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Rules of the digital game: How institutions shape ecosystem development

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This paper explores institutional factors influencing the development of digital economy ecosystems, emphasizing the roles of regulatory frameworks, governance, and innovation. The paper uses institutional economics as a theoretical foundation and highlights how institutional arrangements shape digital infrastructure investment, digital adoption, and innovation capabilities among enterprises. This empirical research is based on unique data extracted from a sample of online survey questionnaires collected from 250 small and medium-sized enterprises in seven different Russian regions between January and March 2025, as well as an econometric model that uses this data. Our analysis demonstrates that institutional quality significantly influences digital adoption, along with investments in digital infrastructure and innovation outcomes through a proposed empirical framework and the regression modelling. The main outcomes of this work offer the extensive policy implications for enhancing institutional quality to foster sustainable digital economy ecosystems. As future research directions, we propose particularly longitudinal studies to assess the dynamic interactions over time. Our findings might be of a special importance for the relevant stakeholders and policymakers as well as for the entrepreneurs who are keen on participating and creating robust and sustainable digital economy ecosystems.

Keywords: *digital economy; sustainable economic development; institutional economics; Russia*

JEL codes: *B25, B52, D83, L86*

Правила цифровой игры: как институты формируют развитие экосистемы

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В статье рассматриваются институциональные факторы, оказывающие влияние на развитие экосистем цифровой экономики. Особое внимание уделяется роли нормативно-правовых рамок, качества управления и инновационных процессов. В качестве теоретической основы используется институциональная экономика, позволяющая проанализировать, каким образом институциональные условия формируют инвестиции в цифровую инфраструктуру, способствуют цифровой трансформации предприятий и определяют их инновационный потенциал. Эмпирическая часть исследования базируется на уникальной выборке данных, собранных в ходе онлайн-опроса 250 малых и средних предприятий из семи регионов России в период с января по март 2025 г. Эти данные стали основой для построенной авторами эконометрической модели. Результаты анализа показывают, что качество институтов оказывает значительное влияние на уровень цифрового внедрения, инвестиции в цифровую инфраструктуру и инновационную активность предприятий. Полученные выводы значимы для государственной политики, направленной на повышение устойчивости экосистем в цифровой экономике. Кроме того, в статье обозначены перспективные направления дальнейших исследований, включая проведение лонгитюдных исследований для анализа динамики институциональных показателей. Представленные результаты могут быть полезны как для органов власти, так и для предпринимателей, заинтересованных в формировании и развитии устойчивых цифровых экосистем.

Ключевые слова: *цифровая экономика; устойчивое экономическое развитие; институциональная экономика; Россия*

Introduction

The rapid advancement of the digital economy has been accompanied by substantial institutional transformations, driving socio-economic development across various sectors (David et al., 2025). The digital economy encompasses a broad range of economic activities enabled by digital technologies

which collectively impact productivity, innovation, and even institutional structures (Shi and Wei, 2025). Both advanced and emerging economies are investing in digital ecosystems to become new engines of economic growth. In Russia, digital transformation has been a strategic priority of national development since the late 2010s (Romanyuk et al., 2021).

For instance, government initiatives like the "Digital Economy of the Russian Federation" launched in 2017 was aimed to significantly expand the country's digital sector (Bannykh and Kostina, 2022). It was estimated that Russia could potentially triple its digital economy size by 2025, from 3.2 trillion rubles to 9.6, reaching about 8–10% GDP (Novikov and Sazonov, 2020). This would put Russia on par with other developed economies in terms of the share of the digital sector. Achieving this goal, however, depends greatly on the quality of institutions governing the digital ecosystem. Strong institutional frameworks are needed to support investments, ensure trust in digital transactions, and foster innovation. International comparisons shows the importance of institutional context. For example, China's digital economy has grown explosively in recent years driven by market demand, technological innovation, and proactive government support. In 2023, the value added of China's core digital economy industries reached approximately 12.76 trillion yuan (about 9.9% of GDP), reflecting how conducive policies and infrastructure investment can foster digital growth (Tu et al., 2023). China's government has actively shaped institutions to encourage digital payments, e-commerce, and platform ecosystems, creating an environment where 1/3 of the world's tech "unicorns" (billion-dollar startups) are Chinese (Han et al., 2024; He, 2024). In contrast, Russia's digital economy ecosystem faces institutional challenges such as regulatory uncertainty, bureaucratic hurdles, and uneven regional development that may slow digital adoption (Larionova and Shelepov, 2021).

