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Does the regional environment matter in ERP system adoption? Evidence from Russia

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Abstract

Purpose – This paper explores the effect the regional technological environment has on technology-driven performance, measured by enterprise resource planning (ERP).

Design/methodology/approach – This study specifies a productivity-based production function driven by ERP system adoption. Employing a quasi-experimental research design, the author disentangles two effects – the average effect of ERP adoption and the moderation effect of the regional technological environment. The novelty of this study is that it merges publicly available information retrieved via text-mining tools and official financial reports published by companies.

Findings – The total effect of technology adoption on productivity varies from almost 3%–9% in different technological environments. Moreover, this study's results revealed that the regional technological environment could enhance the effect of adopting different ERP systems.

Originality/value – While some papers investigate the relationship between ERP adoption and firm performance regarding the environmental context of a firm, the effect of the regional technological environment on the relationship between technology adoption and firm performance is understudied. Thus, this research tries to contribute to a deeper understanding of the regional context's impact on technology-driven performance. The authors used automated content analysis to collect data on technology adoption; by doing so, this study contributes to the growing body of research utilising the text-mining approach to extract data stored in Internet-based information sources.

Keywords Technology adoption, ERP adoption, Firm productivity, Regional environment, Regional infrastructure

Paper type Research paper

1. Introduction

Technological adoption and its impact on firm performance indicators is a topic that receives substantial attention vfrom researchers and practitioners. The interest is caused by the constant development and active dissemination of information technologies (IT) and digital technologies. Studies, however, report mixed results with both positive and negative effects of technology adoption on firm performance; the ambiguity of the results supports the research interest in the field (Sabherwal and Jeyaraj, 2015; Chen and Srinivasan, 2020). Moreover, technology adoption is a long-term process and a long-term investment: technology, to be implemented in a firm successfully, requires significant financial and managerial resources and demands changes in the internal structure of a company. Therefore, the results of the studies investigating the effect of technology adoption on firm performance are of high practical value.

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The enterprise software (ES) system is one of the complex technologies extensively discussed in the literature (Beheshti and Beheshti, 2010; Gupta *et al.*, 2019). While ES adoption is a complicated task usually associated with high financial costs and considerable changes in the business processes, it can lead to better performance. For example, ES adoption can cause an increase in productivity by improving workflow efficiency, labour efficiency, and resource utilisation efficiency (Bresnahan *et al.*, 2002; Dalenogare *et al.*, 2018). However, the results of technology adoption cannot be noticed immediately.

Recent research has emphasised the role of the environmental context in technology adoption (Luo and Bu, 2016; Xu *et al.*, 2017; Roztocki *et al.*, 2020; Lutfi *et al.*, 2022). This is because of the increasing environmental pressures companies face in this new age of digitalisation (Kung *et al.*, 2015) and understanding the fact that misalignment between a company and its environment may worsen company efficiency and performance (Chen and Liang, 2011; Wu *et al.*, 2021). Furthermore, the external environment includes a range of dimensions, among which the technological ones play an important role. The technological environment, which can be presented by such variables as, for example, the availability of enabling infrastructure or its cost, could act as critical antecedents of technology adoption (Oliveira and Martins, 2011; Awa *et al.*, 2017; Lutfi *et al.*, 2022). Recent studies, however, provide more empirical evidence of the moderating role of the external technological context regarding technology adoption, including ES adoption and firm performance relationship (Karim *et al.*, 2022).

Despite increasing interest in the relationship between ES adoption and firm performance in its environmental context (Xu *et al.*, 2017; Lutfi *et al.*, 2022), the number of studies taking into consideration the technological environment is rather limited (Kohli and Melville, 2019; Lutfi *et al.*, 2022). One of the reasons is that studies usually employ the technology–organisation–environment (TOE) framework, where technological and organisational factors represent the internal environment, and the external environment may include a vast number of factors. The TOE framework is backed by a considerable amount of theoretical and empirical data; however, it is still restricted, and the technological environment is considered only from the internal side.

Another limitation that we see in the studies investigating the relationship between ES adoption and firm performance in the technological context is that most empirical papers employ a cross-sectional research design, and, what is also essential, use self-reported data (Lutfi, 2020). However, as the impact of technology adoption cannot be noticed immediately (Lam, 2005), longitudinal data is necessary to capture the effects of technology adoption on business outcomes (Karim *et al.*, 2022). Furthermore, self-reported data might be limited because of their being nonrepresentational, having a nonresponse bias, and being prone to self-selection problems (Forman, 2005).

Thus, to close this gap, this paper seeks to explore the effect the regional technological environment has on technology-driven performance. Framing our research on the literature on the behavioural theory of the firm (BTF) and the resource-based view (RBV), we investigate the extent to which the regional technological environment moderates the relationship between ES adoption, namely the adoption of an Enterprise Resource Planning (ERP) system, and firm labour productivity. With regard to the regional technological environment, we measure it by using three indicators: firm access to high-speed Internet, ICT expenditures, and the use of ERP systems in the region. In order to answer the research question of the study, we employs new data from around 900 of the largest companies affiliated with different industries and located in most Russian regions, conducted over almost 10 years, starting from 2009.

The paper is organised as follows. First, we provide the theoretical background of our research and develop the hypothesis. Then, we describe the research approach, data, and findings. In the discussion section, we consider the contributions, limitations, and avenues for future research.

2. Theory and hypotheses development

2.1 The behavioural theory of the firm and resource-based view

Theoretical lenses of BTF and RBV were adopted to investigate to what extent the regional technological environment moderates the relationship between ES adoption and firm labour productivity. BTF enables to address how external context shapes or pressures the strategic decision-making behaviour, while RBV outlines the role the strategic firms' resources play in the firm's ability to gain a competitive advantage and better outcomes (Majumdar and Venkataraman, 1993; Yang and Meyer, 2015). One more reason to combine these theoretical approaches is that BTF enriches RBV by putting additional emphasis on the dynamic aspect that implies that a firm should constantly learn how to manage its resources effectively, taking into account the external environment, competitive behaviour of rivals, and so on. Thus, this study uses BTF to consider the external context under which the adoption decision is made and RBV view to explain the relationship between such a strategic resource as an enterprise system and firm productivity.

