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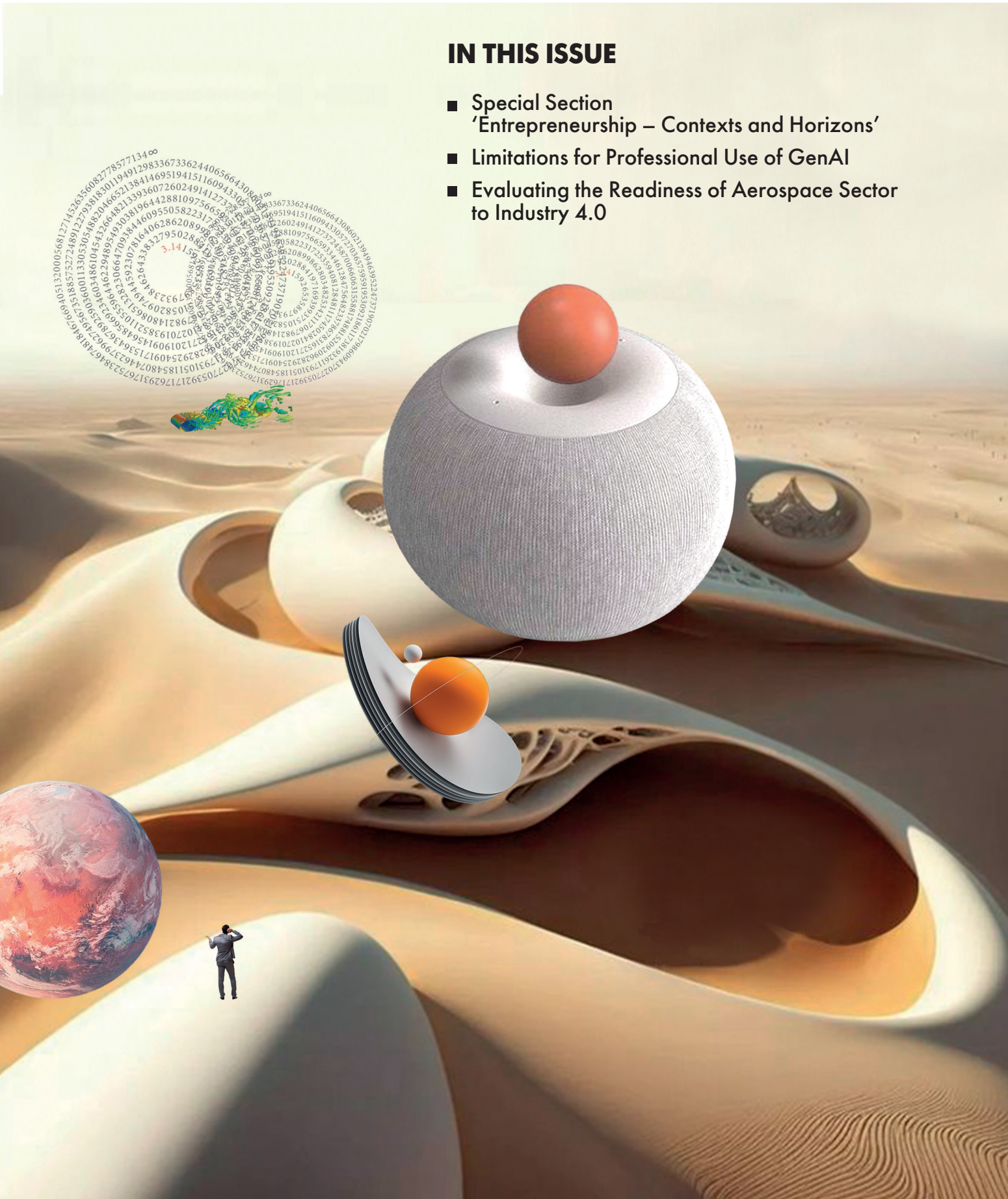

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Foresight and STI Governance is an international interdisciplinary peer-reviewed open-access journal. It publishes original research articles, offering new theoretical insights and practice-oriented knowledge in important areas of strategic planning and the creation of science, technology, and innovation (STI) policy, and it examines possible and alternative futures in all human endeavors in order to make such insights available to the right person at the right time to ensure the right decision.