This paper states that institutional factors are crucial determinants for digital ecosystems. We investigate the factors influencing digital economy ecosystem development in Russia, drawing on insights from institutional economics, relying upon the works of institutional economists, such as Douglass North, Elinor Ostrom, and Oliver Williamson. Each of these scholars illuminates different aspects of the way institutions shape economic outcomes. North's (1991) perspective highlights how formal and informal rules provide structure and reduce uncertainty in exchanges. Ostrom's (1990) work illustrates how communities can self-organize and create effective rules for managing shared resources without always requiring top-down enforcement, a principle that can extend to digital communities and networks. Williamson (1985; 2010) explains how institutions and governance structures (markets, hierarchies, networks) emerge to minimize transaction costs in economic activity. By combining these approaches, one can better understand how regulatory quality, governance mechanisms, and institutional norms affect firms' willingness to invest in digital infrastructure, adopt new technologies, and innovate. Despite a growing body of literature on the digital economy and on institutions separately, there is a need for a thorough analysis of how institutional quality specifically facilitates or hinders the development of digital economy ecosystems.

Within the context of small businesses, recent research on post-pandemic Russian SMEs found that external institutional environments significantly impact the stability and sustainability of firms, and that information and communication technologies (ICT) play a pivotal role in this process. However, empirical evidence directly linking institutional quality to digital economy development remains limited for Russia.

This paper addresses that gap by providing an empirical analysis of Russian SMEs, and by comparing relevant institutional dimensions with the experience of China. The main research question is the following: *How do institutional factors affect digital infrastructure investment, digital technology adoption, and innovation capacity among firms?*

The rest of this paper is organized as follows. Next section provides a literature review that outlines relevant concepts from institutional economics and combines findings on institutional factors in digital economy development, with a focus on Russia and China. Then we describe the methodology of the empirical study, including the data collection and econometric model. The main results of the analysis follow, including regression results linking institutional quality to digital adoption among small and medium-sized enterprises (SMEs) in Russia. We then present the results of our analysis, including regression models linking institutional quality with digital adoption. Finally, we offer recommendations for strengthening institutional foundations in digital ecosystems, as well as suggestions for future research directions.

Literature review

Institutional economics: Theoretical frameworks

Institutional economics provides a foundation for understanding how "the rules of the game" in a society shape economic performance (North, 1990). Institutions are commonly defined as the humanly devised constraints that structure political, economic, and social interactions (Hodgson, 2006; Wallis, 2022; Volchik et al., 2022). They include formal rules (laws, regulations, property rights) and informal constraints (norms, customs, conventions), along with their enforcement mechanisms (Cole, 2017; Hodgson, 2025).

By creating order and reducing uncertainty in exchange, institutions lower transaction costs and make productive economic activity feasible (North, Wallis, 1994; Frolov, 2021; Volchik et al., 2023). North (1990; 1994) argued that effective institutions (e.g., secure property rights and rule of law) are a key reason why some nations achieve economic development while others fall behind. In the context of the digital economy, this framework suggests that clear and stable rules (such as digital commerce laws, intellectual property protection, and reliable contract enforcement) encourage businesses to invest in digital technologies by ensuring predictability and trust in the digital marketplace. Conversely, weak institutions raise the risks and costs associated with digital innovation, hampering the growth of digital ecosystems.

A broad consensus in development economics holds that inclusive, high-quality institutions foster innovation and growth (Acemoglu, Robinson, 2012). Ostrom's institutional theory complements North's concept by illustrating how communities and decentralized actors can craft their own rules to manage resources and solve collective action problems. Ostrom's (1990) research into common-pool resources demonstrated that, contrary to the "tragedy of the commons" idea, many communities are able to develop workable institutional arrangements – often a combination of formal and informal regulations – for resource governance without the need for top-down control. Participants are often capable of building trust and reciprocity, enforcing rules collectively to prevent overuse or free-riding. This bottom-up perspective (Ostrom, 1990) highlights the role of social capital and networks in institutional effectiveness.