As articulated by Cyert and March (1963), BTF brings the idea of the constant development of the firm and its decision-making process together. The idea of firm development is connected to the mechanism of continuous changes in the firm. The changes in the firm's behaviour (which, in the logic of BTF, means changes in the firm's routines) either come from inside the firm or happen in the firm because of outside factors. In the first case, the firm refines its routines on the basis of its accumulated experience signalling the inconsistency of routines with the current outcomes of the company; in the second case, changes could be brought about by pressure from the external environment. Regardless of the trigger for a change, a firm is learning how to execute its routines efficiently; over time, it leads to the buildup of organisational slack – a "pool of resources in an organisation that is in excess of the minimum necessary to produce a given level of organisational output" (Nohria and Gulati, 1996, p. 1, 246; van Mossel *et al.*, 2018). When the level of slack is relatively high, a firm initiates the decision-making process on how to exploit the available resource again efficiently. The decision-making process also starts when a firm realises it performs worse due to its misalignment with the external environment. Such a situation stimulates a firm to search for new decisions, solutions, or practices that are all outside the present scope of the firm's ordinary routines (Argote and Greve, 2007; van Rijnsoever *et al.*, 2012). Thus, an external environment is a valuable source of novelty because it can provoke the creation of new routines (Lant and Mezias, 1992).

RBV postulates that a firm that possesses strategic resources could create and maintain a competitive advantage over its rivals. To qualify as strategic, resources should meet four criteria: be valuable, rare, imperfectly imitable, and non-substitutable (Barney, 1991). Resource ownership helps firms to attain a superior competitive advantage that is further reflected in improved performance, financial and operational. Considering the question of whether IT and digital technologies can be considered resources, researchers argue that not all these technologies – only those that are enabling technologies – could be regarded as strategic resources (Liang *et al.*, 2010; Karim *et al.*, 2022). For Teece (2018), it means a "junior general purpose technology" (GPT) that facilitates continual technical improvement and fosters complementary innovations but is used much less often than general-purpose technology. A subset of enabling technologies include, among others, all scopes of enterprise systems, cloud computing, big data, machine learning, and artificial intelligence (Karim *et al.*, 2022). Therefore, following RBV, adopting and using some IT and digital technologies as a strategic resource could bring a competitive advantage and impact firm performance.

Previous research findings into the technology adoption – firm performance relationship have been inconsistent and contradictory (Liang *et al.*, 2010), thereby challenging the underlying proposition about the direct effect of strategic resources on the firm outcome.

However, the results of a recent meta-analysis study, based on 147 studies published between 1998 and 2020, provided convincing evidence of the positive and significant impact that the adoption of enabling technologies has on firm performance (Karim *et al.*, 2022). Thus, while the dependence of firm performance upon technology adoption is now supported, factors that could strengthen this relationship are of more importance and greater interest (Melville *et al.*, 2004; Luo and Bu, 2016).

Thereby, the combination of two lines of theory – BTF and the RBV framework – would explain the mechanism through which strategic resources influence firm performance. The endeavours of this study seek to discover this particular mechanism considering IT and digital technologies, one of the companies' most valuable strategic resources. Furthermore, it is vital to see if this mechanism can be different for a different context. In this study, we employ BTF and the RBV view and investigate to what extent the regional technological environment moderates the relationship between such an enabling technology as ERP and firm productivity. The following section discusses the hypotheses underlying the research model (Figure 1).

2.2 Technology-driven productivity in the context of ERP adoption

Adoption of ES systems, one of the most critical investments in IT and digital assets that a company may make over its history, is associated with the great potential to raise firm productivity (Ali and Miller, 2017; Gal *et al.*, 2019; Taştan and Gönel, 2020). There is already considerable empirical evidence indicating causality between ES systems usage and productivity growth. One of the first studies trying to answer the question of which factor triggers productivity – the use of IT technologies or the desire of productive companies to adopt technologies – was conducted by Aral *et al.* (2006). With US panel data on different stages of technology adoption of three ES systems, namely ERP, SRM, and CRM, the authors could assess the impact of separate purchase and "go-live" events on performance indicators. It was found that, on average, ERP adoption increased productivity by 6.9%. While the combined effect of the ES systems was also positively associated with productivity, it is interesting to note that in the case of successful ERP implementation, firms are ready to continue investing in other ES systems. Similarly, Romero and Abad (2022) note that SAP adoption creates an advantage over non-adopter productivity and technical efficiency, providing a foundation for later adopting more complex systems.

Engelstätter (2009) used German firm-level panel data to analyse the relationship between different ES systems (including ERP) and productivity. The findings of the study largely confirmed the results that Aral *et al.* (2006) obtained. In particular, it was shown that using ERP leads to productivity growth: the effect varies from 11% to 18%, according to the estimated model specifications. A test of joint effects between different ES systems provides the meaningful insight that ERP can be seen as a necessary infrastructure for adopting other ES suites. A recent study by Taştan and Gönel (2020), using longitudinal data from Turkey, showed that firms adopting ERP systems experience a 16% increase in productivity compared to firms that do not use such a system.

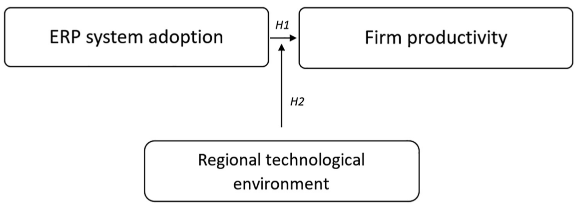

Figure 1.
Research model

The empirical evidence indicating a positive association between ES systems and firm productivity from the studies mentioned above (however, not limited by them – see, for example, Shin, 2006; Ruivo *et al.*, 2014; Xu *et al.*, 2017; Romero and Abad, 2022) comes from single countries. A comprehensive analysis performed by Gal *et al.* (2019) on cross-country data from 20 countries supports such a link. Based on prior literature on technology adoption and specifically on the results of quantitative studies on ERP adoption, we hypothesise as follows:

H1. The adoption of an ERP system positively impacts labour productivity.