The journal acts as a scientific forum, contributing to the interaction between researchers, policy makers, and other actors involved in innovation processes. It encompasses all facets of STI policy and the creation of technological, managerial, product, and social innovations. *Foresight and STI Governance* welcomes works from scholars based in all parts of the world.

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- The exploration of the innovation lifecycle from idea to market;
- Technological trends, breakthroughs, and grand challenges;
- Technological change and its implications for economy, policy-making, and society;
- Corporate innovation management;
- Human capital in STI;

and many others.

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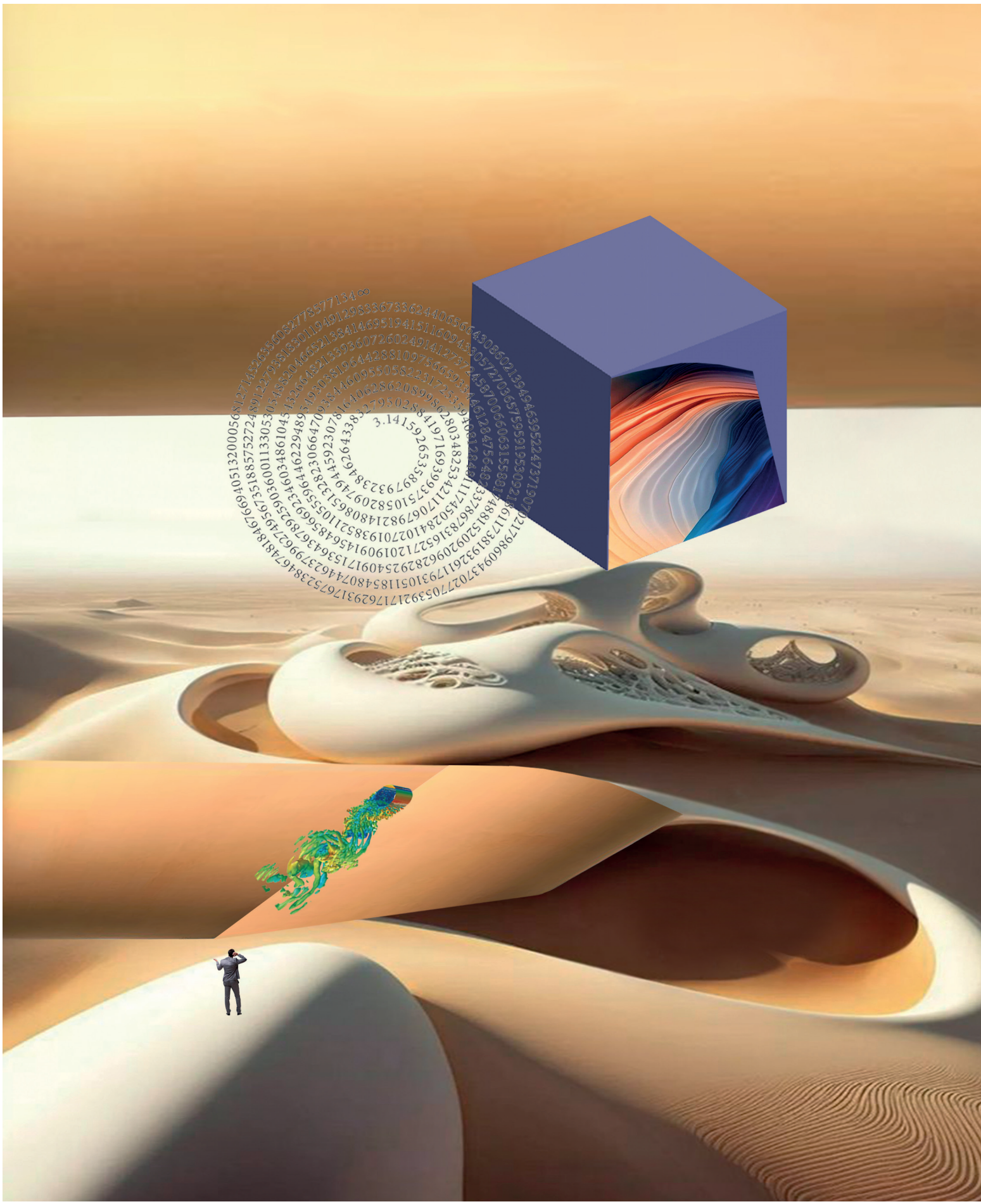
INNOVATION



