DOI: 10.17747/2618-947X-2024-2-134-151

Decision-making factors for adopting artificial intelligence technologies and transforming sources of sustainable competitive advantage

A.V. Trachuk[1, 2]
N.V. Linder[1, 2]
[1] Financial University under the Government of the Russian Federation (Moscow, Russia)
[2] Goznak JSC (Moscow, Russia)

Abstract

Technologies based on artificial intelligence are increasingly replacing and augmenting humans in managerial tasks such as decision-making. Modern artificial intelligence (AI) technologies are capable of performing cognitive functions previously associated only with the human mind. According to the company's resource concept (RBV), people's cognitive abilities are a source of non-copyable competitive advantages because they are difficult to simulate, so AI technologies can change the sources of competitive advantages. This study aims to identify the factors that influence the decision of industrial companies to adopt artificial intelligence technologies, as well as to examine the relationship between the adoption of AI technologies with the effects of replacing and/or complementing the cognitive abilities of employees and their impact on the formation of a competitive advantage. The study was conducted on the database of 147 industrial companies, empirically estimating the occurrence of the substitution effect during the introduction of AI technologies. The complementarity effect was estimated using two models: a random effect probit model with random effects (random effect probit) and a fixed effect logit model with fixed effects (fixed effect logit). This made it possible to assess the intra-firm dynamics of resource changes during the implementation of AI technologies in the business process – that is, to trace the effect of resource substitution during the implementation of AI. The results showed that: (1) The decision to invest in AI technologies depends on factors such as the availability of skills to implement AI, the cost of implementing new technologies and the level of current costs in the company as a whole, the expectation of financial and economic impact. (2) The decision to invest in AI is significantly more prevalent among companies that are currently waiting to implement it. The benefits of such investment are manifold. Firstly, it allows for a reduction in the time taken to complete operations. Secondly, it enables a reduction in the number of employees required, due to a reduction in the volume of routine operations. Thirdly, it allows for a reduction in the cost of personnel management. Finally, it facilitates a greater speed of development and promotion of new products. (3) The introduction of AI has the greatest impact on the formation of non-copied competitive advantages, particularly in the following areas: marketing and analytics, development and IT, sales and customer service and the development of new products. (4) The introduction of AI gives rise to both a substitution effect and a complementarity effect, which together result in a shift in the sources of competitive advantages. While the replacement of traditional, domain-specific human cognitive capabilities with numerous computing capabilities of AI leads to the destruction of existing advantages, the complementarity of human and machine capabilities allows for the creation of new, permanent non-copied advantages. The company's resource concept is augmented, and it is shown that heterogeneous unrelated resources, such as human capital and machinery, can also serve as a source of distinctive competitive advantages.

Keywords: machine learning, neural networks, industrial companies, company resource theory, substitution effect, complementarity effect.

For citation:

Trachuk A.V., Linder N.V. (2024). Decision-making factors for adopting artificial intelligence technologies and transforming sources of sustainable competitive advantage. *Strategic Decisions and Risk Management*, 15(2): 134-151. DOI: 10.17747/2618-947X-2024-2-134-151. (In Russ.)

Acknowledgment

The article was prepared on the basis of the results of research carried out at the expense of the budget within the framework of the state mission of Financial
University under the Government of the Russian Federation.

引入人工智能技术的决策因素及其对可持续竞争优势来源的转型

A.V. Trachuk[1, 2]
N.V. Linder[1, 2]
[1] 俄罗斯联邦政府财政金融大学 (俄罗斯，莫斯科)
[2] Goznak股份公司（俄罗斯，莫斯科）

简介

基于人工智能（AI）的技术在管理任务（如决策制定）中越来越多地替代和补充人类。现代人工智能技术能够执行以前仅与人类思维相关的认知功能。根据资源基础观（RBV），人类的认知能力是难以复制的竞争优势来源，因为它们难以模仿。因此，人工智能技术能够改变竞争优势的来源。

本研究旨在探讨影响工业公司引入人工智能技术决策的因素，以及研究引入人工智能技术与替代和/或补充员工认知能力的效果及其对形成竞争优势的影响之间的关系。本研究基于147家工业公司的数据进行。采用两种模型对引入人工智能技术时出现的替代效应和互补效应进行了实证评估：随机效应Probit模型和固定效应Logit模型。通过这些模型，可以评估公司内部在将人工智能技术引入业务流程时资源变化的动态，从而追踪人工智能引入过程中资源替代的效果。

研究结果表明：(1)决定投资人工智能技术的因素包括：实施人工智能的能力、引入新技术的成本、公司整体的现有成本水平，以及对财务和经济效益的预期。(2) 预期通过人工智能技术减少操作时间、减少员工数量（因为减少了常规操作的工作量）、降低人力资源管理成本，以及加快新产品的开发和推广速度的公司，其投资人工智能的决策和投资强度显著更高。（3）　将人工智能引入市场营销和分析、研发和IT、销售和客户服务以及新产品开发，对形成不可复制的竞争优势影响最大。（4）在引入人工智能的过程中，同时出现了替代效应和互补效应，这改变了竞争优势的来源。虽然用人工智能的计算能力替代传统的行业特定人类认知能力会破坏现有优势，但通过人类和机器能力的互补，能够创建新的、持久的不可复制优势。本研究补充了资源基础观，表明异质的、不相关的资源（如人类和机器）也可以成为独特竞争优势的来源。

关键词： 机器学习、神经网络、工业公司、资源基础理论、替代效应、互补效应。

引用文本：

Trachuk A.V., Linder N.V. (2024). 引入人工智能技术的决策因素及其对可持续竞争优势来源的转型.战略决策和风险管理, 15(2): 134–151. DOI: 10.17747/2618-947X-2024-2-134-151.

致谢

该论文是使用财政大学政府任务拨款资助的研究结果编写的。

Introduction

Artificial intelligence (AI) technologies are becoming increasingly important in optimising business processes. According to the consulting company ‘Yakov and Partners’, the Russian AI market in 2022 is estimated at 30-50 billion roubles per year, and is expected to grow to 26-36 trillion roubles by 2028.[1] At the same time, the speed of development of AI technologies is making them increasingly accessible to companies that use AI to solve problems in business functions.

A kind of inflection point in the development of these technologies was passed with the creation of generative AI technology. Modern artificial intelligence technologies are capable of performing cognitive functions previously associated only with the human mind [Rai et al., 2019]. Management researchers have suggested that AI is changing the sources of competitive advantage [Davenport, Kirby, 2016, p. 204; Wilson, Daugherty, 2018, p. 214], but their views on how this change is occurring are contradictory.

[1] Artificial Intelligence in Russia – 2023: Trends and Perspectives. Moscow, 2023. https://yakov.partners/upload/iblock/c5e/c8t1wrkdne5y9a4nqlicderalwny7xh4/20231218_AI_future.pdf?ysclid=lz13ttscls470347383.

A number of studies have shown that AI is replacing human cognitive skills [Balasubramanian et al., 2022] and described how AI technologies are replacing investors [Noonan, 2017], hiring managers [Chamorro-Premuzic et al., 2019] and doctors, including for diagnosis or surgery [Blakely, 2020].

Other studies argue that AI technologies merely complement rather than replace human cognitive abilities [Murray et al., 2021], with investors, managers and doctors using AI to assist with investments, hiring or treatment [Topol, 2019].

According to the resource-based view of the firm (RBV) [Barney, 1991], people's cognitive abilities are a source of non-copyable competitive advantages because they are difficult to imitate. These advantages are a source of competitiveness and allow firms to become leaders due to higher productivity, unique strategies, innovation efficiency and the formation of a better value proposition [Kunc, Morecroft, 2010; Helfat, Peteraf, 2015].

If AI technologies replace human cognitive abilities, then from the perspective of the resource concept, human cognitive abilities cease to be non-copyable competitive advantages because the technologies created and commercialised have low imitation barriers [Brynjolfsson, McAfee, 2014, p. 31]. Conversely, if AI technologies complement human cognitive capabilities, then this will be an added value from an RBV perspective [Argyres, Zenger, 2012], because widely applicable AI technology enables the creation of unique bundles of previously unrelated resources, such as the expertise of doctors and the machine prediction of AI [Agrawal et al., 20-24]. That is, this claim is based on the unique properties of AI technology itself.

Stadler et al [2021] show that when organisations use both familiar and new technologies, a dual effect of resource substitution[2] and complementation occurs[3]. However, in the case of the use of AI technologies, the authors found a substitution effect, but no complementation effect.

However, the results of such studies do not provide answers to questions about the relationships between substitution and complementarity effects, the drivers of these relationships, and possible pathways to new non-copyable advantages.

The article aims to analyse the factors that influence industrial companies' decisions to implement artificial intelligence technologies, the relationship of these technologies with the effects of substitution or complementarity of employees' cognitive abilities, and the impact on sources of competitive advantage.

1. Theoretical review of the literature

Artificial intelligence technologies are systems and services based on machine learning models. Machine learning models have a long history of development, from finding a linear relationship between several factors to using neural network architecture with billions of parameters, which allows them to find complex relationships in data. Today, the following types of models are used in business[4]:

- Predictive AI models are used to predict future events or outcomes based on historical data. They can be used in a variety of fields, including finance, healthcare, marketing and many others. In finance, for example, they are used to predict exchange rates and stock prices or to identify fraudulent transactions; in manufacturing, they are used to predict raw material requirements, prevent breakdowns and plan repairs; in commerce, they are used to predict demand for goods or services;
- AI optimisation models are used to solve optimisation problems or to find the best solution among a number of possible options; they are also widely used in various fields: for example, in medicine – to determine the most effective method of treatment or the best way to perform surgery and prevent complications; in logistics – to optimise routes, predict traffic congestion; in procurement – to reduce costs; in manufacturing – to optimise production processes and reduce costs;
- Generative AI models – models that use the data used for training to create new data of different modalities; in business, they are mainly used to generate text and images;
- Large Language Models (LLMs) – machine learning algorithms that can generate text based on input; used to generate, summarise or modify text;
- Natural Language Processing NLP (Speech, Recommendation and Personalisation) – Technologies that analyse and interpret human language; used in chatbots, customer support, search engines, etc;
- Computer vision CV – an area of AI concerned with the analysis of images and video by computers, including pattern recognition, image segmentation, etc.; used in medicine, robotics, security, etc.