2.3 The role of regional context in technology adoption

The context for any company is multilevel. Specifically, it can be formed by the firm's industry, country, and region (Camisón and Forés, 2015; Fávero *et al.*, 2018). There is some empirical evidence demonstrating significant discrepancies in technology adoption modes for different industries (Shin, 2006; Taştan and Gönel, 2020) and various countries (Luo and Bu, 2016; Andrews *et al.*, 2018; Gal *et al.*, 2019; Nicoletti *et al.*, 2020). However, it appears that the regional environment is not considered when studying the effect of technology adoption.

The country's characteristics representing the geographical environment of a company can be used to explain differences in technology adoption (Luo and Bu, 2016; Nicoletti *et al.*, 2020). Meanwhile, in the case of large countries or emerging economies, where the local context can vary significantly, the average country characteristics do not reflect in-country heterogeneity (Ma *et al.*, 2013). Moreover, due to varying structural and policy factors, countries are less comparable than the regions within the same country (Camisón and Forés, 2015; Hitt *et al.*, 2021). Hence, the regional level should also be considered an important avenue of investigation.

When adopting technologies, a firm should consider the availability of enabling infrastructure. For example, DeStefano *et al.* (2018) reported that the adoption of some ICT technologies is correlated with technological infrastructure. They also found that adoption of software technologies such as ERP and VPN require more sophisticated technological infrastructure and took place only when the required infrastructure had been built. Significant differences in penetration of cloud computing technology and broadband Internet between large and small companies across 13 countries were recently documented by Berlingieri *et al.* (2020). While they did not test the relationship between the adoption of these technologies, they observed that small companies experience a technological gap on both indicators. A broader perspective has been explored by Pradhan *et al.* (2021), who argue that regional technological infrastructure may be an antecedent of technology adoption. The relationship between regional technological infrastructure and technology adoption was out of the focus of Pradhan *et al.* (2021). Still, they use them to explain the part of the mechanism that connects regional ICT infrastructure and country economic development. Altogether, this suggests that technological infrastructure can complement the adoption of some IT technologies. However, it can also act as a critical prerequisite for adopting more complex technologies, especially digital ones (Nicoletti *et al.*, 2020; Andres *et al.*, 2020).

Apart from technological infrastructure, the regional environment includes the technology adoption behaviour of other companies which operate in the same region. In this sense, the regional environment reflects competitive pressure and competitor orientation towards technology adoption (Awa *et al.*, 2017). For example, Li *et al.* (2010) found that competitive-oriented firms are likelier to adopt internet technologies and Internet-based applications. In line with this result, the latest study by Nuryyev *et al.* (2020) also provides empirical evidence on the impact of competitive orientation (here, it was measured as a part of the strategic orientation of a firm) on a company's intention to adopt blockchain technology and cryptocurrency payments. Regarding competitive pressure, it appears to be a driver of technology adoption (Ghobakhloo *et al.*, 2011; Xu *et al.*, 2017). For instance, in a study conducted by Xu *et al.* (2017), it was shown that competitive pressure has a significant effect on ERP use. Interestingly, such a driver plays a more critical role for private companies than state-owned firms, which means that firms operating in a highly-competitive environment react to changes happening around them quicker and, therefore, could adopt technologies more intensively.

Considering all of this evidence, it seems that the regional technological environment plays a vital role in technology adoption. Technological infrastructure can potentially enhance the adoption of IT and digital technologies. It may also be supposed that technology adoption could be strengthened if the technology behaviour of other firms operating in the same environment is active and sophisticated. Accordingly, the second hypothesis is formulated as follows:

H2. The effect of the adoption of ERP systems on labour productivity is enhanced by the regional technological environment.

3. Research design and methodology

3.1 Research approach

Seeking to test both hypotheses in our study, we need to specify a productivity-based production function driven by ES system adoption. Moreover, we need to disentangle two effects – the average effect of ES adoption and the moderation effect of the regional technological environment. The latter should be considered a contrafactual condition. One of the possible ways of doing that is to involve in the analysis those companies which are exposed to the technological environment of a region (the treatment group) and those which do not experience this effect (the control group).

In our study, we tested the hypotheses on data from almost 900 large Russian companies in different industries located in most Russian regions for 9 years, starting from 2009. It is notable that, being selected from the population of the largest companies in the Russian economy, we may observe the companies that operate in all Russian regions and those that are localised in certain regions. Thus, both treatment and control groups are covered.

The choice of Russia is justified on the ground that Russia is a very heterogeneity country – it consists of 85 regions whose levels of economic development and geographical positions vary widely; a similar variance can be seen in the regions' institutional and regulatory quality (Russia Integrates: Deepening the Country's Integration in the Global Economy, 2019). Additionally, the digital divide between Russian regions is significant despite Russia's being in the middle of the IMD World Digital Competitiveness Ranking between 2017 and 2021 (Korovkin, 2020; IMD World Competitiveness Center, 2021). The third reason explaining the choice of Russia relates to the persistent call to examine ES in transition economies (Roztocki *et al.*, 2020), representing a particular business environment regarding ES adoption and its use. While the value of focussing on these economies is emphasised (Lutfi, 2020), the number of studies on this topic is scant. For example, according to Roztocki *et al.* (2020), who systematically reviewed the literature on ES in transition economies from 2004 to 2016, few considered the Russian context.

3.2 Sample selection and sample description

We collect longitudinal data on the largest Russian companies by revenue (both public and non-public) for the years 2009–2017. The list of companies was formed based on the RAEX-600 independent rating, one of the representative lists of Russian companies. To create a sample, we took all companies included in the RAEX rating at least once from 2009 –2017. We deleted the companies that had gone bankrupt from the list, and in case of those that merged, we used data on the newly created company or, if possible, collected separate data on the companies that merged. At this stage, the sample included 964 companies. Then, the data were screened out to remove or transform the outliers and missing values. After this data validation process, the final sample included 888 companies. Table 1 reports descriptive characteristics of the sample.

