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CONTENTS / 目录

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Normalized Dysfunction: The Persistence of ICT Governance Failure in a Highly Regulated Public Sector

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Abstract

Public-sector ICT environments are typically characterized by dense governance architectures intended to ensure accountability, compliance, and effective oversight. In South Africa, this architecture includes statutory financial management legislation, treasury regulations, audit regimes, and corporate governance codes that collectively prescribe how information systems should be governed. Despite this extensive framework, ICT governance failures continue to recur across public-sector organizations, appearing consistently in audit outcomes and practitioner accounts. Rather than being isolated breakdowns, such failures often persist across reporting cycles and leadership changes. This study examines how ICT governance failure becomes normalized and sustained over time in a highly regulated public-sector context. Drawing on qualitative interviews with 55 government information technology officers across national, provincial, and local government, the analysis shifts attention from why governance fails to how failure is accommodated within everyday organizational practice. The findings show that governance failure is routinely treated as an expected and manageable condition, absorbed through audit rituals, ceremonial governance structures, layered accountability arrangements, and the delegation of governance responsibility to technical units. These practices allow organizations to maintain procedural legitimacy while leaving underlying governance deficiencies largely unaddressed. By conceptualising governance failure as a socially produced and institutionally sustained outcome, the study extends institutional and governance-as-practice perspectives in ICT governance research. A system or process that is far from perfect is still able to function efficiently, provided that the necessary procedures are implemented correctly. This demonstrates that a system can accomplish routine tasks despite its flaws. Prior research highlights the difficulty of implementing and sustaining ICT governance in heavily regulated public sector environments. In these areas ICT reform projects have been repeatedly initiated yet have failed to deliver the expected outcomes. In practice, the results can be used to inform diagnostic and risk-focused evaluations of ICT governance by assisting public-sector organizations in recognizing when governance arrangements are perpetuating, rather than resolving, chronic dysfunction.
Keywords: institutional theory, normalization, decoupling, audit ritualism, public sector persistence, South Africa, digital governance

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机能障碍作为常态：严格监管的公共部门内信息通信技术管理系统的持续制度侵权

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摘要

公共部门的信息通信技术（ICT）管理领域通常具有复杂的管理机制体系，旨在确保问责制、合规性和有效监督。在南非，公共部门的ICT管理以"公共财政管理法"、国库法规、审计程序和企业治理准则为基础。这些规范和机制的集合决定了信息系统的管理原则与操作流程。尽管存在广泛的规范管理框架，但公共部门组织中的ICT管理系统违规行为仍在持续重现。这些违规现象在审计报告和实践专家的评估中被系统性发现，并且无论领导层如何更迭，它们往往跨越多个报告周期持续存在。本文分析了在严格监管的公共部门中，ICT管理违规行为如何固化为持久性实践的影响因素。通过对国家级、地区级和市级公共ICT部门负责人进行的55次访谈所获得的定性数据，本研究将焦点从寻找管理问题的成因，转向探究此类违规行为如何在日常组织实践中被稳固。本研究结果表明，ICT管理中的违规行为逐渐被视为一种可接受且可控的状态。其持续存在得益于形式化的审计程序、管理结构的运作，以及将ICT管理责任下放至技术部门，这使得系统能够维持运转，而无需解决根本性的管理问题。本研究将ICT管理系统中的违规行为视为社会与制度因素共同作用的结果，从而为ICT管理研究的制度性及实践导向方法发展作出贡献。即便系统远非完美，只要遵循形式正确的程序，其仍可保持运作能力，从而在存在缺陷的情况下维持常规任务的执行。既有研究表明，在严格监管的公共部门环境中，ICT管理的实施与可持续性面临显著挑战，导致ICT领域的改革虽多次推行，却未能取得预期效果。本研究结果可用于开展ICT管理的诊断性与风险导向评估，以识别现行管理机制并非旨在消除长期存在的违规行为，反而可能使其持续复现的情形。
关键词： 制度理论、制度侵权的稳固、制度分歧、审计的仪式化、公共部门的可持续性、南非、数字管理。

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1. Framing the Paradox

Public-sector ICT environments operate within an extensive and highly formalized governance architecture. Over time, governments have introduced a growing body of statutory instruments, treasury regulations, audit regimes, and governance codes intended to strengthen accountability, enforce compliance, and improve organizational performance. In South Africa's public sector, this architecture is anchored in the *Public Finance Management Act* (PFMA), detailed *Treasury Regulations*, and corporate governance codes such as *King IV*, all of which prescribe how information systems should be governed, controlled, and overseen [Public Finance.., 1999; Treasury Regulations.., 2000; 2012; King IV report.., 2016]. In principle, this density of governance arrangements suggests an environment in which ICT-related failure should be systematically detected, corrected, and prevented.

Empirical evidence from audit outcomes and practitioner accounts, however, presents a more troubling picture. Despite the formal presence of governance frameworks and oversight structures, ICT-related deficiencies continue to recur across public-sector organizations. These include repeated audit findings, persistent control weaknesses, stalled or underperforming systems, and long-standing governance gaps that remain visible across successive reporting cycles [Consolidated general report.., 2022]. Rather than being isolated or exceptional, such failures appear to endure even in organizations that demonstrate ongoing compliance with formal governance requirements.

Governance failure is generally regarded in academic literature as an aberration, or a departure from well-established norms, within otherwise functioning systems. The breakdown is often seen as something that can be rectified through the adoption of better systems, stricter enforcement of existing rules, improvements in leadership, and upgraded technical capabilities. While these explanations are valuable, they do not fully account for the persistence of failure observed in practice. What remains insufficiently examined is how repeated ICT governance failure comes to be accommodated, stabilized, and, over time, accepted as part of normal organizational life. In many public-sector contexts, failure does not trigger sustained correction; instead, it becomes predictable, managed through routine reporting, and absorbed into established governance cycles.

This study shifts attention away from why ICT governance fails and towards how such failure becomes normalized and reproduced over time. Rather than examining governance enactment processes or the conditions under which governance generates value–both addressed elsewhere in the broader research programme–this paper focuses on the organizational and institutional dynamics through which governance breakdown persists. Drawing on qualitative evidence from senior public-sector ICT leaders, the analysis examines how governance failure becomes expected, how formal governance rituals continue in the absence of resolution, and how dysfunctional arrangements are sustained across audit cycles and leadership changes [Latchu, 2022]. The aim of the study is to explain why, despite the presence of extensive governance frameworks, ICT governance failure persists as a normalized condition within the public sector.

2. Selective Literature Review–From Governance Failure to Normalization

2.1. Governance Failure Beyond Absence or Non-Compliance

Traditionally, ICT governance failure within the public sector has been considered the result of poor leadership, limited capability, inadequate compliance with established frameworks, or weak controls. In the context of governance, a breakdown can be understood as a divergence from a preconceived ideal state of governance. This is typically framed as something that be corrected with better system planning, stronger regulations, or enhanced management capabilities. From this perspective, failure is treated as temporary and correctable in nature, signalling the need for intervention rather than constituting a stable organizational condition.

In highly regulated public-sector environments, however, this framing sits uneasily with empirical observations. Formal governance arrangements are often present, compliance processes are routinely performed, and oversight structures continue to operate, even as the same deficiencies reappear across reporting cycles. Recurring audit findings over time indicate that problems often persist despite the implementation of corrective actions and repeated promises of rectification. In such contexts, failure does not necessarily mean a lack of governance; nor does failure necessarily lead to change.

A key limitation of failure-oriented theories is that they assume organizational recovery once deficiencies in corporate governance have been uncovered. These analyses focus mainly on what does not work in governance arrangements rather than on the reasons why effective governance does not occur in such cases; as a result, they offer little insight into situations where governance structures are in place, but the outcomes of this governance are ineffective. What is less well explained is how organizations continue to function, report, and justify performance in the presence of ongoing governance shortcomings.

2.2. Institutional Normalization and Decoupling

Institutional perspectives provide a useful lens for understanding why governance failure may persist even in highly regulated environments. In many government departments, a major role is fulfilled by formal governance structures; these serve to demonstrate department compliance with legal obligations and accountability requirements. Such processes and procedures can be consistently used and preserved even when the impact on organizational practice is either inconsistent or minimal. In these situations, the governance framework is not tightly connected to the organization's ongoing work and activities, which allows the organization to appear as if it is obeying governance framework rules while enabling it to meet internal needs and other pressures [Public Finance.., 1999; King IV report.., 2016].

Evidence from audit outcomes suggests that this condition can become routinized over time. Again and again, the same issues related to ICT controls, risk management, and systems assurance come to light as successive audits are conducted; this persists despite committees being established, policies being put in place, and corrective action plans being implemented. The incorporation of such findings usually leads to the integration of relevant recommendations into existing reporting procedures, as well as audit tests [Consolidated general report.., 2022]. Consequently, a pattern is reinforced in which boards and management teams engage in governance activities without ever addressing the fundamental weaknesses that have been identified [Latchu, 2022].

Importantly, such normalization does not necessarily reflect deliberate non-compliance or governance neglect. Rather, it reflects how organizations adapt to environments characterized by strict regulations, limited capacity for corrective action, and ongoing operational difficulties. Under these conditions, governance arrangements may retain their symbolic and procedural importance, even as their capacity to alter outcomes remains constrained [Treasury Regulations.., 2012; King IV report.., 2016].

2.3. Research Gap

While prior research and audit evidence clearly document recurring ICT governance deficiencies, far less is known about how such failure becomes taken for granted within organizations. Existing accounts tend to emphasize the identification of weaknesses and the formulation of remedial actions, offering limited insight into how repeated failure is accommodated, rationalized, and sustained over time [Consolidated general report.., 2022]. As a result, organizations tend to incorporate such findings into existing reporting processes and audit scrutiny. Consequently, a cycle is reinforced in which boards and management teams engage in governance practices without adequate consideration on the underlying weaknesses that have been identified.

Practitioner-oriented evidence suggests that public-sector organizations often learn to operate within the boundaries of persistent governance breakdown. Formal accountability processes continue, compliance activities are performed, and assurance is repeatedly provided, even as underlying problems remain unresolved [Latchu, 2022]. Outstanding questions remain regarding how failures in public-sector governance are perpetuated and how these systems persist despite ongoing operational failures.

A key issue in the successful adoption of ICT systems is how failures in the governance of these technologies become embedded within organizational culture. This embedding can occur through the normalization and reproduction of failure over time. The present study seeks to examine this process. Specifically, the focus is on why failures in heavily regulated public-sector environments occur and continue to recur, and on the organizational procedures and institutional expectations that allow such failures to persist.

3. Research Methodology

This study draws on the same qualitative dataset that underpins the broader research program, comprising semi-structured interviews with 55 government information technology officers (GITOs) across South Africa's national, provincial, and local spheres of government. GITOs hold senior leadership positions in the field of ICT and operate at the intersection of statutory governance requirements, executive decision-making, and ICT operational delivery. Their position affords them long-term visibility into formal governance arrangements as well as the practical realities of ICT oversight within public-sector organizations [Latchu, 2022].

While the dataset is shared with related analyses, this paper applies a deliberately different analytical lens. Rather than examining how governance instruments are enacted in practice or how governance contributes to the realization of ICT-related benefits, the analysis focuses on how governance failure is experienced, accommodated, and normalized over time. Attention is directed towards moments in which participants describe adaptation, resignation, or routine acceptance of unresolved governance deficiencies, particularly where such conditions recur across audit cycles and leadership transitions. In this sense, the analysis is concerned not with performance or outcomes, but with persistence.

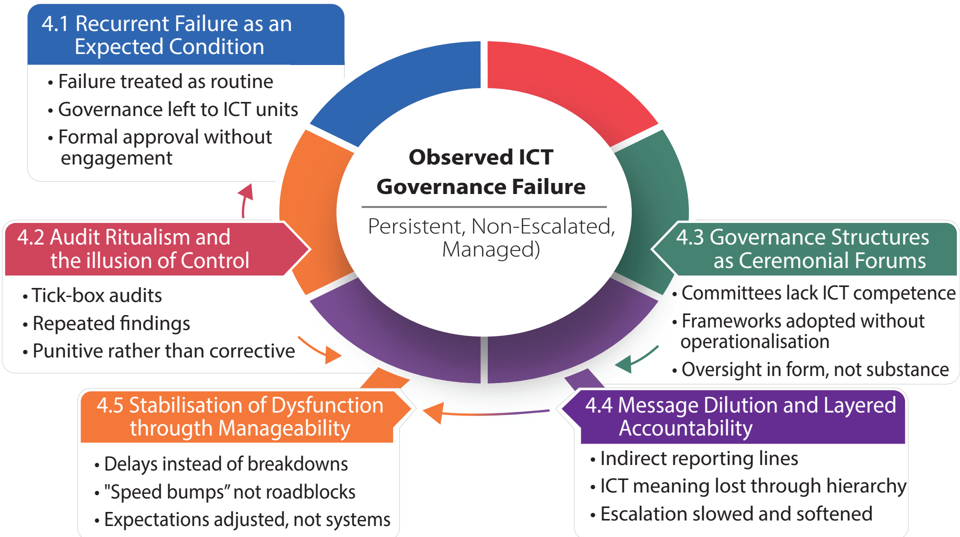
The study adopts an interpretivist qualitative approach, treating participants' accounts as situated interpretations of organizational life rather than objective representations of governance effectiveness. Interview transcripts were examined iteratively, with particular emphasis placed on temporal cues, narrative patterns, and recurring descriptions of "how things tend to be", rather than isolated incidents or critical events. This interpretive reading allowed for the identification of patterns through which governance failure is rendered predictable, manageable, and ultimately taken for granted within organizational routines.

Importantly, this methodological focus is bounded. The analysis does not seek to reassess the effectiveness of specific governance frameworks, nor does it re-evaluate the conditions under which governance generates value. Instead, the emphasis is on how persistent deficiencies in government ICT arrangements are accommodated in the normal workings of the system, how accountability procedures remain in effect despite the absence of resolution, and how the various bodies involved adapt their expectations and objectives to enduring limitations. Accordingly, persistent ICT governance failure within a highly regulated public-sector environment is examined through the lens of organizational adaptation and normalization processes.

4. Findings– Normalization of ICT Governance Failure

To provide an overview of the empirical patterns identified across the findings, Figure 1 summarizes the recurrent practices through which ICT governance failure is experienced, managed, and stabilized within public-sector organizations. The figure is

Fig. 1. Empirical patterns underpinning the normalization of ICT governance failure



Source: prepared by the authors.

intended as an orienting device, illustrating how these patterns coexist rather than unfold sequentially.

As illustrated in Figure 1, the findings reveal a set of recurring and interconnected patterns through which ICT governance failure is absorbed into routine organizational practice. Across the cases, failure is not treated as an exceptional event requiring escalation or structural correction, but as a manageable condition accommodated within existing governance arrangements. The five patterns do not operate independently or in a linear sequence; rather, they coexist and reinforce one another, shaping how governance shortcomings are interpreted, responded to, and ultimately stabilized over time. The practical manifestation of each pattern is outlined below, with direct quotes from the interviews illustrating how normalization occurs in everyday circumstances.

Recurrent Failure as an Expected Condition

Interview accounts indicate that ICT governance challenges are experienced as persistent and largely unmanaged at the executive level. Rather than triggering escalation or structural correction, governance responsibility is frequently delegated to ICT units, which are expected to manage these issues in isolation.

"Due to executive management's lack of IT knowledge, the IT section is generally left to wade through the morass of IT governance unaided."

In some cases, formal approval mechanisms exist without substantive strategic engagement. One participant noted that ICT matters receive approval while remaining excluded from executive deliberation:

"IT is still not represented at EXCO, but there is support from EXCO and the board because they always approve the IT requests."

Together, these accounts suggest that governance failure is not treated as exceptional, but as an expected condition managed within existing organizational arrangements.

Overall, these accounts indicate that governance failure is not framed as an anomaly requiring escalation, but as a predictable condition embedded within routine executive–ICT relations. By relegating governance responsibility to ICT units while maintaining formal approval structures, organizations effectively absorb failure into existing accountability arrangements. This enables continuity of operations without triggering structural correction, reinforcing failure as an expected and managed state rather than a governance breakdown.

Audit Ritualism and the Illusion of Control

Audit processes were frequently described as procedural and repetitive, with limited corrective impact. Participants characterized audits as compliance-driven exercises that consume significant organizational effort while allowing the same issues to persist.

"In my view, <AGSA auditing> is a tick-box exercise."

Another participant described the burden and consequences of audit engagement: "It is a tick-box, and the amount of time and effort that goes into answering audit requests is huge… any deviation results in an audit finding."

Audits were also described as punitive rather than developmental: "Audit findings are not there to assist; they are used as a tool to punish units."

These accounts indicate that audit compliance becomes a ritualized activity, reinforcing the appearance of control without resolving underlying governance deficiencies.

Governance Structures as Ceremonial Forums

Formal governance structures, including ICT steering committees and frameworks, were frequently described as existing in form rather than in function. According to many participants, these forums failed to fulfil their intended role because they lacked sufficient understanding of technical issues and the authority to make decisions.

"Currently, the ICT Steering Committees are a tick-box because most members do not understand ICT and cannot provide critical oversight."

Framework adoption was also described as superficial:

"Frameworks are adopted without SOPs or a thorough understanding of what is required."

Although governance structures appear to fulfil the formal expectations of their roles, they frequently have little substantive impact on ICT governance practice.

Message Dilution and Layered Accountability

Participants also described how ICT governance concerns are diluted as they move through organizational hierarchies, limiting escalation and accountability.

"When the ICT message goes to the CEO, it has to go via different persons, like CIO, and the DG, and they don't understand ICT; thus, the conversation gets muddied by the time it reaches the CEO. Direct CIO to CEO is needed."

This layered routing of governance messages contributes to the absorption of governance failure into routine communication processes rather than its resolution.

Stabilization of Dysfunction through Manageability

Governance failure appears to persist in part because it remains manageable within existing procedural constraints. Participants described governance controls as creating delay and friction rather than complete breakdown.

"Introduce delays and lots of red tape."

"PFMA SCM processes hamper IT to respond quickly."

"Not roadblocks, but rather speed bumps to IS service delivery."

These descriptions suggest that governance failure is tolerated because it does not halt operations entirely. Instead, organizations adjust expectations and pace, allowing dysfunction to stabilize as part of everyday practice.

5. Discussion

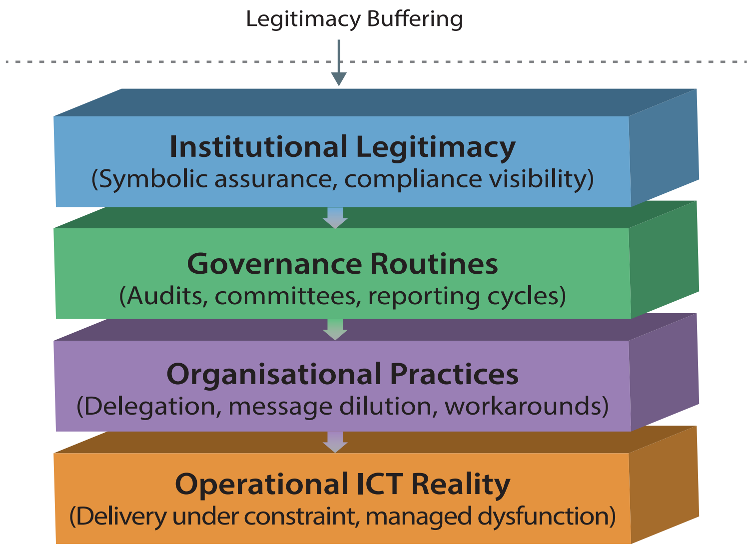
To synthesize the empirical findings at an institutional level, Figure 2 presents an analytical model illustrating how ICT governance failure becomes stabilized and normalized over time. The figure moves beyond descriptive patterns to explain how everyday governance practices collectively reproduce failure as a predictable organizational condition.

As depicted in Figure 2, ICT governance failure is not sustained by the absence of governance arrangements, but by their layered enactment across institutional domains. Mechanisms such as audit committees and reporting procedures provide a buffer between operational IT and executive management. This buffering allows organizational inefficiencies to be identified and addressed before they escalate into crisis requiring major restructuring. These routines help to maintain institutional credibility by signaling that rules are being upheld, even though the systems in place for oversight are not closely tied to the operational decision-making processes. Through this layered buffering, governance failure becomes normalized as a stable and acceptable condition within organizational life.

5.1. Governance Failure as an Institutionalized Outcome

The findings indicate that ICT governance failure in South Africa's public sector should not be understood as an episodic

Fig. 2. Layered institutional mechanisms normalizing ICT governance failure



Source: prepared by the authors.

breakdown or a temporary deviation from an otherwise functional system. As a result of established organizational procedures, failure is often entrenched as a norm—a regular occurrence that is anticipated and accepted by staff during their daily activities. Rather than triggering escalation or structural correction, governance shortcomings are repeatedly accommodated through existing accountability arrangements, committee structures, and audit cycles. Governance is regarded as stable rather than collapsing because its shortcomings has become routine. The authors' observation closely resemble the work of [Meyer, Rowan, 1977], who argued that formal governance mechanisms are used by institutions to achieve legitimacy even though they are not actually implemented in day-to-day activities.

According to extensive audit histories, ICT control weaknesses consistently occur and continue to recur despite the implementation of measures to address them, including assurance processes, monitoring committees, and action plans [Consolidated general report.., 2022]. In many cases, as earlier research has shown through analysis of Auditor-General reports, a strong ICT governance culture is not present even in organizations that continually produce compliance artifacts [Latchu, 2022; Latchu, Singh, 2024b]. Under a normalization lens, these recurring findings are not simply unresolved problems; they represent governance conditions that have become expected and managed within institutional life.

Importantly, the findings show that executive–ICT relations play a central role in stabilizing this condition. While many organizations retain formal oversight of their ICT functions, the manner in which this oversight is exercised often does not result in significant change to existing power structures. Many ICT projects still have their approval processed through conventional channels that do not lead to any alteration in organizational culture. This is consistent with evidence that governance effectiveness depends on senior-management-level integration and aligned organizational elements, rather than documented frameworks alone [Masilela, Nel, 2021]. Previous research has described similar situations as instances of "symbolic compliance," referring to practices in which formal rules and regulations do not meaningfully affect how operational decisions are made within an organization [Latchu, Singh, 2024a]. Governance failure, in this sense, becomes absorbed into organizational normality, enabling continuity across leadership changes and administrative cycles. Prior studies demonstrate that CIO reporting lines and executive inclusion are critical for effective IT–business alignment [Ayat, Farajkhah, 2014]; the findings of this study show how the routine absence of such arrangements contributes to the normalization of governance failure rather than its correction.

Seen this way, the persistence of ICT governance failure across administrations is not paradoxical. It is the outcome of institutional procedures that prioritize stability, the maintenance of procedure, and risk avoidance over disruption and structural change. Failure endures precisely because it is manageable, predictable, and compatible with existing governance rituals.

5.2. Why Governance Reform Often Fails to Disrupt Failure

The persistence of normalized governance failure also helps explain successive reform efforts repeatedly fail to bring about genuine change in settings where similar patterns of compliance-driven governance and delayed escalation have been observed at the regional level [Latchu, Singh, 2025a]. Rather than disrupting dysfunctional arrangements, new governance frameworks are typically layered onto existing routines, reinforcing compliance density without altering behaviour. The findings show that reforms are absorbed into established governance cycles—committee meetings, audit responses, and reporting templates—where they are enacted ceremonially rather than transformationally. As [Brunsson, 2002] describes through the concept of organized hypocrisy, reforms often function as signals of responsiveness, while decoupled practices preserve organizational continuity, allowing governance failure to persist beneath an appearance of change. While meta-analytic evidence confirms the importance of top management support for IS success [Hwang, 2019], the present findings demonstrate how formal support can coexist with limited substantive engagement, producing ritualized rather than transformative governance.

This pattern is evident in the repeated introduction of ICT governance instruments such as the *CGICTPF, King IV* principles, and Treasury-driven controls, which are formally adopted but unevenly enacted [Corporate governance.., 2012; Ferguson, 2019; Phahlane, 2023]. Past studies drawing on Zondo Commission evidence also indicate that governance reforms introduced to address state capture led to increased procedural control, alongside heightened risk aversion and bureaucratic inertia [Latchu, Singh, 2024a]. Under conditions of limited capacity and weak executive ownership, reform initiatives are interpreted through existing institutional logics rather than reshaping them.

The findings further demonstrate that audit-led reform plays a particularly ambivalent role. While the primary aim of audits is the rectification of corporate governance weaknesses, audits can also foster reliance on ritualistic compliance. Public entities often focus on satisfying auditor requirements rather than addressing the root causes of identified issues. [Latchu, 2022; Latchu, Singh, 2024b]. As a result, reforms may be accepted and incorporated into existing systems without producing significant changes to underlying arrangements. This conclusion aligns with the broader view that audits frequently operate as rituals that create an appearance of control while substantive problems remain unresolved [Power, 1997].

The key factor in the persistence of failure is not merely the resistance to reform,, but institutional adaptation. In constrained environments, governance actors and GITOs develop survival strategies: they make do with limited resources, negotiate regulatory requirements, and manage expectations in order to keep ICT systems operational. While these practices sustain delivery, they also reduce pressure for systemic correction. As a result, reform initiatives are accommodated rather than contested, reinforcing the normalization of failure rather than interrupting it.

5.3. Contribution to ICT Governance Theory

This study extends ICT governance scholarship by moving beyond dominant explanatory frames that treat failure primarily as a function of framework absence, design weakness, or maturity shortfall. While such approaches remain valuable, they are insufficient to explain why governance failure persists in environments where frameworks are present, oversight is active, and compliance is routinely demonstrated.

By conceptualizing governance failure as socially produced and institutionally maintained, this research shifts the focus from a lack of governance to the dynamics of governance in practice. In bureaucratic context, organizational failure occurs as a result of normalized, day-to-day procedures, including the delegation of tasks, audits, committee meetings, and accountability processes. The continuation of existing structures within institutions reflects decoupling, whereby an organization's formal structure does not necessarily correspond to its actual practices [Meyer, Rowan, 1977].

The conventional process-maturity approach can be understood to stall once process-based practices are reduced to ritual. In this scenario, models based on COBIT and those relying on ISO standards fail to account for how organizations that appear stable and mature may nevertheless experience stagnation when processes lose their substantive relevance. The findings show that governance systems can mature procedurally while stagnating substantively, producing increasingly sophisticated compliance architectures that coexist with persistent failure. In doing so, the study complements prior work on symbolic governance and decoupling [Latchu, 2022; Latchu, Singh, 2024a] by explaining how such conditions persist rather than dissolve.

By foregrounding normalization, the study contributes a distinct analytical lens to ICT governance research—one that explains persistence without defaulting to explanations of incompetence, neglect, or resistance. Governance failure, in this account, is not merely the absence of effectiveness; it is an institutional outcome actively maintained through organizational routines. This insight provides a foundation for rethinking how ICT governance failure is diagnosed and addressed, shifting attention from the proliferation of frameworks toward the institutional conditions that stabilize dysfunctional governance outcomes.

6. Implications

6.1. Theoretical Implications

This study makes several contributions to ICT governance theory by reframing how governance failure is conceptualized and explained in highly regulated public-sector environments.

First, the findings challenge dominant deficit-oriented explanations of ICT governance failure that treat breakdowns as episodic, temporary, or correctable through improved framework design, maturity progression, or tighter compliance. Governance failure is instead understood as an institutional process that produces and sustains itself through regular organizational activity. By demonstrating how governance shortcomings are repeatedly accommodated within existing accountability structures, audit cycles, and committee arrangements, the study shifts analytical attention away from isolated failure events toward the normalization of failure as a governance condition. Through this reframing, institutional theory is extended by showing how high levels of regulation and risk aversion encourage governance systems to prioritize stability over effectiveness as their core organizing principle.

By drawing on institutional decoupling theory, this study examines how and to what extent ICT governance arrangements are coupled to—and decoupled from—institutional rules and pressures. Institutional theory predicts that organizations increase formal structures to secure legitimacy while simultaneously reducing practical efficacy; this research shows how such decoupling occurs in practice, through four concrete means: delegation, audit responses, committee meetings, and accountability procedures. In doing so, it demonstrates that decoupling is not a passive condition but an actively maintained governance arrangement, reproduced through recurrent organizational action.

This paper also advances understanding of the role of enactment in governance by demonstrating how enactment can function as a stabilizing influence rather than as a corrective response to perceived organizational failure. Prior governance-as-practice perspectives often assume that closer attention to practice will surface misalignments and enable improvement. This study complicates that assumption by showing how everyday enactment can normalize dysfunction, absorb reform initiatives, and sustain ineffective governance arrangements over time. Enactment, in this account, does not necessarily resolve governance failure; it can also embed and protect it.

Finally, the study challenges linear, maturity-based models of ICT governance—particularly those inspired by COBIT and ISO standards—that assume increased formalization and procedural sophistication will lead to substantive improvement. The findings demonstrate that governance systems can mature procedurally while stagnating substantively, producing increasingly elaborate compliance architectures that coexist with persistent failure. Governance reform efforts often appear to reach a plateau despite the proliferation of checklists, monitoring mechanisms, and audit processes.

Taken together, these insights transform understanding of ICT governance into a socially and institutionally maintained process that evolves over time. This perspective opens new avenues for theorizing stability, reform, and the continued use of ICT within government institutions.

6.2. Practical Implications

The practical implications of this study caution against reflexive, framework-centric responses to ICT governance failure and highlight the limitations of audit-led reform as a primary corrective mechanism.

First, the findings warn against the pervasive "more governance" reflex that characterizes many public-sector reform efforts. When governance failure is interpreted primarily as a deficit of frameworks, policies, or controls, organizations respond by layering additional instruments onto existing arrangements. This study shows that such responses often increase compliance density without altering underlying practices, reinforcing procedural conformity while leaving governance outcomes unchanged. Given the inbuilt propensity of governance failures to persist, caution is required when assuming that further regulations or structures will actually prevent these entrenched problems.

Second, the research reveals that the structural reform efforts face significant inherent constraints, particularly where auditing is used as the primary instrument of reform. While thorough auditing is widely regarded as essential for ensuring accountability, organizations subjected to persistent and intensive audit scrutiny may apopt a superficial compliance orientation. In such cases, the primary objective shifts from identifying and rectifying weaknesses to minimizing exposure under audit. Over time, organizations may become accustomed to recurring deficiencies, coming to view them as normal and therefore acceptable. This process renders weaknesses predictable, manageable, and readily accommodated. Audit bodies should not relinquish their oversight role; rather, they must recognize that audits alone cannot generate substantive change without sustained commitment from executive leadership and other critical organizational actors.

Third, the findings underscore the importance of executive engagement and governance ownership beyond formal approval structures. By transferring responsibility for ICT governance to technical personnel, senior management can maintain a favorable public image while avoiding substantive accountability for ICT governance decisions. This implies that genuinely enhancing the effectiveness of ICT governance requires more than formal policy compliance; it demands ongoing high-level managerial engagement in governance deliberation, prioritization, and decision-making processes.

Importantly, this study does not propose a prescriptive reform roadmap or a set of best-practice interventions. That omission is deliberate. Given the institutionalized nature of governance failure identified here, prescriptive solutions risk reproducing the very dynamics they seek to resolve. Instead, the practical implications offered are diagnostic and cautionary, aimed at reshaping how governance failure is understood before solutions are advanced. The design of reform strategies capable of disrupting normalized governance failure is addressed in a complementary analysis and is therefore not developed here.

Conclusion

This article set out to explain why ICT governance failure in South Africa's public sector persists despite the proliferation of governance frameworks, oversight mechanisms, and repeated reform initiatives. Rather than treating failure as an episodic breakdown or a temporary deviation from otherwise functional governance systems, the analysis reconceptualized failure as a normalized and institutionalized outcome, sustained through everyday governance routines and organizational practices.

Comparative studies demonstrate that ICT-enabled governance reform can yield significant transformation under enabling institutional conditions [Latchu, Singh, 2025c]. The present paper explains why such outcomes remain elusive in the South African public sector, where governance failure has become institutionalized rather than episodic.

The findings show that the stabilization of governance failure is achieved in a set of mutually reinforcing mechanisms, including the routinization of accountability through committee structure and audit cycles, the ritualized implementation of reform via the formal adoption of governance instruments, and the delegation of governance responsibility to technical units, which shields executive leadership from substantive involvement. The combination of these mechanisms allows organizations to maintain procedural legitimacy while largely leaving underlying governance practices unchanged. In this way, failure persists not despite governance arrangements, but because of how those arrangements are enacted in practice. Although project governance research links top management support to improved performance outcomes [Fareed, Su, 2022], this study explains why similar governance arrangements fail to disrupt entrenched dysfunction in highly institutionalized public-sector settings.

While prior work demonstrates that corporate governance can enhance ICT outcomes under certain enabling conditions [Latchu, Singh, 2025b], the present study explains why such benefits often fail to materialize in highly institutionalized public-sector environments.

By foregrounding normalization, the study contributes a distinct explanatory lens to ICT governance scholarship—one that shifts attention from governance deficits and framework design toward governance dynamics and institutional reproduction. This perspective helps explain why successive reform efforts often fail to disrupt entrenched governance failures, and why procedural maturation can coexist with substantive stagnation. Importantly, the findings suggest that governance failure endures precisely because it is predictable, manageable, and compatible with existing organizational rituals and risk-avoidance strategies.

The scope of this article is deliberately analytical rather than prescriptive. While the research identifies fundamental structural conditions that enable recurrent ICT governance failures, it does not propose new policy measures to remedy these conditions. This boundary is intentional: without first understanding how governance failure is normalized and sustained, prescriptive solutions risk being absorbed into the very routines they seek to transform.

Viewed in this light, the article contributes to a broader research program concerned with understanding and addressing persistent governance failure in highly regulated public-sector environments. By clarifying the mechanisms through which failure is institutionalized, it provides a necessary foundation for subsequent analyses that engage with the design of governance interventions capable of disrupting normalized failure conditions, without duplicating or pre-empting those efforts here.

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Classification of Priority Product Markets for the Strategic Implementation of Competition Policy

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Abstract

The need of differentiating state competition policy in Russia is consistent with the National Competition Development Plan and the Standard for the Development of Competition in the Constituent Entities of the Russian Federation. The purpose of this study is to classify priority product markets and regions to ensure effective monitoring and implementation of competition policy. Based on Rosstat data for the period 2019–2023, four clusters of regions were identified: diversified, industrial, agricultural, and developing. The findings are supported by expert analysis and include quantitative economic characteristics of each cluster. The practical significance of the study lies in the potential use of its results by public authorities for more targeted monitoring of market conditions and support of competitive environments in product markets. The proposed classification enhances the effectiveness of competition policy implementation and contributes to the development of competition in regional product markets. The scientific novelty of the article lies in a comprehensive approach to the classification of product markets and regions based on up-to-date socio-economic data, as well as in development of policy-oriented tools.