Introductory Note

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This special section of the journal is aiming to re-examine some of the current trends in entrepreneurship and entrepreneurship literature as well explore some recent challenges, which have strongly influenced the socioeconomic context of the field globally and, thus, set a new agenda for academic research.

The beginning of the 2020s was marked with the outbreak of the COVID-19 pandemic, which soon led to a series of dramatic measures by national governments such as imposing several constraints and limitations for many entrepreneurs and firms, but also facilitating the exploration of new niches and opportunities. How dramatic was the general impact of the pandemic on the entrepreneurship? In the paper by Ondřej Dvouletý, which opens this section, using available statistics it is shown that in Central Europe, more concretely in the Czech Republic, Hungary, Poland, and Slovakia, entrepreneurship after COVID-19 is recovering rapidly and there are no signs of any significant decline. Most of the related indicators even increased compared to the pre-pandemic period, according to Eurostat data. Moreover, in some sectors COVID-19 played the role of an 'enabler', therefore, the highest increase of entrepreneurial activity was reported in the information and communication sectors of these economies, which might be associated with the need to shift economic and social life online. This article shows that external shocks should be viewed not only as 'black swans', but also as a source of new business opportunities and entrepreneurship activities.

In particular, the pandemic has increased the implementation of digital processes and technologies by entrepreneurial firms. This is the central point of the next paper by László Szerb, Enikő Czigler and Gergely Zoltán Horváth. The paper is based on the results of the Digital Entrepreneurship Ecosystem (DEE) Index methodology created by Szerb et al. (2021) and compares the former socialist Central and Eastern European (CEE) countries' progress in the development of their digital entrepreneurship ecosystem. Here, the authors have elucidated the possible role played by transitional economies' socialist heritage in the digitalization of entrepreneurial activity. The analysis of the data showed that among 170 countries, European nations generally perform quite well. CEE countries do not belong to the top tiers in Europe, but they did form a group trailing close behind the leaders, especially the group of Southern European countries in their DEE development. Moreover, former Soviet countries and non-EU Balkan countries are very similar to one another. This paper also contains the DEE profile of Russia, where the four-sub-indices, twelve pillars, and 24 variables illustrate Russia's modest performance in the development of its own digital entrepreneurship ecosystem. Generally, after examining the DEE of the former socialist countries of Central and Eastern Europe, the authors came to the conclusion that, despite significant variations in the DEE scores, these differences can be explained by recent economic developments, but not by the long-lasting effects of the formerly socialist economy. This is important evidence, indicating that more than 30 years after the beginning of systemic changes in these countries, it is the features of the transition and the institutional traps of respective development trajectories that should be taken into consideration when assessing entrepreneurship ecosystems and performance in this region.