The geographical profile of companies can be described in terms of the federal district the companies belong to and the federal regions the companies represent. Russia comprises 8 federal districts that group 85 federal regions; companies constituting the sample represent all federal districts (Figure 2) and 58 federal regions. In general, the firms' geographical location is diverse. Despite a clear bias toward central regions and capitals (Figure 2),

Industry code	Industry title	No. of companies	Percent of companies
11	Agriculture, forestry, fishing and hunting	6	0.68
21	Mining	37	4.17
22	Utilities	67	7.55
23	Construction	88	9.91
31–33	Manufacturing	182	20.50
42	Wholesale trade	244	27.48
44–45	Retail trade	56	6.31
48–49	Transportation and warehousing	39	4.39
51	Information	14	1.58
52	Finance and Insurance	32	3.60
53	Real estate rental and leasing	13	1.46
54	Professional, scientific, and technical services	70	7.88
55	Management of companies and enterprises	25	2.82
56	Administrative and support and waste management and remediation services	4	0.45
71	Arts, entertainment, and recreation	3	0.34
72	Accommodation and food services	4	0.45
81	Other services (except public administration)	2	0.23
92	Public administration	2	0.23
Total		888	100.00

Table 1. Distribution of companies by industry type at the NAICS 2-digit level

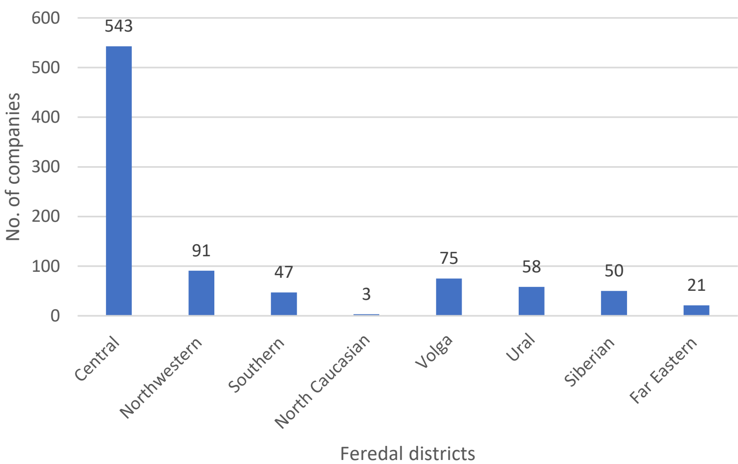

Figure 2. Regional structure of the sample by federal districts

in particular, towards the Central federal district that includes the capital of Russia–Moscow, the rest of the distribution across the Russian federal districts is relatively even and representative, according to the intensity of the economic activities and business life (Barkhatov *et al.*, 2018). The distribution of companies by status – federal or local – shows that just over 81% of companies are federal, and almost 19% are localised in specific regions. Since companies in the sample are large in sales, it is natural to expect that they operate across many regions rather than within the geographical boundaries of the region where they are registered. This is what the data show.

3.3 Data collection

We collected quantitative data on Russian companies and the regions where they are located, using multiple databases and different approaches to data collection. To gather data on company performance and general characteristics such as industrial classification, location of company, etc., we used the database Ruslana, provided by Bureau van Dijk. All data describing the technological development of the Russian regions were obtained from The Federal Service for State Statistics (Rosstat) database, which contains aggregated data at the regional level based on the firms' annual reports over the period 2010–2017.

We used open-access sources of information to describe the usage of ES systems in companies quantitatively over almost 10 years. We find it appropriate for four reasons. *First,* ES system adoption is a long process that, to be completed, requires changes in the firms' business processes (Ruivo *et al.*, 2014). *Second,* there is a time lag between the "go-live" moment, the moment of its full acceptance, and the occurrence of fundamental changes in organisational performance (Chan, 2000; Wu and Chen, 2014). In other words, complete technology adoption facilitates redesigning organisational processes/structures, which is time-consuming. Therefore, companies also take substantial amount of time to properly reflect on the true changes, especially in non-financial measures. *Third,* most of the studies on ES adoption are based on survey methodology using self-reported data (e.g. see Engelstätter, 2009; Nicoletti *et al.*, 2020). However, such data reflect the respondents' perceptions or subjective opinions (Benitez-Amado and Walczuch, 2012). This data also might be limited due to its being nonrepresentational, nonresponse bias, and prone to self-selection problems (Forman, 2005). *Fourth,* an empirical investigation based on secondary data, especially collected through Internet-based open sources using web-scraping, has evident advantages compared with research based on primary data (Nieto *et al.*, 2011; Smithson *et al.*, 2011). One such advantage is that secondary data are considered more objective; using them allows one to access information on a greater number of firms more efficiently (Kohli and Devaraj, 2003). While using secondary data based on manual collection may be limited in detail and may not match the research's exact needs, automatic data collection allows one to obtain the great amount of information required. In addition, the use of secondary data to measure IT constructs is consistent with the research in the field of information systems (Santhanam and Hartono, 2003).

In this study, we use automated content analysis (CA) – the precoding of narrative constructs found in the entire corpus of information associated with a company name published on the internet. There are two reasons why this approach to data collection is considered confirmatory. First, this CA procedure has already been used in several studies (Ritala *et al.*, 2018; Parshakov and Shakina, 2020; Shakina *et al.*, 2021). Second, CA is a research methodology designed to manifest latent variables (Drisko and Maschi, 2015). Despite criticism that it is simplistic (Krippendorff, 1980) and devoid of a consistent coding framework (Abeysekera, 2006), CA has been utilised to research a vast array of research questions, particularly in the field of management.