All the models described are based on three types of machine learning models:

1) the model is trained on a database with target response values;
2) the model is trained on data without a target outcome (the model itself looks for patterns in the data);
3) training on feedback based on rules or the trainer's judgement.

Thus, unlike previous technologies, AI technologies enable machines to learn and act autonomously [Balasubramanian et al., 2022], which in turn enables AI to interact with humans in decision making and problem solving [Murray et al., 2021]. As a result, AI has the potential to both replace and augment human cognitive abilities [Raisch, Krakowski, 2021].

Existing literature in the resource-based approach argues that the substitution effect eliminates competitive advantage when new resources with high availability

[2] The substitution effect occurs when the use of one resource leads to a reduction in the use of another (substitute resources).
[3] A complementarity effect occurs when the use of one resource increases the use of another (complementary resources).
[4] Artificial intelligence in Russia… https://yakov.partners/upload/iblock/c5e/c8t1wrkdne5y9a4nqlicderalwny7xh4/20231218_AI_future.pdf?ysclid=lz13ttscls470347383.

replace traditional resources providing the same functionality, while the complementarity effect creates competitive advantage when traditional and new resources are integrated to form new unique resource bundles [Peteraf, Bergen, 2003; Levinthal, Wu, 2010; Polidoro, Toh, 2011; Argyres, Zenger, 2012].

Works [Brynjolfsson, McAfee, 2014; Agrawal et al., 2018; Choudhury et al., 2020; Raisch, Krakowski, 2021] describe AI as a new technological resource of strategic importance that can learn and act independently of humans. Humans and AI differ in the way they process information to generate knowledge, as AI can process much larger amounts of information with greater speed and accuracy, while humans use information processing 'templates' that may introduce potential errors or biases, but also make humans more versatile in complex information environments [Raisch, Krakowski, 2021]. From an RBV perspective, these different characteristics suggest the interplay of substitution and complementarity effects.

Substitution effect in the adoption of AI technologies

The substitution effect in the resource-based concept of RBV is based on the concept of resource substitutability [Peteraf, Bergen, 2003; Polidoro, Toh, 2011], i.e. the ability of resources to replace others that provide the same functionality [Levinthal, Wu, 2010]. Resources with low substitutability are specific or unique, whereas resources with high substitutability can be widely used. At the same time, resources that are highly substitutable can be moved between activities at no additional cost, while resources that are difficult to scale will incur costs for their use in other activities. Thus, general human cognitive abilities have high interchangeability, while cognitive abilities in a narrow, specific domain have low interchangeability and may also be unsuitable for scaling [Helfat, Peteraf, 2015]. This limits the use of their skills in related areas of the company's activities [Wernerfelt, Montgomery, 1988], because their use for substitution in unrelated areas requires additional study and accumulation of experience, with significant economic costs that quickly outweigh any potential benefits [Helfat, Peteraf, 2015].

The introduction of AI technologies can create a substitution effect for cognitive skills. For example, the combination of speech technologies and generative AI makes it possible to write a business letter, suggest ideas for promoting a business in a particular niche, and create personalised offers for customers. In addition, AI is now widely used for forecasting, making strategic decisions, and solving problems that traditionally only humans could do, relying on their cognitive abilities [Shrestha et al., 2019]. Unlike humans, machines have a virtually unlimited capacity to process information and often make better predictions than humans [Raisch, Krakowski, 2021]. For example, AI-powered machines now match or outperform doctors in diagnosing and treating cancer, predicting a candidate's ability to perform in an available position [Chamorro-Premuzic et al., 2019], generating alternative product designs [Verganti et al., 2020], and predicting angel investment opportunities [Blohm et al., 2022]. Thus, the precision and diversity of AI technologies are likely to reduce the traditional value of human resource capabilities as a source of non-copyable competitive advantage, or even render these competitive advantages obsolete [Agrawal et al., 2018, p. 80].

However, there are still open questions in the literature about the substitution effect of AI. To what extent do technical limitations prevent machines from fully making decisions or solving problems [Raisch, Krakowski, 2021]? After all, prediction is only one component of decision making, which also includes tasks such as goal setting, data selection, judgement and action generation [Shrestha et al., 2019]. The nature of substitution may differ when machines replace humans, while previous studies have described the substitution of similar resources (between humans, technologies, etc.) [Peteraf, Bergen, 2003; Levinthal, Wu, 2010]. Therefore, the first question that requires study is whether and how AI replaces human cognitive abilities that form non-copyable competitive advantages?

Complementarity in the implementation of AI technologies

According to the resource-based concept, the complementarity effect creates an uncopiable competitive advantage by forming unique combinations of resources [Newbert, 2007]. Companies that want to create new competitive advantages integrate existing and new resources into resource packages that 'uniquely complement each other' [Argyres, Zenger, 2012, p. 1648]. In [Milgrom, Roberts, 1990] it is emphasised that in order to form a package of unique, complementary resources, they must not only be super-modular, but also unrelated. Such unrelatedness ensures that the resulting resource packages are completely new and capable of creating a sustainable, non-copyable competitive advantage [Argyres, Zenger, 2012].

If we apply this theory to the formation of complementation effects in relation to AI, we can assume that complementation can occur both for different types of tasks [Raisch, Krakowski, 2021] and for the performance of a single task [Agrawal et al., 2018]. For example, the diagnosis of equipment failures is performed by AI, while humans focus on performing the repair or replacement of equipment (different types of tasks). Or humans may use AI to diagnose, but use their contextual understanding to avoid bias. That is, in the case of AI, we can talk about the simultaneous dynamics of substitution and complementarity effects [Brynjolfsson, McAfee, 2014; Raisch, Krakowski, 2021]. However, [Shrestha et al., 2019] note that the combination of human and machine capabilities in the context of AI can lead to negative complementarity effects, as AI learning can occur without human supervision.

In this study, we examine whether and how AI can complement human skills with technological resources, and how such complementation is related to the substitution effect.

2. Research methodology

Since there is little research on the factors that drive the decision to adopt AI technologies and no established theory on how sustainable competitive advantages are generated by adopting AI, we use a survey-based approach [Berry et al., 2021] to compare the substitution and complementarity effects of adopting AI technologies.

2.1. Formation of the research sample

For the analysis, 38 in-depth interviews of about one hour were conducted with senior managers of companies. Questions were then developed for a questionnaire which was sent to around 600 industrial companies with more than 500 employees, with a response rate of 19.3% (116 companies). After excluding questionnaires with missing data for any of the questions, the final sample consisted of 109 enterprises. This brings the total number of industrial companies in the sample to 147. The questionnaire data were supplemented with company performance indicators available from open sources on their websites and in the Amadeus and Ruslana BvD databases as of May 2024.

The companies included in the sample belong to industrial production in three sectors: high, medium and low tech; more than half of the companies surveyed have been operating in the market for more than 15 years; the age of the companies in the sample varies from 2 to 205 years, with an average of 44 years.

The share of international enterprises in the sample presented is 13%, the share of foreign enterprises operating in the Russian market is 7%, the share of Russian enterprises operating in the domestic and foreign markets is 28%, and the share of Russian enterprises operating only in the domestic market is 52%. The characteristics of the sample companies are presented in Table 1.

It should be noted that the expenditures on AI implementation by the companies in the sample are characterised by an extremely wide range: less than 1% of the companies surveyed spend more than 10% of their revenues on AI implementation, 7% of the companies spend 5-10% of their revenues, 16% of the companies – 3-5% of their revenues, the majority of the companies surveyed – 67% – invest 1-3% of their revenues in AI technologies, the remaining 9% – less than 1%.

2.2. Research model

The choice of methods for analysing the drivers of new technology adoption largely depends on the problem under consideration. The authors of [Mairesse, Robin, 2009] use the maximum likelihood method (MLE) to simultaneously analyse all aspects of firms' innovation activities, including investment in new technologies. However, we will use the Tobit II model, which answers two different questions: 'Why do firms invest in AI?' and 'What influences the level of investment in AI?' At the same time, the composition of the factors influencing investments in AI and their size can both differ and coincide.

For the analysis, we use a system of structural equations that allows us to assess the factors of AI technology implementation, their impact on the creation of competitive advantages and, consequently, the competitiveness of industrial companies.

Equation (1) estimates the probability that industrial firms will invest in AI technologies:

$$AI\_doing_{it} = \begin{cases} 1, \text{если } AI\_doing^{*}_{it} = x_{it} b_{it} + u_{1it} > \tau \\ 0, \text{если } AI\_doing^{*}_{it} = x_{it} b_{it} + u_{1it} \leq \tau \end{cases}. \quad (1)$$

Table 1
Characteristics of the sample companies

	All industries	High-tech industries	Medium-tech industries	Low-tech industries
Number of companies	147	16	82	49
Percentage of sample companies implementing AI in their business processes	0.32	0.94	0.53	0.27
Total cost of technological, marketing and organisational innovations (million roubles)	87 162 000	42 064 000	28 092 000	17 006 000
including the total cost of implementing new technologies (million roubles)	29 278 100	17 354 600	7 318 000	4 605 500
Average cost of AI (million roubles)	5030	10391	2938	2774
Median real expenditure on AI (million roubles)	267	401	232	104

The explanatory variable *AI_doing* takes the value 1 if firm *i* decides to invest in AI technologies at time *t*, and 0 otherwise.

