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Influence of the technological environment and digital transformation on firm performance

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1 GENERAL CHARACTERISTICS OF THESIS RESEARCH

Motivation & Research Gap. In a world of constant change, uncertainty, and complexity of the business environment, company-environment fit has a pivotal role in company success, both in terms of performance and longevity. Indeed, scholars claim that misalignment between a company and its environment may worsen company efficiency and performance, and lead to its potential demise (Pérez-Nordtvedt et al., 2008; D.-N. Chen & Liang, 2011). Therefore, many researchers suggest that in the case of a significant shift within the external environment, a company needs to respond to the environmental demand by rethinking its external orientation and taking some internal changes to be better synchronised with its environment (Lam, 2005; Pérez-Nordtvedt et al., 2008).

The transformational potential of new technologies, especially information technologies (IT) and digital technologies (DT), constitutes a challenge for contemporary companies (Martin & Leurent, 2017; Vial, 2019). Companies seeking to utilise IT and digital technologies and implement some organisational changes based on these technologies undergo a digital transformation (Nwankpa & Roumani, 2016; Morakanyane et al., 2017; Vial, 2019; Sousa-Zomer et al., 2020). In other words, the digital transformation of companies is associated with organizational changes related to the introduction and use of information and digital technologies.

According to a global survey of managers and executives conducted by Kane, Palmer, Phillips, Kiron, and Buckley (2018) (Kane et al., 2018), 25% of companies already consider themselves to be digitally maturing, and 44% of companies regard themselves as digitally developing companies. However, as the majority of companies embrace digital technologies and rapidly transform their technological structures, almost one-third (30%) of companies are in the early stages of digital development. That means that now, companies approach the issue of technology adoption and initiate digital transformation based on the adopted technologies heterogeneously: some companies have decided to start the digital transformation and, therefore, could recognise its impact on business outcomes; at the same time some companies are still struggling to initiate change in their technological structure or even postpone the start of their digital transformation.

Currently, the range of information and digital technologies that can be implemented in a company to start digital transformation is quite wide. The strategic behavior of companies regarding the start of digital transformation, which requires technology adoption, can also be different. There are several basic strategies of the company's behavior regarding technology adoption – the "excess momentum" strategy, which implies that the firms adopt technologies at any moment prior other firms do the same, and the "excess inertia" strategy, which implies that the firms adopt technologies at any moment later than other companies. A comprehensive analysis of technology-enabled transformation, run by Besson and Rowe (2012), revealed that an understanding of the context and external circumstances under which companies initiate technology adoption[1] and overcome company inertia, one of the main factors that complicate the implementation of necessary changes, successfully, is one of the research streams that can be considered as very promising. Moreover, recent research has emphasised the role of environmental context in technology adoption (Luo and Bu, 2016; Xu et al., 2017; Cruz-Jesus et al., 2019; Roztocki et al., 2020; Lutfi et al., 2022).

The external environment includes a range of dimensions, among which the technological ones play an important role. The technological environment could act as critical antecedents of technology adoption (Oliveira and Martins, 2011; Awa et al., 2017; Oliveira et al., 2019; Lutfi et al., 2022); recent studies, however, provide more empirical evidence of the moderating role of the external technological context regarding technology adoption, and firm performance relationship (DeStefano et al., 2018; Berlingieri et al., 2020; Lei et al., 2021; Karim et al., 2022).

Some papers consider different environmental aspects companies found to be critical to overcome company inertia (Li et al., 2018; Hur et al., 2019). The relationship between technology adoption and firm performance with regard to the environmental context of a firm also attracts considerable interest (Xu et al., 2017; Cruz-Jesus et al., 2019, Lutfi et al., 2022); still, the number of studies considering different aspects companies found to be essential to overcome company inertia and/or taking into consideration the technological environment is limited (Kung et al., 2015; Kohli and Melville, 2019; Lutfi, 2020). Based on the analysis of the existing studies, we see some limitations here. First, digital transformation is a fairly new phenomenon, and it is already seen as multifaceted ones, which is why it has received significant attention from scholars who discuss it from different theoretical angles (Morakanyane et al., 2017; Vial, 2019). Nevertheless, there is still a lack of empirical studies regarding this concept, and empirical papers are vital for a better understanding of the current state of digital transformation with regard to what technologies are adopted by the firms and the further theoretical development of the digital transformation concept. Second, studies taking into consideration the technological environment 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. Third, most empirical papers investigating the relationship between technology adoption and firm performance in the technological context employ a cross-sectional research design and, is also important, use self-reported data (Y.-Y.

[1] We want to make a remark, that, here and after, technology adoption refers to the adoption of IT and digital technologies.

K. Chen et al., 2016; Nwankpa & Roumani, 2016; Dalenogare et al., 2018; 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 they are nonrepresentational, have a nonresponse bias, and are prone to self-selection problems (Forman, 2005).

Research purpose and objectives. Based on the research background, this study seeks to profoundly explore the phenomenon of digital transformation and its effect on company performance under various contexts. Specifically, the purpose of this study is to evaluate the impact of technology adoption on sales and labour productivity in different technological environments. To reach the overarching goal of the study, we attempt to answer the following specific research questions (RQ):

1) How does the company's business model change under the influence of digitalization?

2) How does the moment that companies choose to initiate a technological change relative to other companies from the same regional and industrial context influence sales of the firm and its labour productivity?

3) To what extent does the regional technological environment moderate the relationship between the enterprise software (ES) system adoption, namely the adoption of an Enterprise Resource Planning (ERP) system, and firm labour productivity?

To reach the purpose of the study, we subdivided it into specific research objectives connected to the three distinct research questions:

1) To consider digital manufacturing a specific pattern of digital transformation and comprehensively review the literature on the organizational changes occurring in the company and, specifically, its business model, due to digital manufacturing.

