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A New Concept of Techno-Economic Institutions within Institutional Economics: Integrating Technologies and Institutional Frameworks

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Abstract

This study investigates the concept of techno-economic institutions within institutional economics, focusing on the integration of technologies into economic frameworks to foster development. The primary objective is to introduce and advocate for the novel concept of "techno-economic institutions," which is essential for embedding technologies into the socio-economic environment. This research employs a comprehensive methodological approach, including theoretical analysis, literature review, comparative studies, and case studies, to develop a new analytical model and provide fresh insights. The key findings include a comparative analysis of the interplay between institutions and technologies, a variational model detailing the life cycles of General-Purpose Technologies (GPTs), and an in-depth examination of institutional roles. The econometric models developed in this study demonstrate the significant impact of ICT patents and SCM systems on government efficiency, empirically validating the proposed theoretical framework. This paper contributes to the academic discourse by offering a methodologically robust and empirically substantiated examination of technological advancements in institutional frameworks, highlighting the importance of flexible institutional structures capable of adapting to technological change. These insights provide actionable recommendations for policymakers and suggest strategic investments in technological infrastructure to enhance government performance. Future research should explore the generalizability of these findings in different institutional contexts and examine variability in technology-institution interactions across diverse geopolitical landscapes.

Keywords:

Techno-Economic Institutions;
Technological Determinism;
Technological Integration;
Techno-Institutional Mechanisms;
Governmental Efficiency;
Interaction of Technology and Institutions;
General-Purpose Technologies (GPTs);
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1- Introduction

The field of institutional economics is at a critical juncture where the integration of technological innovations into institutional frameworks poses unique challenges and opportunities. Brette [1], Davidson [2], and Veblen [3, 4], highlighted the role of technology in institutional development, yet many aspects of this interaction remain insufficiently explored. Current literature, including works by Khan [5], Margaryan & Terzyan [6], and Hanna [7], indicates gaps in understanding how institutional frameworks facilitate or hinder technological innovations, particularly under conditions of economic volatility. This study introduces the concept of "techno-economic institutions," which represent the nexus where technology and economic institutions intersect and co-evolve, fundamentally influencing economic development pathways [1, 2]. Our research aims to empirically validate the hypothesis that the integration of information and communication technologies (ICT) within techno-economic institutional frameworks significantly enhances the operational effectiveness of government bodies in Russia, as evidenced by measurable improvements in the World Bank's "government effectiveness" index [7, 8].

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Based on the theoretical framework of institutional and evolutionary economics, this study proposes a new analytical model to explore the reciprocal influence of technology and institutions [9, 10]. Brette's analysis [1] provides a nuanced interpretation of Veblen's ideas, describing him as a "weak" technological determinist who saw technology and institutions as intertwined, opposing the purely techno-optimist view. This framework underpins our exploration of the global relevance of techno-economic institutions in the formation of economic strategies and policies in an increasingly technology-driven landscape [11, 12].

The methodological framework encompasses comparative analysis and case studies that elucidate the diverse effects and assimilation of technology across various institutional contexts. This approach is informed by the theories of distinguished economists such as Acemoglu & Robinson [11], Faundez [13], and North [14], who highlighted the critical influence of institutions on economic performance and development. The findings propose a variational model of General-Purpose Technologies (GPTs), showcasing their life cycles and the transformative impacts they have on economies. Further, the description of GPTs as foundational economic transformers was underscored by Lipsey et al. [15]. This discussion examines institutions' dual role as both facilitators and barriers to technology adoption, emphasizing the dynamic and sometimes inertial nature of institutional frameworks, as discussed by Horner [10] and Ayres [16].

Furthermore, this paper discusses the pivotal role of techno-economic institutions in leveraging innovations such as artificial intelligence within economic systems, ensuring that technological advancements contribute to efficiency and innovation in compliance with social and regulatory norms [2]. It concludes by integrating insights on how well-crafted techno-economic institutions can facilitate the incorporation of technologies into economic frameworks, suggesting new avenues for future research based on the identified gaps in this study [17-20]. These findings are crucial for policymakers and economic strategists, providing actionable insights into structuring institutions to efficiently harness and exploit technological innovations for economic advancement. Ultimately, this introduction and subsequent sections advocate for a nuanced understanding of the interplay between institutions and technology, emphasizing the necessity for policies that support sustainable and adaptable economic environments capable of leveraging technological benefits comprehensively [21, 22].

This paper introduces an innovative conceptual framework for examining the integration of technology into institutional economics, underscored by a rigorous econometric analysis. The novelty of this approach lies in its combination of theoretical and empirical methodologies to investigate the direct impacts of specific technological advancements on institutional efficiency. By empirically validating the proposed theoretical relationships through robust statistical analysis, this study provides new insights into the dynamics of techno-economic institutions. These insights not only advance our understanding of the practical implications of technological integration but also highlight the potential for digital transformation to significantly enhance the effectiveness of government operations. Consequently, this research addresses a substantial lacuna in existing scholarship by offering a methodologically robust and empirically substantiated examination of the impact of technological advancements on institutional frameworks.

The structure of this paper is as follows: The next section provides a detailed literature review, highlighting key studies and identifying gaps that this research aims to fill. The methodology section details the analytical framework and outlines the approaches used in the study, including theoretical analysis, comparative analysis, and case studies. The results section presents the key findings, including the variational model of GPTs and insights into techno-economic institutions. Finally, the discussion and conclusion sections synthesize the research findings, discuss their implications for theory and policy, and suggest directions for future research.

2- Literature Review

Mid-20th century institutionalists on technology development divided themselves into two camps: technological optimists (led by DeGregori [18]) and pessimists (headed by Hayden [9]). The works of technooptimists did not stem from a naive perception of technologies as sources of exclusively positive effects but from a more balanced interpretation, proposing a comparative analysis of the benefits and drawbacks of new technologies. Proponents of technological optimism, aligned with the liberal economic perspective, contended that curbing technological advancement might precipitate substantial detriments for marginal benefits [10]. Therefore, effective institutions promoting technological development should primarily involve framework regulation that does not impede technological innovations and the establishment of voluntary self-regulatory standards. This approach in modern economics is expressed in the "hands-off" regulatory model, which has been particularly developed in the United States. However, the safety of new technologies should be a central concern and regulated as a priority.

Technopessimists adopted a more balanced stance, emphasizing the inertia of institutional structures and the influence of existing institutions in maintaining the status quo. Hayden [9] believed that large corporations controlling agricultural product markets are more interested in maximizing profits than improving product quality, moderate use of chemicals and preservatives, and enhancing people's standard of living. Thus, these major players support market rules that allow them to increase profits, not institutional conditions that stimulate progressive technological innovations. The

implementation of new technologies, from the technopessimists' perspective, should be assessed in consideration of the broadest possible range of potential risks. For example, Hayden [9] noted that automobiles eliminated horse manure pollution in city streets, but more importantly, they caused massive atmospheric pollution and adversely affected the ozone layer [10]. Therefore, technological regulation should not be surrendered to free market mechanisms. Large corporations should be subject to public control, especially regarding technological changes. In the agricultural sector, directing governmental support predominantly toward large-scale farmers facilitates the adoption of predatory capital-intensive technologies, resulting in environmental degradation and overexploitation. Thus, technopessimists suggest that governmental policies should encourage the proliferation of various agricultural models, especially by providing support to small-scale farmers. This segment uses more labor-intensive techniques that are believed to incur minimal ecological harm. A contemporary version of this approach to regulating new technologies is embodied in the European model, focusing on maximizing safety.

Within institutionalist discourse, institutions are broadly viewed as mechanisms that exert a stabilizing influence on the trajectory of technological progress, often acting as inertial forces that may restrain or decelerate development. These institutions are considered essential for maintaining continuity and stability in economic systems. For instance, the renowned institutionalist Ayres [16] considered institutions as "conservators of the past," and behavior driven by institutions as static. He viewed technological progress as the "dynamic force" of economic development and institutions as the "static force" that changes under the influence of technological development and the material conditions of society's existence [16]. Thus, institutions are not the cause but the consequence of progressive technological changes. This viewpoint can be seen as a "strong" version of technological determinism, with many institutional economic theory adherents. For example, when North [14] attempted to explain the Glorious Revolution of 1688, which initiated England's transformation into a leading economic power, by establishing firmer private property rights, his approach was critiqued. Many institutionalists have demonstrated that the cause-and-effect relationship is the opposite: technological innovations create a demand for more protected property rights and lead to institutional changes [14, 23]. Conversely, the renowned institutional economist Chang [22] criticized understanding institutions as the cause of socio-economic development: in his view, the rapid growth of many Third World countries was achieved through accelerating technological dynamics and export-oriented economies, not due to the implementation of exemplary foreign institutions [22].

Nobel laureate Douglass North advocated what he termed "strong" institutional determinism, emphasizing the substantial role of institutions in shaping socioeconomic development [14]. According to North [14], the transformation of resources—land, labor, and capital—into goods and services is influenced not only by applied technology but also significantly by institutional frameworks, making institutions pivotal in determining production costs. He argued that technological and institutional changes are intertwined as the primary drivers of social and economic development. However, North [14] critiqued the neoclassical economic perspective, which predominantly credits technology as the creator of human well-being and highlighted the critical role of institutional structures in setting incentives for education, invention, and the introduction of new technologies. This perspective is predominant among scholars working in the field of new institutional economic theory. Their general position was expressed by Kingston & Caballero [17]: "institutions, behavior, and performance outcomes cannot be derived solely from technological constraints". For instance, according to contemporary representatives of the new institutional theory, optimal resource allocation in the economic system is provided not by technology but by inclusive institutions. Such institutions protect property rights, competition, the rule of law and democratic freedoms [11].

"Weak" institutional determinism has gained less traction among economists. Its representatives include Nelson [12], the founder of evolutionary economics. He believed that institutions and technologies are both causes and consequences of mutual influence because they co-evolve. He considered institutions as social technologies that are inseparable from standard (physical) technologies. According to Nelson, technological development is the coevolution of physical and social technologies, with social technologies (institutions) playing the role in socio-economic development as "door openers" for physical technologies [12], thus triggering technological changes. DeGregori [18], paralleling Nelson, proposed a similar concept, distinguishing between production (physical in Nelson's terms) and social technologies, with the latter referring to institutions. The key to socioeconomic development lies in the complementarity (mutual supplementation) of production and social technologies.

Schrepel's [19] analysis highlights the dynamic co-evolution of technologies and institutions, corroborating the theory that techno-economic institutions play a crucial role in facilitating technological integration and ensuring that technological advancements are congruent with and bolster broader economic and institutional objectives. This perspective is reflected through the lens of W. Brian Arthur's insights into the evolution of economies and technologies and explains the interdependencies and mutual adaptations between evolving technological landscapes and the institutional structures that govern them. This passage emphasizes the essential role that techno-economic institutions play in moderating the impacts of technological changes within the framework of institutional economics. Based on Davidson's study [2], the conclusion relevant to the concept of techno-economic institutions as a bridge between technologies and institutions in institutional economics might emphasize that techno-economic institutions are crucial

for harnessing artificial intelligence (AI) within economic systems. Davidson emphasized that such institutions not only facilitate the integration of AI technologies but also regulate their economic impacts, ensuring that these technologies enhance efficiency and innovation while maintaining social and regulatory norms. This bridging role is vital for enabling sustainable and adaptable economic environments that fully leverage the benefits of AI in line with institutional frameworks. The work "Digital Capitalism and New Institutionalism" by Frolov [21] explored the dynamic interplay between the modern digital economy and evolving institutional structures. This aligns closely with the concept of techno-economic institutions, emphasizing the crucial connections between technological innovation and institutional development within this context [21]. This illustrates how digital technologies catalyze new institutional frameworks and transform economic structures, underscoring the need for institutions that can bridge the gap between rapid technological advancements and existing economic systems. This research underscores the essential role of dynamic and adaptable techno-economic institutions in promoting the integration of new technologies within the broad framework of institutional economics.

