age and a different form of economic regulation. Current technological conditions have made it possible to reassess more than a century of economic regulation problems and to create new forms of economic regulation. At the top of the list of economic regulation problems is the 'economic calculation problem. Therefore, this article examines the digital aspects of the economic calculation problem, which covers almost a century of debates, and conceptualises a digital cybernetic model of regulation. The study used abstract logical methods that examine the relationships and validity between concepts using logical rules.

2. The Role of Digital Economy in Data-Driven Policy Making

The social transformation that has taken place with digitalisation has led to the discussion of relations that characterise new conditions under different names such as digital economy, information economy, data economy, internet economy, and network economy. The digital economy can be considered as the common name of the new situation that is handled in different frameworks. The term 'digital economy' was first proposed by Don Tapscott in 1996 in his study 'The Digital Economy: Promise and Peril in the Age of Networked Intelligence' when he tried to explain how digitalisation was transforming the economy (Don, 1996). Although the initial definition of new economic relations focused on technological infrastructure, over time this focus shifted towards processes and regulations (Lane, 1999; Mesenbourg, 2001). When we look at the literature analysis, we see that the framework of the digital economy has been determined in terms of policy making and regulation since 2013 (House of Commons, 2016; OECD, 2013) (Van Gorp & Batura, 2015). Today, the digital economy has become a global economic model as a stage of social development in which information and communication technologies are widely used in different areas of the economy (Gumah & Jamaluddin, 2006). The realisation of economic activities in computer networks has increased the economic value of digital information processes and has become a tool for policymaking. Whether it is consumers comparing prices, searching for new goods and services, providing feedback and reviews, or businesses determining demand, supply, production, marketing, etc., these processes take place in digital networks.

Over the past 20 years, the digital economy has been defined from many different perspectives. Without dwelling on these definitions, we can briefly summarise the digital economy as "the realisation of economic activities in the digital environment". When characterising the digital economy, we encounter two basic choices. The first is to consider the digital economy as a sector of the economy. In our view, this is completely wrong. The second is to think of the digital

economy as characterising the economy as a whole. The correct identification of the digital economy allows the selection of the right analyses in policymaking and the timely determination of the processes of data-driven decisions.

Data-driven policymaking is only possible if the digital economy is fully realised. This is because the digital economy enables the transformation of economic activity into data through digital means and the collection of data. Data-driven economic policy-making starts with the collection of data arising from economic activities through the provision of information channels. In fact, the problem of collecting and calculating information on economic activity predates Internet technologies. This problem is based on the feasibility of economic planning, known in history as the "economic calculation debate." Today, the rise of the digital economy has enabled us to look at the economic calculation debate from the perspective of data-driven economics.

3. Digital Solution of Economic Calculation

As we have seen, the practical history of the idea of subjecting the economy to quantitative calculation is not new. It goes back to the 'socialist calculation debate' of the 1920s. The socialist calculation debate began with the problem of how to implement economic calculation (regulation) to implement planning in a socialist economy where capital and the market did not drive regulation and there was no private ownership of the means of production. Ludwig Mises argued that the planned economy has the problem of rational allocation of resources, citing the market economy as an example where supply and demand play a regulating and determining role. In a market economy, the price of the product provides information about the demand for the product. Without this information, it is not possible for the planned economy to make proper use of the means of production (Adler, 1990). The efforts of the planners (managers) of the socialist economy, who do not have accurate information about value, to correct the inaccuracies in value-price determination lead to economic costs, reallocation of resources, and social injustice. According to Friedrich Hayek, the economics of central planning, which determines the allocation of resources, often leads to the emergence of managers who take resources and impose penalties for the effective implementation of the plan (Hayek et al., 2005). Bryan Caplan argues that the source of the economic failings of socialism is not the lack of economic rationality that the Austrian school claims, but the weak incentives that result from the system of party rule (Caplan, 2004). In fact, by denying economic rationality in this way, Bryan is, on the other hand, defending Hayek's view. We believe that in this case it is unnecessary to question the egg or the dwarf. Unsuccessful economic planning by the party power is also a failure of the Soviet rulers.