2) To examine how the timely and untimely technological shifts in companies contribute to the company's sales and productivity. To achieve this objective, we need to explore different types of companies' strategic responses to changes happening in the competitive environment of a firm, including the "first mover" strategy, which means that a company reflects the external demand, and "follower" strategy, which means that a company prefers to stay inert, choosing to compare itself with other companies from the same environment; to consider these strategic responses regarding digital technology adoption and examine how they affect organisational performance; to suggest how to measure such a theoretical construct as excess momentum and excess inertia that reflect "first mover" and "follower" strategy; to run empirical tests to capture the effects of the competitive technological environment on technology-driven performance.

3) To examine how different technological environment impacts technology-driven productivity. To accomplish this objective, we need to explain the mechanism that connects

technologies as a firm strategic resource with firm productivity regarding the regional technological environment of a company and develop the research model reflecting the relationship between technology adoption, firm productivity and technological environment; to create the research design that allows disentangling two effects — the average effect of technology adoption and the moderation effect of the regional technological environment; to run empirical tests to measure the effect that regional technological environment has on technology-driven productivity[2];

Research object and subject. The object of the dissertation is digital transformation, undertaken across different environmental conditions. The research subject refers to the technological behaviour of the largest Russian companies.

Theoretical framework. We frame our study on the behavioural theory of the firm (BTF), structural inertia theory, and resource-based view (RBV)[3]. BTF enables us to address how external context shapes or pressures strategic decision-making behaviour. Structural inertia theory places great emphasis on the idea of the fit between the company and its environment. It discusses two modes of behaviour – adaptive and inertia – as a possible strategic response to changes in the firm environment. RBV outlines the role the strategic firms' resources play in the firm's ability to gain a competitive advantage and better outcomes. Figure 1 presents the relationship between the main theories and theoretical approaches, and central concepts used in this study.

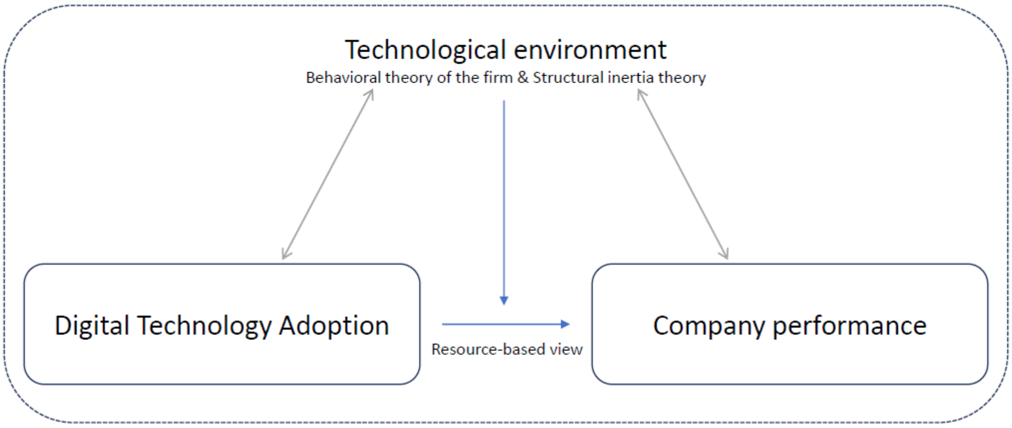

Fig.1 Theoretical framework of the study[4]

<u>The behavioural theory of the firm:</u> 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

[2] We want to clarify, that, here and after, technology-driven performance refers to the performance associated with the adoption of IT and digital technologies.

[3] The theories and theoretical approaches are listed by their creation date.
[4] Elaborated by the author.

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 based on its accumulated experience signaling 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. 1246; 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).

Structural inertia theory: According to a structural inertia theory proposed by Hannan and Freeman (1984), effective organisational performance requires establishing organisational routines. As organising implies routinising, it creates organisational patterns, procedures, and practices that become inflexible with time (Besson & Rowe, 2012). At the same time, in the era of high-level volatility and uncertainty, a company cannot help but notice the changes in its environment and consider a response to them, punctuating two different modes of behaviour – adaptive and inertia. In this perspective, adaptive behaviour requires organisational change; it, in turn, necessitates the constant overcoming of the accepted and established routines, that is, organisational inertia, to realign the organisation with its environment. On the other hand, the core organisational structures – the organisational strategy, legitimacy, technology, and marketing – are thought to contain a lot of sources of inertia. Any change of the core organisational structures requires a lot of effort from the company to reorganise its central processes, and as a result, entails a significant risk of failure (Hannan & Freeman, 1984).

Some crucial comments on inertia were added by Sastry (1997) in her causal model of the punctuated change theory. Sastry suggested that inertia should be considered interconnected with the organisational ability to change. According to the model, a high level of inertia is associated with a low organisational ability to change. Part of the explanation is related to the idea of creating a company's routines, as this formalisation of the internal processes and the external relationship between the company and its environment hinders a manager’s ability to notice and react to the need for a timely change. Moreover, long stable periods of organisational life weaken the organisational skills to promptly scan environmental signals and respond to them innovatively. That means that the organisational ability to change declines. The counterintuitive consequences of this situation are the following. First, inertia increases constantly, and secondly, inertia is built up through the self-reinforcing mechanism, as the routinisation of some processes facilitates their further formalisation. However, what is interesting, high levels of inertia do not mean that a company cannot change: while inertia impedes change, it does not make it impossible.

Well-timed organisational changes are assumed to result in better financial performance as they are a means of adapting the company's fit to its environment (Haveman, 1992; Burton et al., 2002; Pérez-Nordtvedt et al., 2008). In this sense, the inertia should be defeated, and change should be initiated. The moment when the level of external pressure (for example, manifested through an environmental shift or a drop in performance provoked by a misalignment between the company and the considered environment) exceeds the level of inertia should be recognised by companies and should be taken as a starting point for any changes (Sastry, 1997). Speaking about the moment when change takes place, one may think of two approaches to change – proactive and reactive; both reflect the idea of the temporal moment. Proactive and reactive reorientations also stress the importance of companies using comparison as a mechanism to recognise, and the appropriate moment to introduce changes (Ancona et al., 2001). Specifically, comparison allows companies to compare their position, structure, and progress relative to other companies they compete with. While researchers claim that reactive reorientation is considered riskier than a proactive one, they also insist that resistance to change and remaining inert is even riskier behaviour for a company (Ancona et al., 2001). As such, although we can see that companies practice organisational change seldom and under very specific conditions (both external and internal) to increase their survival chances and benefit performance, they do resolve to initiate change.