The research conducted by Allen et al. [24] on the "Exchange Theory of Web3 Governance" and offered significant insights into the dynamics of techno-economic institutions within the framework of institutional economics. The study highlights the significance of Web3 governance models as foundational elements that facilitate the alignment of technological capabilities with institutional requirements. This underscores the role of decentralized governance in enhancing economic systems through more responsive and adaptive institutional structures. This aligns with the concept of techno-economic institutions as essential mediators that ensure technologies are effectively integrated and used within prevailing economic frameworks. The study by Amable [25] discusses the co-evolution of regulation theory and evolutionary economics, shedding light on the nuanced interplay between economic systems and technological evolution. This perspective enriches our understanding of techno-economic institutions by illustrating how they function as bridges in institutional economics, facilitating the alignment of technological progress with regulatory and economic frameworks. Amable's insights help frame techno-economic institutions not just as mediators but as dynamic entities that evolve and adapt within the broader context of economic and institutional changes. This study significantly advances discussions on the integration and management of technological innovations within structured economic systems, reinforcing the notion of sustainable development in technology-driven economies.

Marchant's research underscores the crucial role of techno-economic institutions in mediating the integration of artificial intelligence into economic systems [26]. By examining how AI technologies necessitate new institutional frameworks for effective governance, his work illustrates the importance of these institutions in aligning technological advancements with broader economic and societal goals. This supports our study's focus on techno-economic institutions as essential connectors between technology and traditional institutional structures, facilitating the balanced development of new technologies within existing economic frameworks. Murtazashvili et al. [27] on blockchain networks significantly enriches the understanding of techno-economic institutions. This analysis elucidates the role of blockchain technology within the realm of institutional economics, illustrating its function as a conduit connecting evolving technological innovations with established institutional frameworks. This aligns with the concept of techno-economic institutions by highlighting how blockchain facilitates a decentralized yet regulated development environment, integrating technology into broader economic systems, and promoting institutional adaptability.

Davidson & Potts [28] explored the role of the entrepreneurial state in shaping the platform economy, illustrating the critical intersection of state-driven initiatives and platform technologies within institutional frameworks. This analysis reinforces the concept of techno-economic institutions by exemplifying how government policies and digital platforms interact to cultivate innovation and technological integration. Their discussion underscores the necessity for credible policies that not only foster technological advancement but also ensure that such advancements are seamlessly integrated into existing economic and institutional landscapes to promote sustainable development and innovation. The exploration of the alegality of blockchain technology reveals how this innovative field can stretch beyond current legal norms and frameworks, underscoring the importance of evolving institutional structures to accommodate new technological paradigms [29]. This observation corroborates the theory of techno-economic institutions, which asserts that strong, adaptable institutions are essential for harnessing the economic potential of emerging technologies and ensure their effective integration within established economic and regulatory frameworks. Alston et al. [30] examined blockchain networks as embodiments of constitutional and competitive polycentric orders. This analysis illuminates the role of such technologies as techno-economic institutions within the field of institutional economics, providing a distinct perspective on their operational and governance structures. Their findings suggest that blockchain's decentralized and polycentric governance structures can bridge the gap between technological innovation and institutional adaptability, providing a robust framework for managing complex economic interactions and fostering institutional evolution in line with technological advancements.

The scientometric analysis by Vasconcellos et al. [31] highlights institutions' significant role in international business research and demonstrates their impact on the field. Applying these insights to the concept of techno-economic institutions, we can deduce that such institutions serve as pivotal elements that not only bridge but also sculpt the interaction between technology and the economic landscape. They help guide technological innovations to align with

established institutional practices and facilitate a symbiotic evolution within the global business environment. This perspective reinforces the significance of techno-economic institutions in fostering an integrated, adaptive, and forward-looking approach to institutional economics.

In recent years, significant attention has been devoted to studying the role of institutions in shaping technological trajectories, as reflected in contemporary literature on institutional economics. Researchers focus on how institutional environments influence innovation and technological development. For instance, Grebennikova & Zyuzin [32] outlined a broad spectrum of state management technologies. Eller et al. [33] emphasized the importance of evidence-based management in the context of the digitalization of state governance. Tikhomirov & Frenkel [34] considered state programs as a tool for achieving socioeconomic priorities. This view is echoed in the work of James & Van Ryzin [35], who focused on indicative program planning. Polterovich et al. [36], and Grinberg & Komolov [37] analyzed the effectiveness of program-targeted planning in the Russian Federation and its impact on regional development.

Significant contributions to the theory of institutional analysis have been made by researchers such as Acemoglu & Robinson [11], North [14], Grinberg & Komolov [37], and Tambovtsev [38]. They explore the processes of institution formation and evolution, highlighting their role in economic development and state governance. Kupryashin [39] and Smorgunov [40] focused on the specificity and regional differentiation of institutional structures in Russia, pointing out issues of "path dependence" and methodological arbitrariness in governance.

Research in public administration actively integrates digitalization as a crucial element of modern management practices. Tromp et al. [41] discussed the potential of artificial intelligence and big data in program and policy evaluation. Shash [42] underscores the necessity of evaluating managerial decisions using objective data, a point corroborated by Moynihan & Kroll [43]. In the work by Alvesson & Spicer [44], the issue of a mid-life crisis in neo-institutional theory and organizational studies is raised, pointing to the need for a new perspective on the development of this theory. Research in economic theory also contributes to understanding the role of institutions. For instance, Choi & Rocheteau [45] investigated the methods and applications of new monetarism in continuous time and explored its framework and implications. Similarly, Galí [46] offers a critical evaluation of new Keynesian economics, emphasizing its successes and challenges. Eichenbaum et al. [47] analyzed the effects of epidemics in neoclassical and new Keynesian models, illustrating the necessity of updating economic theories to reflect dynamic external conditions.

A review of contemporary approaches to public administration is presented in Byrkjeflot et al. [48], who analyzed the concept of the "Neo-Weberian State" as a regime of public administration. Reiter & Klenk [49] in their systematic literature review discussed the manifold meanings of "post-New Public Management", and Mungiu-Pippidi [50] examined the rise and fall of good governance promotion, focusing on changes in global governance.

An important aspect of research is evaluating effectiveness and transparency in public administration. Parkhurst [51] critically analyzed evidence-based policy and the good governance of evidence and identified the complexities and challenges of implementing these approaches. Tromp et al. [41] explored expressive modeling for trusted big-data analysis, demonstrating the capabilities of artificial intelligence and big data in analyzing public opinion and preferences. The study by Smith et al. [52] complements our exploration of the role of institutions in shaping technological trajectories by providing insights into the interaction between technology, legal frameworks, and societal expectations within the public sector. It contributes to the broader discourse on institutional economics by illustrating how institutions both constrain and enable the pathways through which technological innovations unfold in society. The research by Jang et al. [53] provided a methodological and empirical foundation that supports and enhances the discussion in our article on the role of institutions in shaping technological trajectories. Lowe & Genovese [54] explored theories of value in relation to circular economies and provided critical insights into how economic and institutional theories intersect to shape sustainable technological futures. Their work enriches our article by offering a complex understanding of the value-based institutional frameworks that underpin technological trajectories, thus contributing to a broader discourse on the role of institutions in guiding sustainable development within the field of institutional economics.

In the evolving discourse on techno-economic institutions within institutional economics, recent scholarly work underscores the complex interplay between technological advancements and institutional frameworks, revealing their pivotal roles in guiding economic and environmental strategies.

Wu et al. [55] examined how institutional investors with shared Environmental, Social, and Governance (ESG) preferences significantly propel low-carbon innovations within family firms. Their study elucidates the critical alignment between investor-driven environmental goals and sustainable corporate practices, highlighting that institutional investors can act as key catalysts for green innovation, particularly in settings traditionally less exposed to institutional pressure [55]. This insight is invaluable for understanding the mechanisms through which institutional structures can drive sustainable outcomes. Amin et al. [56] further explored this narrative by examining the intersection of green technological innovations and institutional quality and their collective impact on environmental mitigation. Their findings suggest that the efficacy of green technologies is contingent upon the robustness of the institutional frameworks that support them, indicating that technological impact is significantly enhanced or hindered by the quality of institutional

governance [56]. This relationship is crucial for policymakers seeking to optimize environmental policies through institutional strengthening. Buffa & Hodor [57] improved our understanding of institutional influence in financial markets by analyzing how institutional investors affect asset price co-movements. Their research illuminates the broader economic ramifications of institutional investment behaviors and demonstrates how these entities can influence market dynamics and stability [57]. This provides a foundation for further inquiry into how institutional behaviors and configurations can be optimized to foster economic stability. In the realm of digital innovation, Zhang et al. [58] assessed the transformative role of digital technologies in enabling business model innovation in traditional manufacturing firms. They emphasized the moderating role of institutional environments in leveraging digital technologies for strategic innovation, suggesting that institutional adaptability is essential for harnessing the full potential of digital transformations [58]. This analysis is particularly pertinent because it demonstrates how institutional readiness facilitates or hinders the transformative impact of digital technologies. Looking forward, Betancourt [59] discussed the challenges and opportunities presented by artificial intelligence in organizational settings. He posits that AI not only reshapes organizational processes but also necessitates novel institutional responses to manage these technological disruptions effectively [59]. This discourse is critical as it underscores the need for evolving institutional frameworks to keep pace with rapid technological advancements.

Facchini et al. [60] explored the intricate relationship between institutional quality, trust, and private savings, highlighting how trust—shaped significantly by institutional quality—affects economic behaviors crucial for financing innovation and technological advancement [60]. This interrelation provides deeper insights into the socioeconomic mechanisms underpinning economic development and institutional efficacy. Lastly, Merlo & Paris [61] address the dual role of institutional failures in affecting innovation. They argue that while institutional shortcomings can hinder technological progress, they also present opportunities for institutional learning and innovation [61]. This perspective is essential for understanding how institutional failures can be transformed into drivers of change, fostering a more dynamic interaction between technology and institutions.

These recent studies collectively enrich the conceptualization of techno-economic institutions, illustrating that the integration of robust technological and institutional dynamics is indispensable for fostering sustainable economic growth and innovation. This body of work provides a comprehensive foundation for ongoing research and policy formulation intended to enhance synergy between technology and institutions in modern economies.