Keywords: competition, regional economy, National Competition Development Plan, Standard for the Development of Competition in the Constituent Entities of the Russian Federation

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落实竞争政策战略目标的优先商品市场的分类

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摘要

俄罗斯在国家竞争政策领域实行差异化管理的必要性，符合"国家竞争发展规划"及"俄罗斯联邦各主体竞争发展标准"。本研究旨在对优先商品市场与地区进行分类，以实现对竞争政策执行情况的有效监测与落实。基于俄罗斯联邦统计局2019 – 2023年数据，本研究将各地区划分为四个集群：多元化型、工业主导型、农业主导型和发展中。研究成果通过专家论证获得确认，并涵盖对各集群经济量化特征的系统性分析。本文章的实践价值在于，相关政府部门可运用研究成果，对商品市场竞争环境的状况进行更具针对性的监测，并为维护市场竞争提供精准支持。这一分类方法有助于提升竞争政策的实施效能，并推动各地区商品市场竞争环境的发展。本文章的科学新奇在于，采用综合研究方法对商品市场和区域进行分类，运用最新的社会经济数据，并为国家政策制定提供配套的建议性工具。
关键词：竞争、区域经济、国家竞争发展规划、俄罗斯联邦组成实体的竞争发展标准。

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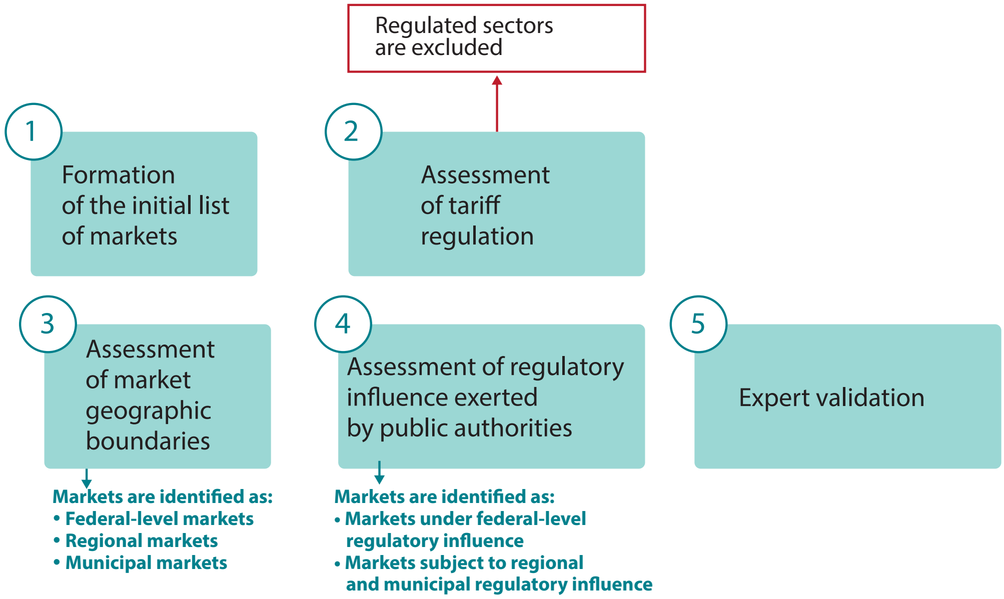
Introduction

Economic theory widely recognizes competition as one of the key determinants of economic efficiency under market conditions. Competition performs a number of essential functions required for the sustainable economic development of a region, industry, or market. These functions include limiting the market power of individual firms; coordinating supply with consumer demand in the long run; improving the efficiency of factor allocation and providing incentives for cost reduction; promoting price formation conducive to social welfare; and stimulating innovation [Chainikov, Kulikov, 2017]. At the same time, competition as a market environment does not necessarily emerge spontaneously, even within relatively free market systems. Moreover, the presence of competition may pose challenges for individual producers, requiring continuous adaptation to a dynamic environment and increasing uncertainty and risk in profitability calculations and future cash flow projections. Both academic research and practical experience indicate that market structures in which a firm acquires monopoly status may remain stable over time [Allingham, 1976], while nevertheless being socially suboptimal. In such cases, the monopolistic firm, acting in its own economic interest, may pursue strategies aimed at reinforcing its dominant position and erecting barriers to market entry for potential competitors. Consequently, purposeful intervention by antitrust and regulatory authorities is required to establish and maintain a competitive environment in markets of public importance.

The set of measures aimed at promoting competition and, as a result, increasing social welfare and overall economic efficiency is commonly referred to as competition policy. Studies in this field emphasize that competition policy represents a key instrument for implementing the main directions of socio-economic development at the regional level including the formation of an institutional environment conducive to innovation, inflation control, improvement of living standards, and enhancement of the overall competitiveness of regional economies [Bobrova et al., 2017].

Historically, competition policy in Russia began to take shape significantly later than in many other countries, which was largely due the relatively recent transition from a centrally planned to a market-based economic system. In Soviet economic literature, competition was predominantly viewed in negative terms as an economic phenomenon. It was defined as an antagonistic form of economic rivalry among private commodity producers, most characteristic of capitalism [Kharlamov, 2005]. Beginning with the perestroika period, this perception gradually shifted toward the opposite view, accompanied by growing recognition of competition as a crucial mechanism for improving

Fig. 1. Approach to the identification and classification of priority product markets



Source: prepared by the authors.

production efficiency, reducing prices, enhancing social welfare, and acting as a driver of economic development at the local and regional levels, as well as at the national level.

At present, the development of competition and the prevention of monopolistic activity are recognized in Russia as priority areas of activity for federal and regional legislative and executive authorities. On April 17, 2019, the Government of the Russian Federation approved the *Standard for the Development of Competition in the Constituent Entities of the Russian Federation*. This document defines the objectives and principles of state policy aimed at promoting competition at the federal, regional, and municipal levels. Subsequently, by Government Decree dated September 2, 2021, the *National Competition Development Plan (Roadmap) for 2021–2025* was adopted. The Plan explicitly states that addressing competition development objectives constitutes one of the elements necessary for achieving national development goals. One of its primary tasks is identified as the promotion of fair competition in product markets.

This article addresses two interrelated issues that arise in the process of designing governance frameworks aimed at shaping efficient product market structures. The first issue concerns the identification and classification of priority product markets, taking into account national goals and the strategic objectives of economic development, in line with the provisions of the Standard concerning the approval of product market lists. To enhance the practical relevance of the study, an expert panel was engaged to verify the results of identifying priority product markets.

The second issue relates to the need for a clear differentiation of the objects of competition policy—namely, markets—according to the levels at which competition policy instruments may be applied by public authorities. In particular, an assessment was conducted of market geographic boundaries and the capacity of public authorities to affect the development of competition within those markets. In determining geographic boundaries, the criterion of mandatory physical presence within the territory of service provision or production was applied.

Addressing both issues is intended to contribute to the refinement of methodologies for assessing the level of competition development in the constituent entities of the Russian Federation, as well as to improving the practical implementation of competition policy measures outlined in the Standard and the National Plan.

The following sections describe the method proposed for determining the list of priority product markets and their classification according to market geographic scope (federal, regional, and municipal) and according to the degree of regulatory influence exerted by public authorities (markets under federal-level regulatory influence and markets subject to regional and municipal regulation). A separate section is devoted to clustering the constituent entities of the Russian Federation based on socio-economic indicators in order to ensure interregional comparability of competition levels, using the structure and scale of gross regional product as key criteria. The results of applying the proposed approach to market classification and regional clustering are presented. The article concludes with a discussion of the feasibility of applying these approaches in the practical implementation of competition policy measures defined in the National Competition Development Plan and the Standard.

1. List and Classification of Product Markets

The identification of priority product markets, taking into account national goals and the strategic objectives of economic development of the Russian Federation, is proposed to be carried out through five successive stages (Figure 1).

The stages presented in Figure 1 are determined by the key criteria used for the classification of product markets:

- alignment with national goals and objectives for competition and economic development;
- whether the market is subject to price or tariff regulation;
- geographic boundaries of the market;
- the scope of regulatory authority and policy instruments available to public authorities.

The initial list of markets is formed in accordance with the priority areas of economic development of the Russian Federation. At the next stage, markets are assessed to determine whether they are subject to tariff regulation, which primarily applies to sectors classified as natural monopolies. For such markets, the promotion of competition between firms is not considered appropriate. Subsequently, the geographic boundaries of markets are assessed, together with the capacity of public authorities to shape competitive conditions within the respective markets. When determining geographic boundaries, the criterion of mandatory physical presence within the relevant geographic area of service provision or production is also applied. In addition, to enhance the practical relevance of the research, an expert panel was engaged to verify the results of identifying priority product markets.

The selection of priority product markets was aligned with national goals and the strategic objectives of economic development of the Russian Federation. In addition, an analysis of priority goods included in the Consumer Price Index (CPI) and Producer Price Index (PPI) baskets was conducted in order to form the initial list of markets (Figure 2).

Within the CPI basket, 65 products were examined for the purpose of identifying priority markets, while within the framework of the National Competition Development Plan, 15 sectors of the economy were considered.

Among the selected markets, three are subject to tariff regulation:

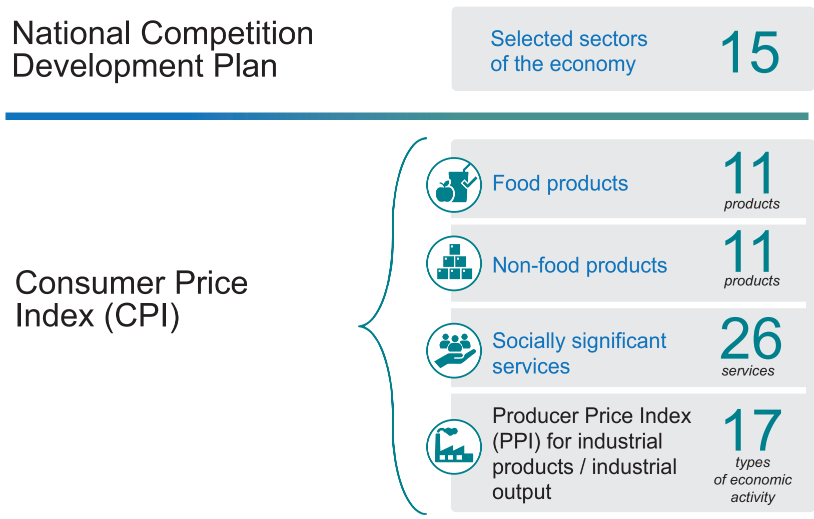
- the market for regional municipal solid waste operators;
- the urban road transport market;
- the gas market.

For these markets, established regulatory frameworks governing the activities of market participants are already in place. As a result, among the 40 non-tariff-regulated markets considered, 12 were classified as federal-level markets, while 28 were classified as regional and municipal markets.

The following product markets were classified as federal industrial markets:

- construction materials;
- thermal (energy) coal;
- crude oil extraction;
- chemical and petrochemical products;
- extraction of ferrous metal ores;
- extraction of non-ferrous metal ores;
- railway transport services;
- timber products.

Fig. 2. Initial set of products and industries used to define priority product markets



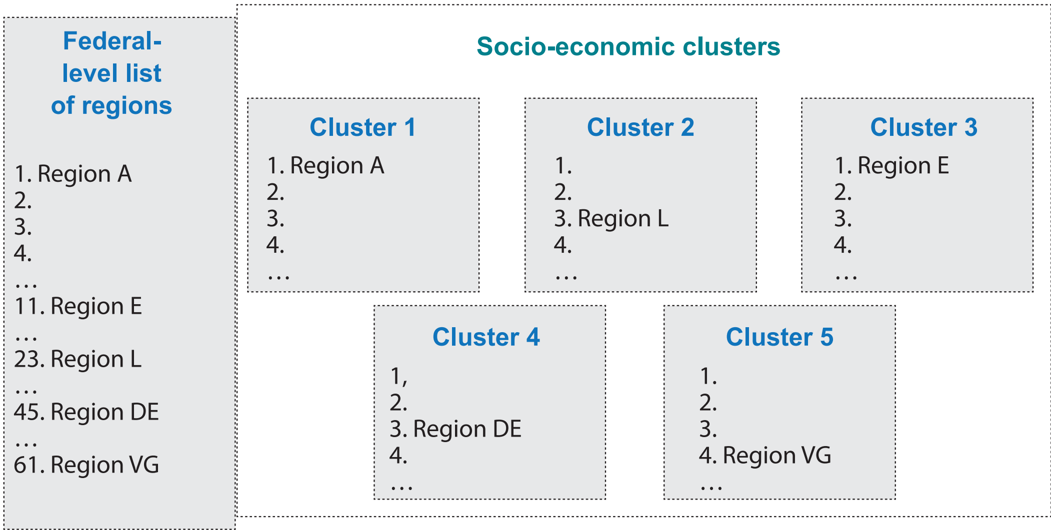
Source: prepared by the authors based on the National Competition Development Plan and official Rosstat statistics.

The following markets were classified as federal-level markets with cross-sectoral characteristics:

- retail financial services;
- higher education (universities);
- software development.

To classify the remaining subnational markets into regional and municipal categories, an expert panel was formed as part of the study. The panel consisted of representatives of regional executive authorities responsible for promoting competition at the regional level. In total, representatives from four constituent entities of the Russian Federation participated in the expert panel (one representative from each region): Leningrad Region, the city of Moscow, Moscow Region, and the Republic of Tatarstan.

Fig. 3. Cluster-based comparison of competition development level across regional product markets



Источник: подготовлено авторами.

The list of subnational markets was distributed to all panel members, who were asked to indicate whether each market should be classified as regional or municipal. As a result of the expert assessment, 20 municipal markets and 8 regional markets were identified.

2. Grouping of Regions into Socio-Economic Clusters

To ensure a comparable analysis of competition development in priority product markets, this study employs a cluster analysis of Russian regions using selected macro- and microeconomic indicators. As of 2024, the Russian Federation comprises 89 constituent entities with equal legal status. These regions exhibit substantial variation in socio-economic indicators that reflect differences in economic development and overall social welfare. From a methodological standpoint, the assessment of competition in a particular regional market is more appropriately conducted by comparing that market with markets in regions sharing similar economic characteristics, rather than with all constituent entities of the Russian Federation simultaneously. Accordingly, the initial stage of the analysis focuses on grouping regions into several socio-economic clusters, within which subsequent comparative assessments of competition levels in the examined product markets can be carried out. Figure 3 provides a schematic representation of the principle underlying this cluster-based comparison.

When selecting indicators for regional clustering, several key assumptions were taken into account.

First, the data must be available in a unified format for all constituent entities on a regular (annual) basis. The most reliable sources of such information are official state statistical observations.

Table 1
Variables used in regional clustering

Variable		Data source
Macroeconomic indicators of regional welfare		
Variable 01	Gross regional product (GRP)	Rosstat
Variable 02	Population size	Rosstat
Sectoral structure of gross value added		
Variable 03	Share of agriculture, forestry, hunting, fishing, and aquaculture in GRP	Rosstat
Variable 04	Share of mining and quarrying in GRP	Rosstat
Variable 05	Share of manufacturing in GRP	Rosstat
Variable 06	Share of wholesale and retail trade; repair of motor vehicles and motorcycles in GRP	Rosstat
Entrepreneurial and investment activity		
Variable 07	Share of small and medium-sized enterprises (SMEs)	Rosstat
Variable 08	Investment in fixed capital growth	Rosstat
Retail market characteristics		
Variable 09	Retail trade turnover per capita	Rosstat
Variable 10	Structure of retail trade turnover	Rosstat
Output and productivity dynamics		
Фактор 11	Labor productivity index	Rosstat

Source: prepared by the authors based on a review of relevant academic literature.

Second, the suitability of the selected variables for clustering purposes must be supported by prior academic research.

Third, the indicators must be quantitative in nature, rather than qualitative or quasi-quantitative, allowing for data normalization and the application of mathematical procedures required for the proper functioning of the clustering algorithm.

Finally, the selected indicators should characterize the conditions influencing competition, rather than represent outcomes resulting from an already established level of competition in product markets. The overall research objective involves comparing competition levels among regions assigned by the algorithm to the same cluster. Accordingly, macro- and microeconomic indicators directly related to price levels for goods and services—such as regional inflation rates, price indices, and similar variables—were deliberately excluded from the analysis. This approach is based on the assumption that regional price levels, among other determinants, depend on the degree of competition in product markets. Consequently, price indicators represent dependent rather than explanatory variables. From a methodological perspective, excluding such variables prevents regions from being grouped according to the very level of competition that is subsequently subject to analysis.

The final list of variables selected for clustering is presented in Table 1. Data for all variables included in the analysis are obtained through official state statistical monitoring.

Macroeconomic indicators of regional welfare

Gross regional product (GRP) is a key indicator of regional economic activity and living standards, reflecting the process of producing goods and services intended for final use. As noted by Trofimova [2015], "in the development and implementation of regional socio-economic development programs, primary emphasis is placed on increasing gross regional product (GRP) as the foundation for improving the population's standard and quality of life." Descriptive statistics for GRP by federal districts are presented in Table 2.

The cited study also emphasizes that this indicator should be considered in relation to the level of per capita monetary income of the region's population, as "a balanced relationship between the rate of economic growth and the growth of population welfare constitutes an important determinant of sustainable socio-economic development of regions" [Trofimova, 2015]. Taking into account the methodological features of cluster analysis, population size and gross regional product (GRP) are therefore used jointly for regional classification. Descriptive statistics for population size by federal districts are presented in Table 3.

Table 2
Descriptive statistics for gross regional product (GRP) (RUB bln)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	1,541	177	16,019	3,750	2.43
NWFD	802	168	4,364	1,205	1.50
SFD	724	70	2,366	812	1.12
NCFD	293	63	739	280	0.96
VFD	833	179	2,201	612	0.73
UFD	1,762	210	3,114	1,072	0.61
SibFD	741	51	1,946	598	0.81
FEFD	435	51	968	341	0.78
Russian Federation (total)	927	51	16,019	1,862	2.01

Note: CFD — Central Federal District; NWFD — Northwestern Federal District; SFD — Southern Federal District; NCFD — North Caucasian Federal District; VFD — Volga Federal District; UFD — Ural Federal District; SibFD — Siberian Federal District; FEFD — Far Eastern Federal District
Source: prepared by the authors based on Rosstat data.

Table 3
Descriptive statistics for population size in the constituent entities of the Russian Federation (mln)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	2.19	0.64	12.65	3.04	1.39
NWFD	1.27	0.04	5.39	1.44	1.13
SFD	2.06	0.27	5.66	1.97	0.96
NCFD	1.41	0.47	3.10	1.10	0.78
VFD	2.10	0.68	4.04	1.13	0.54
UFD	2.06	0.54	4.31	1.50	0.73
SibFD	1.71	0.22	2.87	1.07	0.62
FEFD	0.74	0.05	1.90	0.58	0.77
Russian Federation (total)	1.73	0.04	12.65	1.81	1.05

Source: prepared by the authors based on Rosstat data.

Indicators Describing the Sectoral Structure of Gross Value Added

The structure of gross regional product (GRP) by type of economic activity reflects the sectoral specialization of regions. In the academic literature, this indicator is widely used as a key determinant of interregional differences in competitiveness [Akhunov, 2015] and in forecasting regional socio-economic development [Trofimova, 2015]. Four major groups of economic activities were analyzed, following the classification used in the Rosstat statistical database:

– agriculture, forestry, hunting, fishing, and aquaculture;
– mining and quarrying;
– manufacturing;
– wholesale and retail trade; repair of motor vehicles and motorcycles.

Descriptive statistics for the share of agriculture in GRP by federal districts are presented in Table 4.

Descriptive statistics for the share of mining and quarrying in GRP by federal districts are presented in Table 5. This indicator exhibits a high coefficient of variation,

Table 4
Descriptive statistics for the share of agriculture in GRP (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	9.52	0.10	25.90	7.26	0.76
NWFD	5.37	0.10	12.30	4.05	0.75
SFD	10.13	2.90	22.50	5.99	0.59
NCFD	14.07	10.20	18.10	3.29	0.23
VFD	7.96	1.60	18.10	4.91	0.62
UFD	3.60	0.10	10.60	3.90	1.08
SibFD	5.50	2.20	12.70	3.60	0.65
FEFD	6.41	1.40	27.40	7.13	1.11
Russian Federation (total)	7.87	0.10	27.40	5.98	0.76

Source: prepared by the authors based on Rosstat data.

indicating substantial disparities in the contribution of mining and quarrying across regions. In particular, this type of economic activity predominates in the Siberian, Ural, and Far Eastern federal districts.

Table 5
Descriptive statistics for the share of mineral extraction in GRP (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	2.00	0.00	19.20	5.24	2.62
NWFD	14.65	0.00	79.20	25.15	1.72
SFD	7.64	0.50	48.00	16.38	2.15
NCFD	0.74	0.10	1.50	0.53	0.71
VFD	10.51	0.00	40.80	14.00	1.33
UFD	27.75	1.00	72.50	34.35	1.24
SibFD	14.50	0.30	29.20	12.14	0.84
FEFD	23.35	1.00	64.30	22.20	0.95
Russian Federation (total)	11.52	0.00	79.20	18.67	1.62

Source: prepared by the authors based on Rosstat data.

Descriptive statistics for the share of manufacturing in GRP by federal districts are presented in Table 6.

Table 6
Descriptive statistics for the share of manufacturing in GRP (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	22.17	11.80	38.20	8.76	0.40
NWFD	20.32	0.20	38.30	11.14	0.55
SFD	10.56	0.80	24.40	7.71	0.73
NCFD	5.97	1.90	11.50	3.68	0.62
VFD	22.68	11.40	31.10	5.88	0.26
UFD	17.45	1.70	32.20	13.12	0.75
SibFD	15.61	0.70	36.30	11.62	0.74
FEFD	4.44	0.30	9.40	3.53	0.80
Russian Federation (total)	16.19	0.20	38.30	10.71	0.66

Source: prepared by the authors based on Rosstat data.

Descriptive statistics for the share of wholesale and retail trade in GRP by federal districts are presented in Table 7.

Table 7
Descriptive statistics for the share of trade in GRP (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	14.38	9.00	25.30	4.04	0.28
NWFD	9.05	0.70	16.10	4.28	0.47
SFD	11.78	5.10	15.90	4.01	0.34
NCFD	14.09	8.90	20.30	3.86	0.27
VFD	10.83	6.20	16.40	2.65	0.24
UFD	7.97	1.70	12.90	4.83	0.61
SibFD	10.36	5.20	15.60	3.36	0.32
FEFD	8.82	3.70	15.90	3.78	0.43
Russian Federation (total)	11.19	0.70	25.30	4.29	0.38

Source: prepared by the authors based on Rosstat data.

Indicators of Entrepreneurial and Investment Activity

A substantial body of domestic research highlights the role of small and medium-sized enterprises (SMEs) in the socio-economic development of Russian regions. First, SMEs play an important role in employment creation and the expansion of self-employment at the regional level. A study conducted by the Institute of Economics of the Russian Academy of Sciences [Vilensky, 2021] notes that "SMEs generate jobs while simultaneously creating additional demand for labor." Second, the contribution of SMEs to regional development is manifested in their capacity to satisfy local demand and supply specialized goods and services adapted to regional market conditions [Vilensky, 2021]. In addition, the influence of small and medium-sized enterprises on regional economic development extends to fiscal, social, and innovation-related dimensions. Research conducted by the Vologda Research Center of the Russian Academy of Sciences [Mazilov, Kremin, 2018] concludes that "small business represents a core component of the region's socio-economic system at the federal, regional, and municipal levels. Its most significant impact is observed at the municipal level, where small enterprises create conditions for accelerated economic growth by stimulating the development and saturation of local markets, mitigating the adverse effects inherent in a market economy (unemployment, cyclical fluctuations, and crisis phenomena), and facilitating the mobilization of available resource potential to improve overall socio-economic development." To reflect interregional differences in SME development, the share of small and medium-sized enterprises was incorporated into the set of clustering variables.

Descriptive statistics for the share of SMEs by federal districts are presented in Table 8.

According to Rosstat, fixed capital investment is defined as "the aggregate of expenditures directed toward

Table 8
Descriptive statistics for the share of small and medium-sized enterprises (SMEs) (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	29.37	22.00	42.20	4.95	0.17
NWFD	20.53	1.50	32.20	9.26	0.45
SFD	26.24	14.60	34.20	6.69	0.25
NCFD	29.96	21.20	38.50	5.40	0.18
VFD	26.69	17.00	34.20	4.73	0.18
UFD	18.68	2.50	27.70	11.58	0.62
SibFD	22.54	11.40	36.90	8.78	0.39
FEFD	19.83	8.00	32.10	7.03	0.35
Russian Federation (total)	24.74	1.50	42.20	7.93	0.32

Source: prepared by the authors based on Rosstat data.

the construction and reconstruction (including expansion and modernization) of facilities resulting in an increase in their initial value; the acquisition of machinery, equipment, vehicles, and production and household inventories; the formation of working, productive, and breeding livestock; and the planting and cultivation of perennial crops."

Recent studies, including the work of N.S. Gichiev from the Dagestan Federal Research Center of the Russian Academy of Sciences, emphasize that "the share of fixed capital investment represents one of the most important indicators determining a region's level of technological leadership" [Gichiev, 2021]. Attention should also be drawn to the study conducted by researchers from the Ryazan State Agrotechnological University named after P.A. Kostychev [Minat, Sudakova, 2020 which presents a cluster analysis of regions based exclusively on variables describing regional investment processes. For this reason, the indicator was included among the variables used for regional clustering.

Descriptive statistics for fixed capital investment growth by federal districts are presented in Table 9.

Table 9
Descriptive statistics for investment growth in fixed capital (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	106.0	79.2	124.6	12.2	0.11
NWFD	88.8	61.6	119.4	15.9	0.18
SFD	99.5	72.2	133.7	20.6	0.21
NCFD	104.2	95.5	116.7	6.5	0.06
VFD	102.8	90.8	119.0	7.9	0.08
UFD	102.8	80.3	140.1	21.1	0.20
SibFD	111.2	88.6	131.9	15.7	0.14
FEFD	110.5	66.9	149.1	23.9	0.22
Russian Federation (total)	103.4	61.6	149.1	16.5	0.16

Source: prepared by the authors based on Rosstat data.

Retail Market Indicators

This group of indicators was incorporated into the set of clustering variables, given the specific objective of conducting a comparative assessment of competition levels across regions. In the study by Markhaichuk [2018], a statistically significant positive relationship was identified between the development of both online and offline retail and the level of gross regional product (GRP). To characterize regional retail trade, two indicators are employed: retail turnover per capita and the structure of retail turnover.

Descriptive statistics for retail turnover per capita by federal districts are presented in Table 10.

Table 10
Descriptive statistics for retail trade turnover per capita (RUB thsnd)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	222.7	171.6	403.4	59.3	0.27
NWFD	215.3	170.2	278.0	31.7	0.15
SFD	180.0	83.2	258.3	56.2	0.31
NCFD	138.2	51.7	191.6	54.0	0.39
VFD	179.7	123.3	244.2	41.7	0.23
UFD	228.0	144.8	277.5	59.6	0.26
SibFD	159.0	80.3	201.7	34.3	0.22
FEFD	225.4	163.3	327.6	47.6	0.21
Russian Federation (total)	196.9	51.7	403.4	55.5	0.28

Source: prepared by the authors based on Rosstat data.

Descriptive statistics for the structure of retail turnover by federal districts are presented in Table 11.

Table 11
Descriptive statistics for the structure of retail trade turnover (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	48.22	39.00	53.90	3.73	0.077
NWFD	51.25	34.30	64.70	7.96	0.155
SFD	44.23	27.20	50.90	7.61	0.172
NCFD	48.91	45.40	51.40	2.16	0.044
VFD	47.76	44.80	51.30	1.74	0.036
UFD	47.13	46.00	48.70	1.06	0.022
SibFD	47.62	44.20	51.70	2.09	0.044
FEFD	53.55	46.00	69.90	6.94	0.130
Russian Federation (total)	48.76	27.20	69.90	5.35	0.110

Source: prepared by the authors based on Rosstat data.

Output and Labor Productivity Indicators

To assess the dynamics of regional development, the labor productivity index is used. According to the Rosstat methodology, this indicator is calculated as "the ratio of the physical volume index of gross domestic product to the index of changes in total labor input."

Descriptive statistics for the labor productivity index by federal districts are presented in Table 12.

As shown in the study by Ismailova and Kupyanskaya [2019], which examines labor productivity across the

Table 12
Descriptive statistics for the labor productivity index (%)

Federal district	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation
CFD	102.4	97.7	108.0	2.46	0.024
NWFD	102.5	100.7	106.1	1.72	0.017
SFD	103.1	98.9	106.3	2.44	0.024
NCFD	102.3	99.2	108.4	3.19	0.031
VFD	103.5	100.2	106.3	1.80	0.017
UFD	100.9	96.8	104.8	3.28	0.033
SibFD	102.7	99.9	105.4	1.66	0.016
FEFD	104.7	99.8	114.2	4.37	0.042
Russian Federation (total)	102.9	96.8	114.2	2.72	0.026

Source: prepared by the authors based on Rosstat data.

regions of the Russian Federation, "labor productivity serves as a key efficiency indicator affecting GDP and GRP performance, the level of economic development, and the competitiveness of both the country and its regions. "

3. Description of the Clustering Method

The implementation of cluster analysis involves a sequence of methodological steps, including:

– normalization of statistical data for the selected indicators;
– identification of the set of variables used for clustering;
– selection of an appropriate distance metric in multidimensional space;
– choice of a suitable statistical clustering method;
– determination of the optimal number of clusters, taking into account the distribution of the data.

Data normalization is required to ensure the comparability of measurement scales across all indicators [De Souto et al., 2008] and to ensure that the mean value of each normalized variable across the full regional sample equals zero. For example, gross regional product (GRP) is measured in thousands of rubles, while the values observed for individual regions may reach several billion rubles. At the same time, the share of agriculture in GRP is expressed in percentage terms, that is, as fractions of one. If distances between regions are calculated using non-normalized data, variables with larger numerical scales will dominate the differentiation process due to differences in measurement units. As a result, GRP expressed in monetary terms would exert a disproportionate influence on the clustering outcome, whereas the contribution of indicators measured in percentage terms would become negligible. To avoid such distortions, all variables must be transformed to a common scale prior to clustering. During normalization, data for all regions are compiled into a single dataset, and the following statistics are calculated for each variable:

1) the mean value of the k-th variable M_{rk} across all regions ($r = 1, \ldots, R$, where R – is the total number of regions, $k = 1, \ldots, K$, where K is the total number of variables)
2) the standard deviation of the k-th variable S_{rk} across all regions ($r = 1, \ldots, R$, where R is the total number of regions, $k = 1, \ldots, K$, where K is the total number of variables)
3) the normalized value of each variable is then obtained as:

$$NF_{rk} = (F_{rk} - M_{rk}) \,/\, S_{rk}, \quad (1)$$

where F_{rk} – denotes the original value of the k-th indicator in region r, and NF_{rk} – represents its normalized value.

Within the framework of this study, the units of observation are the constituent entities of the Russian Federation, each represented as a point in a multidimensional space defined by the selected clustering variables. To measure distances between normalized observations, Euclidean distance is

Table 13
Configurations of variables used for cluster formation

Configuration code	Set of variables included in the configuration
"Agriculture"	GRP, population, share of agriculture in GRP
"Mining"	GRP, population, share of mining in GRP
"Manufacturing"	GRP, population, share of manufacturing in GRP
"Trade"	GRP, population, wholesale and retail trade; repair of motor vehicles and motorcycles
"GRP structure"	GRP, population, share of agriculture in GRP, share of mining in GRP, share of manufacturing in GRP
"SMEs"	GRP, population, share of small and medium-sized enterprises
"Investment"	GRP, population, investment growth in fixed capital
"Productivity"	GRP, population, labor productivity index
"Retail"	GRP, population, retail trade turnover per capita, structure of retail trade turnover

Source: prepared by the authors.

employed, which represents one of the most widely used approaches in econometric research. The distance between two regions is calculated as:

$$D_{ij} = \sqrt{\sum_{k=1}^{K}(NF_{ik} - NF_{jk})^2}, \qquad (2)$$

where *I* and *j* denote the indices of the regions being compared, *K* – is the number of variables included in the algorithm, and NF_{ik}, NF_{jk} are the normalized values of the *k*-th variable for regions *i* and *j*, respectively.

The Euclidean distance metric is introduced as a measure of similarity between regional characteristics. When the economic indicators of two regions are close in magnitude (in the limiting hypothetical case, identical), the Euclidean distance calculated using normalized variables approaches a small value (or zero in the case of identical values).

To perform the econometric clustering procedure, the k-means method was applied. This approach belongs to the class of non-hierarchical clustering techniques and is based on the identification of centroids, with observations assigned to clusters according to their proximity to these centroids [Teknomo, 2006]. The *k*-means algorithm is widely used for clustering objects represented by vectors of measurable parameters and is frequently applied in regional economic studies [Akhunov, 2015]. A key feature of the *k*-means method is that the number of clusters must be specified in advance. Consequently, the structure and distribution of the dataset must be carefully considered prior to clustering.

At the initial stage, centroids for the prospective clusters are randomly generated in a number corresponding to the predefined number of clusters. Each observation is then assigned to the centroid to which it has the smallest Euclidean distance, thereby forming preliminary clusters.

Subsequently, new centroids are recalculated for each cluster as the mean values of all variables for the observations included in that cluster. Following centroid updating, the reassignment procedure is repeated, with observations redistributed based on proximity to the updated centroids. This iterative process continues until cluster membership stabilizes and no further changes occur. The resulting groups formed around the final centroids constitute the target clusters.

One limitation of the *k*-means method is its sensitivity to the random initialization of centroids. To mitigate this issue, an enhanced procedure was applied. The clustering algorithm was executed repeatedly (1,000 or more iterations), with the final metric calculated as the total distance between observations and their corresponding centroids. The cluster configuration minimizing this metric was selected as the final solution.

The subsequent stage of clustering involves determining the appropriate number of clusters. Following the approach proposed by Akhunov [2015], who conducted a clustering of Russian regions based on socio-economic development levels, an initial number of five clusters was adopted. However, empirical observations necessitated an important adjustment. The specific distribution of regional economies reveals the presence of a region that substantially deviates from national averages in terms of both GRP and population size—namely, the city of Moscow [Tebekin, 2019]. Preliminary clustering results consistently formed a separate cluster consisting solely of Moscow. Given this feature, the clustering procedure was conducted with five initial clusters; however, the single-element cluster representing Moscow was subsequently merged with one of the remaining four clusters based on proximity to the corresponding centroid. As a result, four final clusters were identified, within which regions were grouped according to similarity in economic indicators.

In total, nine alternative configurations of clustering variables were examined in the analysis (Table 13).

The results of the cluster analysis for all listed configurations are presented below, followed by a comparative assessment aimed at identifying the optimal configuration of variables.

4. Results of the Cluster Analysis

The k-means clustering method was applied to 85 regions of the Russian Federation using data for 2019. This year was selected as representative for two main reasons. First, comprehensive official statistics on the socio-economic development of Russian regions for 2021 were not yet fully available at the time of the study. Second, regional economic indicators for 2020 were significantly affected by the acute phase of the COVID-19 pandemic [Zubarevich, 2021; Mirolyubova, Voronchikhina, 2021], which could lead to biased quantitative estimates and distort analytical conclusions.

The analysis was conducted using nine configurations of variables. The clustering results for each configuration are presented below.

Configuration 1: Agriculture

The results of clustering analysis based on configuration 1 (“Agriculture”) are presented in Table 14.

Table 14
Cluster characteristics for configuration 1: Agriculture

Cluster	1	2	3	4
Number of regions	13	36	17	19
GRP (RUB, bln)	70-841	51-2,593	939-16,019	51-938
Population (mln)	0.3-3.1	0.0-2.0	1.7-12.6	0.2-2.8
Share of agriculture in GRP (%)	14.7-27.4	0.1-7.6	0.1-10.7	7.2-13.3

Source: prepared by the authors.

The selected set of variables predictably resulted in the division of Russian regions into four clusters: agricultural regions (13), two groups of non-agricultural regions (36 and 17), and an intermediate group (19). The non-agricultural regions formed two distinct clusters: regions with relatively high GRP (17) and regions with comparatively low GRP (36).

Configuration 2: Mining

The results of the clustering analysis based on configuration 2 ("Mining") are presented in Table 15.

Table 15
Cluster characteristics for configuration 2: Mining

Cluster	1	2	3	4
Number of regions	51	14	11	9
GRP (RUB, bln)	51–1,043	60–2,201	649–16,019	79–3,114
Population (mln)	0.2–2.8	0.3–3.9	2.8–12.6	0.0–1.7
Share of mining and quarrying in GRP (%)	0.0–14.6	17.7–40.8	0.0–3.5	39.4–79.2

Source: prepared by the authors.

The variables included in this configuration resulted in the identification of the following clusters: intensively mining regions (9), non-mining regions (51 and 11), and regions characterized by a moderate level of mining activity (14).

The non-mining regions were further divided into two subgroups: regions with relatively low population and GRP (51) and regions with relatively high population and GRP (11). Regions belonging to the latter subgroup largely overlap with the cluster of non-agricultural regions with high GRP identified under configuration 1, with the exception of the Republic of Dagestan, which combines low mining activity with a large population and a well-developed agricultural sector.