It is primarily the quality of the initial coding and the quality of the corpus of textual information that determines the output of the process of extracting information from the documents, usually referred to as text mining (Yu *et al.*, 2011; Parshakov and Shakina, 2020). Therefore, we paid particular attention to the reliability of the corpus of textual documents and the validation of the coding framework. A reliable corpus is required for robust CA (Dumay and Cai, 2014). One possible way to get such a corpus is to base it on the collection of publicly available documents extracted from the Internet. This corpus enables access to all the information published on the Internet about companies (Shakina *et al.*, 2021), and its large size creates an opportunity to run more powerful analyses (Hovy *et al.*, 2015). For these reasons, we collected the corpus using the Bing search engine accessed via Microsoft Bing Application Programming Interface (API) (Singhal *et al.*, 2014). While Google search is used more often among search engines, it does not allow query use automatically through API (Wilkinson and Thelwall, 2013); thus, it was not appropriate for this study. To increase the validity of the content, that is, the list of ES systems used in the coding framework, we employed a two-stage approach. First, we made a comprehensive list of ES systems; we generated this list of systems by checking academic literature, mainly in information technology and industry reports. On our way to generating the list of ES systems, we also consider two criteria – the productivity-enhancing potential of ES systems and their relevance for most companies (Hausberg *et al.*, 2019; Nicoletti *et al.*, 2020). These criteria reflect the focus of the study, so they are of considerable importance. Second, we corresponded the list of ES systems with the systems installed in the Russian companies relying on the ES systems market reports (Enterprise Management Systems (ERP) Market of Russia, 2022). This was followed by interviews with the researchers and experts having experience working in the field of IT, including ERP. This iterative process, using different sources of information necessary for data triangulation, resulted in a final list of ES systems matched with a set of keywords and incorporated into the CA algorithm. Figure 3 presents the coding framework employed in this study.

3.4 Dependent and explanatory variables and their operationalisation

3.4.1 Dependent variable. Company performance. To measure company performance, we use labour productivity, calculated for each firm, and year as sales per employee (Aral *et al.*, 2006).

3.4.2 Explanatory variables. ES systems. This study is focused on a specific set of ES systems that are selected based on the following criteria: the productivity-enhancing potential of technology and the relevance of the technology to the vast majority of companies

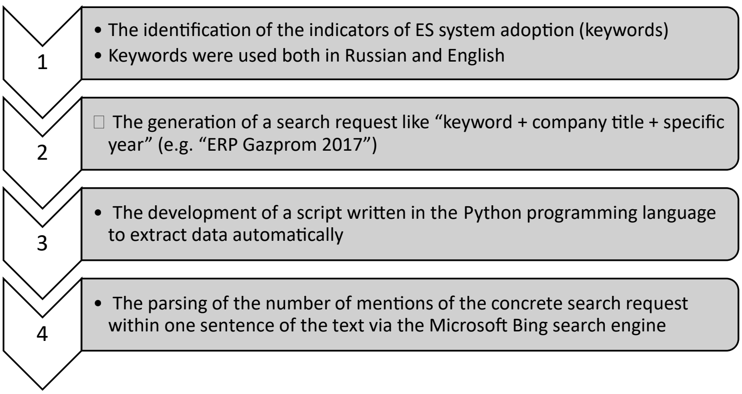

Figure 3.
Steps of the coding framework

(Hausberg *et al.*, 2019; Nicoletti *et al.*, 2020). Taking into account these two criteria, we chose an ERP system using the examples of SAP, ORACLE, and NAVISION for the study (Stubbs and Auchard, 2018; Russian Software Industry 2019, 2019). It is worth noting that ERP is considered a basic infrastructure for the subsequent implementation of other ES systems (Engelstätter, 2009). Therefore, we do not include other ES systems in the list of selected technologies.

3.4.3 Regional measures of technological development. To capture the technological sophistication of a region, we used three ICT measures in total. The first variable, access to high-speed Internet, reflects the availability of enabling infrastructure; it is measured as the share of companies in the region with a broadband download speed of no less than 2 Mbit/s (%). Two other variables – ICT expenditures (in mln. rubles) and share of ERP adoption in a region – are observable ones; they are considered a proxy for the technological environment created by the technology adoption behaviour of other firms.

3.4.4 Local and federal status. To measure the dependence of each firm on the technological environment of the region where each firm is located, we created a new variable. It describes firms regarding their economic activity. Companies localised in a certain region where they do either all or most of its economic activity were designated "local". Companies operating across many regions (not only in the region that they officially belong to) and, in some cases, even across the whole country, were designated "federal". To identify to which group a firm belongs, two independent coders checked all available information for each firm and assigned a status of local or federal to every firm based on the information. In case of differences between given status assigned, a third coder reexamined any problematic case and made a final decision.

3.4 Econometric strategy

As we test the influence of technological adoption on productivity, taking into account differences in regional technological environment and company dependence on its location, we specify our basic econometric model as follows:

$$y_{it} = \beta_o + \sum_{j=1}^{n} \beta_j \cdot (x_{ijt}) + \sum_{j=1}^{n} \partial_j \cdot (x_{ijt} \cdot z_{jrt}) + \sum_{j=1}^{n} \gamma_j \cdot (x_{ijt} \cdot z_{jrt} \cdot loc_i) + CV' + u_{it}$$

where y_j *– the output variable (productivity),*

β_o *– the intercept of the linear specification,*

β_j *– coefficients at the factors* x_{ij} *– technology adoption,*

∂_j *– coefficients at the interaction term between* x_{ij} *(technology adoption)*

and z_{jr} *(technological environment),*

γ_j *– coefficients at the interaction term between* x_{ij} *(technology adoption),*

z_{jr} *(technological environment), and* loc_i *(local status)*

$CV\ (CV')$ *– the vector of control variables,*

u_{it} *– error term*

Our study's panel data fixed effect estimator controls for potential endogeneity through company fixed effects. We use panel data fixed effects. The overall impact of technology adoption on the technological environment is a linear combination of the estimated parameters.