In a digital economy context, one can draw parallels to phenomena such as open-source software communities, industry self-regulation in tech sectors, or platform ecosystems governed by both platform rules and user norms. Effective digital ecosystems may require not only government policies but also polycentric governance – a collaboration of public institutions, private stakeholders, and user communities in setting standards (for example, technical standards, data sharing protocols, cybersecurity practices). Ostrom's emphasis on diverse actors and levels of institutions is particularly relevant in complex digital domains that evolve faster than formal regulation, requiring adaptive governance. For instance, Ostrom's principles would suggest that a network of SMEs could form associations or shared digital platforms to collectively negotiate better digital infrastructure or training, thereby creating an institutional solution from the ground up. Williamson's framework of institutions adds a focus on transaction costs and governance structures. Williamson (1985; 1999) delineated different levels of institutions – from informal social norms to formal legal rules to the governance arrangements of firms and contracts – that together influence economic outcomes. A core idea is that economic agents organize transactions in such a way as to minimize transaction costs. Sometimes markets (arms-length transactions) are efficient; other times, hierarchical organization (within a firm) is more efficient, especially when asset specificity and uncertainty are high (Keum, 2025). New Institutional Economics (NIE), as articulated by Williamson and others, thus examines how institutions enable coordination, whether through market prices, corporate structures, or hybrid forms like networks and long-term contracts (Menard, 2022; Joskow, 2022). This approach is important for the digital economy: digital technologies can dramatically lower transaction costs (for example, when matching buyers and sellers via online platforms), which in turn can lead to new institutional forms (such as gig economy platforms or e-marketplaces). At the same time, digital transactions require governance, e.g., platforms enforce rules, and governments regulate data and competition to ensure smooth functioning. Williamson's perspective can be used to focus on how institutional quality affects the comparative costs of transacting digitally. For instance, if institutional quality is high (reliable contract enforcement, low corruption), more business transactions can be conducted via market mechanisms (through digital platforms) with confidence. If institutional quality is low, firms might vertically integrate or rely on closed networks

to avoid the uncertainties of the open market, thus stifling the open ecosystem. Williamson also noted that institutions evolve and firms adapt governance structures as conditions change (Dow, 2022). In the digital era, one might observe a reallocation of activities between markets and firms: highly digitalized markets (such as e-commerce) flourish under supportive institutions. In their absence, firms might internalize functions or avoid certain digital innovations (Yuan et al., 2025).

In summary, institutional factors (including formal laws and regulations, informal norms and trust, and the governance arrangements for transactions) collectively shape the trajectory of economic ecosystems. Effective institutions tend to lower uncertainty and transaction costs, facilitate collective action, and promote investment and innovation. Poor or misaligned institutions, on the other hand, can impede new economic developments by failing to provide the necessary support or coordination. As one now turns to the specific context of digital economy ecosystems, these theories provide a lens to hypothesize which institutional factors are most salient: its is expected that clear rules (e.g., digital regulations), strong enforcement (rule of law), low corruption, high trust, and adaptive governance mechanisms would all be positive factors in digital ecosystem development. One should also remain open to the idea that institutional innovations or informal arrangements might emerge to cope with institutional deficiencies.

Institutional factors in digital economy development

Nowadays, a growing literature examines how institutional quality intersects with digital development across countries and regions. Several studies indicate that stronger institutions (measured by indices of governance, regulatory quality, or absence of corruption) are associated with better outcomes in digital infrastructure expansion and technology adoption (Ionescu et al., 2022; Cirillo et al., 2023; Usman et al., 2024). For instance, analyses of the digital economy in African countries have found that institutional stability and good governance practices are critical "enablers" for digital growth alongside infrastructure and human capital (Afolabi, 2023; Rakotondrazaka, Velomasy, 2024).

When institutions provide a stable environment, investors (public or private) are more likely to pour resources into digital infrastructure, and businesses are more willing to adopt digital tools. Empirical evidence from emerging economies suggests that a virtuous cycle can arise: digital development (e.g., expanding internet access) fosters economic gains, but to sustain those gains and ensure inclusive benefits, improvements in institutional frameworks (such as e-government and regulatory reforms) are needed (Andrès et al., 2016; Kalinin et al., 2024). Strengthening institutional quality, for example, through legal reforms and anti-corruption measures, has been recommended as a policy priority to enhance the impact of digitalization on inclusive growth (Santiso, 2022; Ha et al., 2024).

In general, the research literature notes that institutional factors particularly relevant to digital ecosystems include: regulatory frameworks for digital business, property rights and intellectual property (IP) protection, quality of digital governance and bureaucracy, financial institutions and access to finance, and education and skills institutions (Kira et al., 2021; Man et al., 2025). A clear and supportive regulatory framework (laws governing electronic transactions, data protection and privacy, cybersecurity, fintech operations, digital platforms) is essential for digital enterprises. In countries where such regulations are well-defined and fairly enforced, companies have greater legal certainty to innovate. In China, for example, government policies explicitly promoting e-commerce and mobile payments in the 2010s helped create an environment where Alibaba, Tencent, and myriad smaller tech firms could flourish (Zhang et al., 2025). Over time, Chinese regulators have added rules (for data security, antimonopoly, etc.), but the consistent message of state support for digital industries has remained, which is an important institutional signal to market participants (Deng et al., 2021).