Recent advancements in information and communication technology (ICT) have significantly influenced public administration dynamics, emphasizing the transformative role of digital platforms in enhancing governmental effectiveness. Significantly, Ahn & Chen [62] examined the incorporation of artificial intelligence (AI) into public sector operations, emphasizing AI's capability to enhance decision-making processes and advance service delivery in public administration [62]. This aligns with the growing recognition of AI's capacity to optimize institutional performance through data-driven insights and automated workflows. Furthermore, the governance of emerging technologies, such as blockchain, presents new paradigms for enhancing transparency and accountability in governmental operations. Tan et al. [63] provided a conceptual framework that details the integration of blockchain technology into public management structures and suggested that such technologies can significantly influence policy frameworks and administrative practices [63]. This supports the notion that when properly governed, advanced technological frameworks can foster more robust and efficient public institutions. In addition to blockchain and AI, the emergence of the metaverse offers a forward-looking perspective on digital public services.

Lnenicka et al. [64] discussed the implications of metaverse technologies for digital governance and proposed that virtual spaces can serve as platforms for innovative public service delivery, thereby expanding the scope and accessibility of governmental functions [64]. This perspective is particularly relevant because it highlights the evolving interface between citizens and public services, which is facilitated by cutting-edge digital environments. Moreover, the analysis of the ICT sector's impact on economic development within Eastern European countries by Dubyna et al. [65] provides empirical evidence of how technological advancements contribute to economic efficiencies and institutional improvements [65]. Their findings underscore the significant role of ICT in driving economic growth and enhancing governmental institutions' capacity to effectively deliver public goods. The literature also reflects on the role of digital readiness in addressing crises, as explored by Spicer et al. [66], who examined how Canadian local governments used ICT professionals during the COVID-19 pandemic to adapt to rapidly changing circumstances. This study illustrates the critical importance of digital agility within public institutions, enabling swift policy adaptation and service continuation during unforeseen challenges.

Collectively, these studies illuminate the multifaceted impacts of digital transformation on public administration. By integrating sophisticated digital technologies into the framework of techno-economic institutions, governments are not only enhancing operational efficiencies but also redefining the interactions between the state and its citizens. These insights are integral to understanding the contemporary landscape of institutional economics and provide a robust

empirical basis for theorizing techno-economic institutions. These studies collectively underscore the need for the ongoing adaptation and integration of technology within institutional frameworks. They highlight the essential role of institutions in not only facilitating but also regulating technological integration to ensure economic stability and growth, thus providing a solid foundation for understanding the complex relationship between technology and institutional dynamics.

3- Research Methodology

As the methodological foundation of our analysis, we employ complexity economics, as developed by Arthur [67]. Its core principles are as follows: firstly, technologies evolve within an ecosystem of other technologies, where regulating one component affects others. Secondly, new technologies fundamentally represent amalgamations of pre-existing ones, a concept resonant with Schumpeter's definition of innovations as novel combinations of resources. Arthur highlights that technological progress is dependent on the principles of combination and selection, proposing that new technologies develop from existing ones through a process he describes as "combinatorial evolution," which is consistent with Schumpeter's theories from 1934. Furthermore, institutions are essential in facilitating this process by promoting widespread access to knowledge and creativity. In addition, technologies not only create new technologies but also new institutions and organizational models, acting as building blocks. Finally, technology operates as complex, adaptive systems shaped by institutional mechanisms. These complex adaptive systems are characterized by internal heterogeneity, nonlinear development, and adaptive activity (i.e., the ability to change their properties and influence their environment). The methodology used in this paper primarily focuses on a comprehensive literature review and theoretical analysis. This involves a detailed examination of various theories and models in the field of institutional economics, particularly those related to technology and institutions. The article employs a comparative approach, critically analyzing and contrasting different theoretical perspectives. It also includes case studies to exemplify theoretical concepts. The methodology is interdisciplinary, combining economic theories with historical and sociological perspectives, and emphasizes the importance of institutions in shaping technological trajectories. This study introduces a methodological framework for exploring the interactions between institutions and technologies, specifically, within the realms of institutional and evolutionary economics. This study focuses on establishing a classification system for diverse analytical approaches to studying these relationships.

This classification is intended to provide a deep understanding of the mechanisms through which institutions and technologies interact and affect each other to facilitate economic development. The classification system serves as a fundamental foundation for the systematic categorization and analysis of different theoretical perspectives and empirical findings. Such structured analysis not only enhances our understanding of the fundamental principles governing the evolution of economic systems and provides valuable insights for developing policies that leverage the synergy of institutions and technologies to promote economic progress.

The research methodology (Figure 1) encompasses the following steps meticulously designed to analyze the dynamic interplay between technology and institutional frameworks within the context of institutional and evolutionary economics:

1. *Development of a Classification Framework*: The first step involved developing a detailed classification of approaches for analyzing the relationship between institutions and technologies. This foundational classification served as a systematic framework to categorize and evaluate theories and empirical findings that elucidate complex interactions in institutional and evolutionary economics.

2. *Critical Analysis of Institutional Roles:* The research undertook a critical examination of the role of institutions within three significant theoretical frameworks: the theory of general-purpose technologies, technological structures, and techno-economic paradigms. This analysis is pivotal in understanding how institutions influence and are influenced by technological advancements.

3. *Articulation of the Concept of Techno-Economic Institutions:* Building on the classification and analysis, the study introduced and defined "techno-economic institutions" as entities that ensure the embeddedness of technologies within the socio-economic environment. This conceptual development aims to bridge gaps in existing theories by highlighting the role of institutions in facilitating the integration of technologies into economic systems. To study the category of "techno-economic institutions," which play a crucial role in the assimilation of technologies into the socio-economic environment, we conducted the following stages of research: the first stage involved a review of literature published on the research topic to identify approaches to analyzing the relationship between institutions and technologies; the second stage focused on defining the key elements of the concept of techno-economic institutions, taking into account the needs of the socio-economic environment at the current stage.

4. *Empirical Validation through Econometric Modeling:* An econometric model was constructed to test the hypotheses regarding the impact of technological innovations on government efficiency in Russia. This model uses data from 2011 to 2022 and applies OLS regression analysis, making it possible to quantify the influence of technological

factors like ICT developments and SCM system integration on the effectiveness of government operations. The evaluation of the impact of digitalization on enhancing the efficiency of a governmental institution—the government—was conducted using econometric modeling. For the analysis, we selected factors that can influence innovative economic development. Some of these factors are used in the composition of innovation economy rankings for individual countries (for instance, the Global Innovation Index [68]) and regions (for example, the Regional Innovation Development Ranking of Russia, compiled by the Higher School of Economics [69]). The data were analyzed using Gretl software, which allows the construction of an econometric model based on the available panel data. The variables, brief descriptions, and data sources are presented in Table 1.

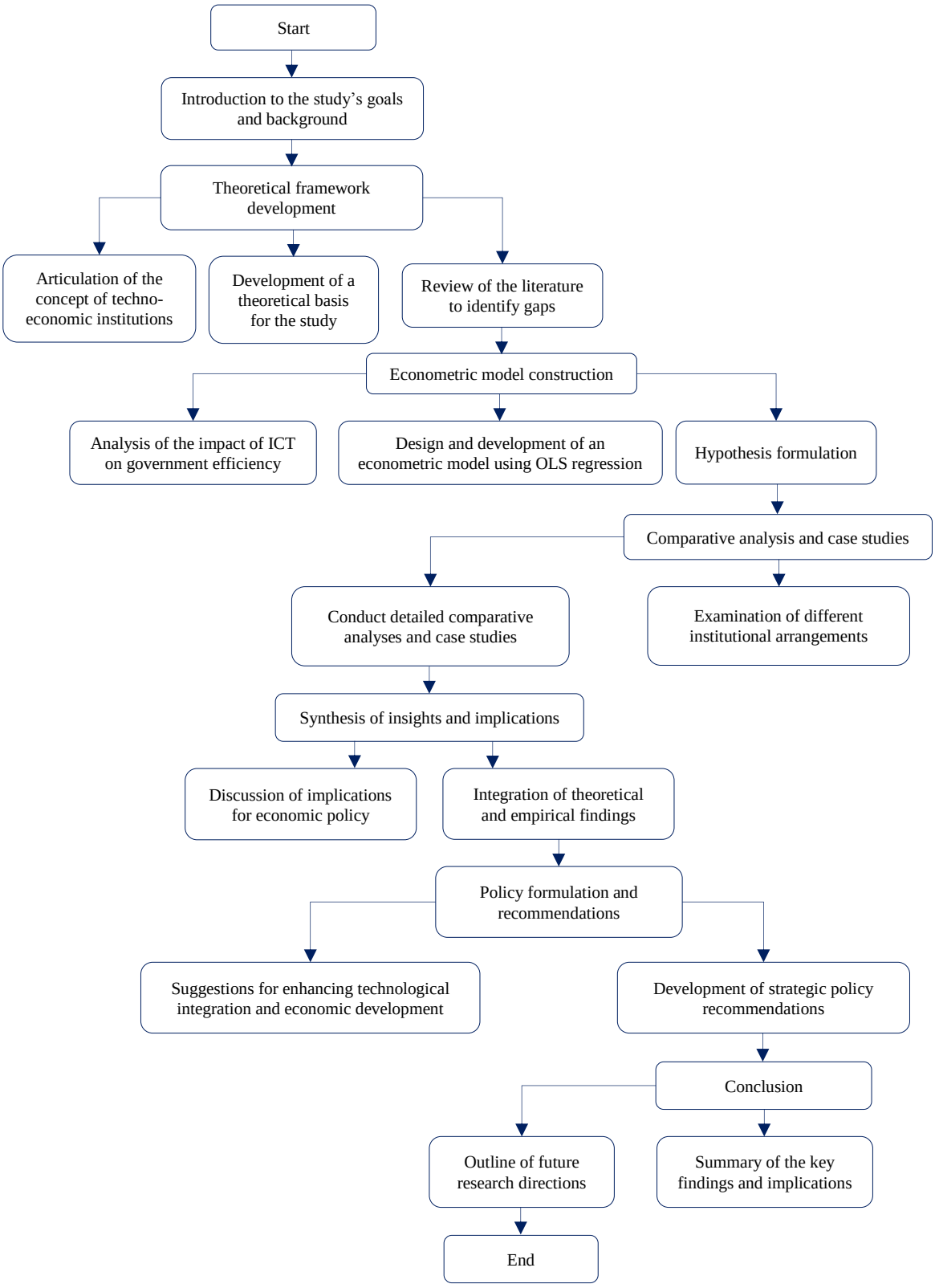

Figure 1. Flowchart of the study

Table 1. Description of variables and data sources

Variable	Unit of Measurement	Source
Publications by Russian authors in the field of ICT in journals indexed by Scopus (Scopus)	Units	Rosstat [70]
Patent applications for inventions in the field of ICT submitted by Russian applicants (Patent)	Units	
Internal expenditures on research and development in the priority area of "Information and Telecommunication Systems" (ER)	Million RUB	
Proportion of organizations that use SCM systems out of the total number surveyed (SCM)	%	
Proportion of households connected to the Internet (Internet)	%	
Proportion of governmental bodies and municipal services with Internet data transfer speeds of at least 2 Mbps out of the total number surveyed (Access)	%	

The selection of the indicators "Scopus", "Patent", and "ER" is justified by the fact that the increase in publication activity, the registration of patent applications, and expenditures on R&D in the field of ICT contribute to innovative economic development. The choice of the "SCM" indicator is based on the need to assess the effectiveness of public administration by considering whether organizations use supply chain management tools at both the level of the government customer (institution) and suppliers. The selection of the "Internet" and "Access" indicators is due to the growing role of computer networks and, in particular, the Internet in creating innovations and transitioning to innovative development. In Russia, the Internet is the primary source of government services. The use of information technologies and the Internet as communication tools between entities such as government bodies, legal entities, and individuals leads to qualitative changes in almost all areas of life, the emergence of new development opportunities for all economic entities, and increases labor productivity, thereby enhancing the efficiency and competitiveness of the economy.