4. Results

4.1 Descriptive analysis

Table 2 reports the summary statistics for the dependent variable and gives an idea of the productivity level of companies in this study. Productivity is strictly positive. The original productivity distribution is far from normal, which is why a logarithmic transformation was applied. This brings the productivity values very close to the normal distribution and decreases the possible heteroscedasticity of the estimated model. We exclude observations with missing values for the explained variable, making the panel balanced.

According to the study's research design, the descriptive statistics of the mentions for ES systems say that the mean values of all explored variables are homogeneous (Table 3). ERP system is mentioned less often than concrete examples of the system; most references were found about ORACLE and NAVISION. All the firm-level variables related to technologies have been logarithmically smoothed. This approximated all distributions to bounded normality as its initial form was binominal, with one of the picks in zero. This can be explained by the high number of companies with no mention of particular ES systems.

Table 3 also presents the summary statistics on variables that represent the technological environment of a region. The average expenditure on ICT in a region is 205 million rubles, while there are regions where these costs are almost 4 times higher. Only 15% of firms in the observed regions have installed ERP systems, with the maximum value recorded at 22%. On

Variable		Mean	Std. dev.	Min	Max	Observations
PRODUCTIVITY	overall	373.0479	4235.491	0	144818.2	N = 7151
	between		4596.016	0	121294.7	n = 888
	within		1603.509	−28782.19	73998.78	T-bar = 8.05293

Table 2. Descriptive statistics of the dependent variable

Variable		Mean	Std. dev.	Min	Max	Observations
ERP	overall	133.033	3093.479	0	149262	N = 7151
	between		2191.517	0	63037	n = 888
	within		2306.7	−62071.97	86358.03	T-bar = 8
SAP	overall	390.1264	5658.806	0	199000	N = 7151
	between		4469.025	0	125980	n = 888
	within		3126.732	−117019.9	73410.13	T-bar = 8
ORACLE	overall	535.9599	8071.4	0	250000	N = 7151
	between		7481.933	0	215444.4	n = 888
	within		1647.457	−30486.26	49954.85	T-bar = 8
NAVISION	overall	530.6054	24705.03	0	2,070,000	N = 7151
	between		8050.662	0	230000	n = 888
	within		23195.32	−229469.4	1,840,531	T-bar = 8
ICT COST	overall	205.6506	226.9481	0.5591589	781.2715	N = 6450
	between		181.4512	0.912899	608.7913	n = 888
	within		141.9363	−142.4264	617.4766	T-bar = 7
HIGH-SPEED INTERNET	overall	66.19803	20.09149	3	90.9	N = 6450
	between		16.93115	8.966667	88.45	n = 888
	within		10.97381	30.51053	107.7105	T-bar = 7
R_ERP	overall	15.66935	6.193082	1.559294	22.60939	N = 6450
	between		5.768649	3.364869	22.60939	n = 888
	within		2.304453	9.352411	27.12594	T-bar = 7

Table 3. Descriptive statistics of the explanatory variable

average, 66% of all firms in the study have access to high-speed Internet. Notably, high-speed Internet has achieved a remarkable increase in penetration in the last seven years; in some regions, this indicator has almost reached full coverage.

4.2 Model estimation results

The fixed effects panel data estimation results are shown in Tables 4 and 5; productivity is the dependent variable. We ran three separate estimations for three variables of the regional technological environment (ICT cost, access to high-speed Internet, and ERP adoption) and two sets of explanatory variables – (1) SAP, ORACLE, and NAVISION and (2) ERP. We decided to estimate the impact of the ERP system separately from solutions provided by SAP, ORACLE, and Microsoft [1] because the latter set could represent both ERP systems (NAVISION being one such system and SAP being closely associated with ERP) and different IT and digital technologies. Thus, the empirical part of this study requires six regression equations.

According to the regression results in Table 4, SAP adoption is a significant driver of productivity. Only one instance was found where the coefficient of ERP adoption was significantly positive (Table 5) – in a specification where the technological environment is measured through ERP usage at the regional level. All estimated coefficients for NAVISION and ORACLE are consistent in their sign (positive coefficients for NAVISION and negative ones for ORACLE), but none is significant. Therefore, the first hypothesis was partly confirmed.

The test of the second hypothesis requires that we introduce two interaction effects: the first is between each of the digital technology metrics and the indicator of the regional technological environment; the second is created by utilising the first effect regarding the local or the federal status of the company. This could help us to estimate whether the regional technological environment of which the firm is a part and the actual company location have any effect on technology-driven productivity. Regarding the statistical significance of the effects found, the results of the empirical test allow us to divide all the coefficients of the estimated models into four groups. Except for ORACLE, each group is represented by a different technology.

In the first group, both interaction terms are statistically significant, and this group of effects applies to SAP and ORACLE. Regarding SAP, in all the estimated models, we see that while adopting this technology positively impacts productivity, the regional environment could weaken this effect. This finding means that the level of technological development of the region can reduce the effect of SAP adoption: in other words, the higher the technological development of a region, the lower the effect of SAP adoption. For local firms, however, this negative effect has been reversed. The opposite is observed for ORACLE adoption: although the technology adoption itself does not impact productivity, with the growth of ICT costs, the relationship between technology and productivity becomes significantly positive, but this is the case only for federal companies.