Resource-based view: RBV postulates that a firm that possesses strategic resources could create and maintain a competitive advantage over its rivals. To be qualified 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 whether IT and digital technologies can be considered resources, researchers argue that not all these technologies — only those 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 includes, 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 strategic resources could bring a competitive advantage and impact firm performance.

Research strategy (research design, data, methods of data analysis). To answer the research questions posed, we conduct preliminary exploratory research that allows to reveal changes in a firms' business model due to their digitalization. The changes occurring in the company's business model were analyzed with the use of Deloitte approach; this approach suggests evaluating changes focusing on four parameters that are fundamental in describing the business model of any company - consumer, product, economy of production and value chain[5]. Main empirical study is quantitative one; it allows us to measure the technological environment's effect on technology-driven firm performance, specifically firm sales and firm productivity. We also employ a quasi-experimental research design to identify companies which are exposed to the technological environment of a region and those which do not experience this effect; by doing this, we could disentangle two effects — the average effect of technology adoption and the moderation effect of the regional technological environment on firm performance. Figure 2 describes the research strategy of the whole study.

[5] Deloitte proposed an approach to evaluate business model with the use of four parameters; these four parameters are consistent with the building blocks of the "The business model canvas" approach, developed by A. Osterwalder and I. Pinie. Specifically, "product" and "consumer" highlighted in the Deloitte approach are synonymous with the "Key Consumers" and "Value Proposition" blocks of the Canvas. The parameters "value chain" and "economy of production" include parts of the Canvas that describe the blocks associated with value creation (what is resulted in the company's product or service), namely: "Key resources", "Key activities", "Key partners", as well as "Cost structure" and "Revenue streams". Thus, Deloitte's approach is largely consistent with one of the most popular approaches to describe the company's business model ― the "The business model canvas" approach.

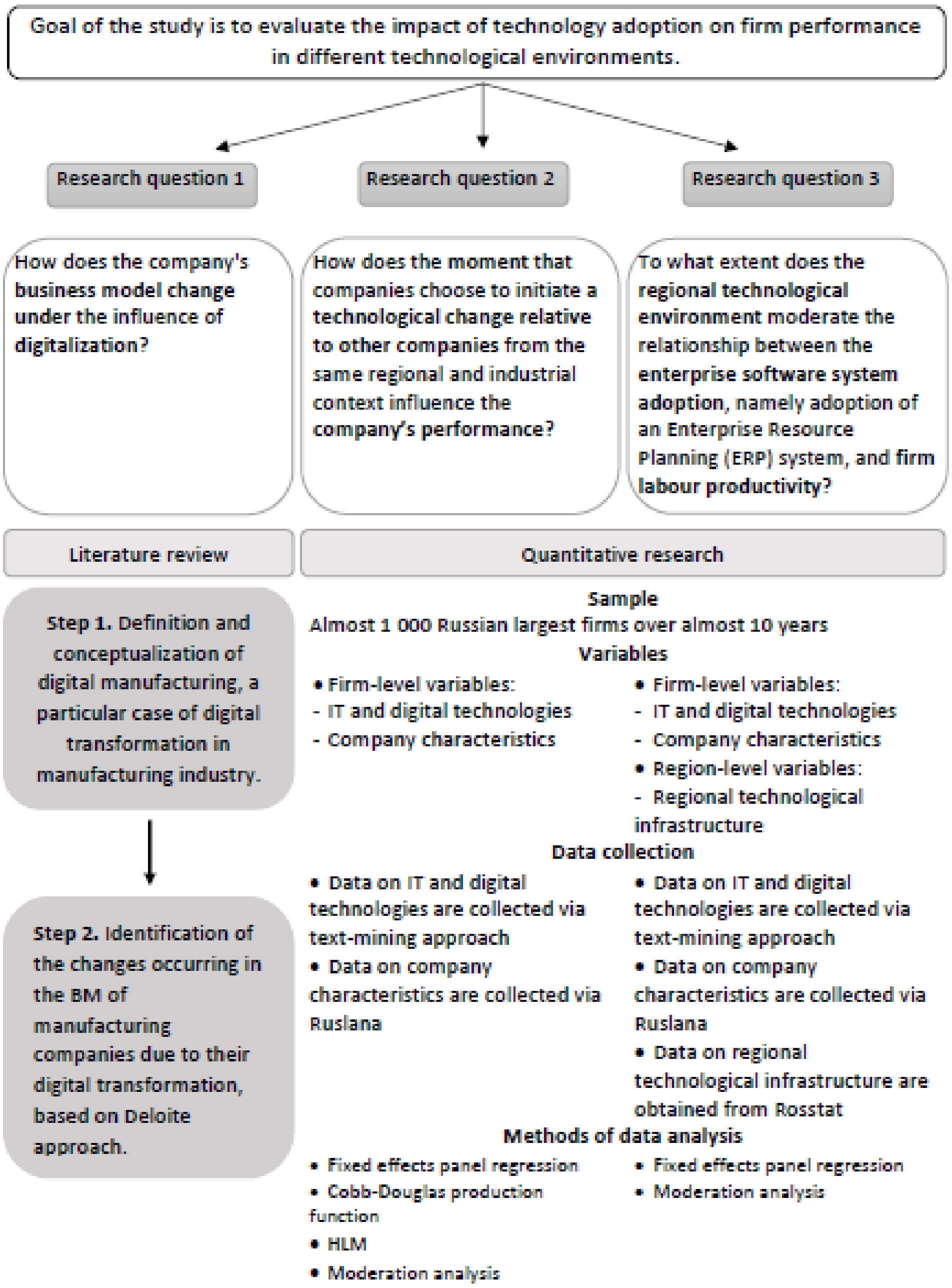

Fig. 2 Scheme of the research strategy[6]

The empirical part of the study is based on the dataset that consists of two parts: firm-level data describing the Russian firms and their technological status and region-level data describing the technological development of the Russian regions. Table 1 presents the dependent, and independent variables used to answer specific RQs of the study.