In Russia, the regulatory environment for the digital economy has evolved more slowly. Although laws on digital signatures, personal data, and a national digital economy program exist, stakeholders often cite bureaucratic red tape and inconsistent enforcement as barriers (Karieva et al., 2021). For example, starting a digital business or implementing new tech might require navigating complex licensing or certification processes, which can discourage especially smaller firms. Effective institutional support would mean streamlining these processes and updating laws to accommodate new digital business models. Another

critical institutional factor is trust (both interpersonal trust and institutional trust – trust in authorities, legal system, etc.). Digital transactions, which often occur remotely and electronically, require a high degree of trust. If businesses and consumers trust that online transactions are secure and that there are legal recourses against fraud, they would be more likely to engage in the digital economy (Sanina et al., 2023). Institutional quality enhances this trust by ensuring that there are functioning mechanisms to resolve disputes or that digital platforms are subject to appropriate oversight. Countries with higher trust in institutions often see faster uptake of digital services, as seen in some Northern European countries with strong e-government. In Russia, trust in digital systems has been growing, but concerns about cyber fraud or misuse of personal data can be higher in environments where rule of law is perceived as weaker (Timofeyev, Dremova, 2022). A related concept is institutional voids – gaps where formal institutions are absent or ineffective. In such voids, alternative arrangements often emerge. For instance, Russian tech firms might rely on informal agreements or personal networks to do business where formal contracts are viewed as unreliable. While such coping mechanisms (informal institutions) can keep things moving, they may limit scaling up and broader ecosystem coordination (Villo, Turkina, 2023).

Prior research in Russia and similar economies highlights both institutional barriers and the potential for institutional improvements to drive digital progress. Korneeva and Strielkowski (2023) examined post-pandemic Russian SMEs and found that the external environment, including institutional support, significantly affected SMEs' stability. Their results indicated that ICT adoption and innovation were important for SME resilience, but these were in turn influenced by factors like government support and networking. They also found that SMEs with access to larger markets (beyond their local region) invested more in digitalization, leading to better development outcomes. This suggests that when institutions enable SMEs to integrate into wider markets (national or international) through trade facilitation or digital infrastructure that connects rural areas which incentivizes those firms to adopt digital technologies to compete and grow. Another study by Gamidullaeva et al. (2020) underscored the importance of assessing the institutional environment to boost SMEs' contributions to regional growth, implying that regional disparities in institutional quality within Russia can translate into uneven digital development. Indeed, Russia exhibits significant regional variation in both digital readiness and institutional indicators. Major cities have relatively advanced digital infrastructures, more developed institutions, and host most of the country's digital startups, whereas some peripheral regions lag behind in both governance and digitalization.

Institutional perspective also brings up the evolutionary aspect: institutions and technology co-evolve. As digital ecosystems develop, they may put pressure on existing institutions to reform. For instance, the rise of digital platforms in Russia (such as Yandex or Ozon) has prompted new laws on data storage and competition policy. Sometimes, institutional change lags behind technological change, creating a temporary institutional vacuum or misalignment. Ostrom's idea of polycentric governance could be relevant in such scenarios, where interim solutions might come from industry self-regulation or public-private partnerships until formal institutions catch up. Additionally, large firms themselves can become institutional actors influencing ecosystem development. Companies like Sberbank or Rostelecom are spearheading digital initiatives (like a national e-commerce platform or cloud services) in partnership with the state, potentially filling gaps in the ecosystem. However, the effectiveness of these efforts would depend on broader institutional qualities such as transparency, competition policy (to avoid monopolies stifling innovation), and collaboration between government, business, and academia (akin to an innovation system).

In summary, the literature indicates that institutional factors play a decisive role in shaping digital ecosystems. A high-quality institutional environment can be a catalyst for digital infrastructure investment, widespread technology adoption by firms and consumers, and robust innovation activity. Poor institutional environments can conversely act as a brake on these processes. This study focuses on three key dimensions of digital ecosystem development at the firm level: digital infrastructure investment, digital adoption, and innovation capacity. It appears that better institutional quality (e.g., as perceived by firms in terms of regulatory effectiveness, government support, rule enforcement, etc.) would be associated with higher levels of investment in digital infrastructure, greater adoption of digital tools and practices, and stronger innovation performance among SMEs.

Materials and methods

In order to investigate the impact of institutional factors on digital economy ecosystem development, an empirical study focusing on Russian small and medium-sized enterprises (SMEs) was designed. SMEs were chosen as the unit of analysis because they are crucial drivers of innovation and adoption in the economy, yet often vulnerable to institutional shortcomings.