In the second and third groups of effects, we observe opposite patterns. The second group includes only the ERP system; all coefficients of the variable representing this system are, as mentioned above, positive but not significant. However, looking at the interaction term between the ERP system and the regional environment, we can see that the coefficients become statistically negative in all the estimated models. This effect is the same regardless of where the company is located. The third group of effects is represented by ORACLE adoption in the models where the technological environment is measured by the availability of high-speed Internet and the share of firms that use ERP systems. According to the estimation results, being a local company has a small but significant negative impact on technology-driven productivity. The signs of all the other coefficients differed from those of the ERP

Variables	Productivity	Variables	Productivity	Variables	Productivity
		NAVISION			
NAVISION	0.0142	NAVISION	0.00683	NAVISION	0.0218
	(0.0250)		(0.00984)		(0.0197)
NAVISION × High speed Internet	−0.000198	NAVISION × ICT cost	−0	NAVISION × r_ERP	−0.00140
	(0.000350)		(0)		(0.00113)
Local status × NAVISION × High speed Internet	−0.000615	Local status × NAVISION × ICT cost	−7.89e−11	Local status × NAVISION × r_ERP	−0.00129
	(0.000755)		(7.15e−11)		(0.00255)
		ORACLE			
ORACLE	−0.0197	ORACLE	−0.00121	ORACLE	−0.00910
	(0.0259)		(0.01000)		(0.0207)
ORACLE × High speed Internet	0.000450	ORACLE × ICT cost	6.43e−11**	ORACLE × r_ERP	0.00137
	(0.000362)		(0)		(0.00119)
Local status × ORACLE × High speed Internet	−0.00158*	Local status × ORACLE × ICT cost	−1.54e−10**	Local status × ORACLE × r_ERP	−0.00510*
	(0.000818)		(7.40e−11)		(0.00273)
		SAP			
SAP	0.0964***	SAP	0.0292***	SAP	0.0777***
	(0.0223)		(0.00937)		(0.0188)
SAP × High speed Internet	−0.00124***	SAP × ICT cost	−7.77e−11***	SAP × r_ERP	−0.00399***
	(0.000321)		(0)		(0.00110)
Local status × SAP × High speed Internet	0.00286***	Local status × SAP × ICT cost	1.96e−10**	Local status × SAP × r_ERP	0.00897***
	(0.000725)		(7.62e−11)		(0.00249)
CV	included	CV	included	CV	included
Constant	2.349***	Constant	2.943***	Constant	2.235***
	(0.230)		(0.110)		(0.236)
Observations	6,450	Observations	6,450	Observations	6,450
Number of groups	888	Number of groups	888	Number of groups	888
		Linear combination of coefficients			
NAVISION	0.0133734	NAVISION	0.0068342	NAVISION	0.0191319
	(0.0250411)		(0.0098435)		(0.0198536)
ORACLE	−0.0208357	ORACLE	−0.0012068	ORACLE	−0.0128292
	(0.0259181)		(0.0099961)		(0.0208306)
SAP	0.097997***	SAP	0.0292315**	SAP	0.0826895***
	(0.0223486)		(0.0093711)		(0.0189152)

Note(s): This table reports estimates of the equation where each ERP system is regressed on the labour productivity, each ERP system interacted with the relevant variables of regional technological environment (access to high-speed Internet, amount of ICT spending in a region, and share of ERP adoption in a region), with fixed effects

Standard errors in parentheses

***$p < 0.01$, **$p < 0.05$, *$p < 0$

Table 4. The output of the estimated technology adoption and effect of technological environment

Variables	Productivity	Variables	Productivity	Variables	Productivity
ERP					
ERP	0.0306	ERP	0.0130	ERP	0.0341*
	(0.0196)		(0.00858)		(0.0178)
ERP × High speed Internet	−0.000447*	ERP × ICT cost	−0**	ERP × r_ERP	−0.00200**
	(0.000266)		(0)		(0.000993)
Local status × ERP × High speed Internet	0.000356	Local status × ERP × ICT cost	−0	Local status × ERP × r_ERP	0.00160
	(0.000639)		(5.84e-11)		(0.00240)
CV	included	CV	included	CV	included
Constant	1.910***	Constant	2.758***	Constant	1.837***
	(0.224)		(0.0853)		(0.220)
Observations	6,450	Observations	6,450	Observations	6,450
Number of groups	888	Number of groups	888	Number of groups	888
		Linear combination of coefficients			
ERP	0.0305478	ERP	0.0130146	ERP	0.0337291*
	(0.0196532)		(0.0085808)		(0.0179523)

Note(s): This table reports estimates of the equation where ERP system is regressed on the labour productivity, ERP system interacted with the relevant variables of regional technological environment (access to high-speed Internet, amount of ICT spending in a region, and share of ERP adoption in a region), with fixed effects
Standard errors in parentheses
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 5.
The output of the estimated technology adoption and effect of technological environment

system but were insignificant. Finally, our analysis failed to reveal any statistically significant interaction effect for NAVISION, which makes up the last group of effects. Thus, the second hypothesis was confirmed for SAP and partly for ERP.

5. Concluding discussion

Employing BTF and RBV, this paper attempts to measure the moderating effect of the technological environment on technology adoption – firm performance relationship. Specifically, we empirically investigated the influence of different ES solutions on labour productivity, taking into account differences in the regional technological environment, namely, firm access to high-speed Internet, ICT expenditures, and the use of ERP systems in a region. The previous research studies the effect of the technological environment on technology-driven performance (see, for example, the results of a meta-analytical study by Karim *et al.*, 2022). Still, usually, these papers measure the technological development on the country level and operationalise the technological development quite broadly. This research is distinct from the previous studies in that it considers the effect that three specific indicators of the regional technological environment could have on labour productivity driven by ERP adoption. Hence, we are trying to contribute to a deeper understanding of the impact that regional context has on technology-driven performance. Furthermore, we used automated CA to collect data on technology adoption; by doing so, we contribute to the growing body of research utilising the text-mining approach to extract data stored in internet-based information sources.

According to the study results, there is a positive relationship between technology adoption and firm productivity. Specifically, we found that among all examples of ERP adoption, only SAP and ERP (in one model specification) demonstrated a significant positive impact on labour productivity. According to the model specification, the total effect of technology adoption on productivity varies from almost 3% to 9% in different technological environments. Our empirical results imply that the labour productivity of the large Russian companies is driven by the adoption of some ERP systems. That appears to be consistent with the existing studies by Aral *et al.* (2006), Engelstätter (2009), Taştan and Gönel (2020). However, the effect size found by other scholars provides an interesting point of comparison. In particular, the minimum effect of ERP adoption on labour productivity – 6.9% – was found by Aral *et al.* (2006), and the highest effect, which is 18%, was observed by Engelstätter (2009). Taştan and Gönel (2020) reported 16% increase in labour productivity. It enables us to see that the effect observed in our study is either at the minimum level reported or even smaller. A possible explanation of these results might be that the Russian firms could be different in the way they incorporate technologies into the firm structure. Of note, it points out how effectively they create managerial and knowledge-based capabilities, organisational practices, and routines to capture the value of adopted technologies.