5. *Comparative Analysis and Case Studies*: The methodology included comparative analyses and case studies to substantiate the theoretical findings. This approach allowed the examination of how institutional arrangements affect technology adoption and efficacy, thus providing a richer empirical context to theoretical insights.

6. *Synthesis of Insights and Policy Implications*: Finally, the study synthesized the findings from both theoretical and empirical analyses to discuss their implications for economic policy and theory. This study offered a comprehensive view of the strategic importance of techno-economic institutions in enhancing technological integration and economic development.

This methodological approach ensures a thorough examination of the interdependencies between technology and institutions, providing a substantive theoretical contribution to the fields of institutional and evolutionary economics. The foundational stage of the methodology is marked by a rigorous examination of scholarly literature, encompassing an array of theoretical discourses, empirical investigations, and seminal contributions within the domain of institutional economics. This extensive review seeks to unearth pivotal theories and models that address the confluence of institutional dynamics and technological progress. Such a review not only enriches the theoretical underpinnings of this study and sets the premise for subsequent analytical endeavors. Central to the methodological framework is the establishment of a classification schema that systematically organizes the myriad theoretical perspectives encountered in the literature. This schema is based on several delineating criteria, including the thematic focus (on institutions versus technologies), methodological approach (quantitative versus qualitative analysis), and theoretical lineage (rooted in institutional theory versus evolutionary economics). This classification facilitates the nuanced comparison and evaluation of the disparate theoretical narratives, thereby enriching the analytical depth of the study. Leveraging the classification schema, this study synthesizes and critically appraises the identified theoretical approaches. This phase involves a meticulous analysis aimed at elucidating the conceptual and empirical strengths and limitations of each approach, thereby uncovering latent research gaps and emergent thematic inquiries. Such a synthesis not only enhances the conceptual clarity of the investigation and paves the way for innovative research trajectories. The apex of the methodological journey involves the articulation of an integrative framework that combines the insights gleaned from the diverse theoretical explorations. This framework aspires to provide a holistic lens through which the interplay between institutional structures and technological innovation can be examined, with a particular emphasis on implications for economic development. In its final step, the proposed framework is subjected to empirical scrutiny through a case study or dataset analysis. This study aims to validate the efficacy and applicability of the framework by employing rigorous analytical techniques to test the hypotheses posed against empirical evidence.

To test the hypothesis regarding the impact of information technology development on the effectiveness of the governmental sector in Russia as an institution, an econometric model was constructed using the Gretl software package and the Ordinary Least Squares (OLS) method. The period considered spans from 2011 to 2022. The dependent variable selected was "government effectiveness" according to the World Bank data (Worldwide Governance Indicators) [71], with factors drawn from Rosstat statistics (Rosstat Data) [70] as follows:

- "Publications by Russian authors in the field of ICT in journals indexed by Scopus" (Scopus);
- "Patent applications for inventions in the ICT field submitted by Russian applicants" (Patent);
- "Internal expenditures on research and development in the priority area of Information and Telecommunication Systems" (ER);
- "Proportion of organizations that used SCM systems out of the total number surveyed" (SCM);
- "Proportion of households connected to the Internet" (Internet);
- "Proportion of governmental bodies and municipal services with Internet data transfer speeds of at least 2 Mbps, out of the total number surveyed" (Access).

Consider the descriptive statistics for the variables used in Table 2. Kurtosis measures how much the tails of the distributions differ from those of a normal distribution, characterizing the relative peak or flatness of the distributions. Patent, SCM, and Access have positive kurtosis, indicating relatively peaked distributions. Scopus, ER, Internet, and Efficiency exhibit negative kurtosis, suggesting relatively flat distributions.

Table 2. Descriptive statistics

	Mean	Median	Minimum	Maximum	Standard Deviation	Variation	Skewness	Kurtosis	Interquartile range	Missing Values
Scopus	**10592**	**10133**	**3174.0**	**18695**	6087.4	0.57474	0.086357	-1.5709	12803	**0**
Patent	2204.7	2208.0	1722.0	2706.0	261.01	0.11839	0.12827	0.026337	272.00	**1**
ER	74242	76116	46610	99673	14629	0.19704	-0.18226	-0.32116	21242	**1**
SCM	5.2250	4.3500	2.5000	14.300	3.1098	0.59519	2.2287	4.3158	2.2000	**0**
Internet	73.908	75.550	56.800	86.600	8.3125	0.11247	-0.47330	-0.20047	9.9250	**0**
Access	59.087	58.650	24.400	87.844	16.261	0.27520	-0.32405	0.22319	21.475	**0**
Efficiency	41.639	42.380	25.940	52.860	7.7751	0.18673	-0.51801	-0.43658	11.360	**0**

Using the Gretl software package, a model was constructed with the following parameters (Table 3):

- Mean of dependent variable: 43.06636
- Standard deviation of dependent variable: 6.293672
- Sum of squared residuals: 20.46378
- Standard error of model: 2.261846
- R-squared: 0.948337
- Adjusted R-squared: 0.870843
- F-statistic (6, 4): 12.23753
- P-value (F): 0.014933

Table 3. Model 1: MNC, observations 1-11 were used. Dependent variable: Efficiency

	Coefficient	St. error	t-statistics	P-value	
Const.	15.5924	21.4496	0.7269	0.5075	
Scopus	−0.000650325	0.000472693	−1.376	0.2409	
Patent	0.00729487	0.00435173	1.676	0.1690	
ER	5.91741e-05	0.000208121	0.2843	0.7903	
SCM	3.67478	1.10449	3.327	0.0292	**
Internet	−0.368169	0.525539	−0.7006	0.5222	
Access	0.418188	0.221442	1.888	0.1320	

The regression equation is as follows:

$$\text{Efficiency} = 15.6 - 0.000650*\text{Scopus} + 0.00729*\text{Patent} + 5.92e\text{-}05*\text{ER} + 3.67*\text{SCM} - 0.368*\text{Internet} + 0.418*\text{Access} \quad (1)$$

The R-squared value serves as a measure of the overall quality of the regression equation. In the model under consideration, the R-squared value is 0.948337, which lies within the range of 0.8–0.95, indicating a satisfactory approximation (the model is generally adequate in describing the phenomenon). The factor "proportion of organizations that used SCM systems out of the total surveyed organizations" (SCM) was significant at the 0.05 level. The multicollinearity analysis revealed that the Variance Inflation Factor (VIF) values ranged from 2.522 to 31.547. This indicates a multicollinearity problem in the evaluated model. The inflation factor method: The minimum possible value is 1.0. Values > 10.0 suggest multicollinearity:

- Scopus – 16.183
- Patent – 2.522
- ER – 18.119
- SCM – 3.944
- Internet – 31.547
- Access – 25.677

In this context, a new model is proposed using the Ordinary Least Squares (OLS) method. The period considered spans from 2011 to 2022. The dependent variable selected was "government effectiveness" according to data from the World Bank (Worldwide Governance Indicators [71]), with factors used from Rosstat statistics [70]:

- "Patent applications for inventions in the field of ICT submitted by Russian applicants" (Patent);
- "Proportion of organizations that used SCM systems out of the total surveyed organizations" (SCM);
- "Proportion of governmental bodies and municipal services with Internet data transfer speeds of at least 2 Mbps, out of the total surveyed organizations" (Access).

The model is characterized by the following parameters (Table 4):

- Mean of dependent variable: 43.06636
- Standard deviation of dependent variable: 6.293672
- Sum of squared residuals: 34.59880
- Standard error of the model: 2.223215
- R-squared: 0.912652
- Adjusted R-squared: 0.875217
- F-statistic (3, 7): 24.37974
- P-value (F): 0.000443

Table 4. Model 2: OLS, observations 1-11 were used. Dependent variable: Efficiency

	Coefficient	St. error	t-statistics	P-value	
Const.	4.70883	6.36875	0.7394	0.4837	
Patent	0.00995982	0.00369351	2.697	0.0308	**
SCM	2.22002	0.626157	3.545	0.0094	***
Access	0.114783	0.0612091	1.875	0.1029	

The regression equation is as follows:

$$\text{Efficiency} = 4.71 + 0.00996*\text{Patent} + 2.22*\text{SCM} + 0.115*\text{Access} \quad (2)$$

In the model under consideration, the R-squared value is 0.912652, which falls within the range of 0.8–0.95, indicating a satisfactory approximation (the model is generally adequate in describing the phenomenon). The factor "patent applications for inventions in the ICT field submitted by Russian applicants" (Patent) was found to be significant at the 0.05 level, and the factor "proportion of organizations that used SCM systems out of the total surveyed organizations" (SCM) was significant at the 0.01 level. Meanwhile, the coefficient for "Access" was found to be insignificant, suggesting the need for its exclusion. The analysis for multicollinearity revealed that the Variance Inflation Factor (VIF) values ranged from 1.312 to 2.031, indicating that the evaluated model did not present a multicollinearity problem: Inflation factor method: The minimum possible value of 1.0. Values greater than 10.0 indicate multicollinearity:

- Patent: 1.880
- SCM: 1.312
- Access: 2.031

Attention is drawn to the alignment of the regression coefficient signs with economic sense: increases in the number of patent applications and the use of SCM systems are associated with increased government efficiency. The Fisher test was applied to check the quality of the regression: the P-value (F) (F) < 0.01 (in the model it equals 0.000443), indicating that the model is significant at the significance level α=0.01. In addition, the calculated F-statistic value is compared with the critical value of the Fisher distribution at the given significance level α: F_calculated > F(α; m; n-m-1). For α=0.05: 24.37974 > 3.3258. Consequently, the null hypothesis of the overall insignificance of the regression is rejected at the significance level α=0.05, indicating that the coefficients are not zero for all regressors and confirming the combined effect of the factors on the dependent variable.

When the number of publications by Russian authors in the field of ICT in journals indexed by Scopus increases by one unit, government efficiency decreases by 0.000650. When the number of patent applications for inventions in the field of ICT increases by one unit, government efficiency increases by 0.00729. When internal expenditures on R&D in the priority area of "Information and Telecommunication Systems" increase by one unit, government efficiency increases by 5.92e-05. When the proportion of organizations that use SCM systems out of the total number surveyed increases by one unit, government efficiency increases by 3.67. When the proportion of households connected to the Internet increases by one unit, government efficiency decreases by 0.368. When the proportion of governmental bodies and municipal services with Internet data transfer speeds of at least 2 Mbps out of the total number surveyed increases by one unit, government efficiency increases by 0.418. Let us highlight the common factors of the two models (Table 5).