Equation (2) estimates the volume of investment in AI technologies per employee:

$$AI_{it} = \begin{cases} AI^*_{it} = x_{it}\, b_{2t} + u_{2it}, \text{если } AI\_doing_{it} = 1 \\ 0, \text{если } AI\_doing_{it} = 0 \end{cases}. \quad (2)$$

Equations (3) and (4) reflect the results of the formation of non-copyable competitive advantages: profits from the sale of new products with unique characteristics ($P_{new}pr_{it}$) and the number of patents obtained by the firm ($Patents_{it}$):

$$P_{new}\, pr_{it} = AI_{1it}\, \alpha_{r1t} + z_{it} b_{3t} + u_{3it}\,, \quad (3)$$

$$Patents_{it} = AI_{2it}\, \alpha_{r2t} + z_{it}\, b_{4t} + u_{4it}\,. \quad (4)$$

To analyse the occurrence of the substitution effect when implementing AI technologies ($Substitution\ AI_{it}$) and the complementarity effect ($Complementation\ AI_{it}$) we will estimate the equations of the results of the formation of non-copiable competitive advantages using two models: a probit model with random effects (random effect probit) and a logit model with fixed effects (fixed effect logit).

Fixed effect logit models allow us to estimate the intra-firm dynamics of resource changes when implementing AI technologies in a business process, i.e. to track the resource substitution effect when implementing AI. In addition, the substitution effect can influence a change in a firm's decision to invest in AI, as well as identify inter-firm differences – why some firms invest in AI more often and more than others.

When estimating a random effect probit equation, factors with low within-group volatility are excluded from the analysis in order to estimate the complementarity effect.

To account for potential non-normality and heteroskedasticity in the residuals, standard errors in all models are bootstrapped from 150 replications [Efron, 1979].

Equation (5) shows the achievement of leadership by a firm through the formation of non-copyable competitive advantages, expressed as the change in the firm's market share (Q_t) as a function of the firm's investment in AI, the release of new products ($P_{new}pr_{it}$) and the number of patents received by the firm ($Patents_{it}$).

In addition, we analysed the influence of the substitution effect ($Substitution\ AI_{it}$) and the complementarity effect ($Complementation\ AI_{it}$). Since a firm's market share depends not only on the introduction of new technologies, but also on its investment in current operations, the quality of the labour force it uses, etc., we add variables that show the influence of other factors:

$$Q_t = a_{NPt}\, P_{new}pr_{it} + a_{Pt}\, Patents_{it} + a_{R3t}\, AI_{it} + h_{it} b_{5t} + u_{5it}. \quad (5)$$

The variables in this model are described below.

2.3. Research variables

Independent variables for the two-stage Heckman model

In order to analyse different aspects of companies' decision making regarding the implementation of AI, we used the following indicators, the selection of which was based on in-depth interviews and existing research on the implementation of new technologies:

- x_{1t} – company size, measured as the logarithm of the number of employees. It can have both positive and negative effects on decisions to implement new technologies: large companies have better access to resources, including financial resources, and therefore have more opportunities to carry out large and expensive implementations of new technologies, including AI; small companies are more flexible in adapting to market and consumer demands and can make decisions more quickly, ahead of large companies in implementing AI to bring new products to market;
- x_{2t} – age of the company, measured as the logarithm of the number of years the company has been in business. Like size, it can have both positive and negative effects. K. Schumpeter wrote that the age of a company reflects experience and well-established business processes, which facilitates the introduction of new technologies. At the same time, young companies have flexibility, fresh ideas and are able to take a leading position through innovation and the introduction of new technologies;
- x_{3t} – the presence of research on AI and innovative developments, a dummy variable equal to 1 if the company has its own departments and 0 if not. Conducting research develops employees' skills in AI, and the results of successful research stimulate further investment in AI;
- x_{4t} – availability of skills to implement AI, measured as the logarithm of the number of employees with skills to implement AI technologies. The presence of employees with skills to implement AI technologies stimulates it;
- x_{5t} – the total cost of current activities, measured as the logarithm of the volume of current investments. This indicator is related to the financial capacity of the enterprise, which also influences the introduction of new technologies in the enterprise;
- x_{6t} – the cost of acquiring new technologies is measured as the logarithm of the sum of the costs of acquiring new technologies. Acquiring new technologies develops the skills of employees and serves as a source of new knowledge;
- x_{7t} – The quality of the workforce is measured as the logarithm of the number of employees with higher education. The higher the qualifications of employees, the more they are prone to complex intellectual work and creativity, their presence increases the efficiency of innovation and encourages companies to further invest in new technologies;

- x_{8t} – return on sales, measured as the logarithm of pre-tax profit as a percentage of sales in the previous year. Profits are an important source of funding for AI implementation costs and can increase the attractiveness of AI investments for companies;
- x_{9t} – international activity, a dummy variable equal to 1 if the firm has export revenues and 0 otherwise. The studies show a positive impact of a firm's international activity on its innovation activity, which is explained by the high level of competition in international markets and the need to implement new technologies in order to achieve leadership;
- x_{10t} – liquidity constraint, a dummy variable that measures the availability of financial resources to the enterprise to support its operations and finance innovative business initiatives, equal to 1 if the enterprise has access to financial capital and 0 if it faces liquidity constraints. Access to financial capital is particularly important for investments in new technologies, which are characterised by high resource intensity and risk;
- x_{11t} – availability of infrastructure – communication and available capacity of the enterprise, a dummy variable equal to 1 if the enterprise has its own infrastructure and 0 otherwise;
- x_{12t} – assessment of the level of perceived risk in implementing AI, a dummy variable equal to 1 if the company assesses the level of risk as low or moderate, and 0 otherwise. If the firm perceives the risks to be low or moderate, it will be able to start implementing AI;
- x_{13t} – expected financial impact, a dummy variable equal to 1 if the firm expects a financial impact and 0 otherwise. If the firm is confident that the implementation of AI will have a financial impact, this will positively influence its decision to implement AI;
- x_{14t} – regulatory conditions and level of government support for AI investment, a dummy variable equal to 1 if the firm uses government support and 0 otherwise. Regulatory conditions and government support encourage firms to invest in AI;
- potential economic effects, a dummy variable equal to 1 if the firm expects an effect and 0 if it does not. The expectation of economic effects contributes to the firm's decision to adopt AI, and we identify and analyse the types of effects:
  - x_{15t} – reducing the working time required to carry out operations,
  - x_{16t} – reducing the number of employees by reducing the volume of routine operations,
  - x_{17t} – increasing loyalty through personalised responses to users,
  - x_{18t} – reducing costs of the HR function by creating off-the-shelf training, writing interview summaries, analysing interviews,
  - x_{19t} – increasing the speed of information retrieval from corporate knowledge bases,
  - x_{20t} – increasing the speed of development and promotion of new products.

Independent variables used to model the results of creating non-copyrightable competitive advantages

In order to analyse various aspects of the creation of non-copyable competitive advantages during the implementation of AI, we used the following indicators, the selection of which was determined by the in-depth interviews conducted:

- business processes in which the company uses AI. In general, the industrial companies surveyed are implementing AI in the following business processes:
  - z_{1t} – HR management and internal corporate functions,
  - z_{2t} – sales and value proposition building,
  - z_{3t} – marketing and analytics,
  - z_{4t} – development and IT,
  - z_{5t} – customer service and support,
  - z_{6t} – research and development,
  - z_{7t} – operations management and production,
  - z_{8t} – logistics and supply chains,
  - z_{9t} – finance and procurement,
  - z_{10t} – legal support and risk management,
  - z_{11t} – forecasting and strategy formation,
  - z_{12t} – communications and security,
  - z_{13t} – development of new products.

The distribution of companies using AI in different business processes is shown in Figure 1.

- The stage of AI implementation will also influence the creation of non-copyable competitive advantages. For example, in the study of the company 'Yakov and Partners'[5] five stages of implementation of artificial intelligence are distinguished, on the basis of which we introduce the following variables:
  - z_{14t} – initiation – when there is no AI implementation strategy and no internal expertise, the company is just starting to think about the need to implement AI;
  - z_{15t} – study – the stage of targeted exploration of potentially interesting solutions;
  - z_{16t} – study – the stage of targeted exploration of potentially interesting solutions;
  - z_{17t} – formalisation – plans and budgets for implementing and scaling AI have been approved;
  - z_{18t} – scaling – AI development and scaling becomes part of the business strategy; AI implementation has a real impact.

The distribution of companies by level of AI adoption is shown in Figure 2.

- Another factor reflecting the influence of substitution or complementarity effects in the creation of non-copyable competitive advantages is the amount of resources required:

[5] Artificial intelligence in Russia… https://yakov.partners/upload/iblock/c5e/c8t1wrkdne5y9a4nqlicderalwny7xh4/20231218_AI_future.pdf?ysclid=lz13ttscls470347383.

– z_{19t} – If the volume of resources used is increased during the implementation of AI, a complementarity effect is observed; otherwise, a substitution effect is observed.

To analyse human involvement in the execution of a business process, we analysed two types of operations:

– the business process is carried out by a person independently, without the use of AI technologies;
– the business process is performed by a human using AI technologies.

- And another variable – z_{20t} – a factor of the presence and implementation of own developments of AI technologies, a dummy variable equal to 1 if the company implements its own developments of AI and 0 otherwise.