Configuration 3: Manufacturing

The results of the clustering analysis based on configuration 3 ("Manufacturing") are presented in Table 16.

Table 16
Cluster characteristics for configuration 3: Manufacturing

Cluster	1	2	3	4
Number of regions	24	20	11	30
GRP (RUB, bln)	51–3,114	177–1,946	1,364–16,019	112–1,228
Population (mln)	0.0–3.1	0.6–2.9	3.2–12.6	0.5–2.8
Share of manufacturing in GRP (%)	0.2–9.5	22.9–38.3	10.4–32.2	8.3–20.8

Source: prepared by the authors.

This clustering configuration yields a different grouping pattern, as many regions with high GRP and large populations also demonstrate medium or high shares of manufacturing activity. As a result, regions were classified into the following categories: regions with a low manufacturing share (24), regions with a high manufacturing share and low GRP (20), regions with a high manufacturing share and high GRP (11), and regions with a medium manufacturing share (30).

Configuration 4: Trade

The results of the clustering analysis based on configuration 4 ("Trade") are presented in Table 17.

Table 17
Cluster characteristics for configuration 4: Trade

Cluster	1	2	3	4
Number of regions	26	17	12	30
GRP (RUB, bln)	51–938	51–3,114	649–16,019	63–1,395
Population (mln)	0.2–2.8	0.0–2.9	2.8–12.6	0.5–3.2
Share of trade in GRP (%)	12.3–18.8	0.7–7.9	10.3–25.3	8.0–12.0

Source: prepared by the authors.

The group of regions with the highest GRP (12) also exhibits the largest population size and the highest share of trade and vehicle repair in GRP. The remaining clusters are formed according to the following characteristics: a high share of trade and low population (26), a low share of trade (17), and a medium level of trade activity (30).

Configuration 5: GRP structure

The results of the clustering analysis based on configuration 5 ("GRP structure") are presented in Table 18.

Table 18
Cluster characteristics for configuration 5: GRP structure

Cluster	1	2	3	4
Number of regions	23	27	10	25
GRP (RUB, bln)	177–2,206	51–16,019	79–3,114	51–882
Population (mln)	0.6–4.3	0.2–12.6	0.0–2.0	0.2–3.1
Share of agriculture in GRP (%)	1.6–11.6	0.1–10.7	0.1–6.7	10.2–27.4
Share of mining and quarrying in GRP (%)	0.0–22.7	0.0–29.2	39.4–79.2	0.0–19.2
Share of manufacturing in GRP (%)	20.5–38.3	0.7–20.0	0.2–11.4	0.8–26.1

Source: prepared by the authors.

The inclusion of a larger number of variables leads to a more balanced distribution of regions across clusters compared with approaches based on a single sectoral indicator. Clusters are formed according to dominant specializations: mining regions (10), agricultural regions (25), manufacturing-oriented regions (23), and regions without a clearly defined specialization within the

GRP structure (27). Within each sectoral category, the dispersion of GRP and population levels is, on average, greater than in approaches based on a single dominant activity.

Configuration 6: SMEs

The results of the clustering analysis based on configuration 6 ("SMEs") are presented in Table 19.

Table 19
Cluster characteristics for configuration 6: SMEs

Cluster	1	2	3	4
Number of regions	11	11	32	31
GRP (RUB, bln)	60–3,114	1,364–16,019	63–1,190	51–1,228
Population (mln)	0.0–2.9	3.2–12.6	0.4–3.1	0.1–2.7
Share of small and medium-sized enterprises (SMEs) (%)	1.5–15.2	22.0–34.2	26.9–42.2	17.0–26.4

Source: prepared by the authors.

The algorithmic grouping identified the following clusters: regions with a low share of SMEs in GRP and low population (11), regions with a high share of SMEs and high population (11), regions with a high share of SMEs and low GRP (32), and regions with a medium level of SME development (31). The group of regions with the highest GRP nationwide exhibits an above-average share of small and medium-sized enterprises; however, this indicator is not the highest among all clusters.

Configuration 7: Investment

The results of the clustering analysis based on configuration 7 ("Investment") are presented in Table 20.

Table 20
Cluster characteristics for configuration 7: Investment

Cluster	1	2	3	4
Number of regions	11	37	17	20
GRP (RUB, bln)	51–692	63–968	51–2,593	649–16,019
Population (mln)	0.0–1.9	0.0–2.4	0.1–1.9	1.7–12.6
Investment in fixed capital growth (%)	119.4–149.1	93.8–117.2	61.6–92.3	81.5–124.6

Source: prepared by the authors.

The clustering algorithm identified groups conventionally characterized by the following features: the highest growth in fixed capital investment (11), the lowest level of fixed capital investment (17), a medium level of fixed capital investment combined with low GRP (37), and a medium level of fixed capital investment combined with high GRP (20). As in the SME-based clustering, the group of regions with the highest GRP does not exhibit the highest value for the selected indicator.

Configuration 8: Productivity

The results of the clustering analysis based on configuration 8 ("Productivity") are presented in Table 21.

Table 21
Cluster characteristics for configuration 8: Productivity

Cluster	1	2	3	4
Number of regions	5	24	19	37
GRP (RUB, bln)	144–938	51–2,593	649–16,019	51–1,082
Population (mln)	0.7–1.9	0.1–2.4	1.7–12.6	0.0–2.4
Labor productivity index (%)	108–114.2	103.4–106.3	98.5–104.9	96.8–102.9

Source: prepared by the authors.

This configuration identified a group of five regions with the highest labor productivity index, a group with above-average labor productivity (24), a group with a medium index level (19), which also includes regions with large population size and high GRP, and a group characterized by a low labor productivity index (37). The latter group is also associated with a comparatively low level of GRP. For this indicator, the clustering produced the most uneven distribution of regions across clusters.

Configuration 9: Retail

The results of the clustering analysis based on configuration 9 ("Retail") are presented in Table 22.

Table 22
Cluster characteristics for configuration 9: Retail

Cluster	1	2	3	4
Number of regions	5	30	27	23
GRP (RUB, bln)	79–693	51–1,364	51–739	112–16,019
Population (mln)	0.0–1.3	0.2–3.5	0.1–3.1	0.5–12.6
Retail trade turnover per capita (RUB, thsnd)	197–262	52–184	165–242	191–403
Share of food products in retail trade (%)	59.4–69.9	39.6–51.4	45.9–56.1	27.2–53.9

Source: prepared by the authors.

The retail-related variables used in this configuration identified the following conditional groups: regions with the highest share of food products in retail trade and below-average population (5), regions with a medium share of food products combined with low GRP and retail trade turnover

Table 23
Socio-economic clusters of the constituent entities of the Russian Federation

Economic structure	Economic scale	Number of regions
Diversified		
No single dominant economic activity (over 30% of GRP)	Population above 0.5 mln; GRP above 1,000 RUB bln, or GRP per capita above 420 thousand RUB	11
Industrial		
Mining or manufacturing account for more than 25% of GRP individually, or more than 30% of GRP in total	GRP per capita above 300 thousand RUB	37
Agricultural		
Share of agriculture in GRP ≥ 10%; share of extractive industries or manufacturing ≤ 25%	GRP per capita above 300 thousand RUB	15
Developing		
No dominant economic activity combined with GRP per capita below 420 thousand RUB	High share of agriculture combined with GRP per capita below 200 thousand RUB	22 + 4*

* The new constituent entities of the Russian Federation (Donetsk People's Republic, Luhansk People's Republic, Zaporizhzhia Region, and Kherson Region) are provisionally assigned to the cluster of developing regions until official statistical data for a representative year become available.

Source: prepared by the authors.

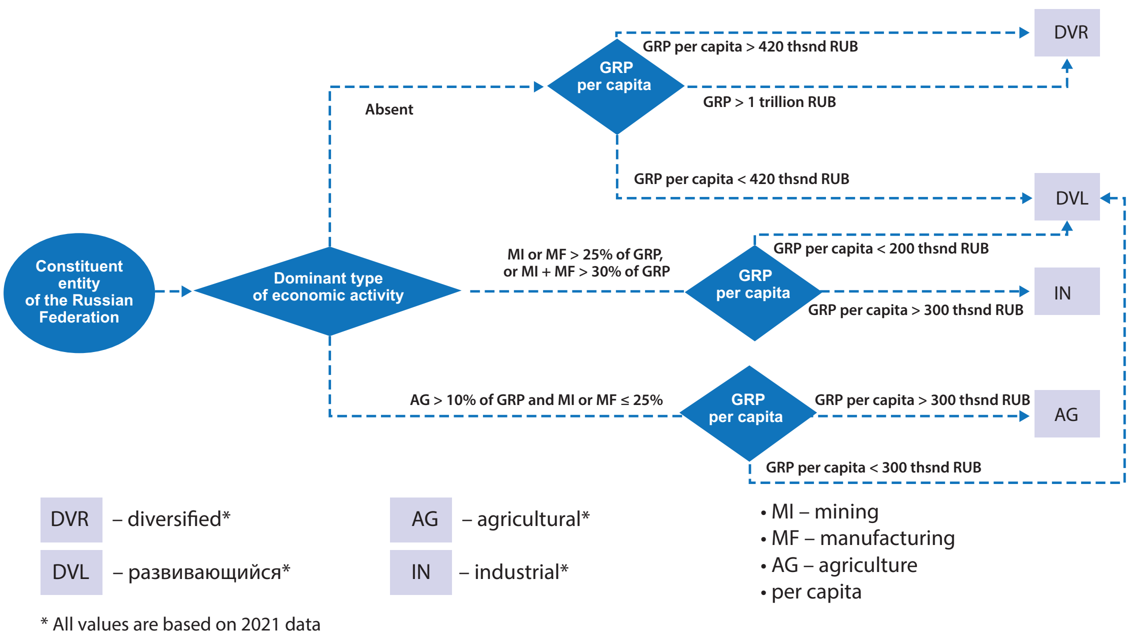
(30), regions with medium levels of both retail indicators and low GRP (27), and regions with high retail trade turnover and high GRP (23). Notably, the group of regions with the highest GRP and population exhibits high, but not the highest nationwide, levels of retail trade activity.

Final set of clusters

During the analysis, several regularities in the clustering of regions were identified. A group of five regions—namely, Moscow Region, the city of Moscow, the city of Saint Petersburg, Krasnodar Krai, and Rostov Region—was assigned to the same cluster across all examined configurations of variables. This indicates a high degree of similarity among these constituent entities with respect to the selected subset of economic indicators.

Arkhangelsk Region (excluding the Nenets Autonomous Okrug) was grouped together with Novgorod Region in all configurations, while never being assigned to the same cluster as the aforementioned group of five regions. This finding suggests that, although these two regions are similar to each other in terms of economic indicators, they are clearly differentiated from the group of leading regions identified above.

Fig. 4. Schematic representation of the algorithm for assigning regions to socio-economic clusters



Source: prepared by the authors.

Table 24
Distribution of constituent entities of the Russian Federation across socio-economic clusters

Cluster	Regions included
Industrial regions cluster	Arkhangelsk Region, Astrakhan Region, Belgorod Region, Vladimir Region, Volgograd Region, Vologda Region, Irkutsk Region, Kaliningrad Region, Kaluga Region, Kemerovo Region – Kuzbass, Krasnoyarsk Krai, Lipetsk Region, Magadan Region, Nenets Autonomous Okrug, Novgorod Region, Omsk Region, Orenburg Region, Perm Krai, Republic of Bashkortostan, Republic of Karelia, Republic of Komi, Republic of Sakha (Yakutia), Republic of Khakassia, Ryazan Region, Samara Region, Sakhalin Region, Sverdlovsk Region, Tomsk Region, Tula Region, Tyumen Region, Udmurt Republic, Ulyanovsk Region, Khanty-Mansi Autonomous Okrug, Chelyabinsk Region, Chukotka Autonomous Okrug, Yamalo-Nenets Autonomous Okrug, Yaroslavl Region.
Developing regions cluster	Amur Region, Sevastopol, Jewish Autonomous Region, Zabaykalsky Krai, Ivanovo Region, Kabardino-Balkarian Republic, Karachay-Cherkess Republic, Kirov Region, Kostroma Region, Kurgan Region, Kursk Region, Republic of Buryatia, Republic of Ingushetia, Republic of Crimea, Republic of Mari El, Republic of Mordovia, Republic of Tuva, Smolensk Region, Tver Region, Khabarovsk Krai, Chechen Republic, Chuvash Republic, Donetsk People's Republic*, Luhansk People's Republic*, Zaporizhzhia Region*, Kherson Region
Agricultural regions cluster	Altai Krai, Bryansk Region, Voronezh Region, Kamchatka Krai, Oryol Region, Penza Region, Pskov Region, Republic of Adygea, Republic of Altai, Republic of Dagestan, Republic of Kalmykia, Republic of North Ossetia–Alania, Saratov Region, Stavropol Krai, Tambov Region.
Diversified regions cluster	The city of Moscow, the city of Saint Petersburg, Krasnodar Krai, Leningrad Region, Moscow Region, Murmansk Region, Nizhny Novgorod Region, Novosibirsk Region, Primorsky Krai, Rostov Region, Republic of Tatarstan

* Newly incorporated constituent entities of the Russian Federation are provisionally assigned to the developing regions cluster pending the availability of official statistical data for a representative year.
Source: prepared by the authors.

In seven out of the nine configurations, Voronezh Region, Pskov Region, and Altai Krai were consistently grouped within the same cluster. This cluster remained distinct from both clusters identified for the previous two regional groups (the group of five regions and the pair of regions). In five of these seven configurations, the Republic of Adygea and Stavropol Krai were also included in the same cluster.

In six out of the nine configurations, Bryansk Region, Oryol Region, and Penza Region were consistently assigned to a single cluster.

Each of the analyzed configurations exhibits its own specific features and potential applicability for further analysis. This raises the question of their comparative performance and the selection of an "optimal" configuration. From this perspective, one possible optimality criterion is the minimization of dispersion in cluster size. In other words, when choosing among alternative configurations, preference may be given to those with the smallest difference between the largest and smallest clusters in terms of the number of regions they contain. Based on this criterion, configurations No. 5 ("GRP Structure"), No. 4 ("Trade"), No. 3 ("Manufacturing"), and No. 6 ("SMEs") can be considered the most balanced.

Based on the clustering results obtained across all configurations, four final socio-economic clusters were identified. Configuration "GRP Structure" was selected as the baseline. The clusters derived from this configuration were subsequently refined taking into account the scale of regional economies. As a result, the following clusters were formed: diversified regions (11 regions), industrial regions (37 regions), agricultural regions (15 regions), and developing regions (22 regions). The complete list of regions by cluster is presented in Table 23, while an approximate visual representation is provided in Figure 4.

Following the statistical clustering stage, an expert assessment stage was conducted. The results and patterns identified in the baseline configuration, as well as in the remaining eight alternative configurations, were systematized and presented to a panel of experts representing regional economic development authorities in various regions of the Russian Federation. This stage was considered necessary for two main reasons. First, regional expert judgment makes it possible to validate or refine the outcomes of the purely statistical analysis. Second, specialists in regional economics typically incorporate a wide range of considerations in their assessments, including qualitative characteristics that cannot be captured through official statistical data or subjected to quantitative processing. The experts were asked to evaluate the adequacy of the proposed grouping of Russian regions into four socio-economic clusters based on the results obtained under the nine model configurations. The survey was conducted using the Delphi method in two rounds. As a result, a final list of constituent entities of the Russian Federation was established for each cluster. This list is presented in Table 24. To ensure a comparable analysis of competition development, it is proposed that competition levels in product markets be compared within the cluster to which each region belongs.

Conclusion

Based on the work carried out to identify the list of priority product markets in accordance with the national goals and strategic objectives of economic development of the Russian Federation, the following key findings can be highlighted:

1. Product markets should be classified according to their geographic scope into federal, regional, and municipal markets, as well as according to the nature of

public intervention—into markets subject to federal-level influence and markets subject to regional and municipal influence.

2. In total, 30 priority markets were identified within the framework of the Standard. The development of competition in these markets should be carried out jointly by federal executive authorities, regional executive authorities, and local self-government bodies.

3. Nineteen markets are considered appropriate for assessing the performance of regional executive authorities in promoting competition. These markets are further subdivided into socially oriented markets and markets focused on value creation.

4. The constituent entities of the Russian Federation were classified into four socio-economic clusters using the k-means clustering method.

The approaches described in this study are proposed as an instrumental framework for the practical implementation of competition policy as articulated in regulatory acts, federal laws, government resolutions, and other foundational documents aimed at fostering competition in the constituent entities of the Russian Federation.

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Cash Holdings Management, Organizational Capital, and Stock Liquidity: The Precautionary Motive for Risk Mitigation

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Abstract

The author examines the combined effects of corporate governance quality, stock liquidity, and asset profitability under conditions of financial constraints. Effective company management serves as an important signal for potential investors. Improving the quality of financial information not only enhances investor trust but also enables management to obtain a comprehensive view of the firm's business activities, thereby supporting informed decision-making. The financial position of a business entity and its investment prospects are largely determined by the quality of management. Organizational capital is used as a proxy variable for corporate governance quality. Management exercises direct control over operational costs, which allows it to effectively manage changes within the firm. Tightening monetary policy not only increases the cost of borrowing but also reduces real incomes and suppresses the investment activity of Russian public companies. A high key interest rate set by the Bank of Russia leads to a sharp decline in industrial investment and extends project investment horizons. As a result, these companies are likely to forgo economically attractive investment projects. Under these conditions, they are likely to behave in line with the precautionary motive by retaining a portion of their funds to finance their business activities and adjust their capital structure amid limited access to debt financing. Stock liquidity serves as an important reference point in investors' analysis and evaluation of stock returns. The preparation of financial reporting in accordance with international standards provides the necessary information for decision-making not only for management but also for investors, thereby sending them a signal that, under adverse conditions (external sanctions), ultimately affects the share prices.
Keywords: corporate governance, asset profitability, international accounting standards

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现金资产管理、组织资本与股票流动性为防止与降低风险

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摘要
本文探讨了在财务约束条件下，公司治理质量、股票流动性和资产收益率对现金持有的综合影响。有效的公司治理是未来投资者的重要参考指标。提高财务信息质量不仅有助于增强潜在投资者的信任，还能使管理层全面了解公司的经营状况，从而做出更明智的决策。企业的财务状况和投资前景在很大程度上与管理质量相关。组织资本是公司治理质量的代理变量。管理层对运营成本拥有直接控制权，这使其能够有效推动公司变革。国家货币政策的收紧不仅导致信贷成本上升，还会侵蚀俄罗斯上市公司的收益并抑制其投资活动。俄罗斯中央银行的高关键利率导致行业投资严重短缺，并延长了项目的投资周期，使得俄罗斯上市公司可能被迫放弃有吸引力的投资项目。在债务融资渠道受限的情况下，俄罗斯企业将基于预防性动机采取行动，即保留部分现金以备后续经营活动和资本结构调整之需。股票流动性指标是投资者分析和评估股票收益的重要风向标。按国际标准编制财务报表不仅为管理层提供了必要的决策信息，也向投资者传递了关键信号。在外部制裁等负面因素影响下，这些信号最终将反映在股价变动中。
关键词：公司治理、资产收益率、财务报告国际准则。

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In assessing a company’s performance, asset profitability alone is insufficient, as the quality of corporate governance plays a significant role. Effective management control over operating costs allows companies to account for structural changes in their development strategy.

A number of studies indicate that profitability indicators constitute the primary source of infor-mation for investors [Liu et al., 2002; Francis et al., 2003; 2004]. Other researchers have exam-ined investor reactions to earnings information in order to evaluate the quality of financial re-porting [Ball, Brown, 1968; Aboody et al., 2002; Venter et al., 2014; Barth et al., 2023]. However, most existing studies focus exclusively on earnings indicators when forming conclusions regarding business development strategies [Dechow et al., 2010].

In practice, potential investors require a clear understanding of the relevance and reliability of business performance indicators disclosed in consolidated financial statements prepared in ac-cordance with International Financial Reporting Standards (IFRS).

IFRS-based reporting provides a comprehensive view of a company’s financial performance and incorporates elements of management reporting, thereby supporting investment decisions that reflect the interests of both investors and shareholders.

International financial reporting is based on the principle of control over assets. Items recorded off balance sheet under Russian accounting standards, such as leased assets, are recognized as assets of the lessee under IFRS. In addition, IFRS reporting enables comparison of the reporting period with prior periods, allowing for an assessment of performance dynamics.

IFRS financial statements also include non-financial disclosures, including Management Discussion and Analysis, as well as information on capital consolidation, such as interests in subsidiaries and associates. Consequently, IFRS reporting provides users with the information necessary for informed decision-making in a market environment.

Improving the quality of financial information enhances transparency regarding a company’s economic position for potential investors and enables management to develop a comprehensive understanding of operating conditions, which is essential for informed managerial decision-making.

The listing and trading of securities, particularly shares, contribute not only to increased market capitalization but also to meeting investor expectations with respect to the transparency of IFRS-based disclosures.

In the present study, the author examines the effects of organizational capital (used as a proxy for corporate governance quality), stock liquidity, and asset profitability on corporate cash holdings.

Alongside technological resources, organizational capital represents a key source of value crea-tion. It reflects the ability of company management to make effective managerial decisions, structure cash flows, control operating expenses, and coordinate operational and technological processes using information technologies and internal resources. Because management exercises direct control over operating costs, positive or negative trends in this indicator serve as an indi-rect measure of managerial decision quality within the organization.

Management quality is reflected across all areas of corporate activity. A company's current fi-nancial condition and its development prospects are largely determined by the effectiveness of corporate governance. In particular, management influences the level of net assets and, to a cer-tain extent, the company's financial position and profitability.

Moreover, company management must take into account not only internal economic risks but also external risks associated with changes in national monetary policy and the imposition of international sanctions on Russian companies, which adversely affect production processes and the ability to meet obligations to creditors.

In February 2022, Western countries began introducing sanction packages against the Russian Federation. The initial restrictive measures were imposed immediately after Russia recognized the independence of the Donetsk and Luhansk People's Republics on February 21, 2022. Following the announcement of the special military operation, sanction pressure intensified.

Major Russian corporations, including Rosneft, Gazprom, and Rostelecom, were subjected to these restrictions. These public companies are included in the sample of the present study.

For potential investors, stock prices and stock liquidity are determined by the market value of assets and the profitability generated through their use in business operations.

In addition, profit constitutes the foundation of a company's financial sustainability, ensures solvency, and enables the implementation of an independent financial policy while maintaining control over development dynamics.

Particular attention should be given to the influence of the Bank of Russia's monetary policy on corporate activity. The tightening of monetary policy through increases in the key interest rate not only raises the cost of borrowed funds but also erodes corporate income through inflationary pressures. One of the key factors constraining financial performance is the elevated key interest rate, which generates an investment deficit across industries and extends project payback peri-ods. In other words, higher borrowing costs significantly limit investment activity and adversely affect corporate financial performance.

The average industry return on assets is several times lower than the key interest rate of the Bank of Russia. Specifically, the average ROA of Russian public companies amounts to 8.7%, whereas the interest rate in 2024 reached 21% (sample period: 2020–2024). For illustrative purposes, the average return on assets and the peak key interest rate observed in 2024 – a period included in the sample – are reported.

Under such conditions, Russian public companies tend to retain a portion of their cash holdings as a reserve in order to mitigate potential losses associated with limited access to the debt capital market, thereby acting in line with the precautionary motive.

Previous studies document the presence of a precautionary or saving motive in corporate cash holdings [Opler et al., 1999; Duchin, 2010; Harford et al., 2014; Cunha et al., 2020; Hong, Liu, 2023]. Other researchers report that the effect of earnings transparency on cash holdings is more pronounced in high-growth firms, as such companies typically maintain larger cash balances to address potential financial constraints [Bates et al., 2009]. Several studies indicate that precautionary cash reserves are particularly valuable, as they are more likely to be used to finance profitable investment projects [Faulkender, Wang, 2006; Pinkowitz, Williamson, 2007; Denis, Sibilkov, 2010; Liu, Wang, 2024]. These findings suggest that firms with lower earnings transparency tend to retain larger cash balances for precautionary purposes.

Financial constraints therefore represent a key reason why firms accumulate cash in accordance with the precautionary motive in order to reduce exposure to adverse future shocks [Keynes, 1936].

In real economic conditions, financial distress increases the cost of external financing, which encourages companies to accumulate internal funds in order to avoid reliance on expensive external capital. However, under financial constraints, investment sensitivity declines, indicating an incomplete realization of investment opportunities [Hennessy et al., 2007]. This implies that companies with stronger growth potential are more likely to forgo high-value investment opportunities as a result of financing constraints.

Consistent with the corporate finance literature, high-growth firms typically hold larger cash reserves than their competitors to support future growth opportunities [Kim et al., 1998; Opler et al., 1999].

It should also be noted that precautionary cash holdings are valued more highly in financially constrained firms [Faulkender, Wang, 2006; Pinkowitz, Williamson, 2007; Denis, Sibilkov, 2010] and in firms exposed to higher refinancing risk [Harford et al., 2014].

Unlike previous studies, the present research extends the analytical framework by incorporating not only traditional firm-level determinants – such as growth opportunities (Tobin's Q), invest-ment, financial leverage, return on assets, and firm size – but also organizational capital (used as a proxy for corporate governance quality) and stock liquidity in order to assess their combined effect on cash holdings within the precautionary motive framework.

A sample of Russian public companies was constructed for the period 2019–2024. The purpose of the sample was to examine the combined effect of organizational capital, stock liquidity, and return on assets on corporate cash holdings.

The sample includes Russian public companies from eleven sectors of the economy that prepare consolidated financial statements in accordance with International Financial Reporting Standards (IFRS). The shares of the sampled entities are traded on the Moscow Exchange. The companies represent the following industries: agriculture; oil and gas; food and chemical industries; ferrous and non-ferrous metallurgy; electric power; construction; trade; transportation; and telecommunications.

The observation period varies across companies (2019–2024 for some firms and 2020–2024 for others). The final sample consists of 25 companies. Econometric analysis was conducted using the Stata statistical software package.

The dependent variable in the regression model is cash holdings ratio (Cash_Holdings), which the author interprets as an indicator of corporate cash management.

Several independent variables were adopted from prior studies [Opler et al., 1999; Bates et al., 2009; Liu, Wang, 2024], including Tobin's Q, firm size, investment, financial leverage, and re-turn on assets.

To extend the scope of the analysis, organizational capital and stock liquidity were additionally included in the regression model.

Measurement of variables

Cash holdings (Cash_Holdings) are defined as the sum of cash and short-term investments scaled by total assets.

Tobin's Q (Q) is defined as the ratio of a company's market capitalization to the book value of equity.

Firm size (Assets) is measured as the natural logarithm of total assets. Fixed assets constitute a substantial component of corporate financial statements and play an important role in determining stock value, investment attractiveness, and stock liquidity.

Investment (Invest) is measured as capital expenditures on the acquisition and construction of tangible fixed assets and intangible assets scaled by total assets.

Financial leverage (Lev) is defined as the ratio of total debt – calculated as the sum of short-term and long-term liabilities – to total assets.

Return on assets (ROA) is calculated as net profit divided by total assets and serves as an indicator of the company's financial sustainability.

Organizational capital (OC) is defined as the ratio of administrative expenses, financial expenses, insurance costs, advertising expenditures, and other overhead costs to total assets.

This indicator serves as a proxy for corporate governance quality. Organizational capital captures the effectiveness of management in controlling operating expenses, as managerial oversight over operational costs enables the company to adjust to changes in its business environment.

Stock liquidity (Liquidity_Stock) is proxied by the natural logarithm of market capitalization.

The choice of this indicator is theoretically motivated by the liquidity framework proposed by [Amihud, 2002], which emphasizes that larger equity issues tend to exert a smaller price impact and are associated with narrower bid – ask spreads. Market indices are commonly constructed using capitalization-weighted components and include the most liquid shares of large and dynamically developing issuers operating in key sectors of the economy. In order to be actively traded on the stock market, a share must exhibit sufficient liquidity, possess market value, and demonstrate investment attractiveness in terms of expected returns.

A one-year lag is applied to all independent variables.

Table 1 presents summary statistics for Russian public companies.

On average, cash holdings account for approximately 11% of total assets. The capital structure of Russian public companies consists, on average, of 61% debt and 39% equity. Investment ex-penditures represent about 8% of total assets, while organizational capital amounts to approxi-mately 12% of assets. The average return on assets is 8.7%. Finally, the growth indicator, meas-ured by Tobin's Q, has an average value of 1.9.

To examine the joint effects of organizational capital, stock liquidity, and return on assets on corporate cash holdings management in Russian public companies, the following regression model is estimated:

$$Cash\_Holdings_t = a_0 + a_1(Q)_{t-1} + a_2(Assets)_{t-1} + a_3(Invest)_{t-1} + a_4(Lev)_{t-1} + a_5(ROA)_{t-1} + a_6(OC)_{t-1} + a_7(Liquidity\_Stock)_{t-1} + \varepsilon_t,$$

where t denotes the time period, a_0 is the intercept, a_1, a_2, a_3, a_3, a_4, a_5, a_6, a_7 are the estimated coefficients of the explanatory variables, ε represents the error term.

To evaluate the overall explanatory power of the model, several diagnostic tests were conducted.

The Wald test was applied to examine the null hypothesis of overall regression insignificance – that is, the hypothesis that the coefficients of the explanatory variables (*Q, Assets, Invest, Lev, ROA, OC, and Liquidity_Stock*) are jointly equal to zero.

The Wald test is based on the Wald statistic defined as $W=qF$, where F denotes the conventional F-statistic used for hypothesis testing, and q represents the number of linear restrictions imposed on the model parameters (in this case, $q = 7$). The Wald statistic follows an asymptotic χ^2 distribution with q degrees of freedom. The observed test statistic equals 4.7 (Prob > χ^2 = 0.000).

Accordingly, the null hypothesis that the coefficients of the explanatory variables are jointly equal to zero is rejected. The results indicate the joint statistical significance of the estimated regression coefficients.

The stationarity of the time series is examined using the Dickey – Fuller test with a constant and a trend. The results confirm that the variables are stationary, as the MacKinnon approximate p-values for the test statistics are below the 5% significance threshold. These findings support the reliability of the estimated regression relationships and indicate the presence of a stable long-run association between the explanatory variables – particularly organizational capital, stock liquidity, and return on assets – and corporate cash holdings.

Multicollinearity among the independent variables is evaluated using the variance inflation factor (VIF). A VIF value exceeding 10 is commonly viewed as indicative of severe multicollinearity. In the estimated model, the maximum VIF equals 6.92, while the average VIF across all explanatory variables is 3.11. These results indicate that multicollinearity does not pose a concern for the regression estimates.

Overall, the empirical results demonstrate that the proposed regression model is statistically ro-bust and provides a sound basis for analyzing and forecasting corporate cash holdings behavior under conditions of financial constraints.

The results of the regression analysis are presented in Table 2.

All independent variables, with the exception of firm size (Assets), are statistically significant at the 5% level.

Stock liquidity serves as an important informational signal for potential investors regarding a company's financial position. When making investment decisions, investors take into account stock market volatility as well as prevailing economic and political risks. In particular, tight monetary policy – reflected in the mismatch between the key interest rate and the average return on assets of Russian public companies – constrains corporate investment activity. Under such financial constraints, firms tend to curtail investment projects, which is reflected in the negative relationship between stock liquidity, investment, and cash holdings.

Table 1
Summary statistics

Variable	Mean	Standard deviation	Minimum	Maximum
Коэффициент управления денежными авуарами (денежный коэффициент)	0.111	0.072	0.01	0.3
Q Тобина	1.893	2.051	0.12	10.8
Величина компании	13.163	1.686	9.4	17.1
Инвестиции	0.083	0.053	0.00	0.28
Финансовый левериджй	0.611	0.236	0.17	1.00
Рентабельность активов	8.668	11.284	−30.6	44.1
Организационный капитал	0.171	0.144	0.02	0.61
Ликвидность акций	12.317	1.793	9.1	15.9

Note. Number of observations: 90.
Source: Author's calculations based on the Stata statistical software package.

Table 2
Regression analysis of cash holdings management:
The impact of organizational capital, stock liquidity,
and asset profitability

Independent variable	Coefficient	*t*-statistic	Significance level of *t*-statistic
Q	0.013	2.84	0.006
Assets	0.018	1.84	0.069
Invest	–0.445	–3.06	0.003
Lev	–0.129	–2.98	0.004
ROA	0.002	2.57	0.012
OC	0.121	2.31	0.023
Liquidity_Stock	–0.029	–2.97	0.004
Constant	0.282	4.14	0.000

Note. Number of observations 90; R^2 = 28.63%; F-statistic = 4.70 [p = 0.000].
Source: Author's calculations.

Within the precautionary motive framework, Russian public companies tend to accumulate cash reserves for subsequent use as internal funds when meeting obligations to creditors and adjusting their capital structure. This behavior is reflected in the negative relationship between financial leverage and cash holdings.

The author agrees with the position advanced by [Chen, Horstman, 2023], who argue that market prices incorporate information not only about a firm's current financial condition but also about its investment potential. This interpretation is supported by the positive relationship between Tobin's Q and cash holdings.

For investors, corporate governance quality plays a critical role, particularly the transparency of financial and operating activities and the reliability of indicators disclosed in IFRS-based finan-cial statements. This relationship is reflected in the positive association between organizational capital and cash holdings.

At the same time, the author does not share the view expressed by [Liu, Wang, 2024] that earn-ings transparency under IFRS is negatively related to cash holdings. On the contrary, managerial actions are directed not only toward controlling operating costs but also toward enhancing corporate profitability. Accordingly, investors expect that higher-quality and more effective business management will be associated with favorable corporate development prospects, which explains the positive relationship between organizational capital, return on assets, and cash holdings.

Through IFRS disclosure, the management of Russian public companies sends informational signals to investors under adverse external conditions – such as restrictive economic policy and external sanctions [Lutsenko, 2020] – that affect firms' financial positions and, ultimately, stock prices. This mechanism is reflected in the negative relationship between stock liquidity, financial leverage, and cash holdings.

It should also be noted that firms with stronger growth prospects tend to maintain larger cash reserves than their competitors in order to finance future growth opportunities. This tendency is reflected in the positive relationship between Tobin's Q, return on assets, and cash holdings.

Finally, under conditions of financial constraints and high borrowing costs, Russian public com-panies are expected to behave in line with the precautionary motive by accumulating cash re-serves and relying on internal funds for the subsequent financing of investment projects. This behavior is reflected in the negative relationship between financial leverage, investment, and cash holdings.

In this study, an attempt is made to examine the combined effects of organizational capital, stock liquidity, and return on assets on corporate cash holdings management within the precautionary motive framework. Under conditions of elevated funding costs, Russian public companies increasingly rely on internal reserves, retaining a portion of cash for future investment financing. High-quality and effective corporate governance contributes not only to higher profitability but also to greater asset value. Investors, in turn, expect corporate financial statements to reflect objective and economically meaningful performance indicators. Stock liquidity remains an important benchmark and informational reference in the evaluation of investment returns. When investing in equity securities, investors independently assess liquidity conditions. Consequently, investors seeking positive returns consider a range of factors, including stock market instability, price volatility, and the stance of monetary policy, as equity investment inherently involves both potential gains and the risk of losses.

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Digital Transformation of Industry: Stable Drivers and Contextual Growth Factors

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Abstract

Digital transformation is recognized as a key driver of industrial development; however, its impact in combination with other factors remains understudied. The objective of the study is to assess the influence of digital transformation, investment, sociodemographic, and structural factors on the development of manufacturing enterprises. This study presents an empirical analysis of the determinants of manufacturing growth in 78 Russian regions from 2013 to 2023. The methodological framework is based on panel regression modeling. The model incorporates an integrated digitalization index, indicators of internet infrastructure (broadband access), as well as variables characterizing fixed capital investment, R&D expenditures, the industry's share in GRP, urbanization, student population, and employment. Specification tests (Breusch-Pagan and Hausman) confirmed the adequacy of the two-way fixed effects model. The study results identified three groups of determinants. Stable drivers include the digitalization index, internet infrastructure development, and fixed capital investment, all of which have a consistently positive effect. The influence of employment, urbanization, and educational potential is contextual: interregional differences correlate positively with output, whereas intraregional growth over time is associated with lower productivity, indicating structural shifts and time lags. R&D expenditures show a positive effect in interregional comparisons but are insignificant or negative in short-term intraregional dynamics. The findings highlight the priority of government and corporate policies aimed at developing digital infrastructure and stimulating technological investment as the most reliable factors of industrial growth.