Table 5. Comparison of econometric models

Indicator	Coefficient in Model 1	Coefficient in Model 2
Publications by Russian authors in the field of ICT in journals indexed by Scopus (Scopus)	– 0.000650	-
Patent applications for inventions in the field of ICT submitted by Russian applicants (Patent)	0.00729	0.00996
Internal expenditures on research and development in the priority area of "Information and Telecommunication Systems" (ER)	5.92e-05	-
Proportion of organizations that use SCM systems out of the total number surveyed (SCM)	3.67	2.22
Proportion of households connected to the Internet (Internet)	- 0.368	-
Proportion of governmental bodies and municipal services with Internet data transfer speeds of at least 2 Mbps out of the total number surveyed (Access)	0.418	0.115

In Model 2, the coefficient for patent applications for inventions in the field of ICT submitted by Russian applicants increased, indicating that the impact of this variable has strengthened. Meanwhile, the influence of the indicators on the proportion of organizations that used SCM systems out of the total number surveyed (SCM) and the proportion of governmental bodies and municipal services with Internet data transfer speeds of at least 2 Mbps out of the total number surveyed (Access) decreased.

This study incorporates a comprehensive econometric model to quantify the impact of advancements in information technology on the effectiveness of the Russian governmental sector. Utilizing data from 2011 to 2022, the model employs Ordinary Least Squares (OLS) regression to explore the relationship between government effectiveness (as indexed by the World Bank) and a suite of independent variables reflecting technological progress. These variables include: the volume of ICT-related publications by Russian authors indexed in Scopus, patent applications in the ICT sector filed by Russian applicants, internal expenditures on R&D in Information and Telecommunication Systems, and the integration of SCM systems into organizations. This approach not only enables a rigorous empirical analysis of the hypothesized impacts but also provides a structured framework to validate the theoretical propositions concerning the symbiotic relationship between technology and institutional efficiency.

The methodology concludes with a reflective assessment of the investigative outcomes, offering powerful recommendations for policy formulation and delineating avenues for future scholarly exploration. This reflective phase is instrumental in highlighting novel research questions that have emerged from the study and charting a future investigation course, thereby contributing to the ongoing discourse on the dynamic interrelation between institutional configurations and technological evolution in the pursuit of sustainable and inclusive economic growth.

4- Results

In our view, technologies do not exist independently of institutions, and institutions are not merely external conditions for technological change; they are essential components of innovation in the form of new combinations. Therefore, institutions are present at the inception of new technologies and throughout their life cycle and are intertwined with the development of corresponding institutions. Consequently, the methodological foundation for the institutional theory of technological development should adopt "soft" institutional determinism, accentuating the coevolution of technologies and institutions.

Institutions associated with specific technologies are pivotal in facilitating economic technological advancement. These institutions encompass all entities connected in some way to a particular technology, facilitating its operation and evolution [70]. For example, blockchain technology has demonstrated that related institutions include not only code-based rules [72] and informal norms, social roles, behavioral practices, organizational models, and collective beliefs [73]. We also propose the concept of techno-economic institutions, which regulate the economic use and corresponding effects of technologies, excluding institutions related to cultural, humanitarian, political, communicative, and other social effects.

Regarding technological innovations, techno-economic institutions play a dual role [74]. They can be both factors of inertia and drivers of technological change. Institutions always have a retrospective nature because they embody the coordination methods that emerged in the past. Thus, any technological change will inevitably confront the growing inadequacy of existing institutions, such as outdated standards and legal norms that do not adequately regulate new technological realities. The inertia of institutions significantly affects technological inertia, often hindering experiments and creating high costs for innovators. Conversely, institutions that provide standardized problem-solving pathways can unleash innovators' creative energy. If institutions adaptively change along with technologies, they can even become "conductors" of technological change, stimulating knowledge exchange and access, creating incentives for innovative activities, and setting new standards for consumption and idealized lifestyles [70]. To achieve a higher level of representation, the author presents a comprehensive characterization of the analyzed approaches to institutions and technologies, and their interrelations with socioeconomic development in Table 6.

Table 6. Comparative analysis of the concepts of the interrelationship between institutions and technologies in institutional economic theory

Concept	Substantive Characteristics	Principal Representatives
"Strong" Technological Determinism	Technologies are the primary driving force of economic development. Institutions exert an inertial and stabilizing influence. Institutions emerge because of technological changes. Outdated institutions hinder technological progress.	Ayres [16]; Demsetz [23], Chang [22]
"Weak" Technological Determinism	Technological advancement occurs within an institutional context; consequently, the formulation of regulations (the creation of institutions) influences the societal impact of contemporary technologies. Depending on the characteristics of these technologies, institutions may play a pivotal role (from the perspective of techno-pessimists) or a less significant one (from the viewpoint of techno-optimists).	Veblen [3, 4], DeGregori [18], Hayden [9] and Old Institutional Theory
"Strong" Institutional Determinism	Institutions are crucial for economic development. Institutional shifts precipitate technological developments. The genesis of novel technologies is impeded in environments with suboptimal institutions. Together, institutions and the application of technologies are pivotal in shaping the extent and configuration of production-related costs.	North [14] and New Institutional Economics
"Weak" Institutional Determinism	Institutions are a special type of social technology. Technological development involves the co-evolution of production (physical) and social technologies. The complementarity of production and social technologies plays a critical role. Institutions function as catalysts for the advancement of production technologies.	Nelson [12], DeGregori [18]

In economic theory, prominent frameworks such as the theory of General Purpose Technologies (GPTs), the theory of techno-economic paradigms, and the theory of technological structures are recognized as pivotal in describing technological transitions.

General Purpose Technologies (GPTs) are large-scale technological innovations that initiate a surge of subsequent technological developments, transforming the material environment, the structure of occupations, lifestyles, etc. [75]. Essentially, GPTs are drivers of qualitative economic changes and not catalysts for economic growth. As noted by R. Lipsey and A. Nakamura, "the real effect of GPTs is the rejuvenation of the growth process" [76]. The development of GPTs is uneven and can be described through a lifecycle model as follows:

- A formation phase of GPTs, where the journey begins with groundbreaking research and advances to applied developments and prototype manufacturing. This period attracts investments and involves the introduction of products based on GPTs, construction of necessary infrastructure, and the start of novel educational programs and disciplines;
- An expansion phase of GPTs is characterized by the recovery of investments, elevated demand for products powered by General-Purpose Technologies, the generation of employment opportunities, and subsequent rises in income, profits, and tax revenues, collectively fostering economic expansion;

- A maturity phase of GPTs during which GPTs achieve optimal integration within the economy. They become foundational to the expansion of all industries and act as critical infrastructure in society, akin to the current role of electricity and the Internet today;
- Decline phase of GPTs, in which GPTs no longer provide a competitive advantage, leading to decreased profitability for businesses that use them. This phase is characterized by gradual phasing out of older GPTs and replacement with new ones.

This representation of the GPT life cycle curve (and technologies in general) is widely accepted in economic theory. In our view, this model is linear (i.e., it does not consider alternative development scenarios for GPTs) and does not fully encapsulate the real processes of technological development. It can be supplemented and presented in the form of a variational model (Figure 2), accounting for two additional GPT development scenarios:

1) Initiation of a re-expansion scenario in the maturity phase;
2) Transition to a re-expansion scenario during the decline phase.

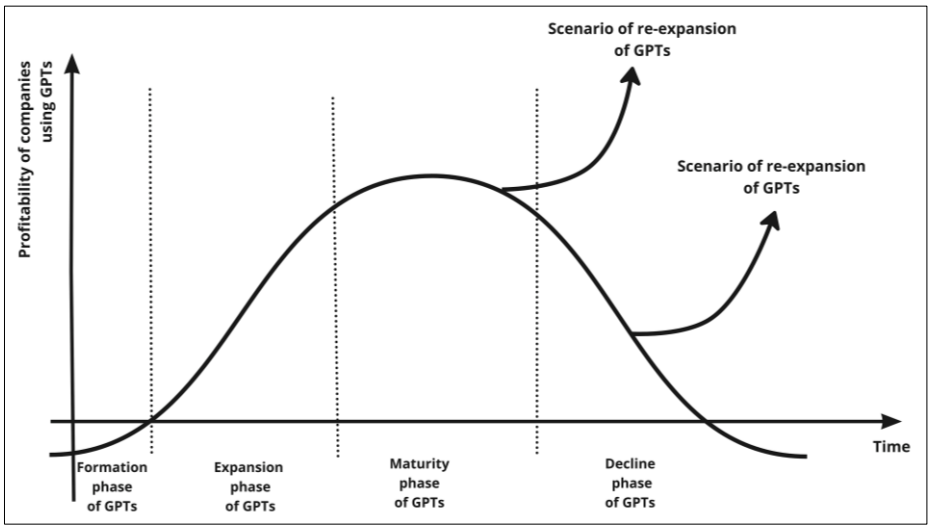

Figure 2. Variational model of the life cycle of general-purpose technologies (GPTs)

Information technologies, embodying a Techno-Economic Paradigm (TEP), have initiated a re-expansion phase during their period of maturity. Technologies linked to the Internet, which were pivotal in shaping technological advancements during the early 21st century, have transitioned to a second generation comprising Big Data, the Internet of Things, blockchain, artificial intelligence, and similar technologies. This transition underscores the TEP's high adaptive potential for changing environmental conditions through continuous innovation generation. Meanwhile, electric motors, whose peak of efficiency has long passed (around the 1930s, according to Glaziev et al. [77]), now embody a scenario of re-expansion in the declining phase: an increasing number of car manufacturers are declaring a shift from internal combustion engines to producing electric vehicles, potentially leading to a significant expansion of this TEP. It is essential to acknowledge that transitions between Techno-Economic Paradigms (TEPs) do not invariably occur in a smooth continuum; there exist circumstances in which the dominant TEP has exhausted its innovative capacity, rendering it incapable of generating a significant volume of progressive (secondary) innovations. Simultaneously, the emerging TEP may not have attained the necessary level of development for active expansion.

The evolutionary economic perspective on techno-economic development is closely aligned with Carlota Perez's theory of techno-economic paradigms. However, Perez's theory, like Glaziev's, focuses not on the evolution of individual technologies within a single industry (as Dosi [78] discusses in his theory of technological trajectories and Nelson & Winter [79] in their theory of technological regimes), but on the evolution of comprehensive technological systems at a macroeconomic level, which transform the technological landscape of entire nations. Another distinguishing aspect of Perez's theory is its correlation of breakthrough technologies with organizational principles, collectively constituting a techno-economic paradigm. Perez [80] asserted, "a techno-economic paradigm is a model of best business practice, encompassing both technological and organizational principles that epitomize the most effective means to materialize a specific technological revolution" [80]. Academics illustrate this paradigm by adopting optimal technological and organizational practices across various economic activities that have become universally acknowledged as common sense among entrepreneurs, essentially forming the foundational principles of any activity or institution [81]. The innovative approach introduced by Perez in her model of techno-economic paradigm shifts is particularly noteworthy. This model, characterized by a four-phase cycle of technological life cycles, is distinguished by the incorporation of an innovative phase – "Turning point" (Figure 3), emphasizing the originality of the author's contribution.