Otto Neurath claims that it is possible to make economic calculations on the basis of natural products instead of financial calculations, citing the example of the military economy in wartime, which is based on natural products. According to him, it is not enough to use only one currency or energy unit in economic evaluation. All information about social life, including population groups, consumption preferences, education, disease, mortality, family life, and the workplace, allows for economic calculation (Cockshott, 2008). It was thought that by using information about available resources and consumer preferences, it would be possible to determine the required amount of production and price. Of course, the information processes and the technological situation at that time did not allow the processing of the large amounts of information that we now define as big data. This approach is central to the viability of the digital economy and the green economy.

The rise of cybernetic science, which is reflected in all areas of social life, has led to the idea that the problem of economic calculation can be solved by considering the economy as a management system. The use of today's digital technologies and powerful computers as important tools in the cybernetic planning and calculation of the economy offers new alternative solutions in the economy. In 1972-1973, Chile gained experience in computerised planning and control of the economy. Normally, statistics for the government's economic policy are delayed by 4-5 months due to conventional methods. The SYBERSEN project, led by Stafford Beer, a decentralised interactive system of social economic regulation, eliminated the problem of delays and enabled the government to provide immediate information for policymaking (Beer, 1994). The computer network set up as part of the project enabled the then Allende government to mobilise transport resources to move products (Brewster, 2004).

The information age, which became more widespread in the early 2000s with the third industrial revolution, has allowed economic activities to be fully integrated into digital systems. The transformation of economic activities has given rise to trends such as the knowledge economy or the digital economy, in which information and digital products are valued. It is an era in which the value of the economic product is determined by completely different social preferences and dynamics and in which performance and marketing have become important in socio-economic relations. This revolution has been discussed as a new stage of capitalism or a post-capitalist formation (informationalism) in which society has undergone a new class stratification. This situation has made it possible to view the problem of economic calculation through a new prism (Jael, 2015). In his 1967 work 'The Computer and the Market,' Oskar Lange equates the market with a computer by likening it to a device that performs calculations (Oskar, 1967). We can conclude that digital networks have replaced the market and computers (algorithms) have replaced the function of the market, as the migration of social life to internet networks allows the accumulation of production and consumption information in large quantities.

The recent development of the economy, followed by the digital transformation of society, has brought about changes in the class structure of society, new ways of organising production and consumption, new functions of social institutions and new areas of responsibility. Digitalisation has had the effect of increasing the possibilities of accumulating and processing economically meaningful information, thus solving the problem of calculation. This situation has mainly affected the proponents of the socialist planned economy and the green economy (Burdack et al., 20-23; Cottrell & Cockshott, 1993; Duffy, 1989; Elson, 1992; Kennedy et al., 2008; Kiker et al., 1996; Mandel, 1986; Peng & Fan, 20-21; Yang et al., 2017). Economic calculation has always been of interest to socialists and neoclassicists for the feasibility of intervention, restriction and full control to ensure accumulation in economic life.

4. The Digital Cybernetic Regulation Scale Model

Although the beginning of negotiations on new economic regulations coincides with post-Fordism, the history of their social institutionalisation, implementation, and manifestation in regulations can be dated to the COVID-19 processes. The main reason for associating the beginning of the new digital cybernetic era with covid-19 is that the regulation model is realised through data-driven cybernetic methods. For example, cybernetic methods and digital calculations based on patient census data have enabled the implementation of socially restrictive and health care policies. This type of regulation can play the role of a tool for many types of accumulation and reproductive alternatives that may emerge after the post-Fordist period. From

the perspective of regulation theory, the accumulation regime encompasses norms relating to the organisation of production and labour, principles of income distribution, norms of demand and consumption in the market, rules governing the management of joint industry and trade, and patterns of exchange and relations between economic sectors. In cyber Fordism, economic regulation can be realised by including a large number of non-economic indicators such as health, environment, disasters, and social tensions. This feature is characterised by the concept of a smart economy.