Keywords: digitalization, industrial growth, manufacturing, econometric modeling, panel data, growth determinants, investment, sociodemographic drivers, structural factor

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工业数字化转型：稳定的驱动力与情境情境生长因子

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摘要

数字化转型被认为是工业增长的关键驱动力，然而，结合其他因素对其影响进行全面的定量评估仍然没有得到充分的研究。本研究的目的是对数字化转型、投资、社会人口和结构因素对制造企业发展的影响进行评估。方法学是根据俄罗斯78个地区2013 — 2023年的面板数据回归分析。在模拟过程中，使用了以下内容：数字化积分指数、互联网基础设施发展指标（宽带接入）以及表征固定资产投资的变量、研发费用、区域生产总值内行业份额、城市化、学生人口和就业率。规格检验（布鲁薛—培根/BP检验、豪斯曼/Hausman检验）证实了具有双向固定效应的模型的充分性。研究结果揭示了三组决定因素。稳定的驱动因素包括：数字化指数、互联网基础设施发展以及固定资产投资。这些一直有积极的影响。就业、城市化和教育潜力的影响是情境性的：它们的区域间差异与产品产出呈正相关，然而区域内增长随时间推移与生产力下降相关。这表明存在结构性转变和时滞。研发费用在区域间比较中显示出积极效果，然而短期区域内动态变化在统计学上不显著或为负值。该研究结果强调，政府和企业应优先采取政策措施，发展数字基础设施并刺激技术投资，因为这是产业增长最可靠的因素。
关键词：数字化、产业增长、加工工业、经济模型、面板数据、增长决定因素、投资、社会人口驱动力、结构因素。

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Introduction

The dynamic processes of digital transformation are shaping a new paradigm of industrial development. This paradigm is marked by changes in production systems, management structures, and models of interaction between enterprises. The adoption of digital technologies – from artificial intelligence and the Internet of Things to cloud solutions and big data analytics – has become a key driver of more efficient production processes and enhanced enterprise competitiveness. At the same time, digital transformation in industry goes far beyond technological upgrades. It spans a wide range of institutional, organizational, investment, and socioeconomic dimensions, forming an integrated system of factors that influence regional development.

In recent years, interest in the digitalization of industry has grown markedly in the academic literature. This is reflected both in the growing number of publications and in the diversification of research themes. However, despite a substantial body of theoretical and empirical work, important questions remain. In particular, there is still limited quantitative evidence on how digital transformation affects industrial development, and how it interacts with related factors such as investment, employment, and educational and innovation potential. These issues become especially salient in the context of regional heterogeneity. Differences in digital maturity, infrastructure, and institutional conditions lead to uneven regional readiness for the adoption of digital solutions, which calls for a more in-depth analysis of their combined effect on industrial performance.

Against this background, the aim of this study is to conduct an econometric assessment of the impact of digital transformation processes, together with investment, sociodemographic, and structural factors, on the performance of manufacturing enterprises.

1. Literature Review

Recent research increasingly emphasizes the importance of digitalization and digital transformation in industry for both technological and institutional – organizational processes that are shaping a new paradigm of regional development. As shown in [Tanina et al., 2022], targeted policy measures play a decisive role, including infrastructure expansion, the promotion of digital platforms, subsidies for IT solutions, and the establishment of regional competence centers. These findings are consistent with the results reported in [Grachev et al., 2020], where the authors examined the relationship between regional industrial development indicators (industrial production index) and the digitalization index of the corresponding region. They concluded that digital maturity is spatially heterogeneous across regions and that industrial policy needs to be adjusted to reflect differences in technological development.

A significant contribution to the study of the socioeconomic effects of digitalization comes from research on sustainable regional development. According to [Mirolyubova, Voronchikhina, 2022], digital transformation enhances environmental, economic, and social sustainability, provided that infrastructural and organizational components of the digital environment develop in a balanced manner. In a related study, [Mirolyubova, Radionova, 2021] show that digital growth factors – digital capital and digital labor – together with traditional factors exert a pronounced influence on regional economic growth. However, the strength of this effect varies depending on the sectoral structure of the economy and the quality of human capital.

In contemporary studies of regional economic growth [Gorbach, Seminog, 2019; Raetskiy, Tereshchenko, 2025], particular attention is paid to the role of fixed capital investment, R&D activity, educational potential, and labor-related factors. For example, a large number of students in a region is indicative of high educational potential and a well-qualified workforce, which in turn facilitates the adoption of new technologies, improves productivity, and contributes to GRP growth. Furthermore, the hypotheses regarding the relevance of economic structure for growth analysis are confirmed in [Kolomak, 2012; Ahmad et al., 2013]. A higher industrial share is found to correlate with faster economic growth [Ahmad et al., 2013], while a 1% increase in the share of the urban population raises average regional productivity by approximately 8% [Kolomak, 2012].

The impact of broadband Internet development on regional economic growth in Russia is confirmed in [Imasheva, Kramin, 2019]. The model presented in that study, based on a Solow-type production function, shows positive GRP elasticity with respect to internet infrastructure indicators. The authors conclude that accelerated broadband expansion acts as a factor stimulating regional economic growth.

At the microlevel, specific digital assets and competencies of enterprises themselves are direct drivers of industrial growth. Empirical evidence confirms that digital technologies are among the key factors influencing labor productivity growth [Milekhina, Adova, 2025]. The publication [Bessonova, Battalov, 2020] emphasizes that digitalization is a core instrument of innovative development, creating conditions for new business models, flexible production systems, and technological entrepreneurship. At the same time, a high level of enterprise readiness for automation is directly linked to the quality of digital infrastructure and access to advanced technologies [Krakovskaya, Korokoshko, 2021]. In particular, the introduction of digital platforms generates sustainable competitive advantages for industrial companies [Trachuk, Linder, 2023a], enhancing both operational efficiency and resilience to sanctions-related pressure [Trachuk, Linder, 2023b].

Effective management of digital transformation requires the development of adequate diagnostic systems. The study [Chursin, Kokuytseva, 2022] proposes a methodology for assessing enterprise digital maturity that takes into account regional specificities, thereby making it possible to identify differences in the pace of digitalization and industrial performance. Building on this approach, [Ilkevich, 2024] develops conceptual foundations for constructing digital transformation indices, which enable comparative analysis and the identification of growth points for industrial assets, thereby supporting more informed managerial decision-making.

Financial resources – and their efficiency and accessibility – represent another important aspect of industrial growth, undergoing transformation in the digital era through new instruments and services. The publication [Zeleneva, 2023] systematizes digital innovations in the financial sector that underpin new models of financing real-sector production. In this context, [Krylova, 2024] analyzes digital currencies as a mechanism for ensuring uninterrupted cross-border settlements under sanctions, which directly affects the resilience of international industrial value chains. As intangible assets become key resources of industrial companies, the accurate valuation of digital intellectual assets becomes critically important for attracting investment and determining the market value of enterprises [Loseva et al., 2022]. Finally, [Bauer et al., 2021] examine the financial mechanisms of platform companies, whose activities shape new competitive landscapes and indirectly stimulate traditional industries to pursue digital adaptation.

Government policy constitutes a separate and powerful driver of contemporary digital transformation processes, aimed at reducing spatial disparities in digital maturity and fostering digitalization. The study [Muzalyov et al., 2025] proposes improvements to the system of criteria used to evaluate industrial policy, allowing for a more accurate measurement of its contribution to sectoral development and digitalization under sanctions. The publication [Borisova et al., 2025] further specifies this approach by focusing on financial support measures for the implementation of industrial robotic systems – key elements of Industry 4.0 – and by analyzing risk factors that influence the cost of such projects. The work [Zotov, Abdikeev, 2021] complements this group of studies by describing new technologies for managing innovation financing as instruments for directly stimulating technological renewal in industry. These measures are directly aligned with the conclusions of [Tanina et al., 2022] regarding the need for targeted government support aimed at infrastructure development, digital-platform promotion, and IT-solution subsidies.

Taken together, the reviewed studies confirm the growing importance of digital technologies as a systemic factor of industrial growth and reinforce the relevance of the present research. At the same time, despite the extensive coverage of digitalization-related issues, the existing literature does not fully address the combined impact of digital, investment, social, and structural factors on the development of manufacturing enterprises.

2. Variables, Data, and Methodology

Guided by the research objective and the findings of the literature review, we selected a set of variables for subsequent analysis and inclusion in the econometric model. The dependent variable is the volume of shipped manufacturing goods per capita (in constant 2013 prices), which is used as an aggregate indicator of both the efficiency and the achieved level of development of manufacturing enterprises in each region. The independent variables were chosen to capture institutional, social, and economic dimensions as comprehensively as possible, including regional structural characteristics, innovation and human potential, institutional quality, and technological readiness for the adoption of digital technologies.

On this basis, we constructed a panel dataset using the variables summarized in Table 1, with a temporal dimension ($T = 11$, (2013–2023) and a cross-sectional dimension $n = 78$ regions. The primary data source is the official website of the Federal State Statistics Service (Rosstat).

To characterize the development of internet infrastructure, we use the variable *BIA* which reflects the use of broadband internet access (Table 1). This indicator is treated as a key component of a region's digital infrastructure, providing the technological foundation for the adoption of more advanced digital solutions, which are captured in the integrated digitalization index (*DT*).

The variable "integration of digital technologies" (*DT*) is a composite index constructed from five indicators representing the share of enterprises, expressed in fractions of one, that used: (1) big-data collection, processing, and analytics technologies; (2) the Internet of Things; (3) cloud services; (4) artificial-intelligence technologies; (5) digital platforms. These indicators are aggregated using the geometric mean. To avoid zero values in some components of the index, all underlying indicators were first shifted upward by one unit.

All absolute economic variables were (1) deflated, (2) converted to per capita values, and (3) log-transformed to reduce skewness. Other variables expressed as percentages or ratios were standardized using z-normalization.

The modeling proceeded in several stages. As an initial diagnostic step, pairwise correlation coefficients and

Table 1
Descriptive statistics of variables

Variable	Symbol	Unit	Mean	Min	Max	SD
Manufacturing output	*MI*	rub./cap. × 10^3 (2013 prices)	181.57	0.91	1,029.0	137.16
Integration of digital technologies	*DT*	composite index	1.08	1.00	1.3	0.07
Use of broadband internet access in organizations	*BIA*	%	78.33	29.00	97.7	9.80
R&D expenditures	*RD*	rub./cap. (2013 prices)	2,496.95	74.12	21,710.5	3,574.31
Share of industry in GRP	*share_MI*	%	52.82	0.57	163.6	31.81
Share of urban population	*UP*	%	70.21	29.60	100.0	12.86
Fixed capital investment	*FCI*	rub./cap. (2013 prices)	83,228.64	19,650.0	497,473.3	73,388.0
Number of students	*SP*	per 10,000 persons	268.40	31.19	737.0	102.94
Employment rate	*EP*	%	75.49	41.00	85.9	6.18

Note. Mean – average value, Min/Max – minimum and maximum values, respectively, SD – standard deviation.
Source: Author's calculations.

variance inflation factors (VIF) were calculated to identify potential multicollinearity issues typical of panel data.

The functional relationship between the selected variables was then analyzed using the following regression specification:

$$MI_{it} = \beta_0 + \beta_1 DT_{it} + \beta_2 BIA_{it} + \beta_3 RD_{it} + \beta_4 share\_MI_{it} + \\ + \beta_5 UP_{it} + \beta_6 FCI_{it} + B_7 SP_{it} + \beta_8 EP_{it} + \varepsilon_{it}, \quad (1)$$

where t denotes the time period ($t = \overline{1,T}$), and i denotes the region $(i = \overline{1,n})$, ($\beta_0 \ldots \beta_8$) are the estimated coefficients, and ε_{it} is the error term.

ДRegression estimates were obtained using three alternative econometric approaches: Ordinary Least Squares (OLS), the Random-Effects (RE) model, and the Fixed-Effects (FE) model. The choice of these estimators reflects the panel structure of the data and allows us to account for both within-region and between-region variation. The OLS model serves as a benchmark, while the RE and FE models control for unobserved heterogeneity across regions and over time. The final model specification (OLS, RE, or FE) was selected on the basis of the Breusch–Pagan Lagrange Multiplier test, the Hausman test, and tests for the joint significance of time dummy variables.

3. Results

To identify potential sources of spurious regression, we assessed the quality of the panel dataset. The presence of multicollinearity was examined using pairwise correlation coefficients and the variance inflation factor (VIF) (Table 2).

As shown in Table 2, the maximum pairwise correlation coefficient was 0.67 (between manufacturing output per capita and the employment rate). Thus, no pair of factors exhibits an extremely high correlation (0.9), indicating that strong linear dependence between variables was not detected. The calculated VIF values ranged from 1.29 to 2.87, which does not exceed the critical threshold of 5. Based on both tests, no substantial multicollinearity was found among the explanatory variables, confirming the appropriateness of including all selected variables in the modeling procedure.

The results of the regression analysis (Table 3) indicate a measurable impact of digitalization and other factors on manufacturing output. Overall, integration of digital technologies (*DT*) has a positive and statistically significant effect on industrial output across all model specifications. In the pooled OLS model, the coefficient for *DT* equals approximately 1.03 ($p < 0.01$), while in models with regional random or fixed effects it ranges from 0.59 to 0.62 ($p < 0.01$), and in the two-way fixed-effects model it equals 0.315 ($p < 0.05$). The positive sign of the coefficients suggests that higher levels of digitalization (adoption of big

Table 2
Correlation matrix and VIF for variables

Variable	*MI*	*DT*	*BIA*	*RD*	*share_MI*	*UP*	*FCI*	*SP*	*EP*	*VIF*
MI	1.00									—
DT	0.13	1.00								1.51
BIA	0.22	–0.42	1.00							1.42
RD	0.52	0.02	0.11	1.00						1.96
share_MI	0.65	0.08	0.15	0.26	1.00					1.74
UP	0.64	0.05	0.14	0.62	0.33	1.00				2.51
FCI	0.29	0.04	0.05	0.43	–0.11	0.44	1.00			1.72
SP	0.05	–0.25	0.04	0.23	–0.03	0.17	–0.10	1.00		1.29
EP	0.67	0.18	0.23	0.52	0.53	0.58	0.36	0.09	1.00	2.87

Source: Author’s calculations.

Table 3
Results of regression analysis

Variable	Pooled OLS	Random effects	Fixed-effects models		
DT	1.031* (0.3195)	0.593* (0.1540)	0.619* (0.1522)	1.722** (0.9893)	0.315** (0.4173)
BIA	0.689* (0.2135)	0.205** (0.0922)	0.181** (0.0894)	1.089* (0.2833)	0.259* (0.1236)
RD	0.041** (0.0205)	0.047*** (0.0289)	–0.014*** (0.0319)	0.037* (0.0208)	–0.007*** (0.0774)
share_MI	2.068* (0.0728)	2.453* (0.0729)	2.454* (0.0757)	2.026* (0.0753)	2.497* (0.077)
UP	1.667* (0.2162)	2.289* (0.4492)	–2.843* (0.9323)	1.638* (0.2162)	–3.112* (0.9311)
FCI	0.324* (0.0387)	0.177* (0.0301)	0.127* (0.0304)	0.312* (0.0397)	0.117* (0.0315)
SP	0.095** (0.0489)	–0.270* (0.5015)	–0.380* (0.0519)	0.934** (0.0586)	–0.343* (0.079)
EP	4.883* (0.4809)	0.348*** (0.3719)	0.139*** (0.1721)	5.068* (0.4961)	–0.475** (0.423)
Constant	–7.239* (0.6713)	–0.010*** (0.6121)	5.692* (0.9224)	–8.174* (1.0822)	6.405* (1.0897)
R^2	0.8162	0.7546	0.9808	0.8194	0.9815
Year fixed effects	—	—	—	+	+
Individual fixed effects	—	—	+	—	+

Note. Standard errors are given in parentheses, * – $p < 0.01$, ** – $p < 0.05$, *** – $p < 0.1$.
Source: Author’s calculations.

data, the Internet of Things, artificial intelligence, cloud services, and digital platforms by enterprises) are associated with increased manufacturing output. Hence, regions that are more active in integrating modern digital technologies demonstrate higher manufacturing output per capita. The effect is also observed over time within regions: an increase in the digitalization index over time corresponds to higher output, although the magnitude of this effect is smaller than in cross-regional comparisons, reflecting structural differences across regions.

Similarly, broadband internet access in organizations (*BIA*) exerts a positive influence on output. In the OLS model, the coefficient for *BIA* is 0.689 ($p < 0.01$). In models accounting for regional effects, the impact of BIA remains positive (β ≈ 0.18–1.09, statistically significant at $p < 0.05$). These findings confirm that improvements in digital infrastructure contribute to higher industrial productivity and output levels.

show a positive association with manufacturing output in cross-regional comparison but a less consistent effect in within-region dynamics. In the OLS model, the coefficient for *RD* is positive (0.041, $p < 0.05$), suggesting that regions with higher R&D spending tend to exhibit greater manufacturing output, likely due to enhanced innovation and technological capacity. The random-effects model yields a similar result (0.047, $p < 0.1$). However, in the fixed-effects models, the sign of the coefficient becomes negative or statistically insignificant (e.g., β ≈ −0.007 in the two-way fixed-effects model). This indicates that increases in R&D spending within the same region do not immediately lead to higher manufacturing output. Economically, this may reflect the time lag of innovation returns, as R&D investments typically yield results in the long term; in the short term, the relationship with current output may be weak or even negative if resources are temporarily redirected from production to research. Nevertheless, the consistently positive cross-regional correlation between RD and output underscores the long-term importance of innovation activity for industrial development.

Fixed capital investment (*FCI*) exerts a strong and positive influence on manufacturing output and remains statistically significant in all specifications. In the OLS model, the coefficient for *FCI* equals 0.324 ($p < 0.01$), and in the two-way fixed-effects model it equals 0.117 ($p < 0.01$). These coefficients can be interpreted as elasticities: for example, a coefficient of 0.117 implies that a 1% increase in fixed capital investment is associated with approximately a 0.12% increase in manufacturing output. Although the magnitude of the effect decreases after controlling for fixed effects (compared with the cross-regional estimate of 0.324), it remains statistically significant. This result indicates that the expansion of production assets – such as equipment modernization and new facility construction – directly contributes to output growth. Both cross-regional and intra-regional variations in investment confirm the central role of fixed capital accumulation in the development of the manufacturing sector.

The employment rate (*EP*) exhibits a notable discrepancy between model specifications. In the pooled OLS model, the coefficient for *EP* is large (+4.883) and statistically significant ($p < 0.01$), suggesting that a higher employment share is associated with substantially higher manufacturing output per capita – consistent with the notion that industrially developed regions typically maintain high employment levels. However, after accounting for unobserved regional and temporal effects, the coefficient value declines sharply: in the random- and fixed-effects models, it falls to +0.348 ($p < 0.1$) and +0.139 ($p < 0.1$), respectively, while in the two-way fixed-effects model it becomes negative (−0.475, $p < 0.05$). In other words, once constant regional and temporal characteristics are controlled for, the relationship between employment and output turns negative. Economically, this may imply that simply increasing the employment share within a region does not necessarily boost manufacturing output. Periods of rising employment may coincide with lower productivity in industry – for example, if new jobs are concentrated in less productive sectors or if output growth stems from technological factors such as automation and process optimization, which allow for higher output without a proportional increase in employment. This finding highlights that expanding industrial production depends less on the quantity of employed workers than on labor productivity and the adoption of advanced, including digital, technologies.

Beyond digitalization, investment, and employment, structural and socio-economic factors also play a significant role. The share of manufacturing in GRP (*share_MI*) unsurprisingly has a positive coefficient across all models (approximately 2.0–2.5, $p < 0.01$). Greater industrialization – measured by a higher industrial-sector share – is associated with higher manufacturing output, which is consistent with economic theory on sectoral structure.

The share of urban population (*UP*) exhibits mixed effects. Across regions, more urbanized territories display higher manufacturing output (coefficients 1.67–2.29 in OLS and RE models, $p < 0.01$), suggesting that higher urbanization typically coincides with a developed industrial base, better infrastructure, and agglomeration effects. However, the panel analysis within regions reveals the opposite pattern: in the regional fixed-effects model, the coefficient for *UP* becomes negative (−2.84, $p < 0.01$) and remains negative (−3.11, $p < 0.01$) when time effects are included. Thus, within a region, an increase in the urban population over time does not lead to higher manufacturing output but rather corresponds to a decline in output per capita. A possible explanation lies in ongoing structural changes in regional economies: as the service sector grows in cities, resources may shift away from industry, or population concentration in large urban centers may not be accompanied by industrial expansion. Historically, urbanization drove industrial growth, but in the current context, further urban growth alone does not guarantee higher industrial production without targeted industrial policies.

The number of students (*SP*), reflecting human-capital development, also demonstrates a dual effect. In the OLS model, the coefficient for *SP* is small and positive (0.095, $p < 0.05$), indicating that regions with higher university enrollment tend to show slightly greater output, partly due to the presence of universities and the training of skilled industrial personnel. However, in the fixed-effects models, the coefficient becomes negative and statistically significant (about −0.38 in the regional FE model and −0.34 in the two-way FE model, $p < 0.01$). This may indicate that a short-term increase in the number of students within a given region corresponds to a temporary decrease in manufacturing output, as part of the young population is engaged in study rather than production. Moreover, regions actively expanding their educational sector may be undergoing structural transformations, with human-capital growth translating into employment in non-industrial sectors such as services or research. In the long term, however, the availability of a qualified workforce remains essential for innovation and productivity, even if the short-term relationship appears negative.

Overall, the regression results make it possible to identify three groups of determinants of industrial development: stable drivers of production efficiency, which include digitalization, internet infrastructure, and fixed capital investment; context-dependent factors, such as employment, urbanization, and educational potential; and a structural factor reflecting established industrial specialization, namely the share of manufacturing in GRP. The positive coefficients for digital technologies and investment confirm the hypothesis about the stimulating influence of digitalization and capital intensity on industrial performance. At the same time, the mixed signs of *EP*, *UP*, and *SP* across OLS and fixed-effects

Table 4
Results of specification selection tests for the panel data model

Test	Compared models	Test statistic, *p*-value
Breusch–Pagan Lagrange Multiplier test	Pooled regression vs. random-effects model	chibar2(01) = 2894.50 Prob > chibar2 = 0.0000
Hausman test	Random-effects model vs. two-way fixed-effects model	chi2(8) = 90.48 Prob > chi2 = 0.0000
Significance test for time dummy variables	Model with individual fixed effects vs. two-way fixed-effects model	F (10, 762) = 2.88 Prob > F = 0.0015
Significance test for individual (regional) effects	Model with year fixed effects vs. two-way fixed-effects model	F (77, 762) = 86.52 Prob > F = 0.0000

Source: Author's calculations.

models underscore the need to account for regional and temporal heterogeneity when analyzing such factors.

All estimated models demonstrate a high level of explanatory power and are statistically significant. For instance, the coefficient of determination for the OLS model (R^2 = 81.62%) indicates that 81.62% of the variation in manufacturing output is explained by the included factors. However, this model ignores regional heterogeneity – historical, geographical, and infrastructural characteristics that affect both digitalization and output levels. If such omitted regional factors correlate with the included variables, OLS estimates may be biased. Models that account for regional (individual) effects also show high R^2 values, ranging from 0.7546 to 0.9815. Therefore, to determine the optimal econometric specification for the panel dataset, a series of specification tests was conducted (Table 4).

Using the Breusch – Pagan Lagrange Multiplier test, we compared the pooled OLS regression with the random-effects model. The resulting statistic (chibar^2 = 2894.5, p = 0.0000) clearly rejects the null hypothesis of no individual effects. In other words, panel heterogeneity across regions is statistically significant, which makes the pooled OLS model inapplicable. This indicates the presence of persistent regional differences (for instance, in development level, resource base, and institutional environment) that influence manufacturing output, and ignoring them would lead to biased estimates. Therefore, preference should be given to a model that accounts for region-specific effects.

To choose between the random-effects and fixed-effects specifications, the Hausman test was applied to verify the null hypothesis that the random-effects model is preferable to the alternative fixed-effects model. The test statistic (chi^2 (8) = 90.48, p = 0.0000) rejects the null hypothesis of consistency of random-effects estimates at the 1% level. This means that the random-effects model is inappropriate for the analyzed sample, as the individual (regional) effects are correlated with the included regressors. Consequently, the random-effects estimates are biased, and the fixed-effects model is more suitable, as it captures unobservable regional characteristics without assuming their independence from digitalization factors and other variables

The relevance of including temporal (year) fixed effects in addition to regional ones was also tested. When comparing the single-factor fixed-effects model (regions only) with the two-factor model (regions and years), the F-statistic for year effects (F (10, 762) = 2.88, p = 0.0015) indicated that the inclusion of time dummies is statistically significant. Accounting for temporal specificity (for example, macroeconomic conditions of each year) substantially improves the model's explanatory power. Similarly, the test of individual (regional) effects – comparing the model with year effects only and the two-way fixed-effects model – yielded F (77, 762) = 86.52 with p = 0.0000, confirming the necessity of regional fixed effects. Both tests indicate that the optimal specification is the two-way fixed-effects model, which captures both the unique characteristics of each region and the common annual shocks.

Taken together, the tests and coefficient diagnostics suggest that, to correctly identify causal relationships, the preferred specification is the two-way fixed-effects model by region and year. This specification explains the largest share of variation in the dependent variable ($R^2 = 0.9815$) by accounting for unobserved heterogeneity across both dimensions. Thus, the two-way fixed-effects model provides the most robust conclusions regarding the impact of digitalization and other factors on manufacturing output.

4. Conclusions and Limitations

The analysis of academic literature on the development of industrial enterprises in the digital transformation era confirms their strong interdependence: digital transformation acts as a driver of efficiency, while successful enterprises, in turn, possess greater capacity for further digital investment.

This study examined the relationship between digital transformation and manufacturing development across Russian regions for the period 2013–2023. The application of the least-squares method, random- and fixed-effects models, and a series of diagnostic and specification tests confirmed that manufacturing output per capita is closely associated with the variables included in the analysis, each of which directly or indirectly reflects digital transformation processes. Depending on the specification, the models explain between 75.5% (random-effects model) and 98.2% (two-way fixed-effects model) of the variation in the dependent variable.

The key determinants of industrial development can be grouped as follows:

(1) Stable drivers of production efficiency – digital transformation, internet infrastructure, and fixed capital investment – represent the investment-digital profile of industrial growth, exerting consistently positive effects on output both in cross-sectional and dynamic terms;

(2) Context-dependent factors – employment, urbanization, and educational potential – represent the socio-demographic profile, whose effects are heterogeneous and vary depending on the dimension of analysis, indicating the complexity and nonlinearity of their relationship with manufacturing output;

(3) Structural factor of industrial specialization – the share of manufacturing in GRP – reflects the structural-economic profile and serves as an indicator of established industrial specialization within the region.

The integration of advanced digital technologies (big data, the Internet of Things, artificial intelligence, and others) into production processes has a statistically significant positive impact on manufacturing output. Widespread broadband internet use by enterprises also contributes to higher productivity and output levels. These findings are consistent with the premise that digital transformation enhances production efficiency by optimizing processes, improving coordination across supply chains, and leveraging data analytics for quality management and process innovation. High levels of investment in production facilities, infrastructure, and technology promote growth in both cross-regional and temporal dimensions, confirming the crucial role of capital accumulation for manufacturing development. Thus, the use of digital technologies, the availability of supporting infrastructure, and sufficient financial capacity for their implementation are among the most important drivers of industrial growth.

Despite the empirical evidence confirming the relationship between the performance of the manufacturing industry and the factors directly or indirectly related to the adoption of digital technologies, the present study has certain limitations. The aggregate nature of the digital technology integration index (DT) at this stage does not allow for assessing the influence of each individual component on the dependent variable. In addition, the quantitative nature of this index may overlook equally important qualitative aspects, such as the ethics of digital technology implementation, data security issues, and other similar dimensions. Considering the complexity and multidimensional character of the phenomena under study, future research should explore the potential existence of a nonlinear relationship between the dependent and independent variables, take into account possible time lags between actions taken and the achievement of measurable results, and expand the range of explanatory variables.

The results of this study provide a more solid basis for designing measures to promote the adoption of digital technologies in manufacturing enterprises. They may also be of value both to the academic community – in terms of developing the theory of the digital economy and industrial policy – and to government authorities responsible for shaping the strategy of digital transformation for regions and the industrial sector.

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Offset Transactions as Part of the Import Substitution Strategy for Industrial Gas Infrastructure

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Abstract

This article examines the legal and technical potential of offset agreements as a strategic tool for addressing the gasification of domestic industrial facilities under the restrictions imposed by nineteen rounds of sanctions. The relevance of this study stems from the need to ensure energy independence and sustainable development of Russian enterprises in a drastically altered foreign economic environment. The authors analyze the legal nature of offset agreements and their advantages in aligning the interests of the state (as a guarantor of demand) and private businesses (as investors and contractors), particularly against the backdrop of global gas market dynamics among producing and consuming countries. Particular attention is given to mechanisms enabling localization of gas equipment production and infrastructure construction in exchange for long-term government contracts. It is shown that this model of interaction can support the gas industry, serve as a catalyst for import substitution, stimulate interregional cooperation, and meet projected energy demand. The paper also identifies key risks and administrative barriers hindering the widespread use of offsets and offers practical recommendations for adapting this mechanism to accelerate gasification of the real sector of the economy. This study may be of interest to government officials, industrial managers, entrepreneurs, and experts in energy and public-private partnerships. The article concludes with several findings illustrated by examples.

Keywords: gasification and pre-gasification, offset transaction, sanctions-related pressure, gas production cluster, underground gas storage, Asian focus of interests

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抵消交易作为工业天然气基础设施的进口替代战略一个要素

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摘要

本文探讨了在十九项制裁措施的限制下，抵消交易作为解决国内工业设施气化问题的战略工具的法律和技术潜力。该研究的相关性取决于在外部经济环境剧烈变化的情况下确保俄罗斯企业能源独立和可持续发展的必要性。在全球天然气市场生产国和消费国之间发生的各种进程的背景下，作者分析了抵消协议的法律性质、它们在协调国家的（作为偿付能力需求的担保人）利益方面具有优势　以及各种所有制形式的企业（作为投资者和执行者）。特别关注的是通过长期政府合同，实现天然气设备生产和基础设施建设本地化的机制。事实证明，这种经济实体间的互动模式能够支撑天然气行业的发展、成为进口替代的催化剂、促进区域间合作与创新应用技术的发展、确保预计的能源需求。该文还指出了阻碍抵消交易广泛应用的关键风险和管理障碍，而且为调整此类协议以加速实体经济部门的气化转型提供切实可行的建议。该出版物可能对政府官员、工业管理者以及能源和公私合作领域的专家有所帮助。文章附有结论，并辅以实例说明。

关键词： 气化和补充气化、抵消交易、制裁压力、天然气产业集群、地下储气库、亚洲兴趣矢量。

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Introduction

Following the adoption of the nineteenth sanctions package by the European Union, the number of restrictions imposed against Russia has exceeded 30,000 – a record that now ranks among the most severe in the world. Preparations for a twentieth package are already underway. The negative impact of such restrictions on any national economy is self-evident, though not always catastrophic. However, any passive or inadequate response to sanctions pressure, particularly where it affects the domestic oil and gas sector, is unacceptable. Swift and deliberate countermeasures – both symmetrical and asymmetrical, or, in diplomatic terms, even disproportionate – are urgently required.

In several recent publications, the authors have drawn attention to the strategic importance of utilizing surplus volumes of natural gas to expand gasification and gas network extension initatives for domestic industrial enterprises across various sectors. This approach fully complements, rather than hinders, the ongoing nationwide program for social gasification [Bykov, Tsatsulin, 2025].

Currently, *Gazprom Group* and *Gazprom Mezhregiongaz LLC* are implementing a large-scale social gasification program. As part of this initiative, approximately 1.5 million applica-tions have been submitted to enable technical connections to gas distribution networks (GDN) for households, apartment buildings, boiler houses, and social and industrial facilities[1]. Yet, the share of applications from industrial enterprises – both new and expanding – in the real sector of the economy remains extremely small, amounting officially to only a few dozen cases.

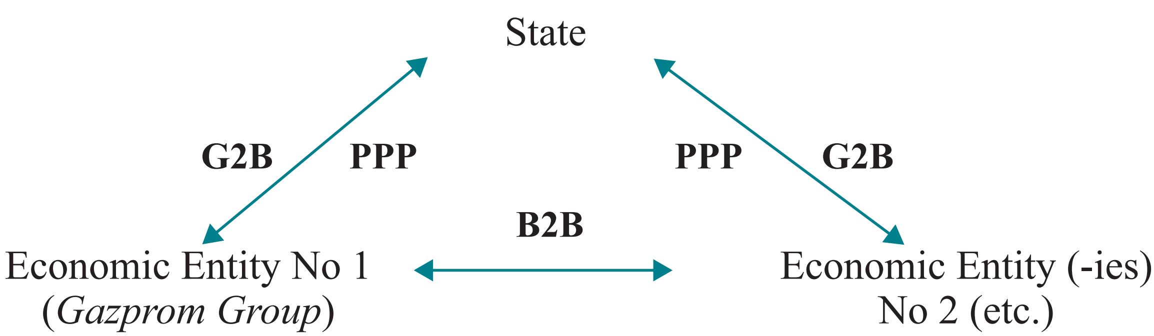
To address this low level of business engagement in submitting applications and imple-menting their own investment projects, and to overcome widespread concerns about the financial risks of participation, the *Gazprom Group* could launch a new Industrial Gasification Program. The concept behind this initiative represents a new strategic approach that introduces an innovative organizational mechanism for cooperation – one that has so far seen limited use in domestic economic practice.

This mechanism draws on the logic of B2B partnership models but in a more complex, structured form (Figure 1), under continuous state supervision [Tretyakova, Adamenko, 2025]. It integrates key elements of public – private partnership (PPP) arrangements[2, 3] and reflects the contractual framework of concession agreements[4]. The resulting model aligns closely with the principles of a long-term commercial agreement implemented through an offset transaction [Diveeva, 2014].

1. Problem Statement, Research Objectives, and Tasks

In the authors' interpretation, an offset transaction (also referred to as an offset agreement, contract, or arrangement) represents, in essence, the state's consent to the viability of a set of reciprocal investment obligations. Under such an arrangement, one party – the supplier – undertakes to establish or modernize its own production facilities using invested funds [Boychuk, 2025]. The counterparty commits to creating the necessary conditions for the estab-lishment or modernization of these facilities and to providing the corresponding services while ensuring efficient and transparent use of the investor's resources. The state, acting as the archi-tect of this framework – its initiator, moderator, and stakeholder – guarantees the uninterrupted implementation of all commitments[5],

Fig. 1. Possible scheme of interactions between economic entities
and government agencies within the framework of an offset transaction



Source: compiled by the authors.

[1] Decree of the President of the Russian Federation No. 216 of May 13, 2019 "On Approval of the Energy Security Doctrine of the Russian Federation.". https://www.garant.ru/products/ipo/prime/doc/721408 84.
[2] The incorporation of key structural elements of classical PPP models, as well as selected features of so-called qua-si-PPP arrangements, into the offset transaction framework primarily concerns the distribution of assessed risks between the contracting parties and is shaped by prevailing legislative practices of recent years.
[3] https://www. consultant.ru/document/cons_doc_LAW_182660/.
[4] https://www.consultant.ru/document/cons_doc_LAW_54572/.
[5] https://www.consultant.ru/document/cons_doc_LAW_144624/.

and the flexible commercialization of products, works, and services originating from modernized production sites[6] All such outputs possess a verified and maximized localization level[7], guaranteed over a long-term horizon of three to ten years or more.