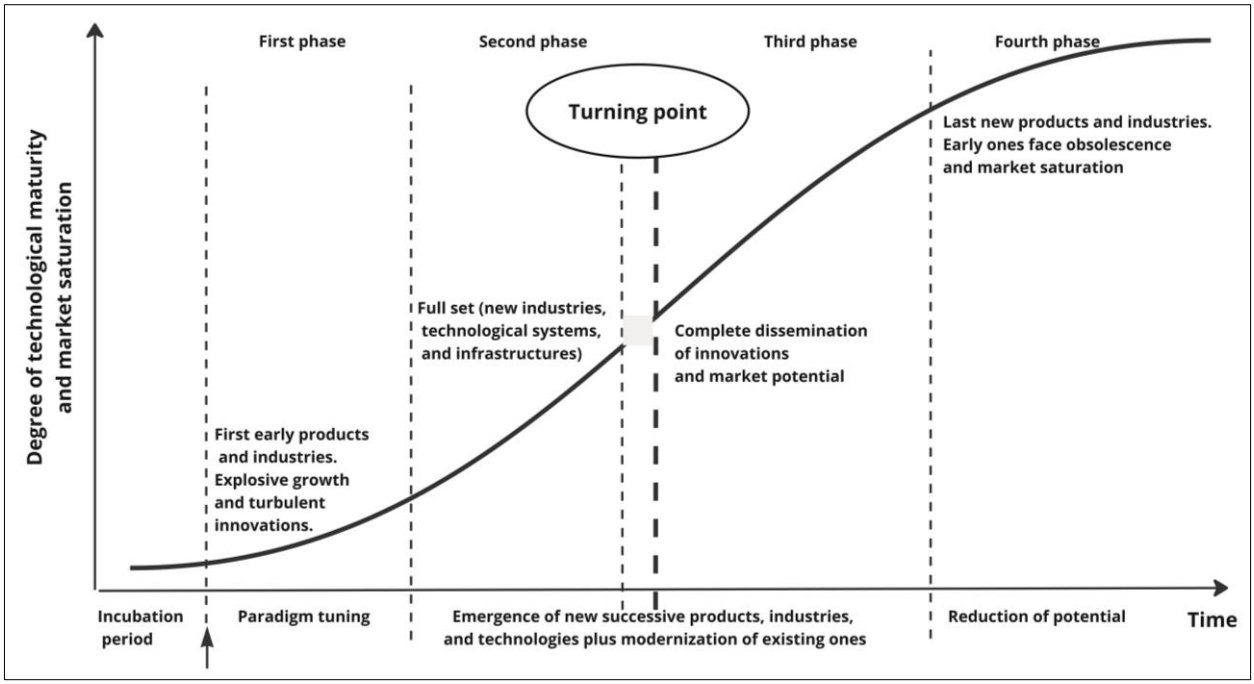

Figure 3. Mechanism of Shift in Techno-Economic Paradigms

A crucial requirement characterizes the pivotal moment in the development of a techno-economic paradigm: the presence of an institutional environment that supports the new paradigm. Until institutions shaped by the previous paradigm undergo transformation, the widespread adoption of the new paradigm will remain obstructed. Carlota Perez posits that the impetus for creating new institutions often originates from a stock market boom driven by novel technology and the subsequent bursting of the financial bubble. This bubble burst, followed by recession, foster conditions conducive to institutional restructuring [80]. It is plausible that this phase corresponds to a realistic reassessment of the potential of the new paradigm's technologies, drawing more conservative investors and entrepreneurs. An illustrative example of this phenomenon is the early 21st-century internet technology sector, where, following the burst of the IT startup bubble (the so-called dotcoms), robust integration of IT technologies across all business and public life domains ensued.

This study applied econometric modeling to investigate the influence of technological advancements on the operational effectiveness of the governmental sector in Russia, with the results corroboring the hypothesized positive impact of information technology on institutional efficiency.

The first employed econometric model (Table 2) yielded a robust R-squared value of 0.948337, indicating that approximately 94.83% of the variation in government effectiveness can be explained by the selected technological and institutional variables. This high degree of model fitness highlights the significant role that technology plays in shaping government operations. The Adjusted R-squared of 0.870843 remains impressive, reinforcing the model's effectiveness despite the complexity and number of predictors. The F-statistic of 12.23753, with a corresponding p-value of 0.014933, substantiates the overall statistical significance of the model, affirming that the regression model provides a meaningful and reliable fit to the data. Among the predictors, the usage of SCM systems emerged as a particularly influential factor, demonstrating a statistically significant correlation with the effectiveness of government operations at the 0.05 level. This finding underscores the critical importance of enhancing logistics and operations in public administration. However, the analysis revealed potential multicollinearity issues, as indicated by Variance Inflation Factor (VIF) values ranging from 2.522 to 31.547. This suggests that some predictors, particularly "Internet", might not provide independent information, which could distort the estimated coefficients and their standard errors.

To address the multicollinearity concerns observed in the first model, a refined Model 2 (Table 4) was constructed. This revised model also demonstrated a strong fit, with an R-squared value of 0.912652, effectively capturing the relationship between technology use and governmental efficiency. In this model, the variable representing patent applications filed in the ICT sector proved significant at the 0.03 level, further illustrating the positive impact of technological innovation on government effectiveness. The usage of SCM systems maintained its significance, thereby affirming its robustness as a predictor.

The consistency of significant results across both models provides compelling evidence that technological advancements, particularly in the form of ICT patents and SCM system utilization, directly contribute to enhancing government institutions' operational effectiveness. These results not only support the theoretical framework proposed in the earlier sections of the article but also offer practical implications for policy formulation aimed at digital transformation in the public sector.

Based on the model obtained, we will construct forecasts for the "government effectiveness" indicator for 11 steps forward, extending to 2033 (Figure 4).

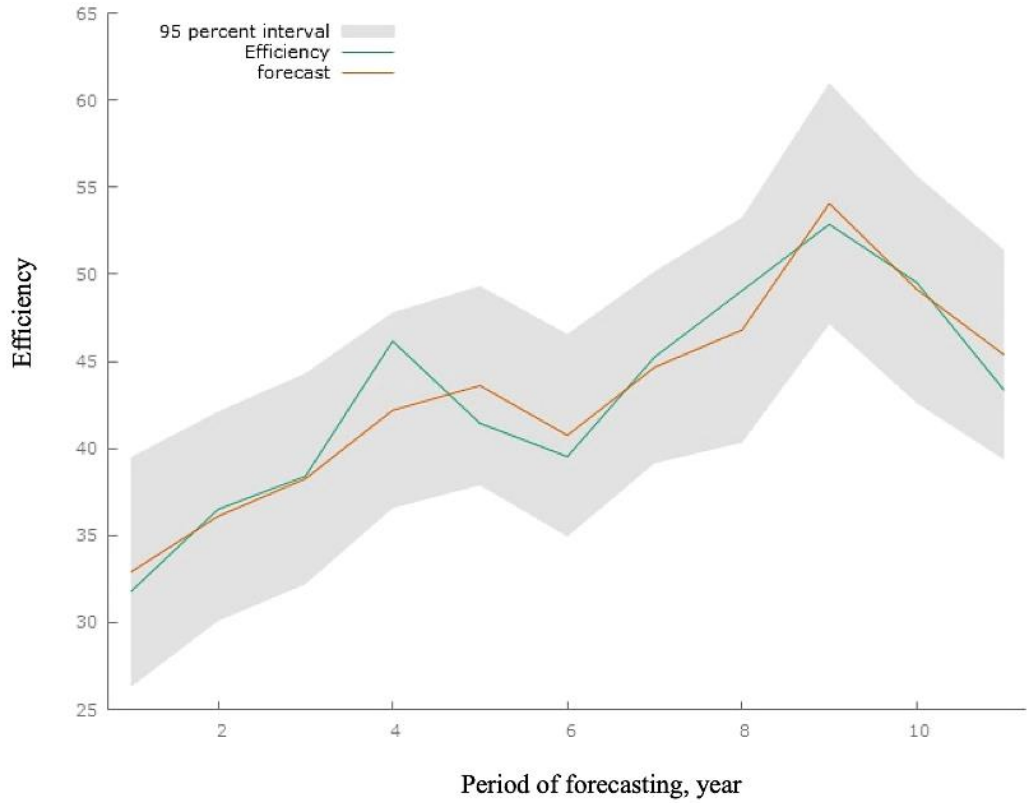

Figure 4. Dynamic forecast of the Efficiency series 11 steps ahead according to the model

According to the forecast values, from 2024 to 2027, an increase in the value of the indicator is observed, with growth expected in 2031, followed by a trend toward a decline. The forecasted values, standard errors, and confidence intervals are presented in Table 7. The "government effectiveness" indicator for 2024 is projected to be 36.0914 with a standard error of 2.54549 and a 95% confidence interval of [30.0723, 42.1105]. A decrease in the indicator to 40.7430 is expected in 2028, with a standard error of 2.46158 and a 95% confidence interval of [34.9223, 46.5638]. In 2031, growth is forecast to reach 54.0601 with a standard error of 2.93276 and a 95% confidence interval of [47.1252, 60.9950], followed by a decrease in 2033 to 45.3706 with a standard error of 2.55170 and a 95% confidence interval of [39.3368, 51.4044].

Table 7. Forecasted efficiency series values for 11 steps forward using the model with 95% confidence intervals t (7, 0.025) = 2.365

Observation	Efficiency	Forecast	Standard Error	95% Confidence Interval
1 (2023)	31.7500	32.8744	2.79373	(26.2683, 39.4806)
2 (2024)	36.4900	36.0914	2.54549	(30.0723, 42.1105)
3 (2025)	38.3900	38.2458	2.56401	(32.1828, 44.3087)
4 (2026)	46.1500	42.1816	2.37925	(36.5556, 47.8077)
5 (2027)	41.4300	43.5961	2.42223	(37.8685, 49.3238)
6 (2028)	39.5200	40.7430	2.46158	(34.9223, 46.5638)
7 (2029)	45.2400	44.6502	2.33168	(39.1367, 50.1637)
8 (2030)	49.0500	46.7888	2.73967	(40.3105, 53.2671)
9 (2031)	52.8600	54.0601	2.93276	(47.1252, 60.9950)
10 (2032)	49.5200	49.1279	2.76397	(42.5922, 55.6637)
11 (2033)	43.3300	45.3706	2.55170	(39.3368, 51.4044)

Lipsey et al. [15] developed a structuralist-evolutionary theory that synthesizes concepts from institutional and evolutionary economics. This theory, focusing primarily on general technologies, strongly emphasizes the path dependence effect, which asserts that economic development is deeply influenced by historical trajectories and predetermined outcomes specific to the development of these technologies. Predetermination is interpreted because of the cumulative influence of a society's institutional, technological, cultural, and social conditions at a given time [15].

The development of general technologies can be most effectively understood by considering the distinctive characteristics of external conditions and the existence of historically predetermined effects. Using Perez's framework, one may deduce that the critical juncture differentiating the establishment and deployment phases of new general technologies and techno-economic paradigms varies in each instance. An important aspect within the scope of this study is the examination of the functions of institutions in technological development. According to the author, techno-economic institutions play a crucial role in organizing the economic application of various technologies, which constitutes their primary function. Such organization encompasses the following complex functions: 1) habituation, characterized by the development of individual habits related to the use of new technology and their subsequent transformation into collective practices; 2) routinization, entailing the creation of organizational routines linked to the employment of new technology within organizations; 3) normalization, which encompasses the conversion of the collective habits of small groups into social norms governing the application of new technology. It also includes the conversion of organizational routines related to the new technology from a narrow circle of organizations into widely practiced norms. Consequently, individual attributes of habits and distinctive elements of routines become "obscured" and standardized into common parameters of social norms [81, 82]; 4) Standardization and regulation entail the establishment of formal rules and mechanisms to guarantee compliance with new technologies, alongside the implementation of monitoring and enforcement measures; 5) coordination of economic activities encompasses (a) networked, horizontal coordination among market participants or within clusters, and (b) hierarchical coordination, which involves organizational interactions across different management levels.