The digitalization of entrepreneurship, establishment of new innovation-driven ventures is inevitably connected with the role of universities and academic innovative entrepreneurship, which is the theme of the paper by Olga Belousova, Aard J. Groen, and Anastasia Sutormina. This paper is focused on the key driver of an entrepreneurial university, academic entrepreneurship, and explains that developing academic entrepreneurship within a university requires a long-lasting process of change. The authors discuss the three main characteristics of entrepreneurship at universities – its content, process, and context - along such dimen-

sions of decision-making and performance, such as anticipation, reflexivity, inclusion, and responsiveness. Based on the findings from international literature and some practical cases, the authors point out the embeddedness of academic entrepreneurship in different contextual settings of institutions and actors and thus explore future research prospects of the phenomenon. They argue that the entrepreneurial journey of each university is unique, because it is embedded in very different internal and external contexts, therefore, a single way to establish and nurture academic entrepreneurship is impossible to define. Consequently, a reflective strategy is needed allowing each university to elaborate upon and implement its own entrepreneurial strategy.

The last paper of the section by Ekaterina Kozachenko, Alexander Chepurenko, and Galina Shirokova is dedicated to the systematic analysis of entrepreneurship research in Russia over the last thirty years. In order to understand the achievements and gaps, as well as methodological problems to be solved in future by Russian researchers, this article provides an overview of relevant papers on Russian entrepreneurship in leading domestic academic journals during the period of 1991-2023. The analysis allowed for the identification of the best reflected topics, advances in the theoretical elaboration of entrepreneurship in Russia, as well as some weak points and contradictions in research programs and empirical methods, compared with the state of art in international journals. As a result of the analysis, the need for a 'double mixed approach' is put forward, that is, in such an contextual exploration of entrepreneurship in Russia, the macro-, meso- and micro-contexts must be considered as must the temporal dynamic of these contexts over the course of systemic changes. Consequently, the authors propose following tasks for entrepreneurship research in Russia: (1) the reconceptualization of standard definitions and concepts of the theory of entrepreneurship, considering the Russian context; (2) building new theories and concepts of the middle level based on the investigation of unique phenomena and institutions in the Russian business environment.

Entrepreneurship in Central Europe after COVID-19: Resilience amid a Crisis

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Abstract

This article aims to provide insights into the development of entrepreneurial activity in selected Central European countries, formerly transition economies, after the global COVID-19 pandemic. The objective of the study is to understand whether and how the pandemic reshaped the structure of entrepreneurship in the Czech Republic, Hungary, Poland, and Slovakia. Data from Eurostat, covering both individual-level activity and structural business statistics, were used to determine the answer three years after the start of the COVID-19 crisis. The results from statistical testing and multivariate regression models provide straightforward answers. In the vast majority of the studied indicators, entrepreneurial activity has even increased compared to the pre-pandemic values, with a few exceptions such as employer entrepreneurship, where the results were not statistically conclusive. From the perspective of structural business statistics, we observe the highest increase in information and communication sectors of the studied economies, which might be associated with the need to shift economic and social activities online. The article demonstrates, using the example of the COVID-19 crisis, that even external shocks can boost the exploitation of new business opportunities and entrepreneurial development. In particular, it is argued that the pandemic has sped up the entrepreneurs' adoption of digital processes and agendas.

Keywords: entrepreneurial activity; entrepreneurship; global pandemic; COVID-19; comparative analysis; Black Swan events; resilience

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Introduction

It has not been so long since the world was plummented into the global COVID-19 pandemic, which spread across the globe in 2020. It affected all aspects of human interactions, led to social distancing, and put an emphasis on the use of technological innovations, allowing for remote work and business. This was reflected in business practices, forcing entrepreneurs and business organizations to adapt to the changes, spreading so far, and testing policymakers and politicians' abilities to assist in adverse times to maintain economic activities, preventing considerable economic collapse and a rise in unemployment.

Researchers started to provide evidence of best practices encapsulated in public policies and government actions to mitigate the adverse effects of the pandemic from the very beginning of the crisis (Apostolopoulos et al., 2021; Cirera et al., 2021; Kuckertz, Brändle, 2022; Brändle et al., 2023; Schøtt et al., 2024). The interaction of global organizations was very fast and dynamic. As one of the interesting initiatives, we recall the establishment of the joint COVID-19 Research Database, incentivized and maintained by the World Health Organization[1], providing a significant body of knowledge and evidence, indexing all relevant COVID-19 publications into a single database.