Despite the complexity of this definition, it captures virtually all essential legal, economic, and organizational aspects, giving the proposed offset transaction the status of a nearly universal partnership mechanism – particularly relevant under the current conditions of heightened sanction pressure.

The primary objectives of launching such offset programs in the domestic gas industry in-clude: supporting Russian businesses, promoting an active import substitution policy [Murashko, 2023], developing large-scale investment scenarios involving single or combined funding sources, creating innovative applied technologies and promising industrial facilities, generating new jobs, and forming regional production clusters. Additional aims include revitalizing and improving the industrial infrastructure and productive capacities of Siberia and the Far East, as well as ensuring workforce retention and settlement stability in the Arctic and northern territories.

Addressing these specific tasks requires close coordination with the ongoing development of the digital economy, accurate assessment of the nation's increasing energy demand, and ex-ploration of new power generation opportunities. It must also take into account the prudent and well-regulated application of artificial intelligence (AI) technologies – whose rapid growth al-ready entails substantial electricity consumption to remain competitive in the global AI race – while simultaneously reinforcing technological independence and advancing a consistent import substitution policy.

Within the current framework of industrial gasification and gas network extension, when an official application for the creation of a technical connection to GDN for a new or modernized industrial facility is submitted, the *Gazprom Group* proposes that such an investor-initiator enter into an offset transaction. Under the terms of this transaction, the investor undertakes, at its own expense and using borrowed funds, to construct or modernize a gas pipeline – and, if necessary, a gas distribution station – to connect its investment facility (hereinafter referred to as the investor's gas pipeline). The *Gazprom Group*, in turn, commits to purchasing the investor's gas pipeline by covering the principal of the investor's loan after the pipeline is commissioned and gas deliveries commence.

An investor who submits a proposal to *Gazprom Group* and signs the corresponding offset transaction then presents this transaction to an authorized bank for review and approval of a dedicated loan to finance the construction and/or modernization of the investor's gas pipeline. As a result, the bank issues two loans: one for the pipeline project and another for the construction or modernization of the investor's industrial facility. With the support of the Government of the Russian Federation (subject to detailed elaboration of the specific mechanism), the loan for the investor's gas pipeline could be granted at a preferential interest rate, analogous to subsidized mortgage schemes – approximately 5–6% per annum [Kruzhkova, 2022].

This mechanism effectively eliminates the commercial risk of investment non-repayment for the *Gazprom Group* [Skripnik, 2024], since the *Gazprom Group* is not required to directly finance the construction or modernization of potentially underutilized gas pipelines. Such a risk often arises in large-scale infrastructure projects that remain unimplemented. In this case, the *Gazprom Group's* financial commitment – the buyout of the investor's pipeline – occurs only after the project's successful completion and commencement of gas transportation.

In accordance with the terms of the offset transaction, *Gazprom Group*, through *Gazprom Mezhregiongaz*, assumes the loan principal for the completed and operational investor's pipeline only after gas deliveries have begun and payments for the supplied gas have started to flow. This approach is equally advantageous for potential investors. The existence of a signed offset transaction between the *Gazprom Group* and the investor serves as an additional guarantee and increases the likelihood of a favorable decision from the authorized bank when reviewing the investment business plan. Consequently, the investor gains access to a fully transparent credit line for project implementation.

The conclusion of such offset transactions could become a regular practice at major eco-nomic forums, conferences, regional visits by *Gazprom Group* executives, and other representa-tional events. The key performance indicators of these transactions – including technical and economic metrics specific to the gas industry – would align with the *Gazprom Group's* strategic priorities and the broader interests of the national economy, as industrial enterprises typically require hundreds of millions of cubic meters of natural gas annually.

With active support from the Presidential Administration and the Government of the Rus-sian Federation, the number of applications for GDN connections from prospective industrial facilities could reach one hundred per year. As a result, the domestic demand for natural gas among industrial consumers could increase by tens of billions of cubic meters annually – volumes comparable to those currently unclaimed in EU markets. One of the significant objec-

[6] https://www.consultant.ru/document/ cons_doc_LAW_116964/.
[7] https://www.consultant.ru/document/cons_doc_ LAW_183175/.

tives of this research is to quantify the gas volumes required for multipurpose industrial gasification and gas network extension of real-sector enterprises and to assess their monetization potential directly at production sites.

The calculation of expenses associated with enterprise gasification services is performed individually during the preparation of each specific project, in full compliance with current legislation[8]. Typically, the total cost depends on the selected organizational and technological system, the length and complexity of the distribution networks, the number and capacity of connected facilities, and other parameters analyzed during the design phase. In standard practice, the de-sign stage for such industrial and energy infrastructure projects takes up to eighteen months.

2. Results

In discussing current priorities for industrial gasification and gas network extension, it is important to recognize that commercial logistics in general rely on diversifying supply routes for virtually all categories of goods, including energy resources and processed products. Such diversification is economically rational and enhances both operational and organisational resilience. Historically, Russian pipeline gas exports to Europe have been delivered via three rather winding routes. Since 2020, this system has been supplemented by an additional route with a notably complex configuration – the TurkStream pipeline.

Problems arise, however, when alternative routes are chosen not for reasons of economic efficiency but under political pressure or in pursuit of short-term gains [Mitrakhovich et al., 2022]. This was the case when Astana (Republic of Kazakhstan) decided to redirect part of its oil exports through the Baku – Tbilisi – Ceyhan (BTC) pipeline in Turkey, bypassing the traditional route via the Russian trunk pipeline network and effectively breaching existing long-term contracts.

TurkStream currently serves as a key route for the delivery of Russian gas to Europe via a hub in Turkey, which has become the largest purchaser of Russian and other gas volumes trans-ported along this corridor. From this hub, and under the present constrained conditions, flows continue through the Balkan Stream pipeline to Greece, Italy, Slovakia, Hungary, Bulgaria, and Romania, and further on to another major gas hub in Austria.

Paradoxically, a portion of these gas volumes still reaches Ukraine via Slovakia and Hun-gary. According to the industry outlet *ExPro Consulting*, more than 70% of all natural gas pur-chased by Ukraine in 2025 is of Russian origin, with deliveries peaking in July 2025 at 568.8 million m³. Under the same geopolitical conditions, Russian gas also continues to flow to Mol-dova, which Russia currently classifies as an “unfriendly” state – a vivid illustration of how complex and internally contradictory contemporary gas logistics can be.

On 31 December 2024, a pilot gas purchase for *Moldovagaz JSC* was successfully execut-ed on the *Balkan Gas Hub* trading platform in Bulgaria. The purchased volume – 240 MWh – was transported along the Trans-Balkan corridor through Bulgaria, Romania, and Ukraine to the interconnection point Căușeni on the Moldovan border. By mid-2025, however, Moldovagaz had accumulated an outstanding debt of USD 709 million to the *Gazprom Group* for gas supplies to the right-bank area of the Dniester. This receivable is reflected in the financial statements of both the Russian and *Moldovan gas* companies and has not been written off.

The TurkStream pipeline remains a critical route for supplying natural gas to Hungary and Central Europe, transporting up to 11.6 billion m³ of Russian gas annually. For many years, it has functioned as a dependable corridor in which operators and transit countries have largely honoured their contractual obligations and behaved in a relatively predictable manner by the standards of the international gas market. The expert community expects that all parties respon-sible for this logistical corridor will ensure its physical security and uninterrupted operation without deviation.

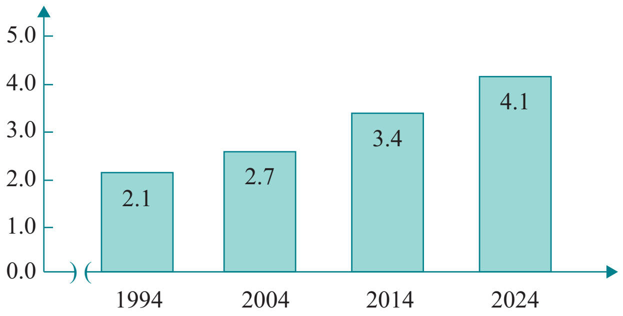
Ultimately, the broader issue of energy security is inseparable from that of national sover-eignty. Any action that undermines Russian energy exports – regardless of destination – should therefore be treated as an encroachment on the country’s sovereignty and met with prompt and proportionate countermeasures. In practice, however, the responses have often been inconsistent and disproportionate, as evidenced by numerous cases that reveal either a striking lack of resolve or an almost breathtaking degree of complacency.

When assessing current gas-market conditions, it is useful to draw on hydrocarbon statis-tics from the Statistical Office of the European Union (Eurostat, Brussels). Over the past quarter century (1994–2024), global natural gas production has increased by 95.24%, almost doubling. This trend is illustrated in Figure 2, which presents a bar chart with ten-year intervals.

Among the leading countries in both natural gas production and consumption are Russia’s nominal – and, in some respects, strategic – counterparts, the United States, Iran, and China, as shown by the final data for 2024 in Figure 3. Taken together, these producers account for 53% of global natural gas output, while their combined consumption is close to 50% of worldwide demand. Within this group, however, only the United States and Russia produce more gas than they consume domestically – by 131 billion m³ and 153 billion m³, respectively.

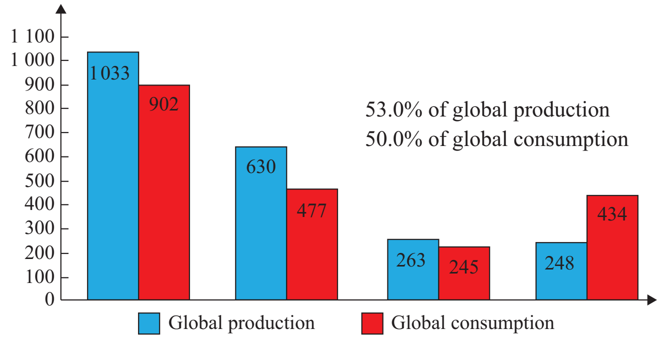
[8] https://www.consultant.ru/document/cons_doc_ LAW_22576.

Fig. 2. Dynamics of global natural gas production volumes, 1994–2024 (tln m^3)



Source: https://ec.europa.eu/eurostat.

Fig. 3. Countries leading in natural gas production and consumption in 2024 (bln m^3)



Source: https://ec.europa.eu/eurostat.

The United States is also the only one of the leading producers to register a decline in gas output in 2024: a 0.3% decrease year-on-year, and the first drop since 2000 (Figure 4). This reduction is largely linked to lower production from the Haynesville shale formation in Arkansas, driven by rising costs of shale gas extraction via hydraulic fracturing[9] and a marked decline in spot gas prices[10].

Of the estimated 153 billion m^3 excess of Russian gas production over domestic con-sumption, part of the volumes that are not demanded on external markets due to extensive EU restrictions could be redirected to industrial gasification of domestic enterprises in Siberia, the Far East, and other Russian territories with acute socio-economic development needs, including via offset gasification transactions.

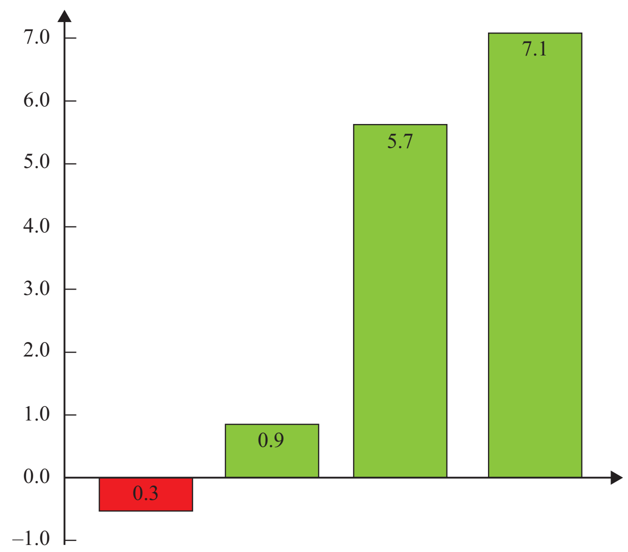
In the years preceding the special military operation, Russian gas exports averaged slightly above 20% of total production. In 2024, gas output reached 685 billion m^3, of which 514 billion m^3 was consumed domestically. The remainder was allocated to storage (replenishing reserves) and exports, including LNG supplies, amounting to 13.27% of total production – significantly below the share observed in earlier "boom years."

Against the backdrop of rapidly growing domestic energy demand – driven by the digitali-sation of the economy, the expansion of large data centres (LDCs), the widespread legalisation of cryptocurrency mining ("white mining"), and the implementation of the industrial gasification programme – the search for additional electricity generation sources becomes critical. The Energy Strategy of the Russian Federation envisages achieving an aggregate installed capacity of 88.5 GW from all generation sources by 2042.

In this context, a comprehensive assessment of options for increasing the role of natural gas in power generation is of paramount importance for the Russian economy. Emerging surplus gas volumes need to be monetised domestically – through industrial gasification initiatives and by converting most thermal power plants (TPPs) and combined heat and power plants (CHPPs) to cleaner gas-fired operation, alongside complementary measures. A telling international benchmark is the Islamic Republic of Iran, which, despite decades of comparable sanctions, uses 15% more natural gas than Russia for energy production – as shown in Figure 5.

Russian transport companies have recently begun to show heightened professional interest in the availability of surplus natural gas, particularly as a motor fuel. As representatives of the Federal Agency for State Reserves have figuratively noted, the sector is preparing for a large-scale "shift to gas," with increasing attention to fuels such as ethane, methane, propane – butane, methanol, hydrogen, and other combustible gaseous options.

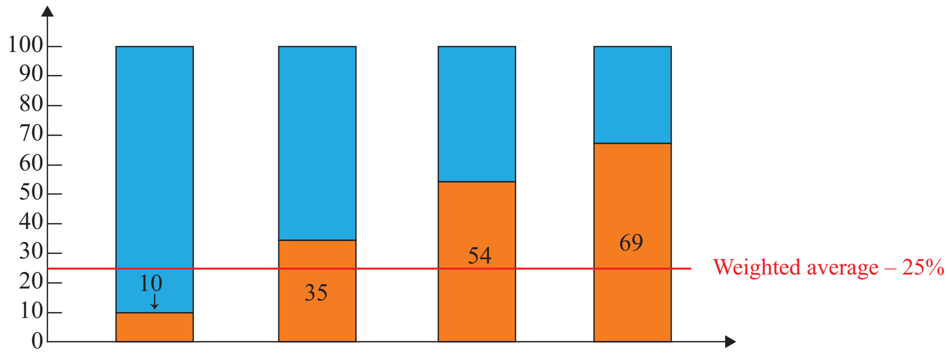
Fig. 4. Growth rates of annual natural gas production among the leaders of the global gas market, 2024 compared to 2023 (%)



Source: https://ec.europa.eu/eurostat.

[9] Hydraulic fracturing (fracking) is a method used to stimulate gas well performance.
[10] Market prices for Russian gas were historically indexed to European exchange quotations.

Fig. 5. Share of natural gas in the energy consumption structure among global gas market leaders in 2024 (%)



Source: Statistical review of world energy. 74th ed. London, 2025: 38–47. ition// chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://assets.kpmg.com/content/dam/kpmg/sk/pdf/2025/Statistical-Review-of-World-Energy-2025.pdf.

A notable technological development was reported on 15 November 2025 by A.G. Ishkov, Head of Department at the *Gazprom Group*. According to his statement, hydrogen with a purity of 99.99%, suitable for direct use in hydrogen-powered transport, was produced at a company-owned technological facility[11]. Unlike water electrolysis or hydrogen sulfide pyrolysis – both significantly more costly methods – this hydrogen was obtained via an energy-efficient methane pyrolysis process developed by Professor A.A. Konoplyanik [Konoplyanik et al., 2024]. The resulting product is virtually carbon-free, while the accompanying by-product, sulfur, has commercial value and is used as feedstock in other industrial processes.

The weighted average share of gas in total energy consumption across the four countries shown in Figure 5 is approximately 25%, pointing to substantial reliance on domestically pro-duced gas rather than imports. In China, most extracted gas is used as feedstock for further in-dustrial processing, whereas Iran primarily channels gas into electricity generation. By contrast, Russia and the United States have traditionally oriented their gas sectors toward large-scale ex-ports. Nevertheless, during the first eight months of 2025, Russia recorded a sharp increase in electricity demand compared with the same period of the previous year. A substantial share of this additional demand was met through expanded gas-fired power generation at domestic TPPs and CHPPs, including both newly commissioned facilities and older plants returned to operation following modernization.

3. Cross-Discussion

The fuel and energy complex (FEC) remains a cornerstone of the Russian economy and one of the most attractive sectors for investment. It accounts for approximately 20% of GDP, while total investment in the sector reached about 10.5 trillion rubles last year. Supported by rising prices for Russian crude oil and relatively stable gas prices, oil and gas revenues contributed roughly 30% of federal budget revenues in 2024. At the same time, this figure reflects an emerging long-term trend toward a gradual decline in the fiscal share of hydrocarbon revenues, partly driven by reduced gas exports to the European Union – a pattern illustrated in Figure 6 for the period 2021–2025.

As shown in Figure 6, Russian natural gas deliveries to Europe fell almost fivefold be-tween early 2021 and early November 2025. This contraction, however, should not be interpret-ed in alarmist terms. Speaking at the plenary session of the St. Petersburg International Econom-ic Forum on 20 June 2025, the President of the Russian Federation noted that “the contribution of the raw-material component to the country’s economic dynamics is no longer decisive; more-over, at the current stage it has even become negative”[12].

Nevertheless, the nineteenth sanctions package targeting Russian gas – both pipeline supplies and LNG – adopted on 19 October 2025, contains clear challenges and risks. Despite this, the national economy is regarded as prepared to absorb their impact. Commenting on the package, Ursula von der Leyen stated: “We are banning imports of Russian LNG to European markets. It is time to turn off the tap. We are ready for this. We have never before saved so much energy, diversified our supplies, and invested in low-carbon energy sources. Today, these efforts are paying off”[13].

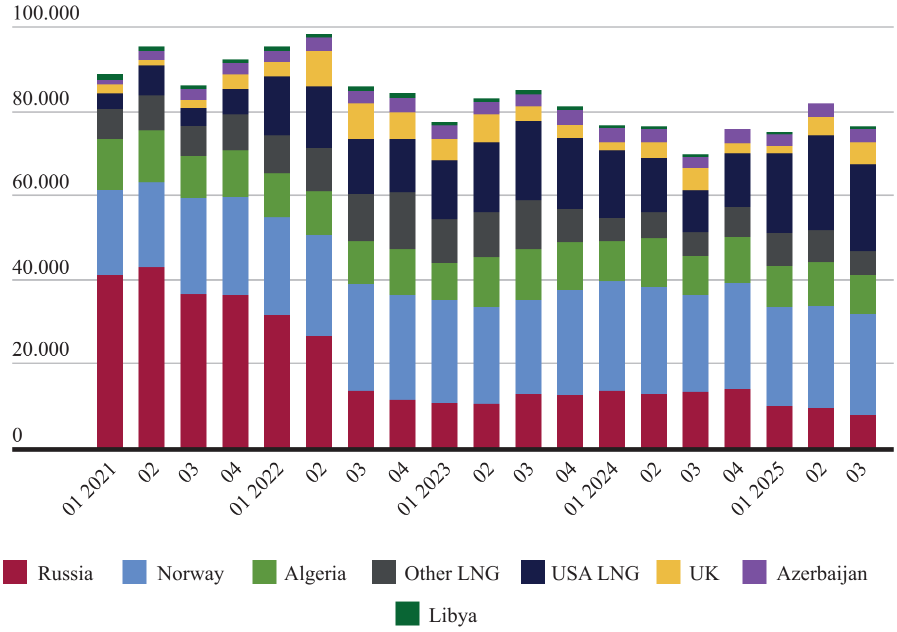
The following day, 20 October 2025, the European Union formally announced its intention to abandon Russian gas imports and adopted a long-term resolution

[11] https://globalenergyprize.org/ru/2025/11/15/gazprom-nachal-issledovanija-prirodnogo-vodoroda/. The Gazprom Group has long-standing experience in hydrogen production using alternative technologies and annually produces 150,000–200,000 tons of hydrogen.

[12] https://forumspb.com/?lang=ru&utm_referrer=https%3A%2F%2Fwww.google.com%2F/.

[13] https://ria.ru/20250919/import-2042987662.html.

Fig. 6. Gas supplies to the EU from various sources for the period from the beginning of 2021 to October 2025 (bln m³)



Source: Statistical review of world energy. 74th ed. London, 2025: 40–46. ition// chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://assets.kpmg.com/content/dam/kpmg/sk/pdf/2025/Statistical-Review-of-World-Energy-2025.pdf.

outlining the parameters of this policy shift. According to the document, "the Council has agreed on its position for negotiations on a draft regulation on the gradual phase-out of imports of Russian natural gas. This regulation constitutes a key element of the European Commission's REPowerEU roadmap aimed at ending dependence on Russian energy resources, in light of allegations that Russia uses gas supplies as a political instrument and has repeatedly disrupted deliveries to the EU, thereby affecting the European energy market"[14].

The resolution further specifies that imports of Russian gas are to be prohibited from 1 January 2026, while a transitional regime will apply to existing contracts. Short-term contracts concluded before 17 June 2025 may remain in force until 17 June 2026, whereas long-term con-tracts may continue until 1 January 2028. Amendments to active contracts are permitted only for narrowly defined operational purposes and must not result in increased contracted volumes, with limited exemptions for landlocked Member States affected by recent changes in supply routes[15].

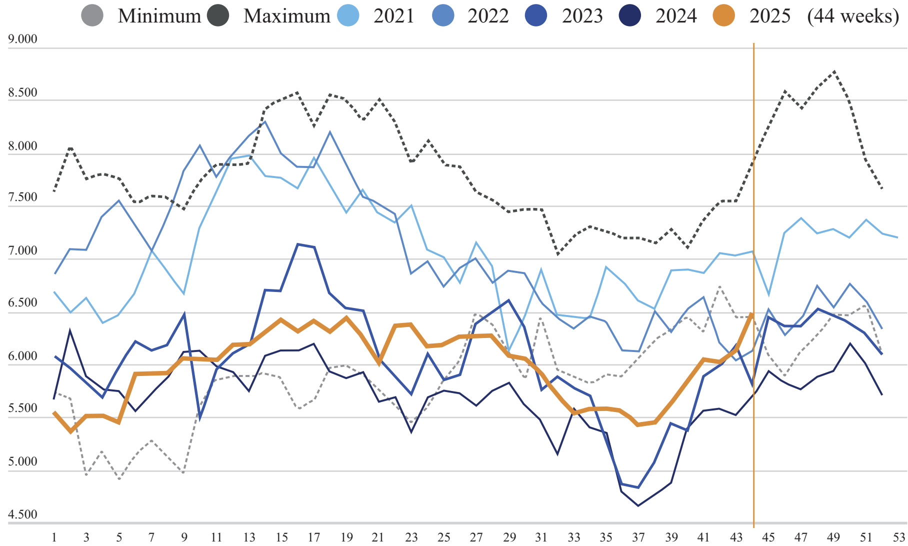
According to assessments by analysts at the Institute for National Energy, including well-known energy-market experts A.S. Frolov and B.L. Martsinkevich, total LNG imports to Europe during the first eight months of 2025 amounted to 88.8 billion m³ (in regasified equivalent)[16]. Russian LNG accounted for 15% of this volume, or 13.5 billion m³ (Figure 7, weekly data). By the end of 2025, Europe's total LNG imports are expected to reach 100 billion m³, with approx-imately 20 billion m³ still supplied from Russia. Accordingly, by 2026, the European market will need to replace an estimated 22–25 billion m³ of Russian gas, although no official documents detailing the replacement mechanisms have yet been published. It is generally assumed that this shortfall will be covered by new production capacities in the United States and Qatar. Reductions in Russian gas imports had already been anticipated by EU institutions as early as May 2025, and by 2026 such supplies are expected to cease entirely. The dynamics presented in Figure 7 clearly point to a persistent gas deficit in the European market over the coming years.

At present, Europe has become the largest consumer of U.S. liquefied natural gas (LNG), with its transportation and trading within EU member states conducted under European ex-change-based pricing mechanisms. Trading companies operate as market intermediaries on the Dutch virtual gas hub Title Transfer Facility (TTF), which serves as Europe's principal natural-gas price benchmark and one of the most liquid gas hubs worldwide.

The Energy Strategy of the Russian Federation explicitly prioritizes the use of natural gas for electricity generation at newly constructed facilities within the fuel and energy complex (FEC). According to TASS,

[14] https://www.rbc.ru/politics/20/10/2025/68f606a69a7947582a37c²e6/.
[15] https://www.rbc.ru/politics/20/10/2025/68f606a69a7947582a37c²e6/.
[16] Regasified volumes are calculated after LNG is converted to gaseous form for grid injection; the volume increases by approximately 250–270 times during regasification.

Fig. 7. Dynamics of total LNG supply volumes to EU countries for 2021–2025, weekly (bln m³)



Source: Агентство BRUEGEL (Brussels European and Global Economic Laboratory). https://www.bruegel.org/dataset/european-natural-gas-imports.

the Ministry of Energy expects that forthcoming legislative amend-ments in the electricity sector will shorten approval timelines and reduce administrative barriers to the construction of new generating capacity. The draft regulatory framework currently under review also introduces an integrated cost-management model for electricity-sector investment projects. Achieving the projected aggregate generating capacity of 88.5 GW by 2042 will require more than 40 trillion rubles in investment in generation infrastructure and an additional 5 trillion rubles for the development of the national transmission-grid system[17].

A dedicated coordination meeting on expanding electricity generation in southern Russia was recently held with the participation of representatives from the Ministry of Energy, the Gazprom Group, major power-generation companies, and regional authorities. During the meeting, participants reported to Deputy Prime Minister A. Novak on the current state of gas infrastructure and the readiness of designated sites for new generating facilities. Particular attention was given to the planned construction of TPPs in the Krasnodar Territory and the Republic of Crimea, with a combined capacity of 2.25 GW.

According to assessments by the Ministry's analytical unit, the annual gas demand re-quired to support new generation capacity in southern Russia is estimated at approximately 4 billion m³. Representatives of the *Gazprom Group* indicated that meeting this demand will require the expansion of two existing gas pipelines, with mandatory alignment to the seven designated land plots selected for TPP construction. Only after these conditions are met will technical specialists proceed with the development of a detailed implementation schedule.

In the Murmansk Region, gasification efforts will rely on the Volkhov – Murmansk main gas pipeline, currently under construction, with a projected annual throughput of 40 billion m³. Priority branch pipelines extending from this mainline will connect to gas distribution stations (GDSs), as well as inter-settlement and intra-settlement networks. By the end of the current year, the first phase of the project will enable 24 regional heat-supply facilities to switch to network gas, including the Apatity TPP operated by TGC-1 PJSC and facilities managed by Murmansk TPP JSC. Under the comprehensive regional infrastructure-development plan, subsequent stages will be implemented through 2036, ultimately providing full gasification of the Kola Peninsula.

At the same time, the possibility of concluding an Arctic Agreement between the United States and Russia remains hypothetical, contingent on the outcomes of the Alaska Summit. Such an agreement could, in theory, initiate energy cooperation on an unprecedented scale, contrib-uting to the normalization of trade and economic relations and to the partial lifting of U.S. re-strictions and sanctions.

From an economic perspective, this hypothetical arrangement would be advantageous for both parties. According to J. Tidmarsh, an analyst for the British journal *The Spectator* (11 Au-gust 2025), the Arctic contains approximately 13% of the world's undiscovered oil reserves (around 90 billion barrels) and 30% of

[17] https://minenergo.gov.ru/ministry/ energy-strategy.

undiscovered natural-gas reserves[18]. Russia exercises legal and de facto control over roughly half of these resources, which geologists estimate at 2.3 billion tons of oil and condensate and 35.7 trillion m³ of natural gas. This effectively identified "new Klondike" may be interpreted as broadly consistent with the principles underlying Donald Trump's "America First" agenda. If U.S. expertise and capital were invested in these currently immobilized Arctic assets, the resulting economic gains could be substantial. However, with the probability of such cooperation now estimated at below 30%, ongoing geopolitical developments have largely eliminated any realistic prospects for implementing this scenario.

The development of the LNG market remains one of the key priorities of the Ministry of Energy of the Russian Federation, encompassing the development, refinement, and deployment of domestic technologies within the FEC. This focus is driven by the fact that Russia is now among the world's leading LNG exporters, producing approximately 34 million tons annually, which accounts for about 8% of global LNG exports. According to S. E. Tsivilev, Minister of Energy of the Russian Federation, Russia's share of the global LNG market should be substan-tially expanded by reaching a target output of 100 million tons of LNG per year by 2030. This ambitious benchmark, however, has prompted well-founded skepticism among gas-market ex-perts, including the authors of the present study.

First, doubts arise with regard to the scale of the export target itself, given intensifying global competition among LNG suppliers – not only in pricing and tariffs, but also in service conditions – alongside the continued presence of sanctions and other restrictions. Second, serious technical uncertainties surround the feasibility of achieving such volumes within the proposed timeframe. The *Murmansk LNG Plant*, taking into account accumulated logistical and technological challenges, is not expected to be completed before 2032, and its current readiness stands at 22%. The completion timeline for the Far *Eastern LNG Plant* has shifted into a zone of strategic uncertainty, while media coverage of the *Baltic LNG Plant*, once regular and detailed, has effectively disappeared from public sources.

At the same time, the national gasification program continues to advance at a steady pace. Speaking at the PMG Forum 2025, A. B. Miller, CEO of the Gazprom Group, assessed the max-imum achievable level of territorial gasification in Russia at 83%. The remaining 17% includes the Magadan Region, the Taimyr Peninsula, and other remote areas. As he noted: "Our primary objective is to ensure that as many Russian citizens as possible can benefit from natural gas. By order of the President of the Russian Federation, Vladimir Putin, we are to achieve 100% technically feasible gasification of the country by 2030. This objective will be fulfilled. Gazprom is currently working on gasification projects in the southern districts of Yakutia"[19].

Overall, the pace of capacity development for gasification can be described as satisfactory, with particularly notable progress recorded east of the Urals. In 2025, a gas pipeline was commissioned in Gorno-Altaysk (Altai Republic), supplying the city's last non-gasified residential area – Microdistrict No. 35. In Poronaysk (Sakhalin Region), the first facility to be connected to the gas network was Boiler House No 4, which provides heat to 25 apartment buildings, approximately 20 private houses, and several socially significant institutions; gasification of the city's central boiler house is scheduled as the next stage. Under the gas network extension program, the first residential properties were connected to gas networks in Svobodny (Amur Region) and Lomtuka (Sakha Republic, Yakutia).

The Power of Siberia pipeline serves as the backbone of the regional gas supply system. Under the program, Gazprom is completing the construction of four branch pipelines equipped with GDSs – Aldan, Aldan-2, Murya, and Chulman. From these nodes, inter-settlement and in-tra-settlement pipelines will extend to the city of Aldan and to settlements in the Aldan and Neryungri districts, including Leninsky, Lebediny, Chulman, Verkhny Kuranakh, Nizhny Ku-ranakh, and Khotystyr. In the Olekminsky District, where a branch pipeline with a GDS and an inter-settlement line from the Power of Siberia pipeline are already in place, the company plans to gasify 16 rural localities. This will require the construction of additional inter-settlement and intra-settlement pipelines. At present, Gazprom continues to implement its ongoing five-year gasification program, with completion of the Iengra GDS branch pipeline scheduled by the end of 2025.

Conclusion

Summarizing the article and outlining prospects for further research, several interim con-clusions can be drawn.

1. Industrial gasification projects implemented under offset transactions have proven, as expected, to be complex and labor-intensive legal, technical, and organizational – economic pro-cesses. They require not only careful consideration of numerous legal and regulatory nuances but also significant financial expenditures. However, these costs are quickly offset, even in the short term, and deliver substantial strategic benefits owing to the comparatively low price of natural gas used in production and energy-intensive industrial processes.

[18] Tidmarsh J. (2025). Could the Arctic be Key to Ending the Ukraine's War? https://www.spectator. co.uk/article/could-the-arctic-be-key-to-ending-the-ukraine-war/.
[19] https://www.expoforum.ru/calendar/peterburgskij-mezhdunarodnyj-gazovyj-forum-pmgf-2025/.

2. Unlike other fuel resources, the use of natural gas does not require expensive filtration systems or other combustion-cleaning equipment [Plautz, 2024]. This contributes to improved environmental safety and preservation of the natural environment, in full compliance with the ESG sustainability standards adopted for regional and sectoral systems and AI-supported technologies. With a socially responsible and transparent contractor, the organization of continuous gas supply can be achieved with minimal time and financial costs.

3. When conducting a techno-economic analysis of offset transactions already implement-ed in other industrial sectors, attention should be given to groups of characteristics and factors that determine the typological classification of such contracts for analytical purposes. These include, first of all, legal and technical characteristics (features of legislative and regulatory acts, boundaries of the legal framework, parties to the transaction, its subject and object, investment volume in production creation, implementation timeline, transaction status, and the consolidated or partial liability of the parties). Another key analytical group consists of risk-related factors, encompassing identified, measured, and distributed risks, forecasted challenges, as well as potential damages and losses of varying nature and significance.

4. The identification and implementation of effective management mechanisms for these and other influencing factors will enhance the appeal of offset transactions within the framework of industrial gasification and gas network extension initiatives, help achieve the ambitious targets of the Energy Strategy of the Russian Federation, and stimulate investment activity across the national economy. A representative example of a successful offset transaction is Turkmenistan's competitive gas market project, involving the supply of steel gas pipelines, specialized technological equipment, and materials for modernization and further development of the Turkmen gas transportation system. The specific offset transaction was concluded between the Turkmen State Concern *Turkmengaz* and the *Gazprom Group* under an intergovernmental agreement on cooperation in the gas sector, valid until 2028. The constructed gas pipeline is intended to transport Turkmen gas not only to Russia, but also to Iran and Afghanistan. Under this offset transaction, *Gazprom Group* purchased 1.155 billion m³ of Turkmen gas for its own needs, while *Rostec* – through the United Engine Corporation – supplied NK-14ST industrial gas-turbine engines to drive compressor units. In turn, the *Chelyabinsk Pipe-Rolling Plant* (*ChTPZ*), which itself operates on gas, produced 214 km of steel pipes worth over USD 219 million.

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Conceptual Foundations of Risk Management within the Economic Security Framework of an Enterprise

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Abstract
Timely risk prevention is a key factor in ensuring the sustainable development of an enterprise. Global changes in supply chains, coupled with local financial conditions, are currently among the main factors destabilizing business operations. This article examines the theoretical and methodological foundations of risk management at the enterprise level and proposes a management model based on G.B. Kleiner's tetrad theory. Drawing on an analysis of various definitions of "risk management," the author offers a definition that incorporates both process and systems approaches and addresses strategic and tactical management levels. A neosystemic paradigm based on the tetrad model was used to develop the risk management model within the economic security system, identifying three levels of tetrads and four subsystems . The proposed enterprise risk management model enables a systematic approach to addressing economic security issues. The study highlights the importance of an integrated approach to risk management that considers theoretical foundations, practical aspects, and methodological, universal, and local factors. The proposed model can be used to design strategies for enterprise and industry sector development, thereby contributing to the long-term sustainability of the economy.
Keywords: risk management, tetrad model, neosystemic paradigm, enterprise sustainability

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企业经济安全体系内风险管理的概念框架

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摘要
企业可持续和发展的最重要因素是及时预防风险。全球供应链变化加上当地的融资条件，是目前破坏企业活动稳定的最重要因素。本文章考察了企业风险管理的理论和方法基础，并提出了基于克列伊涅尔 TETRAD 理论的管理模型。分析"风险管理"一词的各种定义之后作者提出了自己的定义，其中考虑到流程和系统方法而战略和战术水平的管理。采用新系统性范式，在经济安全体系中建立了风险管理模型。它是基 TETRAD 模型构建的：区分出三个层次的四分体和四个子系统。提出的企业风险管理模型允许采用系统的方法来解决经济安全问题。该研究强调，风险管理需要采取综合方法。而且要考虑到理论基础、实践方面以及一般方法论、普遍和地方因素。所提出的模型可用于制定企业和行业综合体的发展战略，从而有助于经济的长期可持续发展。
关键词：风险管理，TETRAD 模型，新系统范式，企业可持续

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Introduction

The relevance of research on economic security is determined by the tight interrelation and direct impact of its parameters on the efficiency of an enterprise's performance. Systematization, timely diagnostics, and forecasting of factors that reduce economic security are essential conditions for the stable operation of an enterprise. From the standpoint of financial stability and economic efficiency, it is therefore important to examine the analytical and organizational – economic mechanisms that underpin economic security. Among these mechanisms, risk management remains the most critical.