Table 1 Dependent and explanatory variables and their operationalisation

Variable level	**Variable**	**Description**	**Usage of the variable**	
Firm-level characteristics			2nd RQ	3rd RQ

[6] Elaborated by the author.

Company performance	Productivity	Labour productivity (sales per employee)	✓	✓
	Sales	Firm sales (in mln. Rubles)	✓	
IT and digital technologies	Enterprise Resource Planning – ERP	Number of mentions of the system associated with the company name on the Internet	✓	✓
	SAP	Number of mentions of the technology associated with the company name on the Internet	✓	✓
	ORACLE	Number of mentions of the technology associated with the company name on the Internet	✓	✓
	NAVISION	Number of mentions of the technology associated with the company name on the Internet	✓	✓
	Customer Relationship Management – CRM	Number of mentions of the technology associated with the company name on the Internet	✓	
	Supplier Relationship Management – SRM	Number of mentions of the technology associated with the company name on the Internet	✓	
	Electronic Document Circulation – EDC	Number of mentions of the technology associated with the company name on the Internet	✓	
	Human-Computer Interaction – HCI	Number of mentions of the technology associated with the company name on the Internet	✓	
	Internet of Things – IoT	Number of mentions of the technology associated with the company name on the Internet	✓	
	Loc_fed	Local or federal status of a company (=1 if local)		✓
Region-level characteristics				
	ICT_cost	Information and communications technology expenditures (in mln. rubles)		✓
	High_speed_internet	Share of companies in the region with a broadband download speed of no less than 2 Mbit/s (%)		✓

	r_ERP	r_ERP Share of companies in the region that use ERP systems (%)		✓

We collected longitudinal data on the 964 largest Russian companies (both public and private) for the years 2009–2017. The list of companies was formed based on the RAEX-600 and RAEX-400 (the previous version of RAEX-600), independent ratings annually prepared by the highly esteemed RAEX rating agency (RA Expert) and the leading Expert magazine. To create a sample, we took all the companies included in RAEX-400 and RAEX-600 at least once from 2009 through 2017. After carefully checking all companies in this rating, the final list of 964 companies was developed. The sample embraces companies affiliated with 19 industries and majority of the Russian regions. Regarding industries, we could say that the largest sector is a wholesale trade, which accounts for approximately a quarter of all companies; manufacturing companies − the next largest sector − accounts for 18,98% of all companies of the sample. Companies involved in finance and insurance operations and construction businesses have approximately the same proportion and together account for around one fifth. Sectors that engage in providing professional, scientific, and technical service and utilities follow then, with 7,26% and 7,05%. All other industries are represented by the remained companies quite equally.

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 as well as 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 technologies in companies quantitatively over almost 10 years. In particular, 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. The coding framework employed follows several steps:

(1) the identification of the indicators of ES system adoption (keywords);[7]

(2) the generation of a search request like "keyword + company title + specific year" (e.g. "ERP Gazprom 2017");

[7] Keywords were used both in Russian and English.

(3) the development of a script written in the Python programming language to extract data automatically;

(4) the parsing of the number of mentions of the concrete search request within one sentence of the text via the Microsoft Bing search engine. This approach to data collection resulted in a database that had a panel structure.

We used fixed effects panel regression to test the influence of technological adoption on firm performance, taking into account differences in the technological environment. To be more precise, to answer the second RQ, we specify the Cobb-Douglas production function to test whether the portfolio of digital technologies jointly affects corporate performance. In addition, we used a hierarchical linear model (HLM) estimator to address the heterogeneity of the effects of technology adoption on firm outcomes across industries and regions. The moderation effect of the correspondent technology adoption with the average lag or lead from the representative company in the industry or region would, in turn, propose either the excess momentum or excess inertia phenomena.

To answer the third RQ, we used the panel data fixed effect estimator to control for potential endogeneity through company fixed effects. The overall impact of technology adoption with regard to the technological environment is calculated as a linear combination of the estimated parameters.

Scientific novelty and main findings to be defended. The scientific novelty comes from three aspects, namely theoretical, methodological, and empirical. The dissertation contributes to management science in the field of technology management by developing a novel research design which allows us to explain the complex relationship between the technological environment and technology-driven firm performance. Scientific novelty in methodology, in its turn, consists of two aspects. First, we suggest a new way of proximizing the fact of technology adoption in a company; this approach requires utilising the text-mining approach to extract data stored in internet-based information sources. Second, we suggest how to empirically test a firm's excess momentum and excess inertia behaviour and proxy it through the technology adoption behaviour of other companies in the same industrial or regional environment. Empirical results based on a quantitative study of almost 1 000 Russian largest firms over nearly 10 years have revealed the firm technological strategy which is demonstrated by most Russian companies. In addition, the empirical results allowed us to measure the technology-driven firm performance, taking into account its technological environment.

The author obtained the following main findings to be defended:

- Russian companies, implementing various information technologies with varying degrees of intensity, are at different stages of digital transformation;

- The industry effect is a major determinant of firm productivity, whereas the region effect mainly influences sales.
- In terms of the technological strategic behavior of companies, Russian companies are more likely to exhibit excess inertia rather than excess momentum; the excess inertia reflects the "follower" strategy and the inert reaction of companies regarding the changes taking place in the competitive environment of the firm;
- While considering different technological environments, the total effect of technology adoption on productivity varies from almost 3 % to 9 %.
- The regional technological environment could enhance the effect of the adoption of some ERP systems.