In this study, it is essential to consider the following three primary types of techno-economic institutions:

- ***Regulatory institutions***: The main functions of these institutions are to impose restrictions on the economic use of technologies, enforce sanctions for violations, and support the mechanisms of law enforcement. Regulatory institutions function as "rules of the game" system for developers, intermediaries, and technology users. This well-defined operational framework of rules and norms enables the coordination of collective economic activities, thereby augmenting the economic value produced.
- ***Cognitive institutions***: This category includes various collective cognitive models, including shared beliefs, social values, collective narratives (stories), and interpretations. Researchers of cognitive institutions note that acts of cognition become possible through certain institutions and institutional mechanisms that allow individuals to perceive, evaluate, and understand the world, as well as share their interpretations with others [83]. Cognitive institutions primarily serve to coordinate mutual expectations within the economy, thereby diminishing uncertainty in economic interactions. In addition, they facilitate mutual learning and establish habitual patterns of technology use.
- ***Ethical institutions***: These are the moral norms, ideals, and principles prevalent in society and in specific spheres of activity. It is important to emphasize that "moral viewpoints are provided by social institutions. An individual rarely and with great difficulty chooses a moral stance on individual rational grounds" [84]. In the context of technological development, ethical institutions play a critical role, particularly when society confronts controversial or "problematic innovations" that pose significant societal risks. Examples of such applications include nuclear energy, GMOs, nanotechnology, and artificial intelligence. When bringing problematic innovations to the market, "the importance of moral-ethical norms and rules, principles of precaution and responsibility increases" [85]. It should be noted that moral norms regarding new technologies do not pre-exist; rather, they are formed based on existing moral norms and cognitive and regulatory institutions. Their formation resembles the cumulative evolution of technologies, as described by Arthur [67].

In our view, digital institutions can also be divided into three groups:

- ***Digital regulatory institutions***: These include code-based rules, i.e., "if... then..." instructions that are foundational to algorithms. Such algorithms govern digital decision-making systems in various aspects of life, from employment processes and employee monitoring to bank lending and judicial decisions. The emergence of "digisprudence", as coined by Diver [86] in 2022, marks the development of a distinct branch of legal science focused on the governance of code-based rules, encapsulating digital jurisprudence.
- ***Digital cognitive institutions***: This group includes collective cognitive models associated with thinking and decision-making in a digital environment. The digital environment consists of various high-tech spaces where interactions among subjects are mediated by digital technologies—from laptops and mobile apps to augmented reality glasses and virtual reality headsets. The actions and interactions of subjects in a digital environment are characterized by anonymity; they are influenced by embedded algorithms (for example, suggesting possible product options in online stores); they are often gamified and reduce the level of seriousness; they encourage information overload, etc. Thus, the role of cognitive institutions is critical.
- ***Digital ethical institutions***: Moral norms are intricately intertwined with digital technologies. In the case of digital technologies, ethical institutions are directly related to their economic use because they set socially acceptable

boundaries for the application of various technologies, as well as methods of their incorporation into economic activities. For example, consider digital platforms. An overwhelming negative public perception of platforms emerged due to active criticism. This negative image is translated into the legislative realm when regulators view platforms as monopolies that merely offer appropriate rents and exploit both partners and consumers [28]. At the core of the extremely negative perception of digital platforms lie ethical institutions—moral norms that define their economic behavior as unethical, violating the principles of fair market conduct. In the case of open-source software technology, ethical institutions also motivated its use on moral grounds, although its actual performance was lower than that of alternative technologies [87].

Based on these results, a classification of the composition and functions of techno-economic institutions in the digital economy is presented in Figure 5.

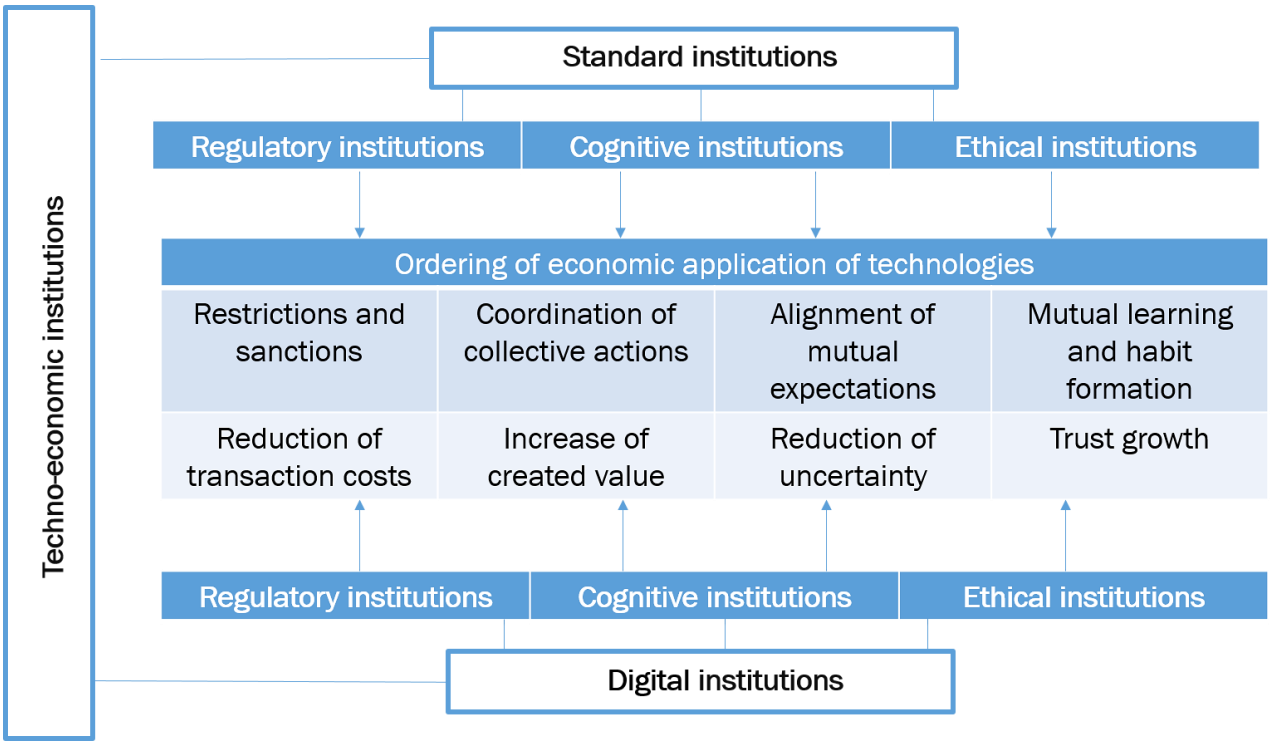

Figure 5. The structure and functions of techno-economic institutions in the digital economy

The ambiguity in the conceptual framework of various theories of techno-economic development presents challenges to their practical application. For these theoretical models to be effectively used in crafting analytical reports and strategies for socioeconomic development at diverse levels, they should facilitate measurability and comparability. However, when it comes to general technologies, there is a notable difficulty in defining the extent of their application. Critics, for instance, point out that markers such as universal use, as seen with polyethylene, do not clearly differentiate them from general technologies [88]. The use of electricity is widespread, and technologies like internet technologies [89], nanotechnology, and biotechnology are all underpinned by this foundational technology. In fact, it is difficult to envision modern advanced technologies functioning without electricity. The theory of techno-economic paradigms, which is similar to paradigm theory, is particularly suited to conducting qualitative economic transformation analyses. However, establishing precise boundaries and quantitative evaluations of these paradigms and technological regimes is a complex task in practice, often yielding only approximate results.

The innovation of this research lies in its integrative approach, which marries the concepts of technological innovation and institutional structures, positing that they are not distinct entities but interact deeply to influence economic trajectories. This study offers new analytical methods and classifications for understanding this relationship, particularly within the frameworks of institutional and evolutionary economics. This enhances current theoretical frameworks by introducing the concept of techno-economic institutions, entities that embed technologies within the socio-economic fabric, underscoring their function in promoting economic progress and devising development strategies that leverage this interaction. The study is underpinned by a thorough analysis of both theoretical and empirical data, thereby enriching the fields of institutional and evolutionary economics and shaping policy-making.

The application of the econometric model yielded significant findings that illuminated the role of technological advancements in enhancing governmental efficiency. The analysis indicates a positive correlation between the efficiency of government operations and both the quantity of ICT patent applications and adoption rates of SCM systems. These

findings empirically substantiate the proposed theoretical framework and demonstrate that the integration of technology into institutional structures significantly enhances the operational effectiveness of governmental bodies. Notably, the model accounted for 94.83% of the variance in government effectiveness (R-squared = 0.948337), underscoring the substantial impact of the included technological variables. This empirical evidence enriches the existing literature by providing a robust quantitative foundation for the proposed theoretical links between technology and institutional development.

5- Discussion

In critiquing traditional economic theories on technological development, this analysis highlights their limited focus on shifts in widely adopted technologies or paradigms, which often overlooks the richness of technological diversity and co-evolution. From the perspective of evolutionary economics, the concept of "uneven continuity in economic evolution" confronts the established notion of periodic "pauses" and "disruptions" in technological progress, suggesting instead a more complex interplay of technological cycles [52]. It is contended that technologies not only compete but also exhibit mutual adaptation. Often, radical innovations in one technological domain trigger "waves" of innovations in other areas. Thus, a coevolutionary, multi-paradigm approach is more appropriate for examining complex technological systems, especially digital technologies and the digital economy at large. This perspective underscores the need for extensive adaptation of the entire technological infrastructure along with a broader economic framework. It transcends simple transitions in technological paradigms and general technologies to encompass an expanding range of applications, alongside the inception of new activities and employment categories grounded in innovative technologies.

Institutions are often relegated to a secondary, inert role in techno-economic development. General technology paradigm theory predominantly perceives institutions through the lens of inertia and path dependence. In the theories of technological and techno-economic paradigms, institutions are seen as reactively and slowly adjusting to technological shifts, thus impeding paradigm replacement and becoming a catalyst for pivotal moments during paradigm transitions. From a technological co-evolution standpoint, routine—the widespread adoption, implementation, and use of recent technologies across various economic domains—is as crucial as innovation. During this routinization phase, knowledge dissemination about recent technology among economic agents occurs alongside the adaptation of various technologies, including related technological standards and business processes. It is within these institutions that the routinization of technological change occurs.

Technologies do not function independently from institutions; similarly, institutions are not just external elements that influence technological transformation. Rather, institutions and technologies are interdependent and act as complementary resources and factors. This aligns with the theory of complementarity of production factors within the meta-production function framework [90, 91]. We argue that the appropriate methodology for analyzing techno-economic development should adopt a weak institutional determinism approach, underscoring the co-evolution of production and social technologies, with the latter being conceptualized as institutions. Consequently, institutions can serve as both catalysts for inertia and drivers of technological transformation.