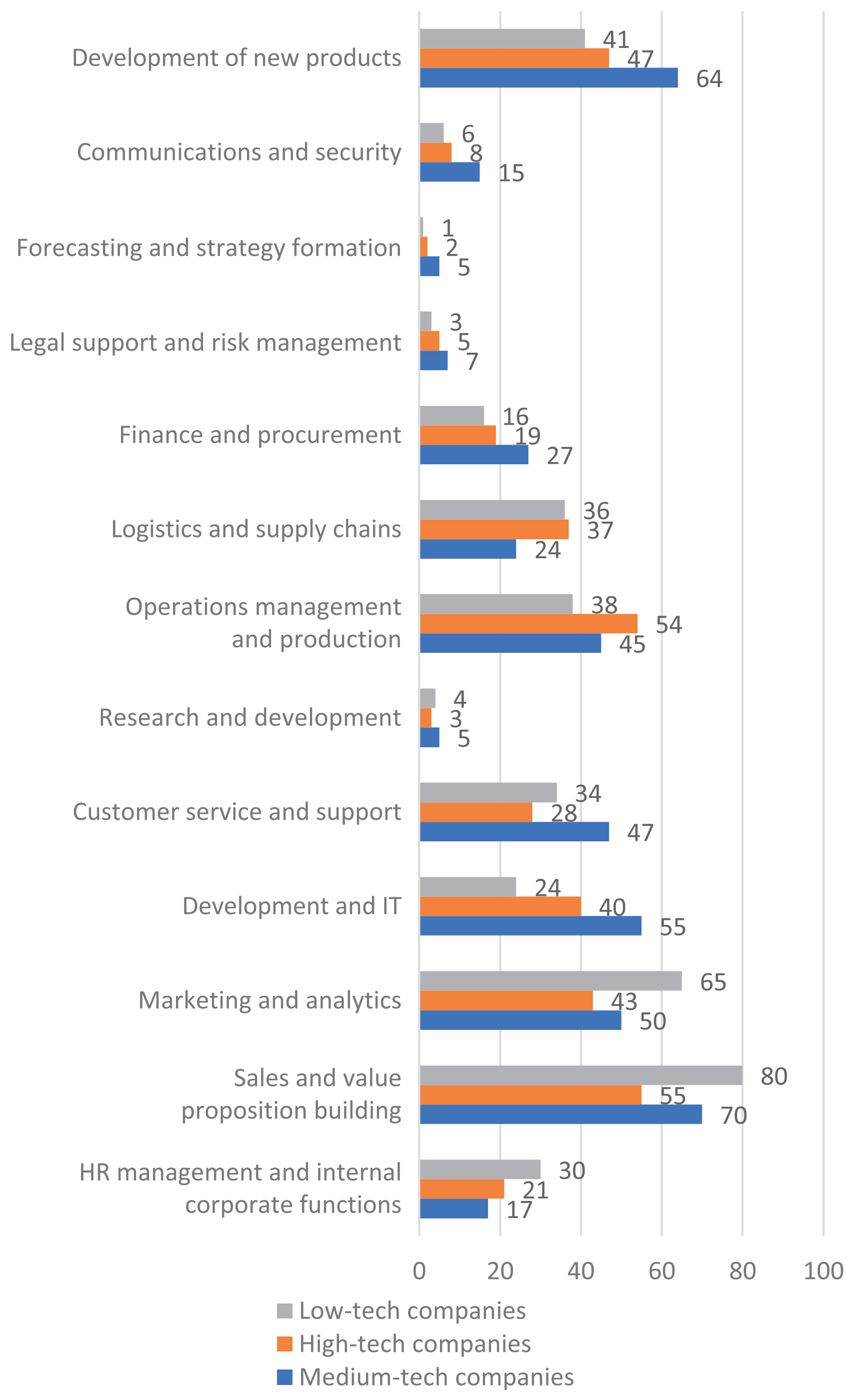
Among the industrial companies that participated in the survey, the share of companies that have and are implementing their own AI developments in the sample was 26%, while the share of companies that only use vendor solutions was 74%.

Control variables

The results of the formation of non-copiable competitive advantages of industrial firms (in our case, market share) may vary depending on the industry and the level of competition in the industry. The following variables were included in the model as control variables.

- The industry in which the company operates. Three main sectors have been identified:
  – High-tech – manufacture of pharmaceuticals, office and computer equipment, electronic components and equipment for radio, television and communications, medical products, aircraft, including spacecraft;
  – Medium high-tech – chemical production, manufacture of machinery and equipment, electrical machinery and equipment, motor vehicles, petroleum products, rubber and plastic products, metallurgical production, manufacture of fabricated metal products;
  – Low-tech – Manufacture of food products, tobacco products, textiles, clothing, wood and wood products, pulp, paper and paper products, publishing and printing, secondary raw materials processing.

Fig. 1. Business processes in which the surveyed companies use AI technologies



- The level of competitive intensity in the $COMP_i$ industry, measured as the combined market share of the three largest competitors in the industry.
- Government participation in the capital of the enterprise is measured as the government's share in the total capital of the enterprise.

The analytical model of the study is shown in Figure 3.

3. Research results

The main model of the first equation of the model is Tobit II, estimated using a two-stage method. In the first stage, the analysis of the sustainable drivers of investment in AI is carried out on data for 2021-2023. In this case, the selection equation is estimated using a random effects probit model.

The coefficient estimates of the equations are very different. The Tobit II investment intensity equation differs significantly from the selection equation (χ^2 (31) = 1894.28, p = 0.000).

The results of the evaluation of the AI investment decision model for 2021-2023 are presented in Table 2.

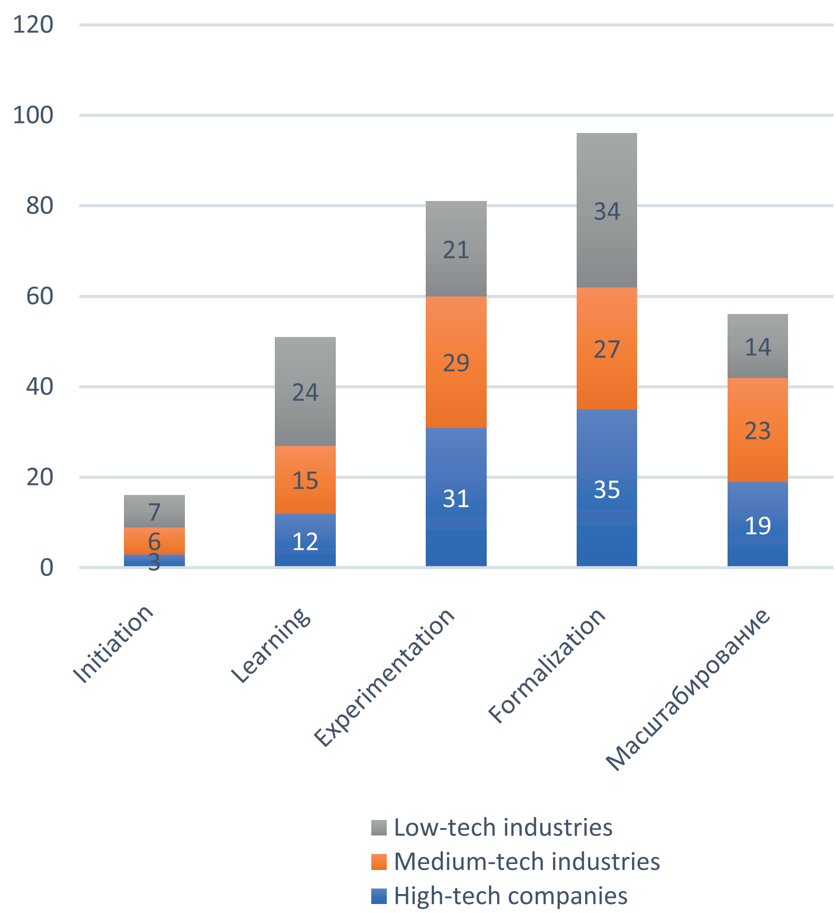
An analysis of the equation assessing the factors influencing the decision to implement AI based on a full random effects model allows us to conclude that, in general, investments in AI technologies are most positively influenced by: the availability of skills to implement AI, the cost of implementing new technologies and the level of current costs in the company as a whole, the expectation of financial effects and the availability of infrastructure.

Company size has a moderate impact, suggesting that larger companies are, on average, more likely to make a positive decision to implement AI in their business processes. However, company size has no impact on the volume of AI investment.

There are also no significant differences in the influence of AI investment factors by industry. In high-tech industries, the intensity of AI investment does not depend on whether the company is an exporter or not. In medium- and low-tech industries, the intensity of AI investment is significantly higher for exporting enterprises than for non-exporters.

The decision to invest in AI is much more often taken by enterprises that expect a potential economic effect from the implementation of AI. For example, the decision to invest in AI and its intensity is much higher for companies that expect to: reduce the time to complete operations; reduce the number of employees due to a reduction in the volume of routine operations; reduce the cost of the HR function; increase the speed of developing and promoting new products.

Fig. 2. Distribution of industrial companies in the sample by levels of adoption of AI technologies



The impact of increasing the speed of information retrieval within corporate knowledge bases does not have a significant impact on the intensity of investment in AI.

Table 3 presents an assessment of the impact of the introduction of AI technologies on the outcomes of the formation of non-copyable competitive advantages, as well as the impact of the effects of substitution (*Substitution* AI_{it}) and complementation (*Complementation* AI_{it}).

When analysing the different versions of the equation for the results of the creation of non-copyable competitive advantages, it should be noted that the fixed effect model has a lower explanatory power due to the weak variation of the factors, although it is not statistically rejected either for the equation of profits from the sale of new products with unique characteristics (χ^2 (19) = 24.89, $p = 0.0091$), or for the equation of patents received (χ^2 (19) = = 29.23, $p = 0.0088$).