Summary of the publications. The first paper aims at identifying the role of digital transformation, specifically, digital manufacturing, in changes in the business models of industrial companies. Authors define and conceptualise the notion of “digital manufacturing”. The exploratory research employs the approach developed by Deloitte Company; this approach is based on the value creation approach. Customers, products, economy of production, and value chain are essential methodology parameters. Our analysis shows that implementing digital manufacturing will necessarily change the company's entire business model and marketing activity that is realized in the main blocks of business model of any firm. Literature analysis was focused on finding changes in the business models of manufacturing companies; based on the analysis, the following changes were revealed: 1) changes in the approach to production: from manufacturer-centric business model towards consumer-centric business model; 2) the emergence of the new opportunities for building relationships with the customers, in particular, the creation of the opportunity to interact with the end customers without intermediaries, involvement of the end consumers in the process of new product development; 3) the emergence of the new opportunities of developing and producing new products, for example, new technical opportunities to create personalized products that combine the features of goods and services; 4) changes in the internal processes aimed at the creation of the new products; these changes are associated with the use of additive technologies and computer modeling to create prototypes in a short time, the use of a large amount of consumer data for the production of economically profitable personalized goods, etc..

The second paper is based on the literature on organisational change, technological change, and inertia. It explores how the moment that companies choose to initiate a technological change relative to other companies from the same regional and industrial context influences the company’s performance. In particular, we test the excess inertia and momentum phenomena that refer to companies' timely and untimely technological shifts. A data set comprising about 1000 of the largest Russian companies, affiliated with 19 industries, located in most of the Russian regions, for 10 years starting from 2009, is used. We used a multi-level hierarchical linear modelling approach to estimate the region's environmental and industry effects on sales and productivity. The moderation effects of the correspondent technology adoption with the average lag or lead from the representative company in the industry or region could help us demonstrate what digital technologies are probably associated with the excess inertia and the excess momentum phenomena on the industry and regional level. The results reveal that the industry effect is a major determinant of firm productivity, whereas the region effect mainly influences sales. Our investigation also found that companies are more likely to exhibit excess inertia than excess momentum.

The third paper explores the regional technological environment's effect on technology-driven performance, measured by enterprise resource planning (ERP). Our study specifies a productivity-based production function driven by ERP system adoption. Employing a quasi-experimental research design, we disentangle two effects — the average effect of ERP adoption and the moderation effect of the regional technological environment. 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. The novelty of this study is that the research employs publicly available information retrieved via text-mining tools merged with official financial reports published by companies. The main finding is that the total effect of technology adoption on productivity, while taking into account different technological environments, varies from almost 3 % to 9 %. Moreover, our results revealed that the regional technological environment could enhance the effect of the adoption of some ERP systems. 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. We used automated content analysis 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.

Theoretical contributions and practical implications. The theoretical contribution of this study is that, first, the study has advanced theoretical knowledge on digital transformation as a particular case of an organisational change; second, we have established and explained the mechanism through which strategic resources, in particular, IT and digital technologies, influence firm performance under a different context.

The practical implications of this study are the following: 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 such as ERP could help companies reach a 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). In addition, knowing the level of technological development of the region, firms at the stage of technology implementation, in particular ERP technologies, can assess the impact of their implementation more carefully. 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.

The results of the conducted study are the average effects calculated on the sample of 964 Russian companies, with the possibility to generalize these results to a wider population. At the same time, based on the results obtained, managers of the firms, considering the industrial and regional characteristics of the environment to which their companies belong to, as well as the set and configuration of the internal resources, can take more informed managerial decisions related to the technology adoption. Specifically, if there are some competing projects dedicated to adoption of different technologies, companies can use the return on these technologies as one of the additional parameters to evaluate such projects and make a final decision. Then, an additional criterion for choosing a potential technology for implementation may be the characteristics of the external environment, including the regional one, and the performance outcome that a firm wants to improve. In particular, as the technological characteristics of the region are able to enhance the effect of the ERP adoption, with the different extent, and, therefore, increase the firm productivity, the companies, knowing the technological parameters of their regions, can predict the effect from technology adoption with greater accuracy.

Further, managers knowing that the industry affiliation of the companies in the context of technology adoption explains a large proportion of performance variation can determine/choose IT and digital technologies for adoption based on the industry benchmarks; this is a more correct basis for comparison than a regional benchmark. This is especially relevant for companies operating in more than one industry.

Approbation of the thesis research results. The results of the thesis research were presented by the author and discussed at research seminars and scientific conferences, including:

1. Research seminar of the International Laboratory of intangible-driven economy (01.11.2019, HSE-St. Petersburg). Title of the presentation: "Technological environment, digital transformation, and firm profitability: an empirical study of Russian companies".
2. International scientific event “Analytics for Management and Economics Conference” (September-December 2020, digital event, HSE-St. Petersburg). Title of the presentation: "Excess momentum or excess inertia: do companies adopt technologies at the right time?"
3. Russian Summer School on Institutional Analysis (18.09.2021, HSE-St. Petersburg). Title of the presentation: "Does regional environment matter in ERP system adoption? Evidence from Russia"
4. Research seminar of the International Laboratory of intangible-driven economy (05.10.2021, HSE-St. Petersburg). Title of the presentation: "Does regional environment matter in ERP system adoption? Evidence from Russia".

In addition, the results of the study were presented in the report of the RNF grant "Competitiveness and Advanced development of Russian business based on intellectual resources" No. 18-18-00270 (2021-2022) and the subproject "Dynamics and economic effects of digital transformation in new conditions" (assessment of the dependence of industries on foreign software (by class) based on the tadviser database)" that is a part of the strategic project "Digital Transformation: technologies, effects, efficiency" made by HSE.