The crisis tested the entrepreneurial mindset of business owners and self-employed individuals, highlighting their ability to adapt and seek timely solutions to maintain their business activities. Those failing to adapt or sustain their activities resulted in postponing or ending their entrepreneurial journey, while for others, it brought a unique chance to exploit new opportunities to start a new business or to foster the existing one (Davidsson et al., 2021; Liñán, Jaén, 2022; Muzaffar, 2023).

What remained an open question, as well as an existing research gap, was the extent to which the pull and push factors have reshaped the overall size and structure of entrepreneurship; in other words, what was the pandemic's macroeconomic effect on the development entrepreneurship as a whole?

This research study aims to look back three years since the beginning of the COVID-19 pandemic and provide, within the geographic scope of Central Europe, evidence on the size and structure of the entrepreneurial activity in four countries, namely the Czech Republic, Hungary, Poland, and Slovakia. The context of the studied countries is based on a joint post-communist history and the nature of small open-market economies, members of the European Union (EU) and the so-called Visegrád alliance. Most of the market-economy-related institutions had to be set up uniquely, from scratch, after the political change of the system in the early 1990s, which makes this group unique compared to the established members of the EU, who already had their institutions set up. This constant lagging behind the "developed West" is also manifested in the continuous development and improvement of the business framework conditions and entrepreneurial ecosystem pillars, which still represent the quality of the entrepreneurs' surroundings and moderate the quality of entrepreneurial activity and its contributions to economic development (Bruothová, Hurný, 2016; Sacio-Szymańska et al., 2016; Dvouletý, Orel, 2020; Jabłońska, Fila, 2021; Csákné Filep et al., 2023).

Looking at the pre-pandemic Global Competitiveness Report data from 2019 (World Economic Forum, 2019), the Czech Republic is the economic leader of the Visegrád alliance, ranked in the Global Competitiveness Index 4.0 as the 32nd most competitive nation out of 140 countries with 10-year average annual GDP growth of 2%, followed by Poland (experiencing average growth of 3.1% and ranked 27th), Slovakia (experiencing average growth of 2.8% and ranked 42nd), and Hungary (experiencing average growth of 2.1% and ranked 47th). We can also recall that the sectoral orientation of the countries differs when looking at the sectoral contributions to value-added according to OECD Economic Surveys data (2020). All countries had the highest contributions from the services sector, in particular, the highest in Slovakia (68.1% in 2019), followed by Hungary (66.6% in 2019), Poland (64.9% in 2018), and the Czech Republic (63.0% in 2019), which on the contrary, boasts the largest industrial sector of the group.

By using the official statistical data from Eurostat on individual-level participation in self-employment and structural business statistics data, we contribute to the long-term understanding of the effects of the global pandemic on overall entrepreneurial development. We do so by collecting a wider range of entrepreneurship-related indicators used for statistical and econometric testing between the pre-pandemic and post-pandemic development trends across the pooled countries, providing a picture of Central Europe and single-country perspectives, thus extending the current knowledge on the COVID-19 crisis effects in the region, studied, for example, by Urbanovics et al. (2021), Koca (2022), or Blažková et al. (2023). Such evidence has value for the policymakers who were active in designing policy actions and aid during the pandemic as a reflection of the efforts and resources invested. The methodology applied in this study might also inspire further research, capturing the effects of the global pandemic, and further developing entrepreneurship in the region.

[1] https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/#, accessed 18.05.2024.

Data

This research focuses on the four small post-transition open economies located in Central Europe, united in the Visegrád group, also called V4 or Visegrád alliance, which includes the Czech Republic, Hungary, Poland, and Slovakia. Prior researchers studying the entrepreneurial context of these countries also called them post-communist economies, already noted the obstacles and data-related barriers that represent a significant challenge when advancing the Central European entrepreneurial context, especially the discontinuity of Global Entrepreneurship Monitor study in some of the countries, such as the Czech Republic or non-homogeneous legal forms of business entities (Holienka et al., 2017; Zygmunt, 2018; Meyer, Meyer, 2019; Gubik, Farkas, 2019; Dvouletý, Orel, 2020).