It can be concluded that both substitution and complementarity effects are occurring simultaneously in the implementation of AI in Russian industrial enterprises. At the same time, the substitution effect is most evident in such functional areas as customer service and support, marketing and analytics, human resources management and internal corporate functions, and communications and security. It should be added that the emergence of the substitution effect is clearly observed only at the stage of scaling AI for industrial companies in all sectors considered.

It should be noted that the introduction of AI technologies has a significant impact both on the creation and sale of new products with unique characteristics and on the registration of patents. At the same time, the adoption of AI has a greater impact on the creation of new products with unique characteristics than on the number of patents registered. The introduction of AI has the greatest impact on the number of patents registered in functions such as development and IT, research and development, forecasting and strategy formulation. The complementarity effect is more important for patent registration in the early stages of implementation, and the substitution effect only in the scaling stage.

The fifth equation for the change in market share is analysed using a short random effects model, which includes only the most important factors, to analyse the influence of

Fig. 3. Analytical research model

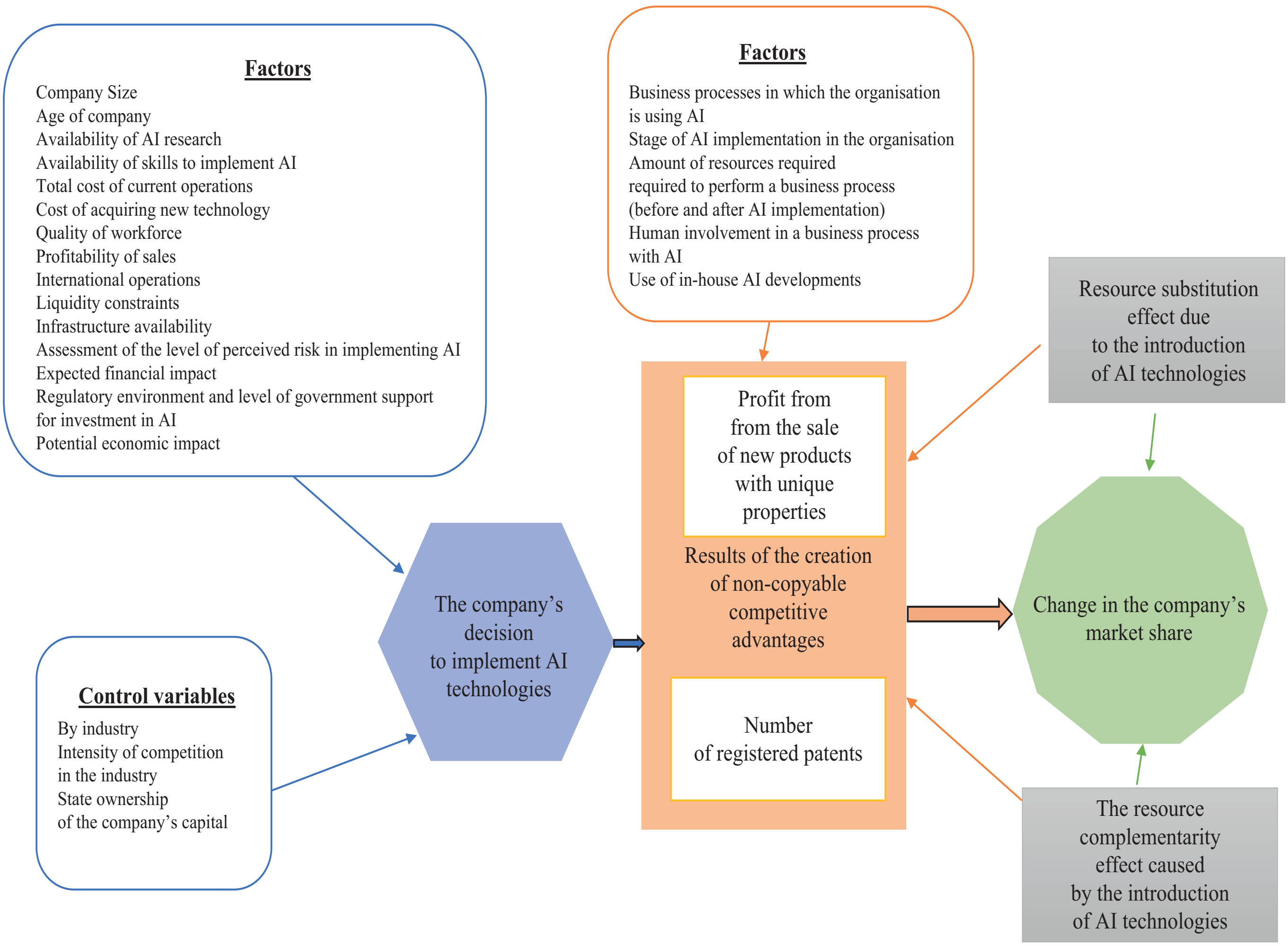


Table 2
Investment decisions based on AI technology (two-stage Heckman model (Tobit II)), 2021–2023

Dependent variable	**High-tech industries**		**Medium-tech industries**		**Low-tech industries**	
Companies' AI investment decisions and investment volumes						
Method of analysis - random effects model	1 Stage	2 Stage	1 Stage	2 Stage	1 Stage	2 Stage
Firm size – x_{1t} (logarithm of average number)	0.187*** (0.007)	0.064* (0.072)	0.142*** (0.081)	0.062* (0.103)	0.145*** (0.111)	0.014** (0.107)
Age of the firm – x_{2t} (logarithm of the average number of years)	0.024*** (0.012)	0.117 (0.037)	0.033*** (0.021)	0.276* (0.043)	0.127*** (0.032)	0.074*** (0.022)
Availability of research on AI and innovative developments – x_{3t} (1 – yes, 0 – no)	0.151*** (0.102)	0.124 (0.112)	0.172** (0.115)	0.177 (0.107)	0.109** (0.134)	0. 171** (0.017)
Availability of skills to implement AI – x_{4t} (1 – yes, 0 – no)	0.216*** (0.046)	0.242 (0.017)	0.361*** (0.029)	0.373* (0.031)	0.309*** (0.033)	0.291*** (0.028)
Total cost of current activities – x_{5t} (log of total cost of current activities)	0.284*** (0.051)	0.297 (0.023)	0.311*** (0.049)	0.304* (0.037)	0.249*** (0.021)	0.264*** (0.012)
Cost of acquiring new technologies – x_{6t}, (logarithm of total cost of acquiring equipment)	0.202** (0.064)	0.219 (0.043)	0.216*** (0.141)	0.274 (0.048)	0.219*** (0.059)	0.174*** (0.106)
Workforce quality – x_{7t} (log of number of employees with tertiary education)	0.134*** (0.009)	0.115*** (0.029)	0.211*** (0.013)	0.118*** (0.104)	0.123*** (0.027)	0. 129*** (0.079)
Profitability of sales – x_{8t} (log of pre-tax profit as a percentage of turnover in the previous year)	0.164*** (0.041)	0.159 (0.139)	0.104*** (0.071)	0.132** (0.298)	0.128** (0.030)	0.076 (0.122)
Availability of export earnings – x_{9t} (1 – yes, 0 – no)	0.093* (0.041)	0.077** (0.088)	0.292*** (0.094)	0.374*** (0.298)	0.152* (0.030)	0.077*** (0.122)
Liquidity constraints – x_{10t} (1 – yes, 0 – no)	0.098 (0.063)	0.084*** (0.032)	0.114*** (0.043)	0.146*** (0.091)	0.131* (0.099)	0.142*** (0.048)
Availability of infrastructure – x_{11t} (1 – yes, 0 – no)	0.203* (0.055)	0.213** (0.065)	0.144* (0.025)	0.158** (0.69)	0.152* (0.030)	0.147*** (0.052)
Assessment of the level of perceived risk in implementing AI – x_{12t} (1 – yes, 0 – no)	0.103 (0.036)	0.157*** (0.042)	0.184*** (0.041)	0.178*** (0.037)	0.157* (0.046)	0.164*** (0.068)
Expected financial impact – x_{13t} (1 – yes, 0 – no)	0.271*** (0.041)	0.269** (0.088)	0.284*** (0.094)	0.293*** (0.298)	0.279* (0.035)	0.276*** (0.112)
Regulatory conditions and level of government support for investment in AI – x_{14t} (1 – yes, 0 – no)	0.065* (0.045)	0.047*** (0.046)	0.016 (0.066)	0.018*** (0.069)	0.014* (0.052)	0.001*** (0.54)
Reduction in working time to carry out activities – x_{15t} (1 – yes, 0 – no)	0.213*** (0.062)	0.246 (0.122)	0.285*** (0.025)	0.219*** (0.094)	0.231* (0.029)	0.292*** (0.047)
Reduction in the number of employees due to a reduction in the volume of routine operations Routine operations – x_{16t} (1 – yes, 0 – no)	0.158*** (0.073)	0.157 (0.097)	0.164*** (0.073)	0.219*** (0.164)	0.148* (0.101)	0.223*** (0.071)
Increase loyalty through personalised responses to users – x_{17t} (1 – yes, 0 – no)	0.094*** (0.059)	0.108 (0.053)	0.123*** (0.066)	0.117*** (0.018)	0.169* (0.051)	0.138*** (0.021)
Reduced costs for the HR function – x_{18t} (1 – yes, 0 – no)	0.183*** (0.081)	0.165 (0.082)	0.178*** (0.072)	0.162*** (0.032)	0.189* (0.046)	0.194*** (0.034)
Increase the speed of searching for information within corporate knowledge bases – x_{19t} (1 – yes, 0 – no)	0.059*** (0.068)	0.026 (0.091)	0.109*** (0.024)	0.101** (0.118)	0.078*** (0.031)	0.038* (0.002)
Increase in speed of new product development and promotion – x_{20t} (1 – yes, 0 – no)	0.238*** (0.092)	0.213 (0.047)	0.183*** (0.062)	0.233** (0.028)	0.265*** (0.044)	0.249** (0.062)
Constant	3.337*** (0.178)	– 2.457 (0.723)	- 6.591*** (0.298)	4.273** (0.524)	- 5.569*** (0.442)	3.845** (0.861)
Pseudo R^2 (%)	39.3	5.17	39.3	5.17	39.3	5.17
Number of observations	16		82		49	

Notes: 1. The figures shown are marginal values. 2. Statistical significance of the coefficients: *** – $p \leq 0.001$; ** – $p \leq 0.01$; * – $p \leq 0.05$. 3. All standard errors (in brackets) are bootstrapped (150 replications).