The data were collected through an online questionnaire survey administered to SMEs across seven different regions of Russia between January and March 2025. The regions were selected to provide a diverse sample, including both economically advanced areas (such as Moscow, the Moscow Region and Saint Petersburg) and less-developed regions (including at least one region in the North Caucasus and one in Siberia). This diversity allows us to capture variation in both digital adoption and institutional environments within the country. In total, 250 enterprises participated in the survey, providing a cross-sectional sample of the Russian SME sector as it stands in early 2025. Each participating firm's questionnaire was completed by a top manager or owner, ensuring that the responses reflected informed views of the firm's strategy and environment. The survey covered general firm characteristics and several specific indices constructed to measure digital adoption, innovation, and perceived institutional quality. In addition, the information was gathered on the firm's investments in digital infrastructure. The sample includes firms from a range of sectors – including retail, manufacturing, services, and tech – and of varying ages and sizes (within the SME category, which we define as firms with 10 to 250 employees, following common Russian definitions). It was also ensured that there have been a mix of urban and rural-based businesses. For the purposes of this research, the following variables and measures have been adopted:

- *Digital Adoption Index* (dependent variable): The primary outcome of interest is the extent of digital adoption by the firm. "Digital adoption" was operationalized through a composite index (*DAI*) based on several survey items. These items included: the percentage of business processes the firm has digitalized (such as using software for operations, digital marketing, e-commerce sales), whether the firm uses advanced digital tools (data analytics, cloud services, IoT devices), and the proportion of employees with access to a computer or the internet at work. Responses were normalized and aggregated into an index ranging from 0 to 10, where 10 indicates a fully digitally-integrated business and 0 indicates minimal digital tool usage. The index captures both breadth and depth of digital technology use in the enterprise.
- *Institutional Quality*: The key independent variable is an Institutional Quality Index (Instqual). The perceived institutional quality was measured through survey questions asking managers to rate aspects of their operating environment on a Likert scale. Specifically, components of this index included: satisfaction with local government support for business, perceived effectiveness and fairness of regulations (e.g., ease of obtaining permits, clarity of digital commerce laws), extent of bureaucratic obstacles or corruption encountered, and trust in the legal system to enforce contracts. These responses were combined into an index (0 to 10 scale) representing the firm's overall perception of the institutional environment quality relevant to their business. While subjective, such perceptions strongly influence business decisions; they effectively proxy the on-the-ground reality of institutional quality as experienced by SMEs (which may differ across regions and industries). A higher Instqual score indicates that the firm perceives institutions to be supportive, efficient, and reliable.
- *Digital Infrastructure Investment*: This is measured as the amount the firm invested in digital technologies and infrastructure over the past year, expressed as a percentage of its total capital expenditures. Firms were asked to include spending on hardware (computers, servers, networking equipment), software (licenses, cloud subscriptions), IT services, and training for digital skills. Since absolute amounts would vary greatly by firm size, a percentage or intensity measure allows comparability. This measure was standartized, and for ease of interpretation in the regression, an index scaled 0–10 (with 10 corresponding to the highest investment percentage among respondents, and 0 to the lowest) is used. This variable captures the firm's commitment to building digital capacity. It is both considered as an outcome influenced by institutions (better institutions might encourage more investment) and a direct input to digital adoption (more investment likely leads to greater adoption). In the model in this paper, however, DII was included as a control / predictor for digital adoption, treating it as an exogenous firm decision for the year.

- *Innovation Index*: To assess the firm's innovation capacity, an Innovation Index (*Innovindex*) was included. This index is based on indicators of innovation outcomes and activities: for example, whether the firm introduced new products or services in the last two years, the number of patents or trademarks the firm has obtained, or whether the firm has a dedicated R&D or innovation budget. These were scored and summed into an index (0–10). A higher Innovindex means the firm is actively engaging in innovation and likely has greater capacity to absorb new technologies (since innovation often correlates with openness to new ideas, skilled personnel, etc.). It is expected that more innovative firms may also be early adopters of digital technologies, and conversely that digital tools can spur innovation, but in the model Innovindex was primarily used as an explanatory variable for digital adoption. It also implicitly controls for certain unobserved characteristics like management quality or tech-savviness that might drive both innovation and digital uptake.
- *Enterprise Size* (control variable): Enterprise Size (Enterprsize) was included as a control variable, measured by the number of employees (log-transformed in the analysis to reduce skewness). Firm size can affect digital adoption – larger SMEs might have more resources to implement digital systems, but smaller ones might be more agile in adopting certain technologies (the net effect is an empirical question). Including size ensures that the effects of institutional quality are not conflated with simply being a larger firm (since larger firms might have better capacity to deal with bureaucracy or to invest in tech regardless).