The research objectives were achieved in several successive stages. At the first stage, the author conducted a comparative analysis of existing definitions of risk management in the scientific literature. This made it possible to identify the key drivers behind the evolution of scientific approaches to the essence of this category and provided the theoretical basis for further analysis. At the second stage, the author proposed an original interpretation of risk management within the enterprise's economic security framework, drawing on both process and systems perspectives. At the third stage, existing research approaches to enterprise risk management were evaluated. At the fourth stage, a neosystemic model of enterprise economic security management based on risk management principles was developed. Each stage contributed to achieving the overall research goal, forming a methodological sequence from theoretical exploration to practical model development.

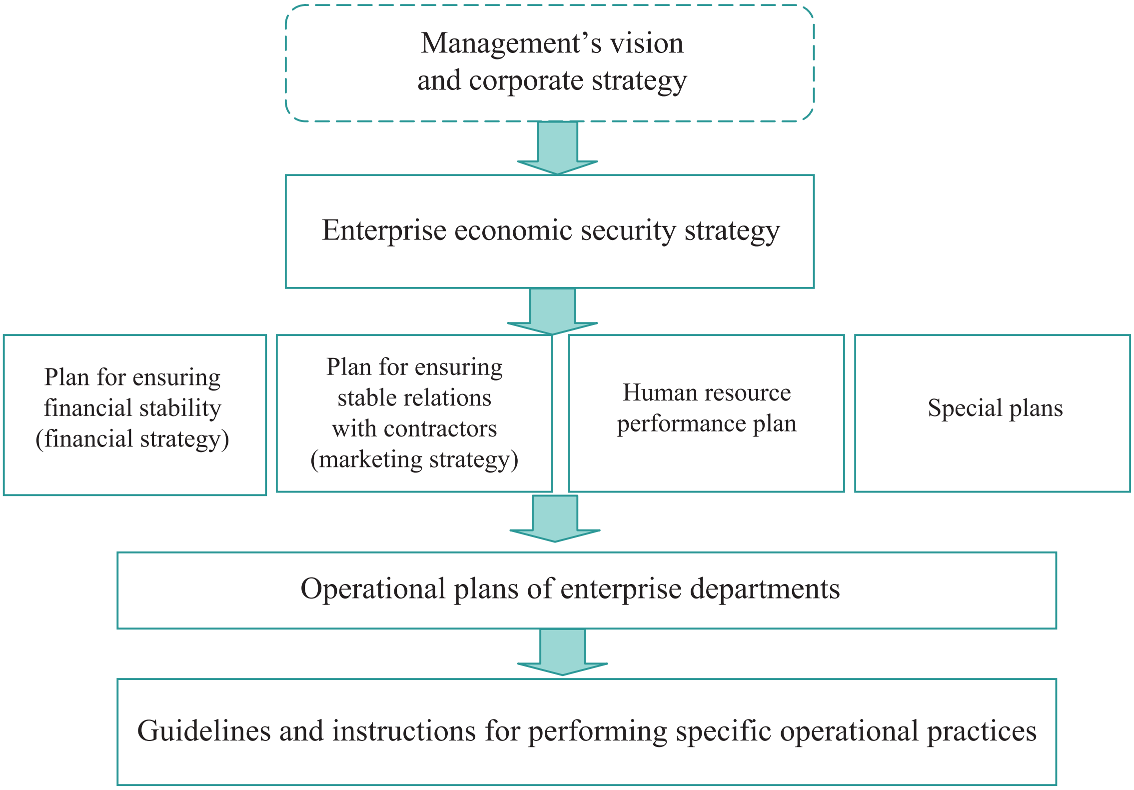
1. Risk Management: Systematization of Concepts

The study of risk management as a scientific category makes it possible to distinguish between two fundamental approaches.

Under the first approach, which adopts a process perspective, risk management is viewed as a process characterized by specific stages, a defined sequence of actions, and corresponding results. This approach presupposes, a priori, the possibility of forecasting and programming the types and levels of risk at the enterprise level. For example, D. Hubbard defines risk management as a process of identifying, assessing, and prioritizing risks that results in the economically justified allocation of resources to minimize, monitor, and control the probability and/or impact of adverse events, or to maximize emerging opportunities [Hubbard, 2020]. A.A. Obukhov notes that it is a continuous, iterative process within the organizational practice [Obukhov, 2015].

The second approach considers risk management as a management system characterized by a systemic description of its elements and the interrelations between them. For example, N.A. Rykhtikova defines risk management as a specific management subsystem designed to develop and implement economically justified recommendations and measures to mitigate the negative effects of risks [Rykhtikova, 2010]. The author of this paper believes that applying the systems paradigm to the study of risks within an enterprise's economic security framework is the most productive perspective.

Fig. 1. Conceptual model of risk management
within the economic security framework of an enterprise



Source: compiled by the author.

It should also be noted that several definitions combine both approaches. For instance, the standard "Risk Management – Guidelines for Application in Design" defines risk management as the systematic application of management policies, procedures, and practices to the tasks of identifying, analyzing, evaluating, treating, and monitoring risk, and to communicating risk-related information[1]. This definition is one of the most comprehensive, as it integrates both process and systems perspectives.

An overview of risk management approaches within the systems paradigm makes it possible to distinguish three levels of enterprise risk management. A number of authors emphasize the strategic role of risk management in enterprise functioning [Kachalov, 1999; Hanley, 1999; Meulbroek, 2000; Korezin, 2008; Rykhtikova, 2010; Kanev, 2014]. The undeniable advantage of this approach lies in the inherent alignment between the goals, tools, and methods of risk management and the enterprise's strategic objectives, as well as in the high degree of systematization of risk management processes. However, this approach requires the effective application of stakeholder management theory, accurate decomposition of key success factors and performance indicators, and awareness of the exponential growth in risk management complexity. Risk management as a tactical management function at the enterprise level has been discussed in the works by [Balabanov, 1996; Khokhlov, 1999; Dubrov et al., 2000; Obukhov, 2015; Hubbard, 2020]. The main focus here is on the instrumentalization of approaches to the identification, categorization, and forecasting of risks. The advantage of this approach is the high level of concreteness and adaptability of risk management methods, which enable efficient accounting and analytical control at the enterprise level. Its limitation lies in the autonomy of the risk management system, which is often examined separately from other management subsystems. This prevents the theoretical model of enterprise economic security from achieving sufficient comprehensiveness and integration. Moreover, the issue of coordinating different risk management functions across multiple decision-making centers within the enterprise remains unresolved. A third approach focuses on local decision-making contexts for risk management at enterprises [Chernova, 2000; Chernova, Kudryavtsev, 2005; Vyatkin et al., 2006; Krui et al., 2011]. This perspective highlights specific categories of risks but, due to its limited linkage with overall strategy and tactics, effectively represents a situational leadership model for addressing individual cases related to an enterprise's economic security.

[1] https://docs.cntd.ru/document/1200041477? ysclid=mihg^{2}vc56v28539121.

As shown in [Shirko, 2022], aligning the enterprise's economic security system with its overall strategy is essential. Economic security thus serves as the methodological foundation for shaping strategic priorities, plans, and policies, while the economic security system itself is grounded in risk management concepts. Consequently, the most comprehensive understanding of risk management is as an element of enterprise's strategic management system. In this context, risk management constitutes a set of functional strategies within the overall framework of the enterprise's economic security. Drawing on the model developed by D. Norton and R. Kaplan, the author identifies four key functional areas of enterprise risk management: finance, stakeholder relations, human resource management, and process administration [Norton & Kaplan, 2000]. In these functional areas, strategy is implemented and goals are achieved, and these same domains serve as primary sources of risks to enterprise sustainability.

Risk management is reflected in the development of enterprise sustainability plans integrated with departmental plans, process notations, and operational practices.

2. Integrated Approach to Risk Management within the Enterprise's Economic Security Framework

Within the conceptual model of risk management within the economic security framework, the author identifies the following elements: the subject, the object, concepts, approaches to organizing risk management, forms, methods and tools, and the regulatory basis.

Choosing a conceptual approach means determining whether the enterprise's economic security system will be based on (1) a preventive approach, (2) a reactive approach, or (3) an integrated approach combining both.

The regulatory basis of enterprise risk management can be divided into four levels:

1. International standards in risk and project management – including PMBOK, APM Body of Knowledge, ISO, FERMA, and COSO ERM.

2. Federal laws and regulations – this category includes federal laws, Government decrees, orders, presidential decrees, and standards that regulate risk management at the organizational level and project risk management. This group, in particular, includes the Civil Code of the

Table
Subject-object matrix of risk management using the example of a road sector enterprise

Strategic dimension	Threat	Risk	Monitoring tools	Risk owner
Finance	Decline in investment activity	Financial risk	Financial records and statements	Finance Department
		Investment risks		
Stakeholder relations	Production downturn and loss of markets	Marketing risk	Data on contract performance and competitor contracts	Marketing Department
Business processes	Losses due to reputational damage; reduction in investment	Operational risk	Database of enforcement proceedings and court rulings	General Director (CEO)
		Technological risks		
		Sales risks	Title documents	
			Official public procurement website	
Human resources	Risk of financial losses	Human resource risk	Primary inventory records	HR Department
			HR records and reports	

Source: compiled by the author.

Russian Federation (Parts One and Two), the Tax Code of the Russian Federation, and the Federal Law "On Public – Private Partnership, Municipal – Private Partnership in the Russian Federation and Amendments to Certain Legislative Acts of the Russian Federation".

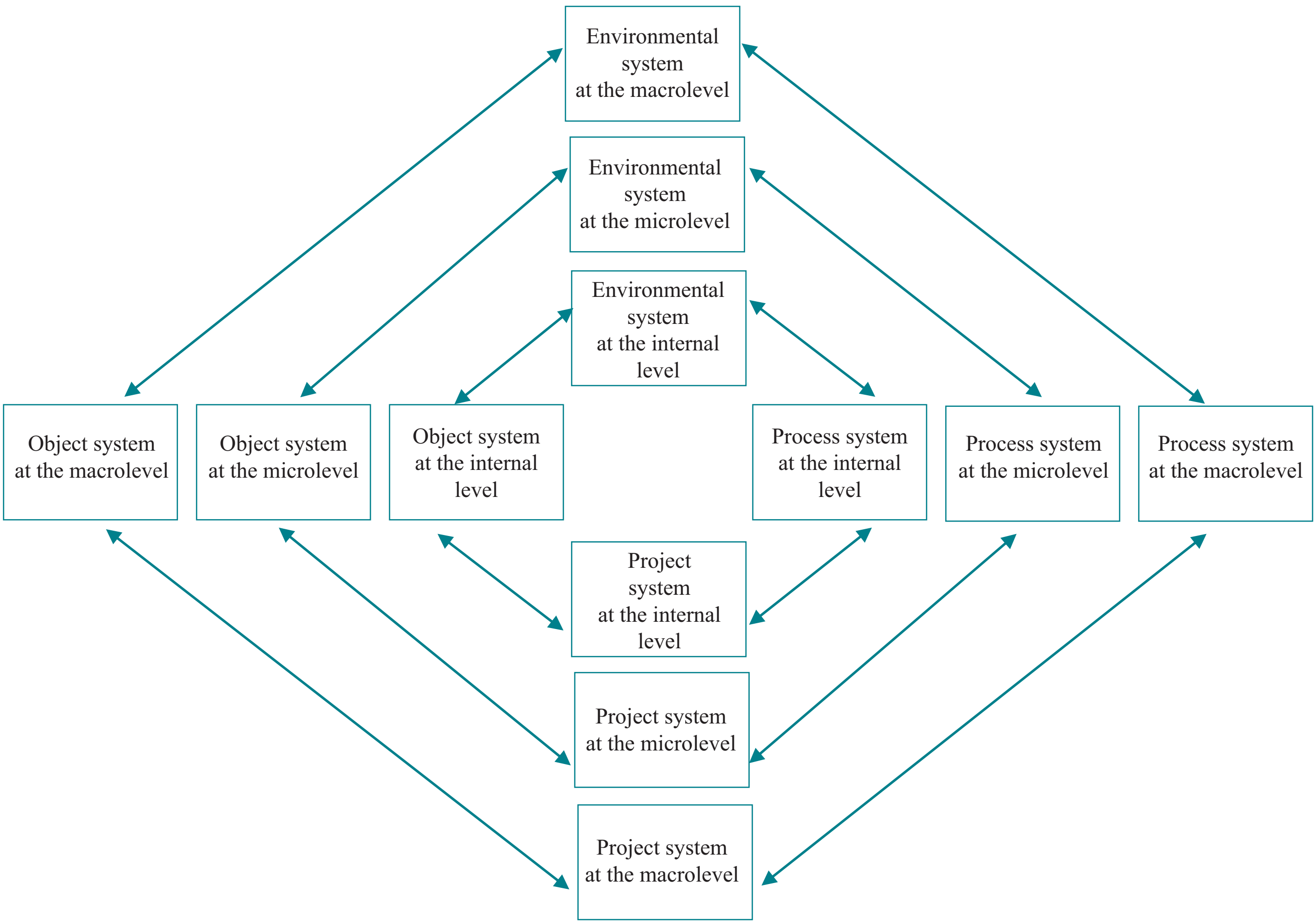
3. Industry-specific laws and regulations – these legal acts govern risk management within organizations, taking into account the particularities of their respective industries. Examples include the Federal Law "On the Organization of Insurance Business in the Russian Federation", the Federal Law "On the Central Depository", the Federal Law "On Banks and Banking Activity", as well as the directive of the Federal Road Agency (Rosavtodor) "On the Approval of the Methodology for Structuring an Investment Project to Enable the Application of Various Investment Mechanisms, Including Public – Private Partnership Mechanisms; the Methodology for Assessing the Effectiveness of Investment Mechanisms, Including Public – Private Partnership Mechanisms; and the Methodology for Selecting Optimal Investment Mechanisms, Including Public – Private Partnership Mechanisms, for the Implementation of Investment Projects".

4. Internal organizational acts, including corporate strategies, plans, project management standards, and procedural documents.

The subjects of risk management within an organization may include the enterprise's top management, project leaders, specific structural units, and employees who exert direct or indirect managerial influence (in various forms of management) on the objects of management – individual or composite risks (both positive and negative) – as well as the economic relations arising among different stakeholders in the process of risk management. An example of a subject – object matrix of risk management for a road sector enterprise is presented in the table below.

Thus, the author offers an extended interpretation of the enterprise's risk management system as part of its economic security strategy, encompassing the planning and implementation of measures aimed at minimizing negative and maximizing positive risks to enhance operational efficiency and sustainability. The novelty of this approach lies in combining systemic and structural perspectives in defining the essence of the risk management system.

Fig. 2. Telescopic model of the tetrad system



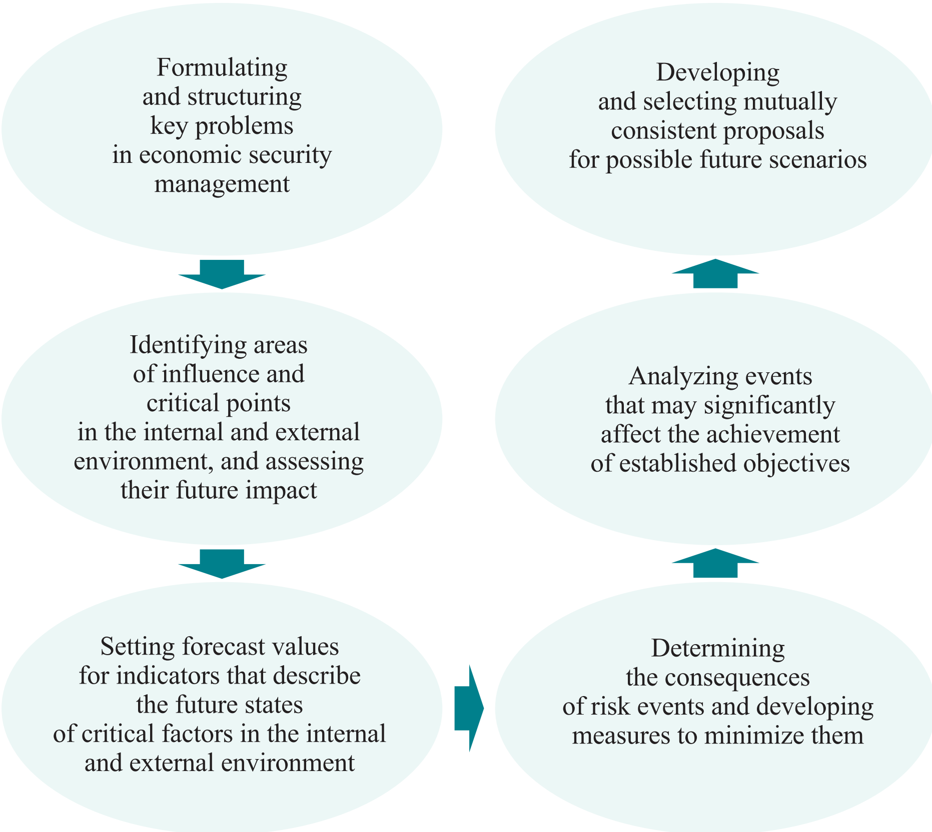
Source: compiled by the author.

3. Methodological Foundations of Risk Management within the Enterprise's Economic Security Framework

For the purposes of this study, the basic paradigm underlying the model is specified. Among the three classical paradigms of economic theory – neoclassical, institutional, and evolutionary – none provides sufficient methodological complexity to address modern risk management challenges. According to the research hypothesis, the current model of enterprise economic security, as the basis of the overall management framework, must be characterized by qualitatively new system-wide properties. This requirement is met by the neosystemic paradigm.

The methodological foundations of risk management within the neosystemic paradigm rest on two key assumptions: that risks cannot be completely eliminated from enterprise activities, and that there exists an optimal state of enterprise functioning in which unavoidable risks are managed most effectively. The author's metamodel incorporates two principal constraints:

Fig. 3. Economic security management processes



Source: compiled by the author.

1) Risk management within the economic security framework is based on the acceptability criterion. The acceptable level of risk depends on the activity domain: the higher the uncertainty (e.g., in R&D), the greater both the deviation potential and tolerance.

2) Risk management must rely on the ability to forecast events and phenomena; fundamentally unpredictable events should not be classified as risks but rather as force-majeure circumstances.

The foundation of the proposed metamodel is G.B. Kleiner's methodological systematics and tetrad model [Kleiner, 2011]. The author presents a telescopic model of the tetrad system, comprising three hierarchical levels: internal level – the enterprise itself; microenvironment – the immediate surroundings of the enterprise; macroenvironment – the broader external context. Interactions among the tetrad systems at each level are illustrated in Figure 2. Object, project, process, and environmental systems together form the object, project, process, and environment systems of the economy.

Within the neosystemic paradigm, the traditional subjects and objects of enterprise risk management are subsystems of the object system. The structure of this object system at the enterprise level includes the following:

1) Internal stakeholders;
2) Internal risks;
3) Internal functional areas of risk management.

At the microenvironment level, the object system includes:

1) External stakeholders in the immediate environment;
2) Market risks arising from competitive forces;
3) External functional risk management areas influenced by the enterprise.

At the macroenvironment level, the object system includes:

1) External stakeholders associated with related subsectors of the road sector;
2) Macrorisks manageable by the enterprise.

The environmental system represents the infrastructure of the object system's surroundings. Following L. von Bertalanffy's general system model [Von Bertalanffy, 1969], the enterprise's internal environment encompasses the factors that generate internal risks, while both the immediate and the broader external environments contain specific and nonspecific sets of factors that constitute sources of risk for all enterprises in the road sector. Environmental factors are reflected in regulations, standards, and actual events that act as triggers for change in road infrastructure projects.

The process system of enterprise economic security can be represented as a set of methods and approaches for ensuring economic security on the basis of risk management. The overall logic of these processes comprises the stages presented in Figure 3.

The project system is represented by the goals and objectives defined by the enterprise in the field of economic security (the internal project environment), as well as the objectives of higher-level systems, such as the regional and national road sector development programs. These objectives are expressed through the system of projects implemented at each project level of the telescopic tetrad.

To ensure the coordinated functioning of the tetrad complex of a road sector enterprise's economic security system, unified management of all four tetrad elements is required. In this model, enterprise economic security should be viewed as a continuous process of managerial decision-making in risk management, embedded within an evolving and increasingly complex accounting – analytical and administrative subsystem.

Conclusion

Despite extensive prior research, the study of enterprise economic security continues to be a matter of academic debate. The author identifies the lack of an integrated perspective as the key limitation of existing studies. This paper presents an original approach based on several management theories and the neosystemic paradigm of tetrad modelling. The principal novelty of the proposed approach lies in the integrative and comprehensive nature of the economic security model, which distinguishes this study from earlier works.

The model makes it possible to consolidate different levels of risk management, form a coherent subject – object framework for enterprise risk management, and embed a risk-oriented approach into the enterprise's core processes.

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How Can National Health Accounts Be Transformed into a Data-Driven Strategic Management Tool

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Abstract

Since the 1970s, OECD countries have struggled to control health care expenditure, which has grown much faster than GDP. One of the responses was the development of National Health Accounts (NHA). Today, NHA provide an accounting, classification, and monitoring framework for health expenditure. Developed by the OECD and recommended by WHO, they are mandatory in all European Union countries and are used by many WHO member states under the international SHA 2011 standard. However, the introduction of NHA has not curbed health care spending in OECD countries, which continues to outpace GDP growth. The authors argue that a key limitation of NHA is the lack of end-to-end integration with financial and managerial accounting systems, which reduces the accuracy, timeliness, and practical value of NHA data and makes them poorly suited for management purposes. As a result, NHA are currently used primarily for retrospective monitoring and sector-level analysis, macroeconomic research, and cross-country comparisons. The authors propose transforming NHA from a method of statistical observation into a data-driven management tool by combining the SHA 2011 standard with end-to-end financial management of the health sector based on line-item budgeting—an approach that ensured the high efficiency of the Soviet health system.

Keywords: national health accounts, SHA 2011, end-to-end integration, accounting, line-item budgeting, data-driven management

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如何把国民健康账户转变基于数据的站略管理方法

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摘要

自20世纪70年代以来，经济合作和发展组织（经合组织）国家一直无法有效控制医疗保健成本，而医疗保健成本的增长速度明显快于国内总产值（GDP）。解决方案之一是为经合组织国家制定国民健康账（NHA）。它今天是一个使用国际标准SHA 2011的会计，分类和跟踪医疗保健成本的系统。这项经合组织的发展是世卫组织推荐的，对所有欧盟国家都是强制性的，并被大量世卫组织成员国使用。然而，NHA的引入并没有帮助经合组织国家控制医疗保健成本，而医疗保健成本仍然比今天的GDP增长得快得多。本文的作者认为NHA的主要缺点是缺乏与会计和管理的End-to-End通积分。这降低NHA数据的准确性及时性和价值，使其不适合管理。因此，今天NHA主要用于行业数据的回顾性监测和分析，宏观经济研究和跨国比较。作者提出将NHA从统计观察方法转变为基于数据的管理工具。该方法基于SHA2011标准与按细账预算为医疗保健提供融资的End-to-End通管理的综合。相同的方法确保了苏联医疗保健的高效率。

关键词： SHA 2011、End-to-End通过程、会计、细账预算。

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Introduction

The establishment of universal access to health care services in developed OECD countries took place under exceptionally favorable economic conditions during the so-called Golden Age of Capitalism, spanning from the end of World War II to the mid-1970s. During this period, average annual GDP growth in these countries reached 5–8%, while health care expenditure remained relatively low for an extended time, not exceeding 2–3% of GDP [Political economy and innovations.., 2024]. However, between the 1970s and the 1990s, the global economy entered a prolonged period of recession marked by pronounced stagflation, characterized by declining production, rising inflation, and increasing unemployment. GDP growth rates in Western countries declined sharply. At the same time, medical specialties expanded rapidly and a technological revolution in medicine took place, life expectancy began to increase rapidly, and an epidemic of chronic non-communicable diseases emerged. As a result, health care expenditure in OECD countries started to grow rapidly, significantly outpacing GDP growth. Notably, the Soviet Union demonstrated effective control over health care spending and its alignment with the level of economic output (Table 1).

The persistent difficulty OECD countries have faced in controlling health care spending – and in keeping it aligned with overall economic output – was a major impetus for creating centralized systems to track health sector financial resources in the form of National Health Accounts (NHA). NHA are a standardized organizational framework, integrated with the System of National Accounts (SNA), for the systematic accounting, classification, and analysis of health care expenditure. NHA first developed within OECD countries, shaped by national health-system specificities. In 2000, the first international standard, SHA 1.0, was adopted [A system of health.., 2000], and in 2011 it was replaced by a revised and expanded version, SHA 2011 [A system of health.., 2017].

Under SHA 2011, NHA capture all monetary flows related to the consumption of health care goods and services within a country using a single, harmonized classification system. NHA data answer three core questions: what health care goods and services are financed, who provides them, and through which financing schemes and sources they are financed (health care functions HC, providers HP, and financing schemes HF). SHA 2011 specifies detailed classifications by expenditure (e.g., inpatient care, outpatient care, pharmaceuticals, long-term care), by provider (hospitals, outpatient clinics, pharmacies, etc.), and by financing source or scheme (government budgets, compulsory health insurance, voluntary insurance, and out-of-pocket payments).

Table 1
Health care expenditure in developed OECD countries (% of GDP) and the USSR (% of gross social product)

Country	1970	1980	1990
United States	6.9	8.7	11.9
United Kingdom	4.5	5.6	6.0
Canada	7.0	7.0	9.0
Australia	4.6	7.0	7.8
Austria	5.1	7.4	7.0
Belgium	4.0	6.4	7.4
Denmark	8.0	9.1	8.5
Finland	5.6	6.4	7.8
France	5.4	7.1	8.6
Germany	6.2	8.7	8.5
Greece	6.1	6.6	7.4
Ireland	5.1	8.4	6.1
Japan	4.5	6.5	5.9
Netherlands	6.9	7.5	8.0
New Zealand	5.1	5.9	6.9
Norway	4.4	7.0	7.7
Portugal	2.6	5.6	6.2
Spain	3.6	5.4	6.7
Sweden	6.9	9.1	8.4
Switzerland	5.5	7.4	8.3
USSR	1.8	1.8	1.7

Source: Authors' calculations based on: National economy of the USSR in 1980: A statistical yearbook. Moscow, 1981; National economy of the USSR in 1990: A statistical yearbook. Moscow, 1991; [Colombo, Morgan, 2006].

Based on the SHA 2011 NHA tables, it is possible to derive indicators of the level and composition of health care expenditure, track its dynamics and share of GDP, assess the relative contributions of public and private financing, and carry out cross-country comparisons. Because SHA 2011 is aligned with the SNA, health care aggregates can be directly linked to key macroeconomic indicators such as GDP and government expenditure. Under SHA 2011, the primary purpose of NHA is to support regular, time-consistent, and internationally comparable monitoring and analysis of health care financing and to inform health policy development[1, 2].

Today, regular compilation of NHA under the SHA 2011 standard is recommended and supported by the World Health Organization. According to information published on the official WHO website[3], around 100 WHO member states – more than half of all countries worldwide – periodically compile national health accounts using the SHA 2011 methodology.

In the European Union, annual compilation and publication of national health accounts in accordance with SHA 2011 has been mandatory since 2013 under Regulation (EC) No. 1338/2008 and Regulation (EC) No. 2015/359. Regulation (EC) No. 1338/2008 of the European Parliament and of the Council of 16 December 2008 on Community statistics on public health provides a unified legal framework for the collection, production, transmission, and evaluation of European health statistics, including statistics on health care financing and expenditure.

EU member states are required to submit detailed annual data on health care expenditure and its financing to Eurostat in accordance with the SHA 2011 methodology. Regulation (EU) 2021/1901 of 29 October 2021, which approves the technical specifications for the transmission of SHA data, defines the specific rules and data formats for SHA 2011 reporting, including breakdowns by functions, providers, and financing schemes, thereby making compliance with the system mandatory throughout the EU. Failure to comply with these regulations may result in sanctions. The European Commission is entitled to initiate financial penalties against a member state in cases of systematic non-compliance or falsification of mandatory statistical data[4]. Non-compliant countries may face restrictions on access to EU funding, suspension of financial support or grants, limitations on participation in international comparative projects, restricted access to shared statistical and analytical platforms, and constraints affecting national insurance systems and intergovernmental planning. Eurostat may formally designate a country as non-compliant with established standards, leading to public disclosure and the imposition of corrective measures subject to strict timelines and ongoing monitoring.

However, the very fact that NHA compilation requires strong administrative enforcement even within the European Union indicates that the development and operation of NHA systems involve substantial challenges, and that the benefits of NHA are not as unequivocal as they are often perceived by European bureaucratic institutions.

For example, the 2025 OECD report on best practices in NHA implementation [Best practice.., 2025] shows that a number of OECD countries limit themselves to the minimum basic set of tables recommended by the SHA 2011 standard and fail to ensure the regular availability of complete datasets for all years covered by the joint OECD – Eurostat – WHO questionnaire.

Moreover, despite the risk of penalties and sanctions, some OECD countries (e.g., New Zealand) periodically fail to submit NHA data in the SHA 2011 format altogether. Unsurprisingly, the situation with NHA implementation in non-EU countries is even less favorable. As of 2017, only around 40 such countries compiled NHA on a routine basis, that is, with relative regularity [Rathe et al., 2018]. At the same time, in most post-Soviet countries, attempts to establish NHA systems either remained at the pilot stage or were never initiated (Table 2).

Thus, significant challenges persist in NHA implementation even among OECD countries. Yet the introduction of NHA has not enabled these countries to control health care expenditure which, according to WHO data for 2000–2017, grew at approximately twice the rate of economic growth in OECD countries [Global spending.., 2019].

Overall, these observations point to a systemic limitation in the current national health accounts methodology. NHA implementation remains difficult, while the benefits of adoption clearly fall short of initial expectations.

The authors hypothesize that the main methodological limitation of national health accounts is the lack of end-to-end integration with financial and managerial accounting systems. This disconnect deprives NHA data of practical managerial value, confining their use largely to retrospective monitoring, sector-level analysis, macroeconomic research, and cross-country comparisons. As a result, the financial resources and administrative effort devoted to developing and maintaining NHA are, at best, disproportionate to the returns these systems generate. This helps explain the limited interest in NHA even among OECD countries, and even more so among low- and middle-income countries.

[1] http://data.europa.eu/eli/reg/2008/1338/oj.
[2] http://data.europa.eu/eli/reg/2015/359/oj.
[3] https://apps.who.int/nha/database.
[4] http://data.europa.eu/eli/dec_del/2012/678/oj.

Table 2
Establishment of NHA systems in former Soviet republics (excluding the Baltic States and Ukraine)

Country	Year of most recent publication (public report or health accounts data)	Health accounts standard
Belarus	2024	National standard, not aligned with SHA 2011
Armenia	2023	SHA 2011
Kazakhstan	2018	SHA 2011
Kyrgyzstan	2009	Pilot project
Russia	2007	National standard, partially aligned with SHA 1.0.
Georgia	2004	SHA 1.0 (pilot project)
Moldova	2011	Prepared under SHA 1.0 as part of a pilot project; however, no evidence of publication or any related data could be found in open sources.
Uzbekistan	—	—
Azerbaijan	—	—
Turkmenistan	—	—

Source: Compiled by the authors based on: https://minzdrav.gov.by/ru/ministerstvo/sistema-schetov-zdravookhraneniya.php; https://nih.am/assets/pdf/atvk/b05a6b3ef948a86a63234817d55869df.pdf; https://doi.org/10.1787/9789264289604-en; http://hpac.kg/wp-content/uploads/2016/02/prp71_rus.pdf; https://www.researchgate.net/publication/237437542_national_health_accounts_for_georgia_2001-2003_national_health_accounts_for_georgia; [Starodubov et al., 2007; Turcanu et al., 2012].

1. Convergence of National Health Accounts and End-to-End Accounting as a Pathway for Institutional Development

To substantiate their hypothesis, the authors reviewed international methodological guidelines and reports on the establishment (institutionalization) and operation of National Health Accounts (NHA) [Berman, 1997; Guide to producing.., 2003; Maeda et al., 2012; A system of health.., 2017; Framework for assessing.., 2023; Best practice.., 2025; Mon et al., 2025].

These sources consistently identify the lack of end-to-end integration between NHA and financial and managerial accounting as a major systemic limitation of NHA and as a key source of the difficulties encountered in their development and operation.

Author of [Berman, 1997] argues that the key question is whether health accounts data can be derived consistently from providers' financial statements. In most developing countries, such a direct correspondence does not exist; as a result, health accounts require substantial estimation, reconciliation, and reclassification.

The Producers Guide [Guide to producing.., 2003] notes that most countries have complex health financing arrangements with multiple funding sources and agents. Tracking these flows and producing comparable accounts is challenging, as the complexity and diversity of financing mechanisms pose a significant barrier to standardization and to the implementation of national health accounts. At the same time, providers' financial and managerial accounting systems are poorly aligned with NHA classifications, making data reconciliation and interpretation resource-intensive.

The SHA 2011 standard description [A system of health.., 2017] emphasizes that fragmentation of health financing schemes and the presence of numerous reporting agents substantially complicate mapping financial flows to SHA categories. In practice, there is seldom a one-to-one mapping between providers' accounting records and SHA functional categories, which necessitates the use of bridge tables, aggregation procedures, and, in many cases, expert judgment.

The World Bank guide [Maeda et al., 2012] highlights that the diversity and complexity of financing mechanisms make data collection and consolidation for health accounts a major institutional challenge. The multiplicity of financial flows, sources, and implementing actors hampers both routine reporting and verification. In turn, weak alignment between health accounts and financial accounting systems reduces reliability and complicates quality assurance and audit.

A review of NHA implementation in OECD countries [Best practice.., 2025] indicates that countries with highly fragmented or decentralized financing systems, multiple insurers, or a substantial private sector face significant obstacles in producing robust and comprehensive health accounts. A persistent challenge is the lack of direct correspondence between managerial accounting categories and SHA reporting requirements. Consequently, many countries often have to rely on manual adjustments and reconciliation. In most cases, SHA 2011 relies on the aggregation of heterogeneous sources (budgets, insurance funds, surveys, provider reports) rather than on direct data extraction from an integrated financial and managerial accounting system. This can create discrepancies between national accounts indicators and actual financial records at the level of institutions and funding authorities.

According to the Framework for assessing health accounts maturity [Framework for assessing.., 2023], diversified financing flows and multiple reporting agents create a major barrier, often leading to incomplete data and limited comparability. The framework further emphasizes that maturity requires full integration with providers' routine accounting and managerial reporting; however, progress has been slow in most countries.

Although the establishment of NHA in non-OECD countries is more recent, available evidence indicates that the lack of integration between NHA and financial and managerial accounting is equally consequential in these settings. Reports on NHA implementation in Eastern Mediterranean countries show that most reports are published with delays of several years; only three countries in the region have managed to establish annual reporting. This outcome is directly linked to difficulties in accessing data, collecting information from multiple fragmented sources, and manually reconciling it with budgetary and accounting records. As a result, many countries are unable to institutionalize regular NHA production because of difficulties in obtaining and processing primary financial data and the lack of a standardized interface between accounting systems and the SHA 2011 framework. Evidence from pilot NHA projects in Egypt and Palestine indicates that source data from national accounting systems do not align with SHA 2011 requirements in structure. The South Africa report emphasizes that NHA construction relies on on compiling data from numerous fragmented sources (national and provincial budgets, insurance schemes, household surveys, and hospital administrative records), while highlighting mismatches between classifications and the need for recoding and reconciliation with SHA 2011 classifications. This indicates the absence of end-to-end linkage with providers' accounting systems [Best practice.., 2025].