Table 3
Results of the assessment of the impact of the introduction of AI on the creation of non-copycat competitive advantages

Dependent variable	High-tech industries		Medium-tech industries		Low-tech industries	
Method of analysis: Substitution effect - random effects model Complementarity - fixed effects model	Substitution effect	Complementation effect	Substitution effect	Complementation effect	Substitution effect	Complementation effect
Profit from the sale of products with unique properties						
AI investment intensity – AI_{it}	0.223*** (0.087)	0.214* (0.065)	0.192*** (0.071)	0.174* (0.103)	0.143*** (0.051)	0.166** (0. 071)
Human resources management and internal corporate functions – z_{1t} (1 – yes, 0 – no)	0.254*** (0.032)	0.071* (0.043)	0.242*** (0.064)	0.162* (0.051)	0.245*** (0.041)	0.112** (0.053)
Sales and value proposition formation – z_{2t} (1 – yes, 0 – no)	0.038*** (0.025)	0.062 (0.033)	0.053*** (0.021)	0.057* (0.036)	0.071*** (0.034)	0.067*** (0.031)
Marketing and analytics – z_{3t} (1 – yes, 0 – no)	0.221*** (0.068)	0.254 (0.073)	0.172** (0.061)	0.151 (0.053)	0.179** (0.032)	0. 182** (0.051)
Development and IT – z_{4t} (1 – yes, 0 – no)	0.102*** (0.049)	0.195 (0.054)	0.106*** (0.059)	0.204* (0.068)	0.154*** (0.063)	0.211*** (0.072)
Customer service and support – z_{5t} (1 – yes, 0 – no)	0.402** (0.051)	0.119 (0.048)	0.314*** (0.027)	0.123 (0.032)	0.271*** (0.039)	0.083*** (0.046)
Research and development – z_{6t} (1 – yes, 0 – no)	0.155*** (0.046)	0.129*** (0.034)	0.191*** (0.042)	0.178*** (0.061)	0.203*** (0.062)	0. 179*** (0.049)
Operations and production – z_{7t} (1 – yes, 0 – no)	0.121*** (0.057)	0.159 (0.073)	0.165*** (0.062)	0.179** (0.081)	0.215** (0.053)	0.192 (0.066)
Logistics and supply chain – z_{8t} (1 – yes, 0 – no)	0.162*** (0.056)	0.172 (0.063)	0.211*** (0.058)	0.261*** (0.054)	0.222* (0.068)	0.238*** (0.072)
Finance and procurement – z_{9t} (1 – yes, 0 – no)	0.106*** (0.038)	0.102 (0.059)	0.123*** (0.034)	0.164*** (0.078)	0.152*** (0.041)	0.138* (0.057)
Legal and risk management – z_{10t} (1 – yes, 0 – no)	0.176*** (0.051)	0.181 (0.048)	0.166*** (0.037)	0.178*** (0.049)	0.192*** (0.052)	0.188* (0.047)
Forecasting and strategy development – z_{11t} (1 – yes, 0 – no)	0.102*** (0.046)	0.109 (0.055)	0.093*** (0.035)	0.072*** (0.048)	0.112*** (0.051)	0.118* (0.064)
Communication and security – z_{12t} (1 – yes, 0 – no)	0.224*** (0.064)	0.121 (0.059)	0.263*** (0.052)	0.189*** (0.061)	0.296*** (0.083)	0.179* (0.072)
New product development – z_{13t} (1 – yes, 0 – no)	0.274*** (0.098)	0.252 (0.109)	0.228*** (0.065)	0.264*** (0.153)	0.184*** (0.059)	0.198* (0.085)
Stage of initiation – z_{14t} (1 – yes, 0 – no)	0.106*** (0.058)	0.109 (0.053)	0.129*** (0.037)	0.131*** (0.044)	0.136* (0.053)	0.098*** (0.039)
Trial stage – z_{15t} (1 – yes, 0 – no)	0.154*** (0.063)	0.132 (0.097)	0.138*** (0.052)	0.125*** (0.046)	0.146* (0.041)	0.125*** (0.039)
Stage of experimentation – z_{16t} (1 – yes, 0 – no)	0.062*** (0.031)	0.045 (0.037)	0.082*** (0.053)	0.065*** (0.066)	0.053* (0.031)	0.021*** (0.016)
Formalisation stage – z_{17t} (1 – yes, 0 – no)	0.024*** (0.065)	0.032 (0.078)	0.036*** (0.064)	0.048*** (0.073)	0.055* (0.058)	0.067*** (0.081)
Scaling stage – z_{18t} (1 – yes, 0 – no)	0.458*** (0.065)	0.074 (0.043)	0.387*** (0.062)	0.094*** (0.032)	0.381* (0.046)	0.089*** (0.034)
Change in volume of resources required – z_{19t} (logarithm of total resource costs)	0.069*** (0.053)	0.056 (0.084)	0.069*** (0.073)	0.053** (0.049)	0.035*** (0.051)	0.046* (0.042)

Table 3 *(ending)*

Dependent variable	High-tech industries		Medium-tech industries		Low-tech industries	
Method of analysis: Substitution effect - random effects model Complementarity - fixed effects model	Substitution effect	Complementation effect	Substitution effect	Complementation effect	Substitution effect	Complementation effect
Availability and implementation of own AI developments – z_{20t} (1 – yes, 0 – no)	0.052*** (0.074)	0.101 (0.053)	0.087*** (0.044)	0.063** (0.058)	0.031*** (0.052)	0.029** (0.041)
Constant	4.591*** (0.263)	3.843 (0.539)	–2.379*** (0.335)	–5.121** (0.423)	4.841*** (0.381)	2.129** (0.482)
Within *R* (%)	7.13	6.73	7.13	6.73	7.13	6.73
Between *R* (%)	34.79	33.55	34.79	33.55	34.79	33.55
Overall *R* (%)	29.23	24.18	29.23	24.18	29.23	24.18
Number of observations	16		82		49	
Number of patents registered						
AI investment intensity – AI_{it}	0.173*** (0.054)	0.161* (0.059)	0.174*** (0.053)	0.189* (0.073)	0.033*** (0.041)	0.056** (0. 069)
HR & internal functions – z_{1t} (1 – yes, 0 – no)	0.094*** (0.054)	0.073*** (0.042)	0.115*** (0.048)	0.101*** (0.059)	0.132*** (0.073)	0.128*** (0.066)
Sales & value proposition – z_{2t} (1 – yes, 0 – no)	0.089*** (0.055)	0.071 (0.041)	0.074*** (0.038)	0.072* (0.061)	0.097*** (0.042)	0.083*** (0.061)
Marketing & Analytics – z_{3t} (1 – yes, 0 – no)	0.249*** (0.042)	0.234 (0.038)	0.203** (0.032)	0.179 (0.067)	0.199** (0.032)	0. 173** (0.046)
Development & IT – z_{4t} (1 – yes, 0 – no)	0.261*** (0.032)	0.275 (0.048)	0.291*** (0.053)	0.283* (0.041)	0.109*** (0.039)	0.194*** (0.052)
Customer service & support – z_{5t} (1 – yes, 0 – no)	0.122** (0.037)	0.119 (0.051)	0.163*** (0.057)	0.179 (0.063)	0.159*** (0.048)	0.162*** (0.037)
Research & development – z_{6t} (1 – yes, 0 – no)	0.373*** (0.113)	0.285*** (0.123)	0.354*** (0.094)	0.337*** (0.108)	0.382*** (0.064)	0.359*** (0.082)
Operations & manufacturing – z_{7t} (1 – yes, 0 – no)	0.188*** (0.035)	0.197 (0.047)	0.201*** (0.069)	0.193** (0.091)	0.237** (0.064)	0.192 (0.104)
Logistics & supply chain – z_{8t} (1 – yes, 0 – no)	0.097*** (0.049)	0.112 (0.064)	0.148*** (0.042)	0.134*** (0.053)	0.108* (0.039)	0.097*** (0.072)
Finance & Procurement – z_{9t} (1 – yes, 0 – no)	0.013*** (0.009)	0.022 (0.014)	0.038*** (0.024)	0.047*** (0.035)	0.018* (0.045)	0.036*** (0.053)
Legal & risk management – z^{10t} (1 – yes, 0 – no)	0.092*** (0.037)	0.063 (0.042)	0.019*** (0.046)	0.028*** (0.059)	0.013* (0.068)	0.091*** (0.072)
Forecasting & strategy development – z_{11t} (1 – yes, 0 – no)	0.202*** (0.053)	0.213* (0.054)	0.217** (0.037)	0.228*** (0.044)	0.223* (0.044)	0.241*** (0.039)
Communication and security – z_{12t} (1 – yes, 0 – no)	0.061*** (0.025)	0.013* (0.054)	0.079** (0.037)	0.028*** (0.044)	0.103* (0.044)	0.124*** (0.039)
New product development – z_{13t} (1 – yes, 0 – no)	0.312*** (0.057)	0.293* (0.099)	0.269** (0.125)	0.274*** (0.113)	0.227* (0.098)	0.249*** (0.079)
Stage of initiation – z_{14t} (1 – yes, 0 – no)	0.027*** (0.053)	0.242 (0.031)	0.038*** (0.026)	0.331*** (0.024)	0.044* (0.035)	0.322*** (0.034)
Trial stage – z_{15t} (1 – yes, 0 – no)	0.064*** (0.039)	0.247 (0.025)	0.041*** (0.063)	0.239*** (0.024)	0.045* (0.032)	0.238*** (0.042)
Stage of experimentation – z_{16t} (1 – yes, 0 – no)	0.016*** (0.009)	0.229 (0.013)	0.032*** (0.036)	0.247*** (0.038)	0.034* (0.024)	0.249*** (0.027)
Stage of formalisation – z_{17t} (1 – yes, 0 – no)	0.362*** (0.031)	0.245 (0.037)	0.382*** (0.053)	0.165*** (0.066)	0.353* (0.031)	0.121*** (0.016)
Scaling stage – z_{18t} (1 – yes, 0 – no)	0.309*** (0.072)	0.106 (0.054)	0.348*** (0.033)	0.054** (0.046)	0.334*** (0.019)	0.049* (0.024)
Change in volume of resources required – z_{19t} (logarithm of total resource costs)	0.134*** (0.065)	0.131 (0.039)	0.082*** (0.035)	0.063** (0.044)	0.051*** (0.035)	0.026** (0.031)
Availability and implementation of in-house AI developments – z_{20t} (1 – yes, 0 – no)	0.202*** (0.046)	0.209 (0.055)	0.293*** (0.035)	0.272*** (0.048)	0.212*** (0.051)	0.218* (0.064)
Within *R* (%)	6.69	7.18	6.69	7.18	6.69	7.18
Between *R* (%)	35.16	39.66	35.16	39.66	35.16	39.66
Overall *R* (%)	24.89	29.23	24.89	29.23	24.89	29.23
Number of observations	16		82		49	