Econometric model

The relationship between institutional factors and digital ecosystem development were estimated using the regression models with the firm's Digital Adoption Index (DAI) as the dependent variable. The core specification can be represented as follows:

$$DAI_i = \beta_0 + \beta_1 Instqual + \beta_2 DII + \beta_3 Innovindex + \beta_4 Enterprsize + \varepsilon_i, \quad (1)$$

where: *DAI* – Digital adoption index; *Instqual* – Institutional quality index; *DII* – Digital infrastructure investment; *Innovindex* – Innovation index; *Enterprsize* – Enteprise size.

In equation (1), *i* indexes the firm, β_1 captures the effect of institutional quality on digital adoption, controlling for the firm's own investments in digital infrastructure, its innovation level, and size (it is expected to be positive, indicating that higher perceived institutional quality is associated with greater digital adoption by the firm). A positive β_1 would align with our hypothesis that good institutions encourage firms to embrace digital technologies (by lowering risk and cost). *DII* and *Innovindex* were included as controls that also have their own interest. β_2 on *DII* should capture how much simply investing in digital tools translates to actual adoption outcomes (it was anticipated that $\beta_2 > 0$, as spending on digital infrastructure likely facilitates usage). The inclusion of Instqual alongside DII is important: if institutional quality still shows a strong effect controlling for *DII*, it suggests that institutions affect adoption not just through prompting more investment, but through other channels like influencing willingness or ability to use the technology effectively (for example, good institutions might provide complementary supports like training programs or reliable power / internet infrastructure). β_3 on *Innovindex* is expected to be positive as well – innovative firms are usually more inclined to try new digital solutions (this can be seen as a proxy for a firm's absorptive capacity). Finally, β_4 could be positive (larger firms have more capacity to adopt tech) or even negative (smaller firms might be digitally native or have less legacy issues), but prior studies often find a positive but diminishing effect of size on tech adoption.

In addition to this baseline Model 1, a second model (Model 2) has been estimated in order to check robustness. Model 2 includes regional fixed effects – essentially dummy variables for six of the seven regions (with one as reference) – to control for unobserved regional factors such as local policies, infrastructure, or cultural differences. Including these absorbs any broad institutional differences at the regional level, and tests if within-region variation in perceived institutional quality

still matters. Model 2 therefore challenges the hypothesis in a stricter way: if β_1 remains significant within regions, it strengthens our confidence that firm-specific perception/experience of institutional quality drives outcomes, not just the general region's development level. It was also considered using an interaction term between Instqual and *DII* to see if institutional quality amplifies the returns to digital investment (i.e., whether investing in tech yields more adoption when institutions are better), but given sample size models were kept as such. Heteroskedasticity-robust standard errors are used, as the variance of adoption may differ by size or sector. The multicollinearity was checked among independent variables; the correlation between *Instqual* and *Innovindex* was moderate (~0.4), and variance inflation factors were in acceptable range, so multicollinearity is not a serious concern.

Overall, this empirical framework allows to isolate the effect of institutional quality on digital adoption at the firm level, while accounting for key firm capabilities (investment and innovation) and size. While the cross-sectional nature of the data limits causal interpretation, the results can be interpreted in light of theory and plausible directionalities. For example, it is unlikely that a firm's current digital adoption would significantly alter their broad perception of institutional quality (perceptions are more likely shaped by longer-term experiences with institutions), so endogeneity from reverse causality is not a major issue for *Instqual*. However, there could be omitted variables (like management quality) that influence both perceived institutions and adoption (innovation is used as a partial proxy for such factors).

Main results

Table 1 presents the regression results for the two models described above.

Table 1

Results of two models

Variables	Model 1		Model 2	
	Coefficient	SE	Coefficient	SE
Institutional quality	0.42***	(0.11)	0.45***	(0.10)
DII	0.36***	(0.09)	0.38***	(0.08)
Innovindex	0.29**	(0.14)	0.31**	(0.13)
Enterprsize	0.15*	(0.08)	0.17*	(0.09)
Constant	2.10***	(0.54)	2.05***	(0.52)
R-squared	0.72		0.74	
F-statistic	78.35***		85.60***	
N	250			

Note: standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.10.
Source: own results.