2. MAIN FINDINGS TO BE DEFENDED

1. Russian companies, implementing various information technologies with varying degrees of intensity, are at different stages of digital transformation.

We found that seven of the nine digital technologies (namely CRM, SRM, EDC, HCI, IoT, ERP, ORACLE) have a significant positive or negative impact on firms’ sales or productivity on the industry level (table 2). The same technologies, except ORACLE, act as the drivers and the inhibitors of corporate performance on the regional level (table 3). The positive effect of the adoption of CRM, SRM, and EDC on firm performance both on the industry and on the regional level is supported by studies indicating that these technologies contribute to better management of information at two levels — of the company as a whole and the company's particular business processes (Aral et al., 2006; Ali & Miller, 2017). At the same time, the negative effect of ERP adoption on firm productivity is contrary to previous studies, which have suggested that implementation and use of ERP technology enhance labour productivity (Aral et al., 2006; Engelstätter, 2009; Taştan & Gönel, 2020). It is somewhat surprising as ERP technology is seen as one that enhances productivity (Hausberg et al., 2019, Nicoletti et al., 2020). This inconsistency may be explained by the fact that the relationship between technology adoption and firm performance could be more sophisticated and indirect (Ruivo et al., 2014; Haislip & Richardson, 2017). However, it also could be a consequence of substantial time lags in the realisation of firm outcomes (Brynjolfsson, 1993). Considering that ORACLE adoption (one of the examples of ERP technology) demonstrates a result opposite to that of ERP adoption, future research should investigate the effect of ERP adoption on firm outcomes. Nevertheless, in general, it seems that we can observe that not all digital technologies are adopted intensively, nor are they adopted by all companies; this fact is in line with previous studies reporting that contemporary companies are at different stages of digital transformation (Kane et al., 2016; Gurumurthy & Schatsky, 2019).

Table 2 The output of the estimated HLM for excess momentum or excess inertia on industry level

VARIABLES	(1) SALES	(2) PRODUCTIVITY
Explained variation	4,8%	20,1%
CRM	0.000191	0.411*
	(0.0116)	(0.235)
SRM	0.0283***	0.298*
	(0.00869)	(0.180)
EDC	0.0538***	0.147
	(0.0102)	(0.204)
HCI	-0.0321**	-0.511*
	(0.0130)	(0.270)
IoT	-0.0269**	0.926***
	(0.0126)	(0.258)
ERP	0.00453	-0.531**
	(0.0126)	(0.253)
ORACLE	0.0155	0.425*
	(0.0125)	(0.252)
INTERACTION TERM WITH		
Lag in adoption_CRM	0.174	6.042*
	(0.307)	(3.156)
Lag in adoption _SRM	0.894	-49.99***
	(0.817)	(9.614)
Lag in adoption _EDC	-3.181***	90.83***
	(1.077)	(13.04)
Lag in adoption _IoT	-0.735*	0.975
	(0.412)	(4.684)
Lag in adoption _ERP	-0.542	59.37***
	(0.685)	(7.572)
Lag in adoption _SAP	0.722	-19.87***
	(0.638)	(7.566)

CV	included	included
Constant	5,051***	-168,937***
	(1,633)	(20,509)
Observations	7,329	5,617
Number of groups	24	24

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3 The output of the estimated HLM for excess momentum or excess inertia on a regional level

	(1)	(2)
VARIABLES	**SALES**	**PRODUCTIVITY**
Explained variation	25,2%	1%
CRM	-0.00507	0.422*
	(0.0115)	(0.235)
SRM	0.0331***	0.309*
	(0.00879)	(0.183)
EDC	0.0543***	0.153
	(0.0102)	(0.204)
HCI	-0.0361***	-0.512*
	(0.0132)	(0.274)
IoT	-0.0253**	0.951***
	(0.0127)	(0.261)
ERP	-0.000357	-0.539**
	(0.0126)	(0.253)
INTERACTION TERM WITH		
Lag in adoption _EDC	-0.820*	2.372
	(0.470)	(7.226)
Lag in adoption _IoT	0.305*	-1.355
	(0.182)	(2.517)
CV	included	included
Constant	288.0	-2,476
	(880.2)	(14,539)
Observations	7,290	5,617
Number of groups	58	58

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2. The industry effect is a major determinant of firm productivity, whereas the region effect mainly influences sales.

Taking into account several technologies adopted, our data suggest that companies focus more on the industry level than the regional level (table 2 and table 3). That means that the technology environment among companies from the same industry plays a more significant role in technology adoption than the technology environment formed by companies from the same region. Our data demonstrate that industrial factors explain a considerable share of productivity variation. A possible explanation for this is that industrial affiliation stimulates information exchange and knowledge dissemination much greater than regional affiliation; therefore, companies from the same industry could adopt technology more effectively. This phenomenon accords with the study of Wang and Lin

(2008). They found that due to competition, industrial rivals within a specific geographical cluster are not ready to cooperate and share knowledge and information. It seems that rivals located within different regions may interact more actively. However, it contradicts the literature on economic geography that suggests that knowledge dissemination is higher within a regional cluster (Tallman et al., 2004).

3. In terms of the technological strategic behavior of companies, Russian companies are more likely to exhibit excess inertia rather than excess momentum; the excess inertia reflects the "follower" strategy and the inert reaction of companies regarding the changes taking place in the competitive environment of the firm.

With regard to excess momentum and excess inertia, our analysis revealed that companies are more likely to exhibit excess inertia rather than excess momentum (table 2 and table 3). Here, two interesting conclusions can be drawn. First, environmental conditions may change the company's reaction towards adopting a specific technology. For instance, on the regional level, IoT technology was adopted too quickly, while companies from the same industry prefer to implement a “follower” strategy concerning this technology. These results might be because different technologies are at various stages of their development. When technology is considered very promising (like, for example, IoT), even at an early stage of its development, some innovative companies or large companies could invest their IT budget in adopting this technology without expecting immediate payback or return on investment (Espinoza et al., 2020). However, such a time lag of benefits realisation could slow other companies' decision to adopt this technology.