Thus, methodological guidelines and institutionalization reviews indicate that even in most OECD countries, alignment between SHA and national accounting systems remains incomplete. Data are typically compiled as samples or aggregates drawn from multiple systems (statistics, budgets, fund accounts) rather than generated through modules built into providers' accounting systems. This systemic limitation is even more pronounced in low- and middle-income countries.

Analysis of OECD countries' experience with NHA implementation – both the limited practical fulfillment of the full set of SHA 2011 requirements and the questionable effectiveness of NHA as a tool for managing health care financing – suggests that, at present, SHA 2011-based NHA fall well short of a mature system in which strict procedures reliably ensure the intended outcomes. At this stage, NHA under SHA 2011 resemble a roadmap, strategic plan, or development tool for centralized accounting and analysis of health care financial resources – one that specifies what should be done and how, but without guaranteeing a concrete outcome.

To date, OECD countries have not achieved end-to-end integration of NHA with financial and managerial accounting. Instead, they have addressed the complexity of health financing systems in line with Ashby's cybernetic principle: NHA systems are designed to be as complex as the financing models they reflect. Separate data collection and verification channels are established and maintained for each function, provider group, and financing scheme. This results in NHA functioning as an additional, highly complex and resource-intensive structure that collects data primarily through requests rather than through automated extraction from accounting and managerial systems. Such an approach reduces data quality, necessitates extensive verification, and limits its usefulness for managerial decision-making. Consequently, the more complex the health financing system, the more complex and costly the NHA system becomes – and the lower the quality and practical value of the resulting data. This gives rise to a range of inherent limitations, shortcomings, and risks associated with NHA.

2. The Soviet Experience as a Potential Policy Model

As shown in Table 1, the Soviet Union demonstrated effective control over health care expenditure and its alignment with overall economic output. This reflected a fundamentally different approach to centralized accounting of health sector financial resources. Despite operating as a low-income country under conditions of severe resource scarcity, the USSR established the world's first system of universal access to health care. Under these circumstances, centralized and highly detailed resource accounting became a core instrument for improving the efficiency of the health care system.

Resource scarcity pushed the architects of the Soviet health system toward a fundamentally different approach – reengineering through a radical redesign of the financing system. On the one hand, this meant simplifying and streamlining the system by eliminating intermediaries and removing redundant or duplicative processes, primarily by integrating the payer (a public administration authority) with providers that were both administratively subordinate and financially accountable to it (state medical organizations). On the other hand, it meant turning line-item budgeting (LIB) into a universal end-to-end method for managing the entire health financing cycle, allowing financial flows to be tracked from the USSR State Planning Committee down to rural feldsher – midwife stations. This approach covered resource norm-setting and planning, organization of resource use, incentives for cost efficiency, accounting of government health expenditures and providers' costs, and control over the targeted use of funds [Popov, 1976].

There are grounds to suggest that this Soviet innovation offered several advantages over the NHA systems adopted in OECD countries. Despite its low-income status, the Soviet Union established the world's first system of universal health coverage (UHC), with health expenditure levels far below those of OECD countries while delivering comparable access to medical care. Unlike OECD countries, the USSR maintained effective control over health care expenditure and kept it aligned with overall economic output.

At the same time, the Soviet system had shortcomings that may also be seen as areas for further development. Because the USSR lagged behind in macroeconomic research and treated health care as a "non-productive" sector, its contribution to social production was not captured in intersectoral balance models. Unlike NHA, Soviet accounting data were designed primarily for day-to-day management and were insufficiently detailed for health policy purposes. In addition, the lack of compatibility with international standards constrained meaningful international comparisons and the exchange of best practices.

Accordingly, there is reason to assume that the main problems of Soviet health care – residual financing, imbalances in resource allocation, and pronounced regional and social inequalities in funding – stemmed not from intrinsic flaws of the Soviet model itself, but from weaknesses in health policy, including the absence of the statistical data required for informed decision-making. This calls into question the scientific basis of the 1990s reforms built around the narrative of the Semashko system's "low economic efficiency" and suggests that convergence between Soviet end-to-end accounting based on LIB and Western NHA frameworks may offer a promising direction.

Why does such convergence appear feasible?

First, in terms of objectives, the Soviet and Western approaches are complementary. In OECD countries, NHA data are not integrated with financial and managerial accounting. As a result, the development and operation of NHA rely on costly data collection and verification subsystems, while the resulting data remain poorly suited for managerial use. This helps explain why NHA have failed to support effective control of health care expenditure in OECD countries. At the same time, NHA are explicitly designed to link health care with the broader economy within the System of National Accounts, to support international comparisons, and to inform policy (strategic) decisions in health financing – an area in which OECD countries have achieved notable success, particularly in reducing imbalances and inequalities in health care financing.

By contrast, in the Soviet health system, the end-to-end LIB approach was fully integrated with financial and managerial accounting and was conceived primarily as an operational management tool rather than a policy instrument. This integration underpinned the USSR's strong performance in expenditure control and its ability to achieve universal access to care at minimal cost. However, in its Soviet form, LIB did not allow for assessment of health care's contribution to GDP, constrained international comparability, and provided decision-makers with a very limited set of indicators for policy (strategic) decision-making in health financing.

In terms of objectives, therefore, OECD NHA and the Soviet LIB approach complement each other, each addressing the key weaknesses and systemic limitations of the other.

Second, both approaches share a common methodological foundation rooted in cybernetics: the principle of decomposition – breaking a complex health expenditure system into simpler elements such as budget lines, accounting categories, or codes – and the use of cross-tabulation (matrix methods). This involves the classification, systematization, and organization of data along integrated axes, facilitating data perception and analysis, and the identification of correlations between them.

At the same time, NHA under the SHA 2011 standard offer a clear advantage over the Soviet LIB format in terms of data classification and analytical capacity. Whereas the Soviet LIB relied on a relatively simple classification structure, SHA 2011 reflects the complexity of modern health care systems. Its extensive and continuously updated classification framework enables much deeper analytical granularity, advancing the cybernetic principle of requisite variety. This increased classification complexity has, in turn, necessitated the development of a more sophisticated analytical apparatus based on cross-tabulation.

Accordingly, while the Soviet LIB relied primarily on two-dimensional and weakly integrated cross-tables, SHA 2011-based NHA operate across multiple, systematically integrated data axes using a wide range of two-, three-, and multidimensional matrices. NHA are also adapted to market economies and multi-level health financing systems through the use of double-entry bookkeeping and accrual accounting. However, the NHA classification framework and its robust analytical toolkit can be used to define the classification of LIB budget lines and tables.

Third, there are no inherent obstacles to combining NHA with end-to-end management of the entire health financing cycle based on LIB, including its adoption as a universal and exclusive payment method for medical providers. Such an approach would address the principal systemic limitation of NHA – their lack of integration with financial and managerial accounting – and eliminate the need for a costly auxiliary bureaucratic structure dedicated to data collection and verification.

During the neoliberal reforms of the 1990s, LIB was widely stigmatized as an “inefficient” method of paying for medical care. The present study reviewed both international and Russian sources in search of objective evidence to substantiate this claim – beyond expert opinion or citation chains – and found none. In practice, LIB remains the conventional methodological foundation of sound financial planning, accounting, and cost control in both the public sector and business. Moreover, in its various forms, LIB is effectively indispensable for pricing complex services and projects characterized by high uncertainty and risk, including construction, infrastructure, shipbuilding, energy, and health care. World Bank experts acknowledge that LIB has long been and continues to be a widely used and effective method of cost control in health care, particularly in low-income countries [Langenbrunner et al., 2009]. In several countries, line-item budgeting remains the primary instrument for ensuring financial control, transparency, and the prevention of overspending in the health sector [Mon et al., 2025]. LIB also demonstrates resilience in primary health care, facilitating regulatory compliance, ensuring stable funding for basic services, and reducing managerial risks – especially in contexts of limited digitalization and weak institutional capacity [Pholpark et al., 2025].

At the same time, LIB has served as the foundation for a broad range of modern budgeting approaches designed to mitigate the shortcomings of classical line-item budgeting while preserving its advantages. These include activity-based budgeting, program- and performance-based budgeting, zero-based budgeting, rolling budgets, and process-oriented budgeting.

The pricing logic underlying LIB is well aligned with the specific characteristics of health care services – their complexity, probabilistic effectiveness, and substantial variability in demand, costs, and cost structures. Advances in information technology make it possible to achieve greater precision, flexibility, adaptability, and managerial control under LIB-based financing than under lump-sum payment models that consolidate all provider costs into a single tariff, such as fee-for-service, capitation, global budgets, diagnosis-related groups, and related mechanisms. LIB is also suitable for contracting both public and private (commercial) medical providers, thereby enhancing transparency in pricing and financial settlements. In business practice, the budget line reflecting a contractor’s margin (profitability) is typically referred to as estimated profit or overheads and profit.

Accordingly, there are strong grounds to believe that convergence between two approaches to health sector financial accounting that emerged under very different historical conditions – the Soviet model and those adopted in OECD countries – can combine their respective strengths within a new approach while mitigating their inherent limitations. The task, therefore, is to design a new health financing system, at least for the public sector, that combines the end-to-end nature of hierarchically planned, implemented, and controlled line-item budgets – in their modern interpretations, including activity-based budgeting, program- and performance-based budgeting, results-oriented budgeting, zero-based budgeting, rolling budgets, and process-oriented budgeting – with organization based on classifications and aligned with the integrated data axes of SHA 2011.

In this way, NHA can be transformed from a tool of retrospective statistical observation into a data-driven instrument for managing health care financing.

Conclusions

1. Analysis of NHA implementation and practical use indicates that this methodology is in crisis, as reflected in low interest in NHA even among OECD countries.

2. The primary driver of this limited interest is the lack of end-to-end integration between NHA and financial and managerial accounting, which reduces the accuracy, timeliness, and practical value of NHA data and makes them poorly suited for management purposes.

3. A feasible and promising way to transform NHA from a passive tool of retrospective statistical observation into a data-driven management instrument is to synthesize (converge) them with the Soviet-developed approach to end-to-end health financing management based on a hierarchical system of line-item budgets.

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Configurational Flexibility of a Firm's Strategic Orientations: An Empirical Study of the Impact of Components on Firm Performance Parameters

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Abstract

This study examines the concept of strategic entrepreneurship through the lens of strategic orientations and introduces a new concept– configurational flexibility of a firm's strategic orientations (hereinafter referred to as–CFSO). Based on an empirical investigation, the study identifies the constituent elements of configurational flexibility and develops a regression model to assess extent to which the components of the proposed indicator (CFSO), influence firm performance outcomes. These outcomes are associated with the speed of launching a new product or project to the market in response to environmental threats and opportunities.

Keywords: firm performance, strategic orientations of the firm, resource-based theory

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企业战略定位的配置灵活性：组件对公司性能参数影响的实践研究

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摘要

本文章作者在通过战略导向视角研究战略创业概念的过程中提出了一个新概念——企业战略定位的配置灵活性。基于所开展的实证研究，文章阐述了企业战略定位配置灵活性的构成要素，并构建了一个回归模型。该模型能够评估新指标——企业战略定位的配置灵活性——各组成部分对企业经营绩效相关参数的影响程度。这些绩效参数涉及企业为应对环境威胁或机遇而将新产品/项目推向市场的速度。

关键词： 企业经营绩效、公司的战略方向、资源理论。

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In an environment characterized by increasing turbulence at both the external and internal organizational levels, modern firms are increasingly confronted with questions of how to achieve superior performance, strengthen their financial outcomes, secure sustainable competitive positions, and maintain customer loyalty. At the same time, the contemporary market economy – within which firms of different sizes operate in a shared economic space – together with the ongoing digitalization of business processes and the growing uncertainty of the external environment, has become a set of defining conditions shaping firms' strategic behavior. These factors compel organizations to continuously search for new approaches to effective development and operation. This challenge becomes particularly acute during periods of economic and political instability, when resource availability is significantly constrained, sanction mechanisms intensify, and the overall level of uncertainty reaches its maximum. Under such conditions, effective performance requires the formation of a flexible course of organizational action – that is, a coherent strategy. In this context, the speed of managerial response and decision implementation increasingly emerges as a critical source of competitive advantage.

The methodological framework of the present study is grounded in a systems-based approach to the analysis of organizational strategic actions and is conceptually anchored in the resource-based theory of the firm.

The empirical basis of the research consists of a sample of 295 domestic non-listed firms, randomly selected through data filtering using the Transparent Business information service available on the website of the Federal Tax Service of the Russian Federation. The firms included in the sample operate across the following sectors defined by the Russian National Classification of Economic Activities:

- manufacturing industries;
- information and communication activities;
- professional, scientific, and technical activities;
- construction;
- healthcare and social services;
- education.

The choice of these sectors reflects the objective of examining organizations operating in industries identified as key drivers of national economic development in the medium term, in accordance with the Forecast of the Socio-Economic Development of the Russian Federation for 2026 and the planned period of 2027–2028 issued by the Ministry of Economic Development of the Russian Federation. A detailed overview of the sample characteristics is presented in Table 1.

The choice of non-listed firms as the focus of this study reflects their distinctive characteristics, most notably their higher degree of structural flexibility and greater capacity to adapt to environmental change when compared with publicly listed organizations. Public firms tend to operate within more stable and formalized structures and often rely on established operational routines, largely due to their longer presence in the market.

Primary data were collected through a series of in-depth interviews involving ten top managers and six product managers. Respondents were selected based on their extensive involvement in organizational processes, product and project development, and the strategic activities of the firms under investigation. The content analysis of the interview materials revealed a set of factors underlying the configurational flexibility of a firm's strategic orientations (hereinafter referred to as CFSO). These factors were subsequently used as the core components of the proposed construct. At the next stage, a structured questionnaire was developed and distributed across the full sample in order to assess the level of development of each CFSO component. Regression analysis was then applied to determine which components exert the strongest influence on firms' ability to achieve positive performance outcomes. Particular attention is devoted to distinguishing the factors that shape the effectiveness of CFSO elements in small and medium-sized enterprises (SMEs) and in large firms.

The theory of strategic orientations, understood as adherence to the principles and behavioral practices embedded within a firm's strategy [Gatignon, Xuereb, 1997], emerged in 1986 as a logical extension of the resource-based view of the firm. Within this framework, organizations are conceptualized as bundles of resources that must be accumulated, configured, and developed in order to generate strategically meaningful outcomes. Strategic orientations provide a mechanism for purposeful resource combination and include market orientation, learning orientation, innovation orientation, digital orientation, value orientation, and social value orientation. When effectively aligned, these orientations can support profit growth, enhance market share, and enable firms to achieve competitive leadership by strengthening the structure and deployment of their resource base [Tarasova, 2025a].

However, in an environment characterized by increasing dynamism and the growing intensity of contextual pressures, competitive advantage depends not only on the ability to combine resources, but also on the speed with which such combinations can be reconfigured. Against this backdrop, the present study introduces the concept of configurational flexibility of a firm's strategic orientations, defined as the speed at which firms are able to shift between selected strategic orientations within an established configuration in response to changing contextual conditions. A high level of CFSO development enables firms to deploy alternative combinations of strategic orientations and resources in pursuit of key strategic objectives, primarily by supporting proactive responses to emerging environmental threats and opportunities. This capability is shaped by the interaction of several interrelated elements, which are discussed in detail below and must each reach a sufficiently advanced level of development within the firm.

Resource base flexibility refers to the firm's level of development of a required pool of heterogeneous resources and their maintenance in a condition that enables proactive reallocation in advance of emerging environmental threats and opportunities driven by ongoing environmental change. This dimension represents a multidimensional construct encompassing the following components:

Table 1
Characteristics of the firms under study

Criterion	Category	Number	Share (%)
Firm size (number of employees)	Microenterprises (≤15 employees)	68	23.05
	Small enterprise (16–100 employees)	118	40
	Medium-sized enterprise (101–250 employees)	79	26.78
	Large firm (>251 employees)	30	10.17
Firm age	≤2 years	57	19.32
	3–5 years	137	46.44
	6–10 years	75	25.42
	>10 years	26	8.81
Industry affiliation (according to the Russian National Classification of Economic Activities, OKVED)	Manufacturing industries	76	25.76
	Information and communication activities	48	16.27
	Professional, scientific, and technical activities	46	15.59
	Construction	25	8.47
	Healthcare and social services	73	24.75
	Education	27	9.15
Federal district	Central	37	12.54
	Southern	38	12.88
	Northwestern	49	16.61
	Far Eastern	31	10.51
	Siberian	28	9.49
	Ural	41	13.9
	Volga	34	11.53
	North Caucasian	37	12.54

Source: compiled by the author.

1) Social capital, defined as a system of internal and external social ties, shared norms, and values that facilitate the acquisition of information from partners (external social capital) and employees (internal social capital), thereby supporting the identification of environmental threats and opportunities [Orlova, 2022];

2) Human capital encompassing the knowledge, skills, and competencies of employees involved in product and project development. In terms of flexibility, this dimension requires the presence of cross-functional teams capable of generating effective responses to environmental challenges through diverse professional experience. In addition, employees should demonstrate adaptability, learning capacity, engagement, and proactive behavior, enabling effective and timely adaptation to changes in the firm's operating environment;

3) Financial capital, representing the firm's monetary resources. Flexibility in this dimension is ensured through flexible budgeting systems that enable the reallocation of specific budget items and financial resources. This allows firms to implement projects, products, or changes within tight time constraints in response to emerging threats or industry trends, thereby supporting market leadership amid shifting internal priorities;

4) Physical capital, defined as the firm's tangible assets supporting the production process. Flexibility in physical capital is intended to be ensured through the availability of resource reserves, effective resource planning systems, and task prioritization.

Flexibility of organizational processes and procedures is understood as the firm's ability to eliminate managerial pathologies from its internal processes [Tarasova, 2025b], among which excessive bureaucratization is the most common. In practice, lengthy multi-level approval procedures, repeated reconsideration of initiatives, the absence of fast-track decision-making mechanisms, and similar constraints significantly extend the time required to bring a new product or project to the market (i.e., increase time to market). This, in turn, has a negative effect on firm performance: competitors with fewer bureaucratic barriers gain market leadership, the potential profit generated by the launched product decreases, and innovations may lose relevance against the backdrop of an increasingly fast-changing environment;

The role of the firm's leader or founder as a source of strategic direction lies in setting the tone from the top by emphasizing the importance of adaptability to change, creativity, and forecasting capability within operational and production processes. The firm's leader establishes the management system – including governance structures, procedures for evaluating and approving new concepts, and related decision-making mechanisms – and shapes organizational culture as well as the firm's approach to clients, suppliers, and partners. Together, these factors exert firm-wide effects, influencing firm performance and the development of other components of CFSO.

Forecasting capability refers to the firm's ability to identify threats and opportunities in the external environment, accurately assess the likelihood of their occurrence, and evaluate their potential implications for subsequent resource-related decisions.

Collectively, these factors constitute the configurational flexibility of a firm's strategic orientations (CFSO) and determine the firm's capacity – depending on how well these elements are developed – to combine strategic orientation components, that is, resources, at varying speeds and thereby achieve specific organizational outcomes.

Based on the component structure of CFSO identified through content analysis of a series of in-depth interviews with managers from the sampled firms, a regression model was developed to examine the positive effects associated with a high level of resource reconfiguration speed:

$$Y_i = \beta_0 + \beta_1 \times SOC.CAP_i + \beta_2 \times HUM.CAP_i + \beta_3 \times FIN.CAP_i + \beta_4 \times PHYS.CAP_i + \beta_5 \times ORG.PR_i + \beta_6 \times FOUND_i + \beta_7 \times FORECAST_i + \varepsilon_i, \quad (1)$$

where Y_i denotes firm performance indicators associated with the level of CFSO, including: (1) reduction in the time required to bring a trend-aligned new product or project to the market; (2) growth in market share; (3) the firm's ability to increase profitability under external shocks (sanctions, exchange rate volatility, etc.);

$SOC.CAP_i$ – social capital, $HUM.CAP_i$ – human capital, $FIN.CAP_i$ – financial capital, $PHYS.CAP_i$ – physical capital, collectively representing the firm's resource base;

$ORG.PR_i$ – flexibility of organizational processes and procedures;

$FOUND_i$ – the role of the firm's leader or founder;

$FORECAST_i$ – forecasting capability;

ε_i – random error term.

The results of the regression analysis based on Model (1) are presented in Tables 2–4.

The results presented in Table 2 explain 57% of the variation in time-to-market reduction among firms in the SME sector and 60% of the variation among large firms. For SMEs, the statistically significant determinants are primarily resource-related factors. The highest standardized β coefficient is associated with the maturity and flexibility of human capital. Small firms are particularly sensitive to resource availability, and under conditions of limited material assets, the team becomes a strategically critical resource that largely determines firm performance. Another important factor is the firm's ability to exhibit forecasting capability as a predictor of emerging threats and opportunities. For large firms, acceleration of time to market is likewise strongly influenced by the resource base and forecasting capability; however, unlike in the SME sector, a more pronounced role is observed for social capital. This is largely attributable to the scale of operations typical of large firms, which facilitates the development of extensive internal and external networks. A second distinguishing feature is the strong effect attributed to organizational flexibility, as large firms are more likely to face bureaucratic procedures that constrain the rapid introduction of new products, projects, or modifications to existing product lines in response to increasing environmental dynamism.

With regard to the impact of CFSO parameters on firms' market share growth, the results presented in Table 3 indicate the following. In the SME sector, the strongest effects are again observed for human capital and forecasting capability, which once more highlights

Table 2
Impact of CFSO parameters on reducing time to market for a new product or project aligned with industry trends

Independent variable	Unstandardized coefficient		Standardized coefficient (β_i)	
	SMEs	Large firms	SMEs	Large firms
Constant (β_0)	- 0.117	- 0.123	- 0.117	- 0.123
Resource base:				
– Social capital ($SOC.CAP_i$)	- 0.145	- 0.301	- 0.155	- 0.306
– Human capital ($HUM.CAP_i$)	- 0.462	- 0.382	- 0.485	- 0.391
– Financial capital ($FIN.CAP_i$)	- 0.301	- 0.113	- 0.322	- 0.123
– Physical capital ($PHYS.CAP_i$)	- 0.299	- 0.091	- 0.301	- 0.108
Flexibility of organizational processes and procedures ($ORG.PR_i$)	- 0.081	- 0.286	- 0.095	- 0.314
Role of the firm's leader/founder ($FOUND_i$)	- 0.274	- 0.042	- 0.296	- 0.053
Forecasting capability ($FORECAST_i$)	- 0.299	- 0.349	- 0.307	- 0.367
Adjusted R^2	0.57	0.6	0.57	0.6
Number of observations	265	30	265	30

Note. $p < 0.05$.
Source: compiled by the author.

Table 3
Impact of CFSO parameters on the of market share growth through rapid modification of existing product or project or the development of a new one in response to environmental

Independent variable	Unstandardized coefficient		Standardized coefficient (β_i)	
	SMEs	Large firms	SMEs	Large firms
Constant (β0)	0.091	0.108	0.091	0.108
Resource base:				
– Social capital ($SOC.CAP_i$)	0.151	0.195	0.168	0.203
– Human capital ($HUM.CAP_i$)	0.199	0.175	0.217	0.198
– Financial capital ($FIN.CAP_i$)	0.098	0.131	0.105	0.137
– Physical capital ($PHYS.CAP_i$)	0.157	0.089	0.163	0.092
Flexibility of organizational processes and procedures ($ORG.PR_i$)	0.070	0.259	0.075	0.267
Role of the firm's leader/founder ($FOUND_i$)	0.247	0.099	0.256	0.107
Forecasting capability ($FORECAST_i$)	0.285	0.296	0.297	0.301
Adjusted R^2	0.52	0.49	0.52	0.49
Number of observations	265	30	265	30

Note. $p < 0.05$.
Source: compiled by the author.

the strategic importance of individual and team-related characteristics for organizations of this type. For large firms, the results are largely consistent with the conclusions obtained from the analysis of Table 2.

With regard to the impact of CFSO parameters on firms' ability to increase financial capital, the model explains 48% of the variance for SMEs and 42% for large firms. For small and medium-sized enterprises, the greatest influence on maintaining financial stability – according to the findings of the present study – was exerted not only by human and financial capital, which have already demonstrated their importance, but also by the flexibility of organizational

Table 4
Impact of CFSO parameters on a firm's ability to increase profitability under external shocks

Independent variable	Unstandardized coefficient		Standardized coefficient (β_i)	
	SMEs	Large firms	SMEs	Large firms
Constant (β_0)	0.081	0.104	0.081	0.104
Resource base:				
– Social capital ($SOC.CAP_i$)	0.051	0.139	0.056	0.146
– Human capital ($HUM.CAP_i$)	0.199	0.091	0.208	0.097
– Financial capital ($FIN.CAP_i$)	0.261	0.196	0.265	0.207
– Physical capital ($PHYS.CAP_i$)	0.085	0.045	0.087	0.049
Flexibility of organizational processes and procedures ($ORG.PR_i$)	0.230	0.192	0.234	0.201
Role of the firm's leader/founder ($FOUND_i$)	0.131	0.132	0.138	0.138
Forecasting capability ($FORECAST_i$)	0.182	0.215	0.199	0.223
Adjusted R^2	0.48	0.42	0.48	0.42
Number of observations	265	30	265	30

Note. $p < 0.05$.
Source: compiled by the author.

processes and procedures. For large organizations, the set of influential parameters remained unchanged.

Overall, the findings suggest that the level of configurational flexibility of a firm's strategic orientations represents an important indicator that enables firms not only to diagnose the current state of development of the elements supporting rapid resource reconfiguration, but also to employ CFSO as an analytical and managerial instrument. When its constituent factors are sufficiently developed, this instrument can allow organizations to increase market share, maintain financial stability under external environmental threats, and achieve market leadership by introducing products or projects earlier in response to emerging industry trends.

Further development of this research will focus on assessing the influence of CFSO factors on firms' strategic orientations and on examining organizations' capacity to develop individual strategic orientation components depending on the level of development of specific CFSO elements.

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The Role of Artificial Intelligence in Knowledge Management: Strategic Implications and Mechanism Transformation

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Abstract

The adoption of artificial intelligence (AI) has affected all areas of activity in modern companies, including knowledge management systems. The aim of this article is to identify the opportunities for implementing and applying AI in the key stages of knowledge management, namely knowledge creation, storage, processing, and utilization in the development of innovations. In addition, the article proposes a mechanism for transforming knowledge management systems through the integration of AI technologies. The process of developing knowledge-based innovations is inherently multifactorial, as such innovations emerge from the functioning of the knowledge management system and the organization's innovation process. Moreover, organizations differ in their levels of maturity with respect to both knowledge management systems and the organization's innovation process. For this reason, the proposed mechanism for generating knowledge-based innovations accounts for the heterogeneity of potential users and is designed to be adaptable for use by different organizations. The article demonstrates the construction of an applied mechanism for fostering knowledge-based innovations.

Keywords: knowledge management system, knowledge-based innovations, knowledge management mechanism, artificial intelligence, innovation process

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AI在知识管理中的作用：战略层面与机制变革

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摘要

人工智能（AI）的引入已触及现代公司经营活动的所有领域，包括知识管理系统。本文旨在揭示将AI应用于知识管理系统关键环节的可能性：即在创新过程中进行知识的创造、存储、处理与运用。此外，文章还提出了与AI系统应用相关的知识管理系统转型机制。基于知识的创新生成机制具有多因素特性，因为知识驱动的创新成果源于知识管理系统与企业创新流程的协同运作。而且每个企业在知识管理系统成熟度与创新活跃度方面处于不同水平。正因如此，此类创新生成机制必须考虑潜在用户的差异性，并能够适配其中每一类用户的需求。本文章展示了基于知识的应用型创新机制的具体构建过程。

关键词： 知识管理体系、以知识为基础的创新、知识管理机制、AI、创新过程

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Introduction

The impact of information technologies on the knowledge management system (hereinafter referred to as the KMS) has been widely examined in academic research (see, for example, [Tsui, 2005]). In particular, [Duffy, 2019] investigates the influence of deep learning technologies on the ability of algorithms to replicate human cognitive functions, including vision (image recognition), hearing (speech recognition and natural language processing), and decision-making based on advanced data analytics. Other studies [Kaplan, Haenlein, 2019; Canhoto, Clear, 2020] demonstrate that artificial intelligence (AI) technologies – such as supervised machine learning (ML), neural networks, and deep learning – are increasingly being adopted for commercial purposes. The authors of [Brynjolfsson, Mitchell, 2017] emphasize that this AI-driven approach to organizational management differs substantially from traditional knowledge management systems, such as expert systems based on symbolic logic, in which rules are explicitly formulated and embedded by human experts within the KMS [Raisch, Krakowski, 2020].

Since both artificial intelligence and knowledge management are associated with the nature of knowledge and learning, AI technologies have the potential to significantly transform the KMS within organizations [Sanzogni et al., 2017]. This transformation affects two techno-organizational domains. The first concerns the knowledge management system itself, which is directly related to knowledge management in organizations. The second relates to artificial intelligence as a technology capable of imitating human knowledge and learning processes.

Firms should explore the potential role of new artificial intelligence technologies in supporting the organizational activities related to the KMS.

To develop a mechanism for creating knowledge-based innovations, its structure must first be defined. In this context, it is important to consider the nature of knowledge-based innovations, which emerge through analysis of the organization's existing KMS to identify knowledge with innovation potential. When incorporated into the innovation process, such knowledge may lead the organization to the creation of innovations.

Accordingly, the mechanism comprises two core components: the knowledge management system and the innovation process. Within this framework, the KMS should be automated to ensure that all available knowledge is consistently systematized and structured for effective use. In addition, this knowledge should be subject to continuous analysis of its innovation potential. Once such knowledge is identified, it is transferred to the innovation process, providing the organization with the opportunity to create innovations. In the current context, artificial intelligence and related technologies represent the most practical tools for organizing the knowledge management system described above. This enables individual KMS elements to interact with appropriate AI technologies, allowing the system to be configured more effectively to identify knowledge with innovation potential and to support the creation of innovations based on such knowledge.

This approach addresses the adaptability of the mechanism. Less mature KMSs may rely on simpler technologies that nonetheless optimize and improve system performance, thereby increasing the likelihood of innovation. In contrast, more mature KMSs may be fully integrated with advanced AI technologies, which can support even the identification of strategic opportunities.

In view of the above, the study seeks to address the following questions:

– Which approach to defining the elements of the knowledge management system is most appropriate for a mechanism aimed at creating knowledge-based innovations?
– How can the maturity level of the KMS be determined, and which categorization of maturity levels should be applied within the proposed mechanism to enable an organization to select the most suitable modification?

1. Literature Review

The literature review begins by examining existing approaches to defining knowledge management system maturity levels in organizations, which provides a basis for identifying the most comprehensive and appropriate approach to developing a mechanism for knowledge-based innovation.

K. Wiig's Model. Wiig's model is based on the view that knowledge serves as the foundation for effective managerial decision-making within an organization [Wiig, 1997]. The model places primary emphasis on knowledge quality, as well as on the organization's capacity to create, apply, and retain knowledge [Wiig, 2004]. Within this framework, KMS maturity develops through the following stages:

1) Awareness of the importance of knowledge. The organization recognizes the value of knowledge; however, its use remains insufficiently structured and systematized, which results in deficiencies in KMS functioning.
2) Development of knowledge infrastructure. Knowledge becomes structured and categorized, and formal standards within the knowledge management system begin to emerge.
3) Knowledge management as a system. The KMS is integrated into business processes and interacts with IT tools, which improves usability as well as the quality and speed of operations.
4) Strategic and optimized use of knowledge. At this level, the KMS is applied in strategic decision-making. Knowledge management is integrated into innovation activities, organizational culture, and employee training. Knowledge becomes a key organizational asset, and regular assessment of knowledge quality is carried out.

R. Maier's Model. Maier conceptualizes knowledge management system maturity as the level of development of the information and communication infrastructure that underpins the KMS [Maier, 2013]. This approach is grounded in the assumption that multifunctional processing of large volumes of knowledge is feasible only in the presence of advanced technological capabilities. On this basis, the author distinguishes the following KMS maturity levels:

1) Basic ICT tools. This stage is characterized by the use of standard office applications (e.g., Word, Excel), local document storage, the absence of centralized repositories, and manual knowledge search through interaction with colleagues. At this level, a knowledge management system does not exist in the academic sense, nor is there sufficient infrastructure to support its implementation.
2) Organized ICT infrastructure. At this stage, integrated digital repositories emerge, enabling the creation of knowledge artifacts. Document classification systems are introduced, and the overall structure of the KMS begins to take shape.
3) Integrated KMS. This level involves automation of knowledge processing, the availability of corporate knowledge bases with intelligent search capabilities, and integration with CRM, ERP, and HRM systems.
4) Optimized and intelligent ICT infrastructure. At the highest level, artificial intelligence is integrated into textual knowledge processing through technologies such as NLP and NER, along with semantic search, knowledge graphs, recommendation systems, and decision support systems.

The Four Pillars Model. The Four Pillars Model evaluates the maturity of the knowledge management system through the balanced development of four components rather than through a linear sequence in which each level represents incremental progress over the previous one [Stankosky, 2005]. As emphasized by the author of the model, R. Stankosky, only coordinated and comprehensive development of all four pillars makes it possible to establish a truly mature knowledge management system. These pillars include:

1) Leadership, referring to the presence of managerial support for the development of the knowledge management system;
2) Organization, reflecting the organization's ability to structure and organize knowledge;
3) Technology, defined as the availability of the IT tools required to support an effective and efficient KMS;
4) Learning, encompassing the organization's capacity to develop employee knowledge, retain it, and transfer accumulated knowledge to those employees who require it.

M. Zack's Model. Zack's model determines the maturity level of the knowledge management system based on the extent to which it is embedded in organizational planning processes [Zack, 1999]. Within this framework, three maturity levels are identified:

1) Operational, at which the KMS is used to address localized organizational tasks;
2) Tactical, where the KMS is applied across all organizational business processes;
3) Strategic, at which the KMS is employed in the formulation of organizational strategies.

Based on the analysis of academic literature on knowledge management system maturity models, the author proposes an original KMS maturity model that will be used in the subsequent development of the mechanism for creating knowledge-based innovations. Although the literature offers a wider range of conceptual approaches, the models reviewed above sufficiently capture the fundamental principles required for the continuation of this study.

2. Author's Model of Knowledge Management System Maturity

The author's model of knowledge management system maturity in organizations is presented below:

Implicit level. The implicit level represents the most basic stage, at which no systematized or formalized knowledge management system or supporting technologies are in place. Knowledge and experience reside primarily with individual employees, while any existing codification remains fragmented and limited in scope. Such partial codification does not contribute to either the innovation process or organizational business processes.

Formalized level. At the formalized level, the internal organizational environment fully recognizes the value of the knowledge management system and therefore takes initial steps toward its formalization – that is, toward presenting knowledge in a clear and usable form. At this stage, organizations seek to develop knowledge bases and codify accumulated experience so that employees can access relevant knowledge in specific work situations. However, specialized technologies and complex systems are not yet applied within the KMS, nor is the system integrated into core business processes.

Organized level. The third maturity level is characterized by the presence of an organized knowledge management system supported by sufficient technological capabilities for storing and processing large volumes of data. The system is continuously enriched with newly codified tacit knowledge generated by employees, as well as with knowledge acquired from external sources. At this stage, the KMS is actively used in the routine tasks of operational and middle-level personnel, serving as a reliable source of guidance when needed. In addition, the system is integrated with tools such as CRM platforms. However, at the organized level, the KMS is not involved in managerial decision-making and is not equipped with AI technologies.

Integrated level. The integrated level reflects a situation in which the organization's knowledge management system is supported by artificial intelligence technologies.

AI facilitates structured knowledge organization, enables intelligent search within knowledge repositories, and supports managerial decision-making processes. At this stage, the KMS is integrated into customer value creation processes. In practical terms, the knowledge management system is actively used within the company's core business processes, which ultimately leads to its widespread application across all levels of organizational activity.