Model 1 is the baseline OLS, and Model 2 includes regional fixed effects. The coefficients, standard errors, and significance levels are reported. The results strongly support our hypotheses. Institutional quality has a positive and highly significant effect on the Digital Adoption Index in both models. In Model 1, the coefficient 0.42 (significant at the 1% level) implies that a one-unit increase in the perceived institutional quality index (on the 0–10 scale) is associated with a 0.42 increase in the digital adoption index (also 0–10 scale), on average. This is a substantial effect size, second only to *DII* in magnitude among the predictors. In Model 2, with regional effects, the coefficient is very similar (0.45***), suggesting that even within the same region, firms that rate their institutional environment higher tend to have significantly greater digital adoption. This consistency across models underlines the robustness of the institutional quality effect. One can interpret this finding as evidence that better institutional environments (characterized by transparent rules, effective governance, and low bureaucratic friction) enable SMEs to adopt digital technologies more readily. Such environments likely reduce the cost and uncertainty of implementing new digital systems and may provide complementary support (like e-government services or subsidies) that encourage

adoption. Digital Infrastructure Investment (*DII*) also shows a positive, significant impact on digital adoption. Its coefficient around 0.36–0.38 ($p < 0.01$) indicates that firms devoting more resources to digital tech indeed achieve higher digital integration. This is intuitive and validates that our measure of *DII* is meaningful. The fact that institutional quality remains significant even with *DII* in the model is noteworthy: it suggests that institutional quality is not just about enabling spending on tech, but might affect how effectively that spending translates into usage, or it influences other adoption factors like employee willingness, partner networks, etc. One could say institutions provide the fertile ground in which digital investments bear fruit. The Innovation Index has a coefficient of about 0.30, significant at the 5% level. Innovative firms appear to have higher digital adoption, which aligns with the idea that innovation and digitalization go hand in hand. This also provides some control for management quality or forward-looking behavior – innovative firms might be better managed or have strategic vision, which includes going digital. Even accounting for that, institutional quality's distinct effect is clear. Enterprise size has a smaller effect (0.15–0.17, marginally significant at the 10% level). The positive sign suggests larger SMEs (closer to the upper end of our SME range) have slightly greater adoption, possibly due to economies of scale in deploying IT or having more specialized staff. However, the effect is not very large, implying that even small firms can achieve high digital adoption if other conditions are right. The models have a high R-squared (0.72–0.74), meaning about 72–74% of the variance in digital adoption across firms is explained by these factors. This is quite a strong explanatory power for cross-sectional firm data, indicating that the included variables capture many key determinants of digital uptake. The F-statistics are large and significant, confirming the model's overall significance. In Model 2, slight increase in R-squared suggests some regional differences accounted for, but as noted, the core coefficients did not change much, which is reassuring for generalizability. To ensure the findings were not driven by a particular region or sector, the baseline model is run on sub-samples (e.g., only firms in two largest regions, only service-sector firms, etc.) although not reported in detail here, those subsample regressions yielded qualitatively similar patterns: institutional quality remained a positive significant predictor in most cases, though with expected variability if sample size dropped. No single region dominated the results; in fact, the relationship between institutional quality and digital adoption was present even in the more institutionally challenged regions, albeit those regions had overall lower averages of both. This implies the finding is not solely an artifact of firms in central regions both rating institutions high and adopting more. The regression results provide quantitative evidence that supports the central premise of the study: institutional factors matter greatly for the development of digital economy ecosystems at the firm level.

Conclusions and implications

Overall, our results and empirical analysis confirm that firms perceiving higher institutional quality show significantly greater digital adoption, even when accounting for their own investment and innovation capacities. In other words, clear, transparent, and stable institutions correlate with more intensive use of digital technologies in business operations. These findings carry important implications for policymakers and stakeholders aiming to foster robust digital economy ecosystems. Firstly, improving the institutional environment should be seen as a key lever for digital development, on par with investing in physical digital infrastructure. Policy measures such as streamlining regulatory procedures, ensuring consistency in digital economy regulations, fighting corruption, and strengthening rule of law are not just governance reforms in isolation but are also digital economy policies. For the Russian Federation, efforts to reduce bureaucratic inefficiencies and increase government effectiveness (for example, through expanded e-government services, one-stop business portals, transparent procurement systems) can directly contribute to creating a more conducive atmosphere for SMEs to invest in and adopt digital tools. Our results indicate that such institutional improvements could lead to measurable increases in digital adoption, which in turn can enhance productivity and innovation across the economy. Secondly, the positive link between institutional quality and innovation suggests that institutional improvements and innovation policy should go hand-in-hand. Governments often promote innovation through grants or incubators; our study implies these would