Furthermore, the discrepant responses of companies regarding different technologies’ adoption are largely affected by their nature and potential complementarity or substitution. In this study, we meant to discover just an average effect, even following the inherent heterogeneity of technologies exposed by our experiment. Further analysis may try to decompose this average effect depending on the relevant characteristics of different groups of companies. Second, companies demonstrate more diverse strategic responses towards a greater number of technologies on the industry level. This result may be explained by the fact that industry competition might be quite fierce, stimulating companies to overcome inertia and make a change (Barnett & Freeman, 2001; Colombo & Delmastro, 2002).

As for technology adoption and excess momentum and inertia phenomena, our findings indicate that firms are interested in technology acquisition behaviour — and by adopting advanced IT and digital technology, they undergo digital transformation. While our results depict the situation in Russia, present-day European firms, as well as firms from the United States, take technology-enabled transformation (*Digitalisation in Europe 2020-2021: Evidence from the EIB Investment Survey*, 2021). Another important finding is that we could detect the empirical evidence of excess momentum and excess inertia phenomena, which could be interpreted as a manifestation of market orientation, precisely competitor orientation. It is possible to hypothesise that competitor-oriented firms are more likely to adopt technologies, and various studies confirm the relationship between competitive orientation and technology adoption (Li et al., 2010; Nuryyev et al., 2020). However, as this aspect was beyond the scope of this study, future research could be undertaken to address this issue.

4. While considering different technological environments, the total effect of technology adoption on productivity varies from almost 3 % to 9 %.

According to the study results, there is a positive relationship between technology adoption and firm productivity (table 4 and table 5). 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, while taking into account different technological environments, varies from almost 3 % to 9 %. Our empirical results, implying that the adoption of some ERP systems drives the labour productivity of large Russian companies, are consistent with existing studies on this topic (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). The highest effect, which is 18%, was observed by Engelstätter (2009); Taştan and Gönel (2020) reported a 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 a way how they incorporate and build the adopted technologies into the firm structure and how effectively they create the managerial and knowledge-based capabilities, organisational practices, and routines to be able to capture the value of adopted technologies.

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

VARIABLES	PRODUCTIVITY
NAVISION	
Navision	0.0142
	(0.0250)
NAVISION × High speed internet	-0.000198
	(0.000350)
Local status × NAVISION × High speed internet	-0.000615
	(0.000755)
ORACLE	
ORACLE	-0.0197
	(0.0259)
ORACLE × High speed internet	0.000450
	(0.000362)
Local status × ORACLE × High speed internet	-0.00158*
	(0.000818)
SAP	
SAP	0.0964***
	(0.0223)
SAP × High speed internet	-0.00124***
	(0.000321)
Local status × SAP × High speed internet	0.00286***
	(0.000725)
CV	included
Constant	2.349***
	(0.230)
Observations	6,450
Number of groups	888
Linear combination of coefficients	
NAVISION	.0133734
	(.0250411)

VARIABLES	PRODUCTIVITY
NAVISION	
Navision	0.00683
	(0.00984)
NAVISION × ICT cost	-0
	(0)
Local status × NAVISION × ICT cost	-7.89e-11
	(7.15e-11)
ORACLE	
ORACLE	-0.00121
	(0.01000)
ORACLE × ICT cost	6.43e-11**
	(0)
Local status × ORACLE × ICT cost	-1.54e-10**
	(7.40e-11)
SAP	
SAP	0.0292***
	(0.00937)
SAP × ICT cost	-7.77e-11***
	(0)
Local status × SAP × ICT cost	1.96e-10**
	(7.62e-11)
CV	included
Constant	2.943***
	(0.110)
Observations	6,450
Number of groups	888
Linear combination of coefficients	
NAVISION	.0068342
	(.0098435)

VARIABLES	PRODUCTIVITY
NAVISION	
Navision	0.0218
	(0.0197)
NAVISION × r_ERP	-0.00140
	(0.00113)
Local status × NAVISION × r_ERP	-0.00129
	(0.00255)
ORACLE	
ORACLE	-0.00910
	(0.0207)
ORACLE × r_ERP	0.00137
	(0.00119)
Local status × ORACLE × r_ERP	-0.00510*
	(0.00273)
SAP	
SAP	0.0777***
	(0.0188)
SAP × r_ERP	-0.00399***
	(0.00110)
Local status × SAP × r_ERP	0.00897***
	(0.00249)
CV	included
Constant	2.235***
	(0.236)
Observations	6,450
Number of groups	888
Linear combination of coefficients	
NAVISION	.0191319
	(.0198536)

ORACLE	-.0208357	ORACLE	-.0012068	ORACLE	-.0128292
	(.0259181)		(.0099961)		(.0208306)
SAP	.097997***	SAP	.0292315**	SAP	.0826895***
	(.0223486)		(.0093711)		(.0189152)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.		Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.		Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.	

Note: This table reports estimates of the equation where each ERP system is regressed on the labour productivity, each ERS 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.

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

VARIABLES	PRODUCTIVITY
ERP	
ERP	0.0306
	(0.0196)
ERP × High speed internet	-0.000447*
	(0.000266)
Local status × ERP × High speed internet	0.000356
	(0.000639)
CV	included
Constant	1.910***
	(0.224)
Observations	6,450
Number of groups	888
Linear combination of coefficients	
ERP	.0305478
	(.0196532)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1	

VARIABLES	PRODUCTIVITY
ERP	
ERP	0.0130
	(0.00858)
ERP × ICT cost	-0**
	(0)
Local status × ERP × ICT cost	-0
	(5.84e-11)
CV	included
Constant	2.758***
	(0.0853)
Observations	6,450
Number of groups	888
Linear combination of coefficients	
ERP	.0130146
	(.0085808)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1	

VARIABLES	PRODUCTIVITY
ERP	
ERP	0.0341*
	(0.0178)
ERP × r_ERP	-0.00200**
	(0.000993)
Local status × ERP × r_ERP	0.00160
	(0.00240)
CV	included
Constant	1.837***
	(0.220)
Observations	6,450
Number of groups	888
Linear combination of coefficients	
ERP	.0337291*
	(.0179523)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1	

Note: This table reports estimates of the equation where ERP system is regressed on the labour productivity, ERS 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.