Table 4
Results of the analysis of changes in the market share of industrial enterprises

Dependent variable	High-tech industries		Medium-tech industries		Low-tech industries	
Method of analysis: Substitution effect - random effects model Complementarity - fixed effects model	Substitution effect	Complementation effect	Substitution effect	Complementation effect	Substitution effect	Complementation effect
Invest in AI – AI_{it}	0.021*** (0.047)	0.023* (0.054)	0.017*** (0.069)	0.016* (0.101)	0.017*** (0.081)	0.014** (0.067)
Profits from sales of new products with unique features – $P_{new}\,pr_{it}$	0.216*** (0.069)	0.215* (0.077)	0.351*** (0.094)	0.354* (0.088)	0.327*** (0.059)	0.303** (0.074)
Number of patents – $Patents_{it}$	0.344*** (0.047)	0.318* (0.054)	0.203*** (0.069)	0.194* (0.101)	0.201*** (0.081)	0.204** (0.067)
Enterprise size – h_{1t} (log of average number of employees)	0.113*** (0.036)	0.109* (0.084)	0.117*** (0.046)	0.094* (0.073)	0.128*** (0.051)	0.137** (0.048)
Age of the enterprise – h_{2t} (logarithm of the average number of years)	0.067*** (0.048)	0.084 (0.061)	0.089*** (0.042)	0.056* (0.069)	0.093*** (0.074)	0.056*** (0.049)
Presence of research in AI – h_{3t} (1 – yes, 0 – no)	0.168*** (0.067)	0.132 (0.102)	0.172** (0.115)	0.059 (0.066)	0.083** (0.052)	0. 079** (0.048)
Total cost of current activities – h_{5t} (log of total cost of current activities)	0.123*** (0.057)	0.154 (0.049)	0.091*** (0.052)	0.099* (0.064)	0.107*** (0.072)	0.116*** (0.058)
Availability of competences for the implementation of AI – h_{7t} (logarithm of the number of employees with higher education)	0.256*** (0.068)	0.249*** (0.073)	0.243*** (0.052)	0.239*** (0.053)	0.261*** (0.098)	0.258*** (0.042)
Expected financial impact – h_{8t} (logarithm of the sum of the financial impact of implementing AI)	0.193*** (0.049)	0.162 (0.108)	0.204*** (0.069)	0.193** (0.096)	0.129** (0.047)	0.166 (0.055)
Availability of export earnings – h_{9t} (1 – yes, 0 – no)	0.179*** (0.054)	0.206 (0.093)	0.221*** (0.088)	0.233*** (0.073)	0.173* (0.035)	0.128*** (0.052)
Reduction in number of employees due to decrease in volume of routine operations routine operations – h_{11t} (1 – yes, 0 – no)	0.014*** (0.019)	0.013* (0.024)	0.029*** (0.021)	0.037* (0.101)	0.039*** (0.081)	0.024** (0.067)
Reduction in costs of human resources function – h_{12t} (1 – yes, 0 – no)	0.107*** (0.019)	0.105* (0.023)	0.104*** (0.094)	0.103* (0.088)	0.107*** (0.059)	0.103** (0.074)
Reduction in working time for routine tasks – h_{13t} (1 – yes, 0 – no)	0.211*** (0.021)	0.206* (0.022)	0.207*** (0.029)	0.205* (0.011)	0.201*** (0.081)	0.204** (0.067)
Increasing the speed of development and promotion of new products – h_{14t} (1 – yes, 0 – no)	0.213*** (0.022)	0.215* (0.023)	0.212*** (0.022)	0.217* (0.021)	0.219*** (0.008)	0.222** (0.007)
Constant	4.663*** (0.151)	5.351 (0.612)	3.044*** (0.371)	2.974** (0.449)	– 4.318*** (0.529)	2.257** (0.721)
Within R (%)	3.98	4.97	3.98	4.97	3.98	4.97
Between R (%)	29.84	35.72	29.84	35.72	29.84	35.72
Overall R (%)	23.75	26.94	23.75	26.94	23.75	26.94
Number of observations	16		82		49	

the substitution effect, and a fixed effects model to analyse the influence of the complementarity effect. Table 4 shows the marginal effects of the productivity of firms in three industries.

As in the previous equations, the fixed effects model has less explanatory power in the equation for market share change, although it is not statistically rejected (χ^2 (22) = 23.75, p = 0.0088). This means that the complementarity effect is more significant than the substitution effect in the adoption of AI.

In high and medium-high tech industries, the relationship between the intensity of investment in AI, the results of the creation of non-copyable competitive advantages and the increase in market share is confirmed. At the same time, the strongest relationship between the results of the creation of non-copyable competitive advantages and market share is observed in the high-tech sector for the number of registered patents (the elasticity of market share with respect to the number of patents is 0.344), in the medium and low-tech industries – for the creation of new products with unique properties (0.351).

4. Discussion and conclusions

The study shows that there is little difference between companies in different industries in their decisions to implement AI technologies. Similar conclusions have been reached in previous studies [Ruzhanskaya et al., 2023]. At the same time, the decision to invest in AI technologies depends on such factors as the availability of skills for implementing AI, the cost of implementing new technologies and the level of current costs in the company as a whole, and the expectation of financial and economic effects.

It should also be noted that the availability of resources (both financial and infrastructural) is an important factor when deciding on the intensity of investment in AI. Among the economic effects expected from the implementation of AI technologies, the most significant are: reduction in the time needed to perform operations; reduction in the number of employees due to a decrease in the volume of routine operations; reduction in the cost of the human resources function; and an increase in the speed of developing and promoting new products.

Our empirical data show that the marginal effect of investment in AI technologies is in the range of 0.021-0.023 in high-tech industries, 0.016-0.017 in medium-tech industries, and 0.014-0.017 in low-tech industries.

The most popular functions for implementing AI technologies are: marketing and analytics (creating creative materials), development and IT (coding assistants for developers), sales and customer service (operator prompts and voice assistants), and internal corporate functions (generating training, writing texts, verifying documents, etc.).

Most industrial companies are currently in the experimentation phase, where there are no common standards for the implementation of AI and in-house developments or vendor solutions are being tested in various functions, or in the formalisation phase, where plans and budgets for the implementation and scaling of AI have been approved. However, in order to achieve significant financial and economic impact from the implementation of AI technologies, it is necessary to optimise business processes and attract specialists with skills in the field of AI implementation. At the same time, in in-depth interviews, almost all – 98% – top managers cited the lack of specialists capable of implementing and using AI as the main obstacle to its development.

The impact of AI on the results of the creation of non-copyable competitive advantages varies between industries. For example, for high-tech industries, the introduction of AI technologies has a significant impact on patenting and a slightly smaller impact on the creation and sale of new products with unique features. For medium- and low-tech industries, AI technologies have a more significant impact on the creation of new products with unique characteristics than on patenting.

Another issue explored in this study is the influence of substitution and complementarity effects in the creation of non-copyable competitive advantages.

Our study confirmed the dualistic effect of AI adoption, i.e. the simultaneous emergence of both the substitution effect and the complementarity effect, which shifts the sources of competitive advantage: although the replacement of traditional domain-specific human cognitive capabilities by the multiple computational capabilities of AI destroys the existing advantage, new permanent, non-copyable advantages are created based on the complementarity of human and machine capabilities.

In terms of substitution, it is currently taking place in functions such as customer service, human resources and corporate functions. And this trend is likely to continue as the gap between human and machine productivity continues to widen [Davenport, Kirby, 2016].