Our findings suggest that the regional technological environment enhances the effect of technology-driven productivity. In fact, we have found all variables of the technological environment, namely firm access to high-speed Internet, ICT expenditures in the region, and the share of companies that use ERP systems in the region, lower the effect of technology adoption. The negative effect is smaller if the firm is limited to the local market. We note that we introduced the local and federal status to empirically separate the average effect of ES adoption and the moderation effect of the regional technological environment. Local companies are assumed to be affected by the technological environment of the region they belong to (Wu *et al.*, 2021). The results of such a quasi-experiment showed that the technological environment could amplify the effect of technology adoption on firm productivity. It seems possible that these results are due to the complementarity feature that regional technological infrastructure has for technology adoption. Some studies focus on the complementarity effect of technological infrastructure; for example, Gal *et al.* (2019) and Nicoletti *et al.* (2020) report a positive effect of broadband Internet on technology adoption. In this sense, our results align with previous studies results. Another possible explanation could be attributed to the pressure or opportunities that regional technological infrastructure creates for companies in a corresponding region. Regional technological infrastructure reflects a region's technological development level, so one may suggest that such a technological environment stimulates companies to be competitive and productive regarding the other firms in a region. Wu *et al.* (2021) support the idea that the regional technological environment contributes to firm-level productivity and find evidence that with an increase in infrastructure investment, less productive firms tend to leave the market, allowing more productive firms to gain more market share. At the same time, geographical proximity could create favourable conditions for companies to observe the behaviour of other companies, share the practices of technology adoption, its integration into the firm infrastructure, and so on. That can be a potential explanation of the enhancing effect that regional technological infrastructure may have on technology adoption (Liang *et al.*, 2007; Lutfi, 2020).

5.1 Practical implications

Altogether, our findings support the idea that managers need to carefully evaluate technologies before adoption because not all technologies will increase productivity. Adoption of enabling technology as ERP could help companies reach competitive advantage and improve their labour productivity; the managers, however, should constantly seek to upgrade the firm technological infrastructure to the level needed to adopt such a sophisticated IT and digital technology and invest in related and complementary resources including human resources and knowledge resource (Liang *et al.*, 2010; Gupta *et al.*, 2018; Karim *et al.*, 2022). Moreover, as ERP technology costs a lot of money and may require some years to be fully integrated into a firm, managers need to keep their fingers on the pulse of the process of adoption and monitor and control how and to what degree the investments are transformed into the real, "tangible" value. Our findings also imply that firms should keep an eye on what technological conditions are necessary for the adoption and successful use of different IT and digital technologies and to what extent the technological infrastructure of a firm and of the region where the firm operates meets these conditions (Gillani *et al.*, 2020). For policymakers, such findings call for the development of the technological infrastructure that enables the adoption of complex IT systems and advanced digital technologies, as well as the creation of favourable conditions for suppliers responsible for building such infrastructure.

5.2 Research implications

Our study shows that BTF is relevant to address the impact of the external technological environment on the results of the firm adoption behaviour. However, as was mentioned before, the external technological context includes many factors, and the findings of this paper represent only a first step in determining the effects that different technological factors could have on the relationship between ES adoption and firm performance. There is further need for research, especially regarding the impact these various technological and environmental conditions have on the outcomes of the firm adoption behaviour. Future research also could closely examine how companies behave in different technological environments. Therefore, we call for more quantitative research; conducting such studies will give us an insight into how different technological environments impact companies and how companies make complex technology-related decisions. From a methodological perspective, we suggest using longitudinal and publicly available data, along with supplementing them with primary objective information about how companies utilise different digital technologies and what their technological environment is like; it will be useful to increase the validity of the research findings. At the same time, qualitative research could also be valuable in providing more details on the mechanism that explains the relationship between technology adoption and firm performance under different regional conditions and clarifying the results of quantitative studies.

5.3 Research limitations

Although this research provides some new empirical evidence on technology-driven productivity regarding environmental context of a firm, it has some limitations. First, the method used to collect our data might be a source of potential bias. We analysed text-based data, calculating how many times a particular technology had been mentioned on the internet for a company name. For this reason, the text corpus may in and of itself be biased, as different companies have different levels of voluntary and involuntary disclosure. Any potential bias notwithstanding, this method allows one to collect large amounts of panel data and capture dynamic effects; therefore, it is now considered among the most advanced ways to collect data. Second, as our data represent the number of mentions we use as a proxy for technology adoption, we cannot determine the causality between technology adoption and firm performance. Third, the object of our analysis is the largest Russian companies in some of the most dynamic industries. This dynamism – and the associated explosive development of technologies – can influence the pace at which new technologies are adopted by companies, along with how this adoption takes place. Fourth, it is to be borne in mind that our context is limited to that of large Russian companies only, for which reason generalisations are somewhat restricted. Still, because the companies in our sample are quite representative of Russian firms (and large enterprises in general), we believe that our data are both valid and applicable in a number of scenarios. The choice of the large companies was motivated by the focus of this study on ES adoption; ES adoption, specifically ERP adoption, seems to be relevant for large companies. Next, digital innovations happen against the backdrop of an already-globalised economy, which means that companies from different countries operate in similar environments. Nevertheless, it is yet too early to write off the national and the institutional contexts. In summary, it is possible to generalise our findings, albeit tentatively. As far as any future developments of this study are concerned, we suppose that it may be of interest to conduct comparative experiments across countries and types of corporations (for instance, SMEs).

Notes

1. NAVISION is an ERP from Microsoft.

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