5. The regional technological environment could enhance the effect of the adoption of some ERP systems.

Our findings suggest that the regional technological environment enhances the effect of technology-driven productivity (table 4 and table 5). In fact, we found that 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 with respect to 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 the level of technological development of a region, so one may suggest that such a technological environment stimulates companies to be competitive and productive regarding the other firms in a region. The results of 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).

3. CONCLUSIONS

Main results of the whole study. This study seeks to profoundly explore the phenomenon of digital transformation and its effect on company performance in various contexts. Secondary data indicate that companies, responding to the external challenges, actively initiate digital transformation, but they approach the decision regarding its beginning in a heterogeneous way (Kane et al., 2018). To understand the changes that are associated with digital transformation within the company, we did a literature review to explore the changes in the firm's business model due to its digitalisation, focusing on manufacturing companies. Having expanded the sample of companies both by industry and by region, we empirically test the effect that IT and digital technology adoption has on firm performance, that is, sales and productivity, taking into account the technological environment of a firm. Considering the technological environment, we distinguish a firm's competitive environment on the level of an industry and a region and regional technological infrastructure of a firm. The theoretical basis of this study was built on a theory of structural inertia, a behavioural theory of the firm and a resource-based view.

Conducting this study, we have explored how the moment chosen for technological change – before or after its industry and regional rivals – impacts companies' performance. By reconciling the technology adoption behaviour of companies, regarding their industrial and regional affiliation, with their performance results, we could demonstrate what digital technologies are probably associated with the excess inertia and excess momentum phenomenon on the industry and region level. Our investigation revealed some new insights about the impact of digital technologies and the industry effect and regional effects on corporate performance.

Assessing the effects of the technology adoption, we found out that some technologies, in particular, ERP, demonstrate ambiguous (relative to the effects recorded in the published studies) effects. Paying attention to these results we have attempted to measure the moderating effect of the technological environment on ERP adoption – firm productivity relationship. In particular, 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.

Our study tries to contribute to a deeper understanding of the impact that the technological context, including the competitive environment and regional technological infrastructure, has on technology-driven performance. We used automated content analysis 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.

Limitations. Our research has some limitations. First, the source of potential bias exists in the data collection method. We employed content analysis that calculated the number of mentions of a particular technology with respect to the company name on the Internet. In this sense, the corpus of textual information depends on available data and might be biased towards companies with a high level of voluntary or involuntary disclosure. This method is currently considered one of the most advanced since it allows the collection of vast panel data and captures comparative dynamic effects. 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, our analysis is performed on the largest Russian companies that have emerged in fast-growing industries. Such a rapid development of industries, along with the rapid development of technologies, can impact how managers make their strategic decisions toward technology adoption. In other words, one may assume that Russian companies tend to the "first mover" strategy more than businesses under more stable economic conditions. As the empirical analysis is carried out on the data of large Russian companies, and this specific context imposed certain restrictions on the generalisation of the findings. However, we would not think about the strict internal validity of the results because this setting is rather representative of the Russian economy and leans upon similarities inherited by the majority of large enterprises. The choice of large companies was motivated by the theoretical framework of organisational shifts, initially developed for relatively big, internally diversified firms. Fourth, digital innovations are adopted in an already globalised economy. This means that borders between companies from different countries are blurring. Still, the national and institutional context matters. Thus, the findings may be generalised with a certain amount of caution.

Suggestions for future research. In seeking to assess all the various environmental conditions, as well as how companies respond to them, more quantitative research is called for. Conducting such studies will give us an insight into how different limitations impact companies and how companies make complex technology-related decisions. Continuing to use 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, will be useful for understanding the effect of technology adoption. 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. In addition, qualitative studies could provide more details and insights on how core organisational structures are changing under the pressure of digitalisation with regard to different contexts; such descriptive studies could enhance the general understanding of the transformation process while paying attention to the details and peculiarities of this process.

4. LIST OF THE AUTHOR’S PUBLICATIONS (WITH THE AUTHOR'S CONTRIBUTIONS)

1. Daviy, A. O., Paklina, S. N. & Prokofyeva, A. S. (2017). Digital manufacturing: new challenges for marketing and business models. *Russian Management Journal, 15* (4), 537-552. (According to HSE, the journal is included in the additional list of journals considered for Research Productivity Assessment).

The author of the dissertation study participated in the search for the theoretical background, the selection and the analysis of scientific literature on the studied topic. The results of this article contribute to the first research question posed in the dissertation.

2. Daviy, A., & Shakina, E. (2021). Excess momentum or excess inertia: Do companies adopt technologies at the right time? *European Research on Management and Business Economics, 27*(3), 100174. (Scopus Q1 Strategy and Management, WoS Q2 Management) Both authors have contributed equally to the paper.

The author of the dissertation study was responsible for the development of the theoretical background, the collection and the analysis of scientific literature, the formulation of research hypotheses. In addition, the author participated in the empirical part of the article, namely, in the process of preliminary data analysis and preparation of a database for subsequent econometric analysis. The results of this article contribute to the first research question posed in the dissertation.

3. Daviy, A. (2023). Does the regional environment matter in ERP system adoption? Evidence from Russia. *Journal of Enterprise Information Management, 36 (2),* 437-458. (Scopus Q1 Management of Technology and Innovation, WoS Q2 Management). The author confirms sole responsibility for the manuscript.

The author of the dissertation study is the only author of the paper and was fully responsible for the whole research process and results presented in this paper. The results of this article contribute to the first research question posed in the dissertation.