Institutions that are technologically interconnected and facilitate technological diversity are pivotal in techno-economic development. This notion, introduced by Frolov [92], encompasses institutions that are, in various capacities, associated with specific technologies. For example, within the domain of blockchain technologies, pertinent institutions encompass not only the code-based rules examined by Lanzara [72] but also established social practices, organizational frameworks, collective perceptions and beliefs, and status functions. This study advocates for establishing techno-economic institutions designed to regulate the economic application and impacts of technology. These institutions are distinct from those influencing the cultural, humanitarian, and social effects of technological advancements. This focus narrows the definition to institutions that systematically standardize, normalize, regulate, and routinize the application of technologies within economic frameworks, thereby facilitating their systematic incorporation into economic activities.

The fundamental nature of digital technologies, when considered independently, does not inherently increase or decrease the efficiency of economic agents. Instead, their true impact is deeply intertwined with the institutional "interface" that accompanies them. Frolov's [92] comprehensive delineation portrays a complex and broad framework comprising norms, behavioral standards, collective beliefs, expectations, social status, and organizational structures, all crucial to economic activities. The diverse effects of distinct digital technologies, considered in isolation, highlight the critical role that the institutional backdrop plays in determining their effects. Social networks exemplify a dual character: on the one hand, they serve as platforms that unify diverse individuals in pursuit of socially advantageous objectives, thereby fostering transparency and inclusiveness. On the other hand, they may also contribute to the proliferation of negative behaviors, such as egoism, narcissism, and misinformation. Similarly, peer-to-peer networks, while facilitating collaboration and file sharing, can inadvertently promote piracy and undermine intellectual property rights. Blockchain technology, despite its capacity to significantly increase the efficiency of a range of activities and transactions, also introduces unique challenges, notably the complexities of adapting smart contracts during critical situations.

Technologically interconnected institutions that promote technological diversity are crucial for techno-economic development. Consistent with contemporary scientific perspectives, this study introduces the concept of techno-economic institutions, defined as entities that regulate the economic use and subsequent impacts of technology. This concept omits institutions connected to the cultural, humanitarian, communicative, and additional social ramifications of technological advances. It focuses instead on techno-economic institutions, which are instrumental in ensuring the systematic (namely, standardized, normalized, regulated, and routinized) application of technologies within economic frameworks.

To transform technological change into stable economic structures, a technology-based system known as a "techno-institutional mechanism" be used. This transformation is facilitated through the creation of techno-economic institutions, entities responsible for the oversight, integration, coordination, and normalization of the application of technologies across various sectors. Techno-institutional mechanisms can be categorized as specialized mechanisms that function within a broader economic mechanism.

Drawing on the insights offered by this theory, scholarly and expert circles must recognize that the digital economy transcends mere digital technologies. Indeed, it rests upon a multifaceted interplay between interconnected physical technologies and institutions, which can be regarded as social technologies. Consequently, it is suggested that these intertwined formations can be categorized as techno-economic institutions.

The introduction of the term "techno-economic institutions" pursues several objectives: 1. To conceptually link institutions and technologies as a combinatorial phenomenon, which will overcome the long tradition of considering them in isolation within economic science. 2. To provide a classification of techno-economic institutions, including those in the context of digitalization, to enable a better understanding of their complex internal structure. 3. A clearer understanding of the nature and classification of techno-economic institutions serves as a scientific basis for policy interventions in the area of technological development. Given that institutions and technologies are co-evolving systems, policymakers should abandon the notion of universal institutions for technological regulation.

The study's major strength lies in its novel approach to combining technological and institutional analyses, providing a new lens through which to view economic and technological development. However, its limitations include potential difficulties in practically implementing the proposed classifications and frameworks due to the rapidly changing nature of technology and its applications in society. Further research is recommended to refine the classification of techno-economic institutions and explore their implications in diverse economic contexts. Future studies should also examine the impact of such institutions on technological innovation and adoption, particularly in emerging economies. This study contributes to the theoretical foundations of institutional and evolutionary economics by detailing the mechanisms through which institutions and technologies co-evolve. This approach challenges the traditional views that separate these elements, offering a new paradigm that could influence future economic modeling and theory development. For practitioners and policymakers, the research provides actionable insights into how institutions can be designed or modified to better support technological innovation and integration. This understanding is crucial for fostering environments that enhance technological effectiveness and economic growth. By elucidating the symbiotic relationship between institutions and technologies, this study offers a comprehensive framework that can aid scholars in dissecting the complexities of technological and institutional evolution. This framework serves as a cornerstone for subsequent studies that focus on integrating these elements. The findings advocate policies that promote flexible institutional frameworks that can adapt to technological advancements. Such policies should focus on developing incentives for innovation while establishing safeguards to mitigate potential social and economic disruptions caused by new technologies. Managers in technology-driven sectors are encouraged to leverage the findings to enhance strategic decision-making. Understanding the dual role of institutions—as both facilitators and barriers to technological adoption—can help managers navigate challenges and capitalize on opportunities presented by technological developments.

In conclusion, the econometric models developed in this study robustly support the hypothesis that technological integration significantly enhances governmental efficiency. The findings encourage further integration of advanced technologies into public administration processes, suggesting a strategic focus on technological development and adoption as a means to improve institutional performance. Future research should address the identified multicollinearity issues and possibly extend the analysis to include additional technological factors to broaden the understanding of this complex relationship. This comprehensive analysis aligns with the objectives outlined in this study and substantiates the significant role of technological innovations in redefining public sector management and governance.

The findings of this study highlight the critical role that information and communication technology developments play in promoting institutional efficiency. By demonstrating the positive impacts of ICT patents and SCM systems on governmental effectiveness, this research substantiates the proposed theoretical model and offers new insights into the mechanisms through which technology can enhance institutional operations. These conclusions not only contribute to academic discussion but also have practical implications for policy formulation, suggesting that strategic investments in technological infrastructure and innovation could significantly improve government performance. Future research should replicate this study in different institutional contexts to verify the generalizability of the findings and explore potential variability in technology-institution interactions across diverse geopolitical landscapes.

6- Conclusions

This study makes several contributions to the field of institutional economics:

The term "techno-economic institutions" has been proposed to unit institutions and technologies as a combinatorial phenomenon. This concept is accompanied by a classification of techno-economic institutions, which is crucial for assessing political interventions in the area of technological development. These institutions are categorized into regulatory, cognitive, and ethical categories, facilitating the systematic (standardized, normalized, regulated, and routinized) application of technologies within economic frameworks.

This study integrates technological and institutional analyses to examine economic and technological development. This underscores that technologies and institutions are not isolated entities but are intricately linked and mutually strengthening. This integrative approach challenges traditional views that separate technological and institutional evolution, significantly contributing to institutional and evolutionary economics.

The mechanisms through which institutions and technologies co-evolve, particularly in the digitalization process, are detailed. This study concludes that flexible institutional frameworks capable of adapting to technological advancements are necessary. Alongside the development of incentives for innovation, these frameworks should also mitigate negative impacts on socioeconomic development.

Econometric models have been developed to demonstrate the significance of innovative technologies in enhancing the efficiency of the public sector. By showing the positive impact of ICT patents and SCM systems on government efficiency, this research substantiates the proposed theoretical model and offers new insights into the mechanisms by which technologies enhance institutional performance. These findings not only contribute to academic discussion but also have practical implications for policy formulation.

The digitalization of the public sector and the digital economy has been popular research topics; however, empirical research primarily relies on literature reviews and rarely employs econometric models. Therefore, this study on the impact of technological advancements on government efficiency, measured through the number of ICT patents and the use of SCM systems, is timely and necessary. Future research should explore how relational and current processes are implemented in the digitalization of the public sector, helping to understand how technologies arise from interactions with the developing organization and how public service delivery technologies are refined and improved considering user experience. Additionally, the role of power, discourse, and algorithmic significance in configuring the functioning of new public service technologies and exercising governmental authority should be examined.

To ensure improved government efficiency, this study considers the factor "Proportion of organizations that used SCM systems out of the total number surveyed." Firstly, SCM-based technologies enhance procurement efficiency for the public sector. The government should continue promoting digitization of procurement procedures, especially in areas without a digital foundation where procurement without bidding is allowed. Secondly, the implementation of SCM systems at the enterprise level is essential. Enterprises should actively respond to the government's digitalization strategy and use digital technologies to improve operational efficiency in production planning, particularly in strategically important industries.

This study underscores the importance of integrating institutional frameworks with technological advancements and advocates for developing flexible institutional frameworks that can adapt to technological change. This understanding is crucial for fostering environments that enhance technological effectiveness and economic growth, providing actionable insights for policymakers when designing institutions to support technological integration. By comparing the results of this study with the existing literature, it is evident that while many studies have explored the impact of technology on economic systems, few have comprehensively examined the role of institutions in this context. This study's approach to integrating technological and institutional analyses offers a new lens through which to view economic and technological development, enhancing the understanding of how institutions can be leveraged to support technological innovation and integration.

Although the study provides robust insights into the co-evolution of technology and institutions, it is limited by its geographical focus on Russia and may not be directly generalizable to other contexts. The reliance on secondary data also limits the ability to capture real-time changes. Future research should explore the impact of techno-economic institutions in diverse economic and geopolitical contexts and examine the effects of such institutions on technological innovation and adoption, particularly in emerging economies.

In conclusion, the developed econometric models robustly support the hypothesis that technological integration significantly enhances governmental efficiency. The findings encourage further integration of advanced technologies into public administration processes, suggesting a strategic focus on technological development and adoption as a means to improve institutional performance. This comprehensive analysis aligns with the study's objectives and substantiates the significant role of technological innovations in redefining public sector management and governance. Future research should address the identified multicollinearity issues and possibly extend the analysis to include additional technological factors to broaden the understanding of this complex relationship.

These findings highlight the critical role that information and communication technology developments play in promoting institutional efficiency. By demonstrating the positive impacts of ICT patents and SCM systems on governmental effectiveness, this research substantiates the proposed theoretical model and offers new insights into the mechanisms through which technology can enhance institutional operations. These conclusions not only contribute to academic discussion but also have practical implications for policy formulation, suggesting that strategic investments in technological infrastructure and innovation could significantly improve government performance. Future research should replicate this study in different institutional contexts to verify the generalizability of the findings and explore potential variability in technology-institution interactions across diverse geopolitical landscapes.

7- Declarations

7-1- Author Contributions

Conceptualization, A.V.S.; methodology, A.V.S.; software, S.A.K.; validation, A.V.S. and S.A.K.; formal analysis, A.V.S.; investigation, A.V.S.; resources, A.V.S. and S.A.K.; data curation A.V.S.; writing—original draft preparation, A.V.S. and S.A.K.; writing—review and editing, A.V.S. and S.A.K.; visualization, A.V.S. and S.A.K.; supervision, A.V.S.; project administration, A.V.S.; funding acquisition, A.V.S. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

The data presented in this study are available in the article.

7-3- Funding

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7-4- Institutional Review Board Statement

Not applicable.

7-5- Informed Consent Statement

Not applicable

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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