The wide range of economic regulation factors is related to the multi-accumulation diversity of today's global economy. This is why, in addition to the green economy, concepts such as the environmental economy, smart economy, knowledge economy, digital economy, behavioural economy, Industry 4.0, and Industry 5.0 have become topical. Suntsova Olesia notes that the scientific basis of these economic concepts has not been sufficiently analysed and that they are only general ideas. Nevertheless, the common feature of all of them is that they are based on a technological infrastructure that enables the accumulation and processing of information, such as big data, cloud technology, artificial intelligence, the Internet of Things, etc (Suntsova, 2022). This technological infrastructure also enables the realisation of digital economic calculation to ensure a smart economy with smart production.

If the role of the state was clearly defined in the periods before the digital economy, the activation of sustainability has led to the need for a complex regulation that plays between the plan and the market (Bagirzade, 2023). The sustainability of the economy is possible with the realisation of the regulations imposed on the planned economy when intervention is required and on the market economy when freedom is required. A smart economy is the regulation situation in which a balance is achieved between the plan and the market.

With regard to the accumulation regime, the planned economy and the market economy differ in method, but not in substance. If the planned economy has the possibility of increasing accumulation by restricting consumption, the market economy has the possibility of increasing accumulation by expanding consumer spending (subsidies). The historical development process has led to the conclusion that the market economy is practically more efficient in terms of the accumulation regime. However, the conclusion of the previous part of the study is that the possibilities offered by information technologies today increase the potential of the planned economy. Therefore, the study does not focus on the antagonism of planned or marketisation of the digital economy but aims to learn about the digital and green accumulation regime. In order not to dwell on this antagonism, the study proposes to make an evaluation within the framework of the ' Balanced Cybernetic Regulation Model' (Fig. 1) which envisages the regulation of both the planned and the market economy at the same time. The main argument for proposing this model is that the new form of economic organisation that is emerging today has a specific and complex political-economic structure. On the one hand, the proposed decarbonisation of the economy suggests planned regulation, and on the other, the realisation of carbon markets (Newell & Paterson, 2010; UN, 1998).

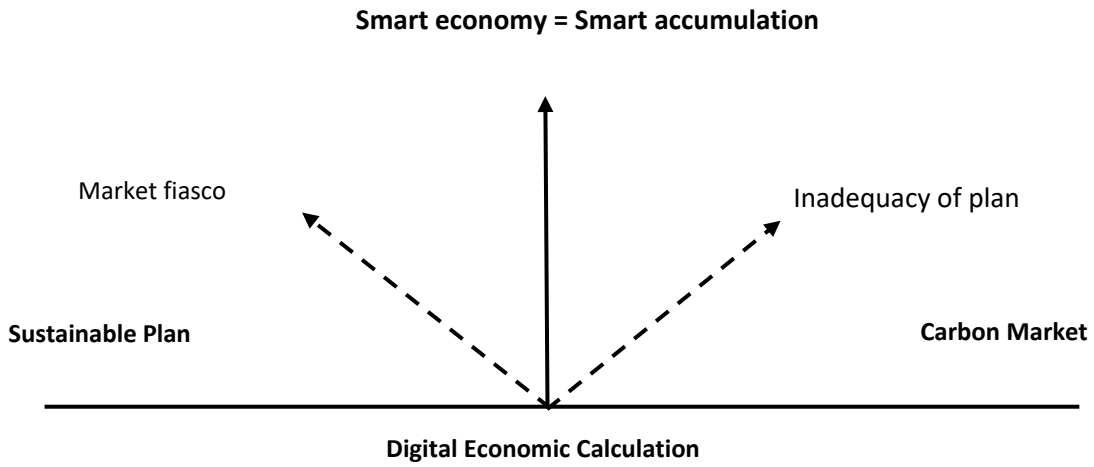

Fig. 1 Balanced Cybernetic Regulation Model

In many sources, the smart economy is referred to as Industry 4.0, which leads to confusion and uncertainty about its true nature (Galperina et al., 2016; Suntsova, 2022). The important feature of the smart economy is its form of regulation. From this point of view, we can define a smart economy as a form of economy in which digital cybernetic regulation is provided on the basis of information processes through digital technologies. The functionality of digital cybernetic regulation is realised through new data-orientated economic calculation tools. The importance of digital economic accounting can be illustrated by the following topics:

- Determination of ecology-based value,
- Determination of the entropy of economic activity,
- Market failure-resources are not allocated efficiently.
- Creation of green economic value,
- Determination of carrying capacity,
- Providing the basic argument in economic regulation,
- To determine the functional infrastructure of the accumulation regime (Bagirzade & Murshudli, 2025).