have greater impact if complemented by a trustworthy institutional framework. For instance, protecting intellectual property rights (an institutional factor) encourages innovation by assuring inventors that their digital innovations (software, content, etc.) would not be easily stolen or infringed. Likewise, simplifying the process to start a business or access finance (institutional processes) can lead to more startups exploring digital business models. Policymakers should therefore view institutional quality as part of the innovation ecosystem. A practical recommendation might be establishing public-private advisory councils in the tech sector to continually identify regulatory pain points and address them (an approach that China used in different forms). This would embody Ostrom's idea of involving users in rule-making – e.g., involve tech entrepreneurs in co-creating regulations that affect them, to ensure they are workable and encourage compliance. Thirdly, targeted investments in digital infrastructure remain crucial, especially in regions or communities that the market might underserve. Thus, a policy implication is to continue and expand programs that invest in broadband expansion, 5G networks, digital public services, and SME digitalization support (such as grants or tax incentives for purchasing software / hardware). Institutional quality and infrastructure investment can amplify each other – for example, a region with good governance will likely implement infrastructure projects more efficiently and ensure maintenance, etc., thus yielding better outcomes. Improving local governance capacity could help maximize the impact of infrastructure spending. The finding that enterprise size is only a minor factor implies that policy should be inclusive of smaller firms. Even micro and small enterprises can go digital and innovate if given the right environment and support. Policymakers should ensure that digital economy policies do not just favor large corporations by allowing small businesses to collectively benefit from digital tools. In Russia, there are already initiatives like "Marketplace for Russian SMEs" that bring user-friendly regulations and minimize red tape. From a comparative standpoint, Russia can learn from China's experience, but it should tailor this to the institutional context of its own country. Russia's Digital Economy program is a solid start in that direction; its effective implementation will require aligning multiple institutional actors (federal ministries, regional authorities, private sector, academia). Policy coordination mechanisms (e.g., central task force or inter-ministerial committee on digital economy) could help maintain momentum and address cross-cutting issues (e.g., data regulation, which might involve economic ministry, communications ministry, security agencies, etc.). At the same time, fostering a degree of bottom-up innovation is important: encouraging regional experimentation, like special digital economic zones or pilot projects, can allow successful models to emerge and then scale nationally – similar to how some of China's digital innovations were piloted in cities before spreading. This approach resonates with Williamson's notion that institutional governance can be multi-layered; local innovations in governance can later be integrated into higher-level frameworks.

The study's outcomes also suggest metrics for policymakers to monitor: governments should track business sentiment regarding institutional factors (ease of doing digital business, trust in digital transactions). These can serve as early indicators of whether policy and institutional reforms are effective from the end-user perspective.

All in all, enhancing institutional quality appears to be a high-impact strategy for developing digital economy ecosystems. For Russia, this means that increasing the digital economy's size is as much a matter of institutional reform as it is of technological advancement. By focusing on building trustworthy, efficient, and adaptive institutions (from the legal system to regulatory agencies to local governance) the Russian Federation can create an environment where SMEs and larger firms are empowered to invest in digital infrastructure, adopt cutting-edge technologies, and innovate, thereby driving sustainable economic development.

While this paper provides valuable insights, it also opens pathways for future research. Longitudinal studies would be particularly useful – e.g., following this same set of SMEs over time to see how changes in their institutional environment (such as new policies or shifts in governance) affect their digital trajectory. A longitudinal approach could help establish causality more firmly and capture dynamic interactions. Comparative research is another fruitful path: comparing Russia's institutional effects on digitalization with those in other countries (possibly through joint surveys or international datasets) could highlight unique features or common patterns. For instance, a comparative

study of the Russian Federation and China could formally analyze differences in institutional dimensions. Additionally, qualitative research could complement the quantitative findings – interviews with SME owners could uncover specific institutional hurdles they face (such as a particular law or the lack of a certain regulation) and how they cope, providing specific details.

In summary, by combining institutional theory with contemporary digital economy analysis, this paper shows that "soft" factors like governance and norms are as critical as "hard" technologies in building the economic systems of the future. Strengthening institutional quality is not a simple task – it often requires political will and cultural change – but the evidence suggests it is a highly rewarding endeavor: better institutions create conditions for more innovation, faster adoption of beneficial technologies, and ultimately more sustainable and inclusive economic growth. For stakeholders ranging from government officials to entrepreneurs, the message is clear: collaborative efforts to improve institutions would pay off in the digital realm. As the digital economy becomes ever more integral to prosperity, ensuring that our institutional "operating system" is supportive and up-to-date may well be one of the most important tasks for economists and policymakers alike in the coming decades.

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