The results of the in-depth expert interviews also confirm that the availability of modern AI technologies will affect the substitution of some functions performed by humans by machines, and that these functions will no longer represent uncopyable competitive advantages, as they will be easy to imitate. At the same time, the expert survey showed that such a substitution effect has significant limitations related to the technical characteristics of software and hardware systems. For example, there are limitations when there is little data or when constant change makes it impossible to use past decision models to predict future outcomes [Raisch, Krakowski, 2021]. In situations of high uncertainty, companies will continue to rely on human intuition. Thus, the limitations of software and hardware make human capabilities difficult to replicate, and they will continue to serve as a source of non-copyable advantages for the foreseeable future [Murray et al., 2021; Raisch, Krakowski, 2021].

Our work confirms the complementarity effect – the importance of combining human and machine capabilities as a new source of competitive advantage. This conclusion was also confirmed by the results of in-depth interviews: experts associated competitive advantage with the complementarity of human and AI capabilities, especially in functional areas such as research and development, IT, creative ideas, production and social interaction. For example, [Raisch, Krakowski, 2021] describe how perfumers, despite the introduction of AI into their fragrance development processes, still work with experts because machines do not have the human ability to perceive odours and predict the human emotions they evoke. This example shows that AI is likely to replace some – but not all – complex business tasks. And this, in turn, will provide opportunities to combine human skills and AI to create unique competitive advantages based on complementarity.

Our study contributes to the resource-based view of the firm, as most previous studies have focused on the complementarity of only homogeneous or related resources [Peteraf, Bergen, 2003; Levinthal, Wu, 2010; Polidoro, Toh, 2011; Argyres, Zenger, 2012]. Our work shows that heterogeneous, unrelated resources, such as people and machines, can also be a source of unique competitive advantage. Such complementarity of unrelated resources is possible because AI is not narrowly applied and can be used in a variety of domains.

However, this study has limitations, mainly related to the sample size of companies. Further field studies are needed to more fully describe the impact of AI technologies and provide insights into the division of labour between humans and AI at the organisational level, as well as to identify related sources of sustainable competitive advantage.

References

Ruzhanskaya L.S., Kuzyk M.G., Simachev Yu.V., Fedyunina A.A. (2023). End-to-end digitalization factors: Challenges for Russian manufacturers. *Voprosy ekonomiki,* (9): 5-28. (In Russ.)

Agrawal A., Gans J.S., Goldfarb A. (2024). Artificial intelligence adoption and system-wide change. *Journal of Economics & Management Strategy,* 33(2): 327-337.

Agrawal M., Zitnik M., Leskovec J. (2018). Large-scale analysis of disease pathways in the human interactome. In: *Pacific symposium on Biocomputing-2018,* 111-122.

Argyres N.S., Zenger T.R. (2012). Capabilities, transaction costs, and firm boundaries. *Organization Science,* 23(6): 1643-1657.

Balasubramanian N., Ye Y., Xu M. (2022). Substituting human decision-making with machine learning: Implications for organizational learning. *Academy of Management Review,* 47(3): 448-465.

Barney J. (1991). Firm resources and sustained competitive advantage. *Journal of Management,* 17(1): 99-120.

Berry H., Kaul A., Lee N. (2021). Follow the smoke: The pollution haven effect on global sourcing. *Strategic Management Journal,* 42(13): 2420-2450.

Blakeley G. (2020). *The Corona crash: How the pandemic will change capitalism.* Verso Books.

Blohm I., Antretter T., Sirén C., Grichnik D., Wincent J. (2022). It's a peoples game, isn't it?! A comparison between the investment returns of business angels and machine learning algorithms. *Entrepreneurship Theory and Practice,* 46(4): 1054-1091.

Brynjolfsson E., McAfee A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies.* WW Norton & Company.

Chamorro-Premuzic T., Polli F., Dattner B. (2019). Building ethical AI for talent management. *Harvard Business Review,* 21: 1-15.

Choudhury P., Starr E., Agarwal R. (2020). Machine learning and human capital complementarities: Experimental evidence on bias mitigation. *Strategic Management Journal,* 41(8): 1381-1411.

Davenport T.H., Kirby J. (2016). Just how smart are smart machines? *MIT Sloan Management Review,* 57(3): 21.

Efron B. (1979). Bootstrap methods: Another look at the jackknife. *Annals of Statistics,* 7(1): 1-26.

Helfat C.E., Peteraf M.A. (2015). Managerial cognitive capabilities and the microfoundations of dynamic capabilities. *Strategic Management Journal,* 36(6): 831-850.

Kunc M.H., Morecroft J.D. (2010). Managerial decision making and firm performance under a resource-based paradigm. *Strategic Management Journal,* 31(11): 1164-1182.

Levinthal D.A., Wu B. (2010). Opportunity costs and non-scale free capabilities: Profit maximization, corporate scope, and profit margins. *Strategic Management Journal,* 31(7): 780-801.

Mairesse J., Robin S. (2009). *Innovation and Productivity: A Firm-level Analysis for French Manufacturing and Services using CIS3 and CIS4 data (1998-2000 and 2002-2004).* Paris, CREST-ENSAE.

Milgrom P., Roberts J. (1990). Rationalizability, learning, and equilibrium in games with strategic complementarities. *Econometrica: Journal of the Econometric Society,* 1255-1277.

Murray A., Rhymer J.E.N., Sirmon D.G. (2021). Humans and technology: Forms of conjoined agency in organizations. *Academy of Management Review,* 46(3): 552-571.

Newbert S.L. (2007). Empirical research on the resource-based view of the firm: An assessment and suggestions for future research. *Strategic Management Journal,* 28(2): 121-146.

Noonan R. (2017). *STEM Jobs: 2017 Update.* ESA Issue Brief 02-17, US Department of Commerce.

Peteraf M.A., Bergen M.E. (2003). Scanning dynamic competitive landscapes: A market-based and resource-based framework. *Strategic Management Journal,* 24(10): 1027-1041.

Polidoro Jr.F., Toh P.K. (2011). Letting rivals come close or warding them off? The effects of substitution threat on imitation deterrence. *Academy of Management Journal,* 54(2): 369-392.

Rai A., Constantinides P., Sarker S. (2019). Next generation digital platforms: Toward human-AI hybrids. *Mis Quarterly,* 43(1): iii-ix.

Raisch S., Krakowski S. (2021). Artificial intelligence and management: The automation-augmentation paradox. *Academy of Management Review,* 46(1): 192-210.

Shrestha Y.R., Ben-Menahem S.M., Von Krogh G. (2019). Organizational decision-making structures in the age of artificial intelligence. *California Management Review,* 61(4): 66-83.

Stadler C., Helfat C.E., Verona G. (2021). Technology usage and organizational performance in multi-unit firms transferring knowledge by transferring individuals: Innovative technology usage and organizational performance in multi-unit firms. *Organization Science, Tuck School of Business Working Paper,* 3779743.

Topol E.J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nature Medicine,* 25(1): 44-56.

Verganti R., Vendraminelli L., Iansiti M. (2020). Innovation and design in the age of artificial intelligence. *Journal of Product Innovation Management,* 37(3): 212-227.

Wernerfelt B., Montgomery C.A. (1988). Tobin's q and the importance of focus in firm performance. *The American Economic Review,* 246-250.

Wilson H.J., Daugherty P.R. (2018). Collaborative intelligence: Humans and AI are joining forces. *Harvard Business Review,* 96(4): 114-123.

About the authors

Arkady V. Trachuk
Doctor of economics, professor, head of the Department of Strategic and Innovative Development, Faculty of Higher School of Management, Financial University under the Government of the Russian Federation, General Director of Goznak JSC (Moscow, Russia). ORCID: 0000-0003-2188-7192.
Research interests: strategy and management of the company's development, innovation, entrepreneurship and modern business models in the financial and real sectors of the economy, dynamics and development of e-business, operating experience and prospects for the development of natural monopolies.
ATrachuk@fa.ru

Natalia V. Linder
Doctor of economics, professor, professor of the Department of Strategic and Innovative Development, Faculty of Higher School of Management, Financial University under the Government of the Russian Federation, Head of the Marketing Department of Goznak JSC (Moscow, Russia). ORCID: 0000-0002-4724-2344.
Research interests: strategy and development management companies, formation of development strategy of industrial companies in the context of the fourth industrial revolution, innovation transformation of business models, dynamics and development of e-business development strategies of companies in the energy sector in the fourth industrial revolution, exit strategies of Russian companies on international markets.
NVLinder@fa.ru

作者信息

Arkady V. Trachuk
经济学博士，教授，战略与创新发展教研室主任，“高级管理学院”系，俄罗斯联邦政府财政金融大学，Goznak股份公司的总经理（莫斯科，俄罗斯）。ORCID: 0000-0003-2188-7192.
科研兴趣领域：公司战略与发展管理、创新、企业家精神及金融和实体经济部门的现代商业模式、电子商务的动态与发展、自然垄断的运营经验及发展前景。
Trachuk_A_V@goznak.ru

Natalia V. Linder
经济学博士，教授，战略与创新发展教研室教授，“高级管理学院”系，俄罗斯联邦政府财政金融大学，Goznak股份公司的市场营销经理（莫斯科，俄罗斯）。ORCID: 0000-0002-4724-2344.
科研兴趣领域： 公司战略与发展管理、在第四次工业革命背景下工业公司发展战略的制定、创新与商业模式转型、电子商务的动态与发展、能源部门公司在第四次工业革命中的发展战略、俄罗斯公司进入国际市场的战略。NVLinder@fa.ru

The article was submitted on 16.04.2024; revised on 15.05.2024 and accepted for publication on 20.05.2024. The authors read and approved the final version of the manuscript.
文章于 16.04.2024 提交给编辑。文章于 15.05.2024 已审稿．之后于 20.05.2024 接受发表。作者已经阅读并批准了手稿的最终版本。