For the above reasons, the smart economy based on digital computing has an important role to play for the realisation of sustainable development and green accumulation. From the perspective of regulation theory, sustainable development strengthens the integrity and position of the emerging global economic order (Böhm et al., 2012). Digital cybernetic regulation utilises the smart economy to ensure balanced carbon markets and decarbonisation schemes. At the same time, it is criticised that digital cybernetic regulation, which functions to ensure green accumulation, serves to monetise and capture environmental goods and to create a new colonial dimension (Bachram, 2004; Mannat, 2023; Müller & Passadakis, 2015; Sullivan, 2011). Harvey associate's green accumulation with unequal development and dispossession processes. Examples of policies of dispossession include commodification, privatisation, deportation of the population, confiscation of assets, taxation, use of migrant labour, financialization, and expansion of the credit system (Harvey, 2005, 2006). His use of the understanding of 'space' in the evaluation of capital accumulation, together with the explanation of Fordist and post-Fordist

production organisation, has shown its importance in sustainable organisation. The possibility of uneven development of green accumulation, its different reflections on the economic situation of countries, and the global economy's inequality between North and South. The development of the digital economy is not only about economic development but also about ensuring the functionality of the environment-based green economy. The digitalisation of economic activity through the digital economy is key to the realisation of the tasks of the green economy, such as green consumption. At the same time, the green economy, which has the potential for the accumulation of large capital resources, can help to direct large investments in the digital economy.

The digital economy helps integrate the green economy into real economic activities and fulfils the demand for data for environmental calculations. This data helps to solve the problems of carbon footprint, green accounting and economic calculation, enabling a new accumulation regime. The digital economy also enables the governance of environmental and economic actors for sustainable development goals (Bagirzade, 2024, p. 38).

Despite the uncertainty of empirical data that maintain scientific objectivity and show the positive impact of the green economy on the environment, data that show the functionality of green accumulation are generating widespread debate. For example, the volume of the global carbon market in 2021 will be $851 billion (Arcos-Vargas et al., 2023). According to the World Bank's Carbon Pricing Dashboard Status and Trends, the volume of government revenues from carbon pricing worldwide reached $97 billion in 2022. Of this, $32 billion will come from carbon taxes. The price range in carbon trading varies from $0.7 to $155.8 (World Bank, 2023). Green savings through carbon markets involve the purchase of carbon credits for emitters to comply with mandatory compliance plans. According to the report of the London Stock Exchange Group for 2023, the global carbon market increased by 2% and reached $948.75 billion (Kozintseva & Wizman, 2024). All these result data of the carbon reduction regime can be considered as digital cybernetic regulation of green savings.

5. Conclusion

The study includes an assessment of the conceptual basis of the regulation model for data-driven policy-making from the perspective of the digital economy. Therefore, it focuses on the basic elements and their conceptualisation that ensure the functionality of the accumulation regime of the digital economy. The problem of economic calculation is the main obstacle to the social organisation of the digital and green economy. This is because the failure to correctly assess the economic value of environmental goods and services leads to uncertainty about the carrying capacity of the environment, the value-price relationship, the distribution of resources, economic regulation, and the functioning of the accumulation regime. In this framework, based on the regulation approach, the sustainable aspect of the reflection of economic calculation on the accumulation regime and the form of regulation is discussed. Especially in recent times, the beginning of a new era of information processes in society has led to the emergence of new solutions and approaches to the problem of economic calculation. The digital and cybernetic aspects of the problem of economic calculation have been evaluated, taking into account the new conditions that can be considered as the era of informationalism. As a result of the evaluation, the "Digital Cybernetic Regulation Scale" model is proposed by modelling the interaction of the elements of the digital and green economy. Considering that the green economy consists of mandatory practices and artificial markets for their realisation, the proposed model reflects the

balance of the dualism of plan and market. The model can also help to determine the political economy that will ensure balanced regulation in a sustainable economy.