Strategic level. At the strategic level, the KMS becomes one of the organization's key instruments for building competitive advantage. The company actively invests financial resources in the development and improvement of its knowledge management system, as the KMS is perceived as a strategic asset. This level of maturity also implies full integration of the KMS into organizational processes, including strategic decision-making. In addition, the system is closely linked to the innovation process, serving as its primary source of new knowledge and ideas.

A schematic representation of the KMS maturity levels is presented in Figure 1.

3. Development of the Knowledge-Based Innovation Mechanism

Following the categorization of KMS maturity levels, it becomes necessary to examine in greater detail the overall concept of the mechanism for creating knowledge-based innovations. At this stage, there is a need to establish – on the basis of theoretical and practical analysis of the research question – a connecting link between the knowledge management system and the innovation process that can generate an additional synergistic effect. Although the findings indicate a close relationship between the KMS and the innovation process, formalizing this relationship may enhance both its potential and its practical applicability. It has also become evident that many organizations are not sufficiently prepared to work effectively with the KMS in order to improve their performance, largely due to the complexity of the issue. This challenge is particularly characteristic of the first two KMS maturity levels. Accordingly, the proposed mechanism should address the identified limitations and provide organizations with practical support in improving the efficiency and effectiveness of their activities.

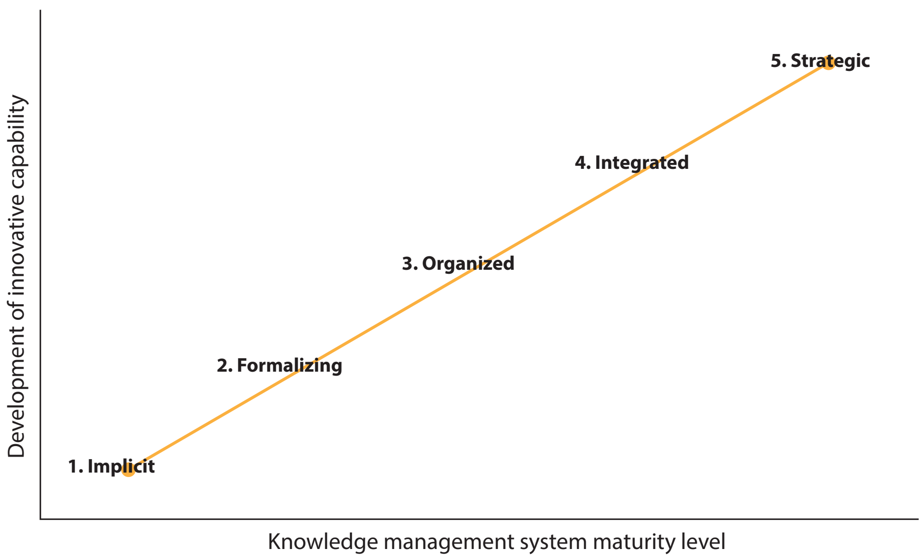
As discussed earlier, artificial intelligence represents the most realistic and appropriate connecting element. This conclusion is supported not only by the empirical component of the present study, but also by the work of internationally recognized scholars whose research was examined in the analysis of KMS maturity models. Contemporary conditions clearly indicate that the presence of artificial intelligence within an organization's technological portfolio will soon determine not only its level of technological development, but also its ability to remain competitive. Beyond its other advantages, AI is a highly practical and adaptive tool capable of responding to specific organizational needs. This flexibility makes it possible to incorporate organization-specific characteristics into the general model of the knowledge-based innovation mechanism, thereby ensuring its applicability across different KMS maturity levels.

Accordingly, the proposed mechanism consists of three components.

Knowledge management system. Within the proposed mechanism, the KMS provides the foundational basis for processes that may result in knowledge-based innovations through the use of various types of knowledge and data related to organizational activities. It is important to note that not all organizations are required to possess a fully developed set of KMS elements in order to apply the mechanism. For example, KMSs at the first two maturity levels remain highly rudimentary; nevertheless, even their integration with AI technologies can optimize a wide range of processes. Such optimization, in essence, represents a form of knowledge-based process innovation.

Artificial intelligence. Artificial intelligence functions as a universal and adaptive analytical component that processes both internal and external knowledge. Its key advantage lies in the ability to rapidly and systematically analyze large volumes of data and convert them into knowledge that is valuable for the organization. In many cases, AI may be integrated into organizational activities as a ready-made external agent, which significantly simplifies implementation and reduces required investment. Interaction between AI and the KMS involves the processing of the full body of available organizational knowledge and information in accordance with the assigned task. Thus, AI performs

Fig. 1. Knowledge management system maturity levels



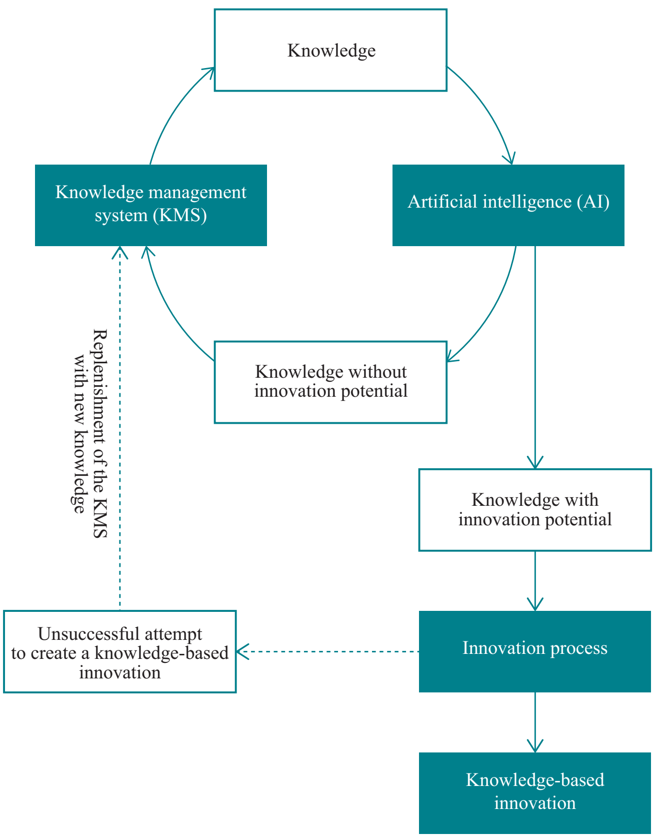
Source: prepared by the author.

task-oriented analysis, thereby increasing productivity and the likelihood of generating new ideas.

Innovation process. The innovation process represents the final stage of interaction between the KMS and artificial intelligence. It is evident that knowledge generated through this interaction will not always lead to innovation, as the development of a universal mechanism for the systematic generation of innovations does not appear feasible. Nevertheless, the proposed mechanism significantly increases these chances.

Figure 2 presents the conceptual framework of the knowledge-based innovation mechanism.

Fig. 2. Conceptual framework of the knowledge-based innovation mechanism



Source: prepared by the author.

The conceptual framework of the knowledge-based innovation mechanism presented in Figure 2 illustrates the continuous interaction between the knowledge management system and artificial intelligence, which enables the large-scale generation of new knowledge and ideas.

To gain a more detailed understanding of how the proposed mechanism operates, it is necessary to examine the manner in which AI interacts with each individual element of the knowledge management system. This, in turn, requires an analysis of existing approaches to defining the set of KMS elements.

Technocentric model. Within the technocentric model, the elements of the knowledge management system are interpreted as components of the information and technological infrastructure. In the works [Becerra-Fernandez, Sabherwal, 2010; 2014], the knowledge management system is conceptualized as a set of technologies supporting four core processes: knowledge creation, storage, transfer, and application. Within this framework, the system includes the following elements:

– knowledge repositories and document and data databases;
– corporate portals and content management systems;
– collaborative editing tools;
– platforms for communication and knowledge sharing;
– expert systems for analytics that support knowledge extraction from data.

The technocentric model provides a detailed representation of the knowledge management system from a technological perspective; however, it does not reflect the full complexity of the KMS, which constitutes its primary limitation.

Sociotechnical model: people, processes, and technologies. The sociotechnical model addresses the limitations of the previous approach by conceptualizing the knowledge management system as an interaction among people, processes, and technologies [Davenport, Prusak, 1998]. A more detailed description of these elements is provided below:

- People are carriers of knowledge and active participants in knowledge creation and exchange processes.
- Processes represent structured activities that organize the creation, codification, storage, dissemination, and application of knowledge in organizational practice.
- Technologies constitute the technological component that enables effective and efficient use of the knowledge management system. This category includes the full range of technologies identified within the technocentric model.

Taken together, this approach offers a practical and applicable representation of KMS elements. Some practitioners additionally introduce a fourth element – strategy – arguing for the need to explicitly distinguish the strategic dimension of knowledge management.

Infrastructure-based model. A key contribution within this approach is the study by [Gold et al., 2001], in which the knowledge management system is described in terms of organizational capabilities. Two groups of such capabilities are identified:

- Infrastructure capabilities, including organizational culture, organizational structure, and technologies;
- Process capabilities, including knowledge acquisition, conversion, application, and protection.

Accordingly, the knowledge management system is formed by these two capability blocks, which function as its core elements.

Following the analysis of the principal approaches to defining the elements of the knowledge management system, it becomes necessary to formulate the approach that will be applied by the author in developing a detailed mechanism for creating knowledge-based innovations. In this context, combining the sociotechnical and infrastructure-based models appears justified. As a result, the following set of KMS elements is proposed:

– people;
– processes;
– technologies;
– culture;
– strategy.

After defining the set of KMS elements, it is necessary to examine their interaction with artificial intelligence, which forms the basis of the knowledge-based innovation mechanism:

People. People are the primary carriers of knowledge within the organization. For this reason, their interaction with artificial intelligence is particularly promising, as it enables the rapid and structured transformation of tacit knowledge into explicit knowledge, as well as the distribution of knowledge among employees. In addition, AI supports employees in optimizing their professional activities, especially in knowledge search, managerial decision-making, and innovation development. When properly organized, interaction between people and AI can therefore be both rational and productive. The AI technologies relevant to this KMS element include generative models, NLP technologies, recommendation systems, personal assistant systems and chatbots, and adaptive learning systems.

Processes. As noted earlier, processes ensure the circulation, generation, dissemination, application, and storage of knowledge. Their interaction with artificial intelligence can therefore significantly enhance productivity. AI technologies enable more effective processing of large volumes of knowledge for the generation of new knowledge, which directly influences the effectiveness of the innovation process. Beyond its impact on innovation, AI facilitates fast and convenient access to organizational knowledge for all employees who require it and improves the continuous enrichment of the KMS with new knowledge. This, in turn, contributes positively to overall organizational performance. The AI technologies proposed for this element include NLP, semantic search, graph-based AI, predictive analytics, AutoML, and RAG systems.

Technologies. Technologies form the infrastructural foundation of the modern knowledge management system, while artificial intelligence enables further development of this infrastructure by extending its capabilities. For example, AI supports automated data processing, cognitive computing, identification of patterns and relationships, and automated structuring of analytical results. Accordingly, integrating AI with organizational technologies makes it possible to create a highly effective environment in which both computational capacity and innovation potential are strengthened. The AI technologies proposed for integration with this KMS element include LLM-based agents, vector databases, knowledge graphs, AutoML and MLOps platforms, artificial simulations, and digital twins.

Culture. Organizational culture serves as a motivating factor encouraging employees to acquire new knowledge and share it within the organization. At the same time, AI

Table 1
Overview of interactions between knowledge management system elements and AI tools

KMS element	AI function	AI technologies
People	Learning, idea generation, and support in task performance	Generative models, NLP technologies, recommendation systems, personal assistant systems and chatbots, adaptive learning systems
Processes	Automation of organizational processes with optimization of their performance and improvement of efficiency and effectiveness	NLP, semantic search, graph-based AI, predictive analytics, AutoML, RAG systems
Technologies	Development of an automated technological environment	LLM-based agents, vector databases, knowledge graphs, AutoML and MLOps platforms, artificial simulations and digital twins
Culture	Creation of a supportive environment for knowledge acquisition and knowledge sharing, increasing the potential for generating new knowledge for innovation	AI-based collaboration platforms, recommendation systems, AI-supported mentoring tools
Strategy	Enhancement of analytics and planning, enabling more informed managerial decision-making	Predictive analytics, scenario modeling and simulation AI, market intelligence AI, graph-based AI for competence mapping, trend identification systems

Source: prepared by the author.

technologies significantly reduce barriers to interaction among employees and provide convenient platforms that ensure broad access to required knowledge. AI also supports the optimization of mentoring processes and the onboarding of new employees. Potential AI technologies for this element include AI-based collaboration platforms, recommendation systems, and AI-supported mentoring tools.

Strategy. This element of the knowledge management system defines the direction of organizational development in the context of knowledge, innovation, and technology. Accordingly, AI technologies can enhance planning, trend identification, analytical activities, and managerial decision-making. AI tools are particularly valuable at the strategic level, as strategy relies heavily on in-depth analysis. Such analysis can be performed by AI technologies rapidly and with high accuracy in collaboration with human decision-makers – and, increasingly, with reduced human involvement. Relevant technologies include predictive analytics, scenario modeling and simulation AI, market intelligence AI, graph-based AI for competence mapping, and trend identification systems.

An overview of interactions between the knowledge management system and artificial intelligence tools is presented in Table 1.

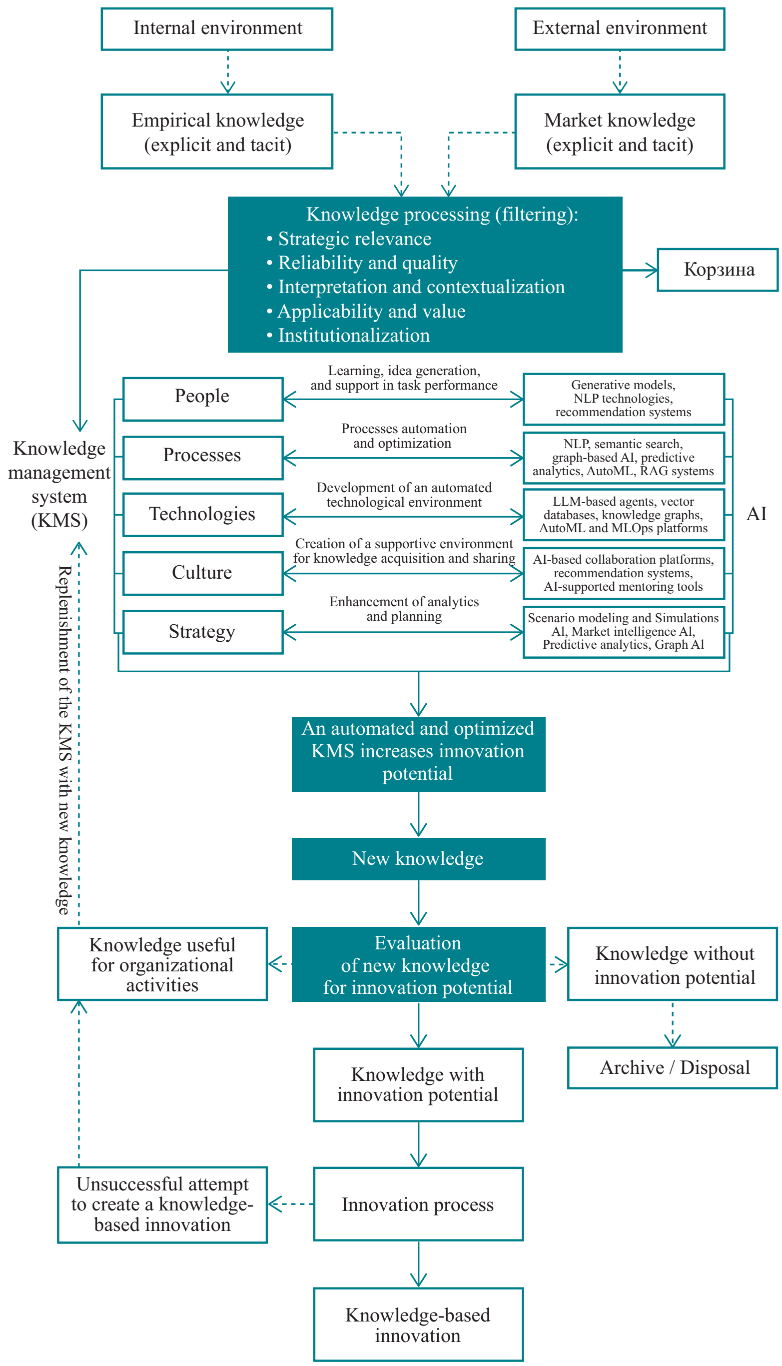
The detailed description of the knowledge-based innovation mechanism is presented in Figure 3.

As shown in Figure 3, once the KMS has been populated with selected knowledge at the filtering stage, interaction between the knowledge management system and artificial intelligence technologies begins. This interaction involves applying a specific set of AI technologies to the relevant elements of the KMS in order to enhance their effectiveness. As a result of integrating AI technologies into each KMS element, the organization obtains an automated and optimized knowledge management system, which increases innovation potential through deeper and more efficient processing and systematization of existing knowledge. The new knowledge generated within the updated KMS is subsequently examined by relevant organizational specialists to assess its innovation potential. At this stage, knowledge is classified into three categories:

1) Knowledge with innovation potential, which is integrated into the innovation process;
2) Knowledge without innovation potential but still useful, which is returned to the organization's KMS for further use;
3) Knowledge without innovation potential and without organizational value, which is transferred to archival storage or discarded.

Knowledge identified as having innovation potential is then used within the innovation process. This may result either in an unsuccessful attempt to create a knowledge-based innovation, in which case the knowledge generated during the process is returned to the KMS due to its practical value, or in a successful attempt leading to the creation of a knowledge-based innovation.

Fig. 3. Detailed description of the knowledge-based innovation mechanism



Source: prepared by the author.

The proposed mechanism was subsequently subjected to verification. For this purpose, a focus group was formed consisting of company specialists responsible for the KMS and involved in organizational innovation processes. In total, seven participants took part in the focus group.

The objective of the verification was to assess the feasibility of applying the proposed mechanism and to identify potential directions for its use.

All focus group participants confirmed the possibility of implementing the proposed mechanism. Potential directions for its application are presented in Table 2.

Thus, the value of artificial intelligence for the KMS lies not only in technological solutions, but also in the development of new infrastructures, a skilled workforce, and transformed organizational processes.

The purpose of the KMS is to connect employees with the appropriate set of resources and knowledge required to create new products and support higher-quality decision-making [Mitchell, 2019]. The expanding capabilities of artificial intelligence and the emergence of advanced functions aimed at achieving these objectives necessitate transformation of the KMS mechanism. Implementation of such a mechanism becomes possible through the development of new skills and competencies among employees. Individuals must cultivate new ways of understanding, working, and interacting with knowledge in order to fully benefit from the use of AI within the KMS. This level of organizational preparedness enables the practical realization of the unique capabilities of artificial intelligence in knowledge management.

Conclusion

The mechanism for creating knowledge-based innovations may contribute both to the theoretical foundations of innovation studies and to practical organizational contexts shaped by contemporary market conditions. Its practical contribution is of particular importance, as current realities lack a universal approach capable of enabling companies of different sizes and operating across diverse market sectors to succeed – or even to substantially increase their chances of success – in such a complex and highly specialized activity as innovation development.

The proposed mechanism requires further refinement and testing under real market conditions, as well as application in organizations representing different industries and varying levels of knowledge management system maturity, before it can be considered fully operational. In this regard, the author intends to continue research into the mechanism for creating knowledge-based innovations.

Table 2
Potential applications of the AI-enabled knowledge management mechanism for knowledge-based innovation

KMS process	Capabilities enabled by AI technologies	Applications within the innovation process
Knowledge creation	Development of predictive analytics using self-learning analytical tools Identification of previously unknown patterns; Analysis of organizational data and identification of relationships generation of new knowledge	Forecasting the sales potential of new products Incremental innovations based on CRM system data
Knowledge storage and retrieval	Collection, classification, organization, storage, and retrieval of explicit knowledge Analysis and filtering of multiple content and communication channels Facilitation of knowledge reuse by teams and individual employees	Knowledge consolidation for the development of new products Extraction of information on shortcomings of previously developed products for their elimination in newly developed products
Knowledge sharing	Connecting employees working on similar problems by strengthening connections within the KMS Support of collective intelligence and shared organizational memory Creation of an integrated view of knowledge sources and bottlenecks Development of more coordinated and interconnected organizational processes	Support for customer and partner feedback mechanisms for expert evaluation of new products Support for real-time knowledge exchange between marketing channels, new product development units, and sales management departments
Knowledge application	Improvement of the use of existing knowledge through identification of new knowledge sources Development of more natural and intuitive system interfaces (e.g., voice assistants) Facilitation of equal access to knowledge for all specialists involved in the innovation process	Chatbot-based support during the development of complex products Creation of user manuals for new products

Source: compiled by the author based on the results of mechanism verification.

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The Role of Dynamic Capabilities in Creating Product Innovations

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Abstract

This paper examines the importance of innovation in the development of new products as a means of increasing organizational competitiveness. It reviews the theoretical foundations of the resource- and capability-based view of the firm, with particular attention to the contemporary concept of dynamic capabilities. The paper identifies four key higher-level competencies – dynamic capabilities – that are used to analyze the impact of specific firm abilities on the effectiveness of product innovation: sensing capability, seizing capability, transformation capability, and entrepreneurial management capability. Based on this review, a general thesis and a theoretical model are proposed that may be applied in empirical research and further tested using real-world cases of product innovation.

Keywords: firm resources and capabilities, digital transformation, strategic analysis

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动态能力在产品创新中的作用

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摘要

本研究阐述了在新产品开发领域开展创新活动对于提升组织竞争力的重要性。文章梳理了当前企业资源与能力领域的理论基础，重点关注最前沿的动态能力理论，并提出了用于论证企业特定能力如何影响产品创新实施效果的四大高层级动态能力：感知能力（sensing capability）、捕捉机会能力（seizing capability）、转型能力（transformation capability）以及管理层的企业家能力（entrepreneurial capability）。结果研究确立了核心论点并构建了理论模型，该模型可用于实证研究，并能在企业实际产品创新案例中进一步验证。

关键词：公司的资源和能力、数字化转型、战略分析

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This paper begins by explaining why product innovations are important for organizations and why their effective and efficient implementation is critical. The issue is examined from the perspective of firm competitiveness and the role of product innovation in sustaining and enhancing competitive positions.

In today's business environment, economic and operational efficiency along are insufficient to ensure competitiveness. Firms must achieve a sustainable competitive advantage that enables them to attain and maintain a leading market position. As M. Porter argues–and as this paper also maintains–sustainable competitive advantage arises from performing different activities from rivals or performing similar activities in different ways [Porter, 1996].

In line with this reasoning, competitive firms should strive to develop sustainable competitive advantage. Innovative activity, particularly in form of product innovation, enables firms to achieve such advantages; therefore, the development of resources and competencies related to innovation is of critical importance.

Having outlined the concept of competitiveness and sustainable competitive advantage within the context of this study, the discussion now turns to the definition of innovation and the specific role of product innovation.

The term innovation was first introduced by the Austrian economist and sociologist J.A. Schumpeter. In *The Theory of Economic Development* (1911), Schumpeter described innovation as a key driver of economic progress and a fundamental source of economic dynamics.

One of Schumpeter's central ideas concerns the importance of the entrepreneurial spirit. He emphasized that entrepreneurs, as initiators and implementers of innovation, are the core agents of economic development. Schumpeter also identified several types of innovation, one of which–"the creation of a new product or provision of a new service"–corresponds to product innovation as defined in this paper.

C. Christensen's research on *disruptive innovation* represent another major contribution to innovation theory and strategic management. Christensen defines disruptive innovation as new technologies, products, or business models that initially emerge in niche or underserved market segments and later transform or displace established market structures by offering a fundamentally different value proposition. A distinctive feature of such innovations is that they are initially focused on small market segments that are underestimated by large players; over time, however, they displace traditional products and gain a large market share. In contrast, Christensen also identifies *sustaining innovations*, which improve existing products and help dominant firms maintain their market positions [Christensen, 1997].

The theories of Schumpeter and Christensen are consistent with one of the interpretations of digital transformation adopted in this paper. According to this perspective, digital transformation involves the creation of digital platforms that enable interaction between sellers and buyers [Teece, 2007], which may be understood as a form of product innovation in the digital domain.

Based on the above discussion, the following definition of product innovation is proposed. Product innovation refers to the creation of new products or the improvement of existing ones through the adoption of innovative technologies, solutions, and approaches. In the context of digital business transformation, product innovation is closely associated with the use of digital tools and platforms to enhance product quality, improve customer experience, and optimize production and delivery processes. As a result, firms increase their competitiveness by achieving sustainable competitive advantages. Product innovations enhance product quality by enabling new functionalities and performance improvements that increase customer satisfaction.

Modern digital platforms allow firms to better understand customer needs and preferences by offering personalized services and solutions, thereby strengthening firm–customer interaction, increasing customer loyalty, and driving sales growth [Dadoun et al., 2021]. Ultimately, firms that successfully innovate their products gain advantages over competitors by differentiating themselves in the market, attracting new customers, and maintaining leadership positions within their industries [Gil-Gomez et al., 2020].

Thus, contemporary product innovation enables firms to achieve sustainable competitive advantage and secure leading market position. However, the question remains how firms can effectively implement such innovations and what type of resources, competencies, and capabilities are required to do so.

The most recent stage in the development of the theory of firm resources and capabilities is the concept of dynamic capabilities, which was developed by D.J. Teece and his co-authors in 1997. In their article *Dynamic Capabilities and Strategic Management*, the authors describe dynamic capabilities as a firm's ability to integrate and reconfigure internal and external competencies in order to operate in a rapidly changing environment [Teece et al., 1997]. Consequently, as the authors note, dynamic capabilities make it possible to achieve new innovative forms of competitive advantage. In addition, achieving new forms of competitive advantage is one of the main goals of an organization's innovation activities. The concept of dynamic capabilities is the most recent theoretical development and, by definition, is more closely related to innovation processes; therefore, the model of product innovation capabilities formulated in this study is based on this concept of dynamic capabilities.

It should be noted that this concept does not negate the classical theories of the resource-based view and core competencies [Hamel, Prahalad, 1989; Barney, 1991]; rather, it extends them. It represents the next step in identifying firm capabilities that enable adaptation to the current business context and changing economic conditions.

Dynamic capabilities differ from static competencies in that they involve the continuous updating and improvement of internal processes and external interactions. They help organizations not only survive under conditions of uncertainty but also actively develop by exploring new markets and creating unique value propositions for customers.

Teece later refined his theory in an effort to make it more practically applicable. At this stage of the concept's development, three clusters of higher-level organizational capabilities were identified: sensing, seizing, and transformation [Teece, 2007]. Organizations and their management must engage in these activities to anticipate market and technological trends, devise strategies to capitalize on these insights, and restructure the firm in accordance with its strategic vision.

Further clarification of the dynamic capabilities concept concerns the role of managers themselves, particularly their entrepreneurial actions and qualities. For dynamic capabilities to be strong, leadership must be entrepreneurial. This implies that managers should participate in developing and testing assumptions about new technological and market trends, refining business models, and managing the resources required within the organization [Teece, 2014].

According to Teece, this entrepreneurial approach should be extended throughout the entire organization. This view is also consistent with Schumpeter's argument regarding the necessity of entrepreneurial skills in corporate management for the development of innovation activities.

At this stage, the role of strategic management within the theory of dynamic capabilities is also clarified. It is argued that the firm strategy is not a derivative of dynamic capabilities. Rather, the deployment of dynamic capabilities must be aligned with a firm's strategy, which is developed by management; competitive advantage emerges from this combination.

Based on this framework, the present study relies on four higher-level organizational capabilities: sensing capability, seizing capability, transformation capability, and entrepreneurial management capability. These capabilities are proposed as the defining components of dynamic capabilities and are examined in greater detail below.

The firm's innovation activities are positioned between dynamic capabilities and competitive advantage. The study by [Zhou et al., 2019] contributes to demonstrating the impact of dynamic capabilities on organizational performance and competitive advantage. That study examines firm's dynamic capabilities influence competitiveness and overall productivity through the process of innovation. The authors identify three key aspects of dynamic capabilities – the abilities to perceive, integrate, and reconfigure–which contribute to different types of innovation [Zhou et al., 2019].

The ability to perceive involves scanning the external environment to identify new opportunities and threats. This is generally consistent with the sensing capability discussed earlier. The integration aspect refers to combining internal and external resources to create new products and services. The authors emphasize several important elements of integration. Internal coordination plays a critical role, particularly the ability to integrate the activities of different departments and specialized units to facilitate effective knowledge and technology exchange. In addition, external resources exchange is also essential, including the integration of knowledge and technologies acquired through cooperation with partners, suppliers, or customers. This enables firms to access new ideas and opportunities. This aspect is closely related to organizational learning and knowledge processes and corresponds to seizing capability. The third aspect of dynamic capabilities identified by [Zhou et al., 2019] is reconfiguration, which refers to adapting business processes and organizational structures to changing conditions and corresponds to the transformation capability. Returning to the relationship between dynamic capabilities and firm performance, [Zhou et al., 2019] argue that innovation is the primary mechanism through which dynamic capabilities affect performance. Notably, the authors do not explicitly distinguish entrepreneurial management capability; therefore, the theory of dynamic capability formation is supplemented by taking this capability into account.

In the context of digital transformation, the relationship between dynamic capabilities and product innovation is examined through four key higher-level capabilities identified above:

1) sensing capability;
2) seizing capability;
3) transformation capability;
4) entrepreneurial management capability.

In digital transformation, the process of developing new products or improving existing ones begins with sensing capability, that is, identifying opportunities related to emerging or underutilized technologies and assessing how they nay address customer needs. Digital technologies enable rapid and cost-effective testing and refinement of hypotheses about customers and technologies, which is particularly important for product innovation. Firm activities associated with sensing capability include scanning, searching, and exploring innovation opportunities [Teece, 2007], which require investments in research and technological experimentation. Prior studies indicate that information and resources influence innovation and firm development [Yam et al., 2011] and that experienced organizations employ specific search routines to enhance innovation outcomes [Nelson, Winter, 1982]. Sensing capability also involves understanding consumer demand, market evolution, and anticipated competitor responses. As a result, when opportunities emerge, sensing capability enables firms to determine which technologies are worth testing and applying and which market segments to target [Teece et al., 1997].

A firm's ability to recognize and act on opportunities is essential for establishing a viable business model for a new product; this constitutes the seizing capability. For a product to be sustainable, it must offer value that allows the firm to charge prices sufficient to cover costs and generate profit, thereby enabling growth. Seizing capability also includes the dissemination, codification, and articulation of knowledge within the organization and the application of this knowledge in digital transformation and corporate innovation systems. As noted by P. Drucker, "Innovation is the application and use of knowledge to create new knowledge" [Drucker, 1993]. This capability places particular emphasis on the presence of effective knowledge management systems among employees involved in product innovation and digital transformation. Seizing capability facilitates organizational learning and the diffusion of know-how and expertise [Teece, 2014]. It also involves attracting external resources, including the integration of knowledge about customers, markets, and technologies acquired during search stage [Iansiti, Clark, 1994]. Previous research suggests that seizing capability represent, to some extent, the conversion of resources and knowledge into innovation [Dutta et al., 2005]. Studies have shown that effective integration of internal and external technological and market knowledge increases the likelihood that firm will incorporate successful features into new products [Marsh, Stock, 2006].

Transformation capability is required for implementing digital solutions and innovations, as well as for making key strategic decisions. This capacity enables firms to identify deficiencies in their existing capabilities. Such gaps may be addressed through internal development, acquisitions, or the formation of strategic alliances. Transformation capability also supports organizational performance over time and helps firms avoid adverse path dependencies [Teece, 2007]. It encompasses actions through which firms add, recombine, or divest resources and business units [Karim, Capron, 2016]. Internal knowledge exchange can be enhanced through appropriate reallocation of human resources and restructuring of business units [Nonaka, 1994]. Employees who possess critical knowledge but are not engaged in key tasks may be reluctant to make necessary decisions, thereby hindering organizational progress [Wang et al., 2009]. Consequently, a loyal and engaged workforce, together with an appropriate degree of autonomy in decision-making within the innovation processes, is a crucial organizational resource.

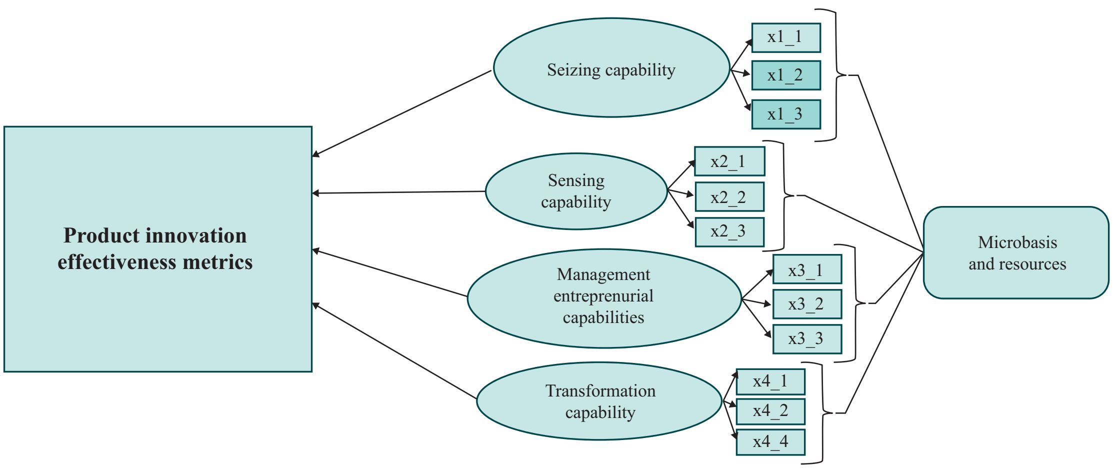
Finally, as noted earlier, this study argues that entrepreneurial management capability should also be considered a key component of dynamic capabilities. The entrepreneurial capabilities of management have only relatively recently been emphasized as an important element of dynamic capabilities [Teece, 2014]. Beyond dynamic capability framework, prior research indicates that managers with entrepreneurial capabilities enhance organizational strategic flexibility and adaptability – an argument that aligns closely with the dynamic capabilities perspective [Bartlett, Ghoshal, 1987]. Firms with strong entrepreneurial capabilities also demonstrate long-term success through sustained values and an entrepreneurial culture [Collins, Porras, 1994]. Accordingly, entrepreneurial culture must be supported by top management to ensure successful adaptation and growth [Kotter, 1996]. Research shows that granting managers the freedom to experiment and develop innovative ideas enhance firm competitiveness [Hackman, 2002].

Thus, in the context of product innovation, dynamic capabilities should be considered not as processes, operations, or routines within an organization, but as higher-level abilities that are set by top management, permeate the organization's human resources, and enable the rapid and effective implementation of product innovations in a firm's digital products.

Based on the review of the existing literature, the following argument is proposed: four groups of higher-level dynamic capabilities should be identified – sensing capability, seizing capability, transformation capability, and entrepreneurial management capability. These groups of capabilities are defined by specific competencies, or *microfoundations*, that contribute to a firm's product innovation activities. Sensing capability enables the identification of opportunities related to new or not yet widespread technologies and their potential to meet customer needs . Seizing capability enables firms to create profit-generating mechanisms and includes planning and configuring the organization's value chain. Transformation capability enables firms to close capability gaps and expand existing competencies through internal development or partnerships with other firms. Entrepreneurial management capability contributes to the development of organizational strategic flexibility and adaptability, as well as to the strengthening of the other three higher-level dynamic capabilities.

Further research should adopt an empirical approach to testing this theoretical framework and applying it to real-world scenarios involving the development of new products within organizations that have cultivated dynamic capabilities based on the microfoundations discussed in the preceding sections of this paper. The model proposed below (see Figure) is intended for use in subsequent empirical studies.

Fig. Theoretical framework of product innovation based on dynamic capabilities



Source: authors' adaptation of theoretical concepts of dynamic capabilities.

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