According to Dan Ciuriak, the following factors explain the privileged importance of data-driven economic policy making:

- Lack of information may lead to market failure,
- Industrialisation of learning through artificial intelligence,
- Multiplication of superstar companies,
- Changes in the traditional economic accounting system,
- Risks arising from inadequacies in the information infrastructure (Ciuriak, 2018).

The asymmetric distribution of information can significantly hinder the achievement of equilibrium and competitiveness in the market. Market players who are able to use big data have more economic regulation tools than market players who treat data as a set of useless information. The proliferation of actors capable of making data-driven decisions leads to a proliferation of superstar firms. Contrary to Dan Ciuriak, we see a current trend towards individualisation rather than industrialisation of learning. The creation of data-driven policies makes it possible to generate information according to individual situations and new data analyses. This information leads to an increase in individual, additive learning compared to the current situation. The analysis of the Fordist and post-Fordist organisation of production shows that with the formation of new economic relations, specialisation and labour relations have changed. Thus, the formation of a data-driven economy creates the need to evaluate and conceptualise social relations in terms of the new organisation of production. For superstar companies, their good position in the data-driven economy neglects the principle of competition and the principle of the market, since they have the best access to economic big data. Only technological innovation can end monopoly in the market, what Schumpeter conceptualised as 'creative destruction' (Aghion & Howitt, 2023). Since the conceptualisation of the realisation of data-driven economic policies is of an overarching nature, the theory of regulation has been applied.

The study evaluates the digital economy within the framework of regulation theory and proposes a cyber Fordist form of organisation in addition to the Fordist, post-Fordist economic organisation. It is argued that the digital and green economy can be realised mainly under the cyber Fordist form of economic organisation, and it is concluded that green accumulation is the cybernetic digital regulation of the carbon reduction regime. This model emphasises the function of the smart economy in achieving green accumulation.

Thus, the article argues that the green economy is part of cyber Fordist economic organisation and that green accumulation, which can be seen as smart accumulation, is achieved through digital cybernetic regulation. The basis of digital cybernetic organisation is digital cybernetic economic calculation. Examples of measures of green economic calculation include green accounting, carbon footprints, ecological footprints and consumption-related footprints. Digital cybernetic regulation takes into account the factors that ensure flexibility of production in economic policymaking, as well as the provision of diversified savings through environmental, health, or other issues. For a more precise specification and conceptualisation of the digital cybernetic regulation of green accumulation, issues such as money and credit relations, the

remuneration of labour, the form of competition, international relations, and the new role of the state should be further explored. These issues encompass the institutional aspects of the form of organisation described by Boyer Robert and determine the institutionalisation of green accumulation (Boyer & Saillard, 2002). Thus, a deeper analysis and conceptualisation of the theoretical basis of cyber Fordism as a new form of economic organisation is proposed.

Despite the tendency of carbon taxes and emissions trading schemes to grow in volume and capital accumulation, no definitive conclusions can be drawn about the carrying capacity of the ecosystem, the limits to growth, the transformation of the environment into commercial goods and services, and the determination of its net value in monetary terms. The scientific methodology and results of studies on these issues have been subject to much criticism. In 1997, for example, a study involving a large number of researchers put a price on the economic value of the world. In this study, the economic valuation assigned to 17 ecosystem services was determined to be 16-54 trillion US dollars (33 trillion per year) (Costanza et al., 1997). This figure is twice the world's gross national product in the year under consideration.

The problem of economic calculation, which has been discussed for almost a century, is coming to a solution with the emergence of the digital economy. New ways of calculating, which we can define as digital economic calculation, can be a solution to problems such as determining the value of environmental products in the green economy and ensuring the relationship between consumption and environmental carrying capacity.

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