The selection of the proper indicators or the overall lack of data was also a central issue in this particular research, relying on the harmonized data obtained from Eurostat (2023a; 2023b; 2023c, 2023d). Several indicators were thus selected to obtain the widest possible holistic picture of post-pandemic entrepreneurial development, relying first on the European Union Labour Force Survey (EU LFS) data (Eurostat, 2023a; 2023b), reflecting individual-level participation in the labor market, i.e., being a self-employed, solo, or employer entrepreneur, which was expressed as a percentage of the economically active population, i.e., those who are15-64 years of age (Dvouletý, Orel, 2020; Audretsch, Belitski, 2021). This choice allows us to control for high-quality entrepreneurship, i.e., employer entrepreneurs (Urbano et al., 2017). In addition, **we use**d the Eurostat (2023c; 2023d) structural business statistics data (SBS), which also accounts for the number of registered business entities in selected sectors (Henrekson, Sanandaji, 2020). Nevertheless, despite the efforts of Eurostat to harmonize the data, we face a structural break/methodological change in the definition of some of the NACE-based indicators that took place in 2020, which caused the whole economy sums not to be comparable, and therefore, we opted as a consensus to study only selected industries, where the methodology of calculating the number of enterprises had not changed.

This selection allowed us to study entrepreneurship with data from the EU LFS from 2000 to 2022 and from the SBS from 2008 to 2022. As a first step, we display the development of the EU LFS indicators across four countries in Figure 1. One can see more or less an increasing trend over time, which is more or less similar to most of the countries in the pre-pandemic years when it comes to the overall self-employment rate and the proportions of solo self-employed individuals and quite constant once we look at the employer entrepreneurship line. Here, we note that an employer entrepreneur is a person who employs himself/herself and at least one additional employee (Burke et al., 2018) and by the beginning of the coronavirus pandemic, by this we refer

Table 1 shows the average values of the obtained indicators, informing readers that entrepreneurial activity was at about 9.4% over the studied period, consisting of 2.4% of employer entrepreneurs and mostly solo self-employed individuals, accounting for 7.4%. This is in line with the most recent studies, showing the proportions of solo self-employed dominate the overall levels of European entrepreneurship (van Stel, van der Zwan, 2020; Cieślik, Van Stel, 2023).

Secondly, we provide insights into the development of the number of operating businesses in the selected sectors (wholesale and retail trade; repair of motor vehicles and motorcycles; accommodation and food service activities; transportation and storage; manufacturing; administrative and support service activities; information and communication). Here, we display developments in each of the countries separately for better readability (see Figures 2-5), and the average values of these indicators are reported in Table 1. What is especially fascinating is the development and growth of the information and communications sector, which had to rapidly respond to the isolation needs of citizens, customers, and employees, providing innovative solutions for remote purchases and workplaces (Storr et al., 2021; Sánchez-Vergara et al., 2023). Surprisingly, we do not see any significant drops in the time trend after 2020. One would assume business closures in the sectors that suffered most from governmental restrictions would occur (Dvouletý, 2021; Gerwe, 2021), such as in the accommodation and food service sector, but the graphical illustration does not support this. Therefore, we proceed toward the statistical-analytical section, where we introduce our empirical approach and results.

Analysis and Results

The analysis combines two methodological approaches. Firstly, we employ panel regression analysis. Particularly, we estimate the Least Squares Dummy Variables model (LSDV, for details, we refer to Kiviet, 1995), accounting for time and country heterogeneity, with a special emphasis on the variable called *COVID-19 Pandemic*, which controls for the pandemic period, i.e., 2020-2022 and should be able to capture the overall effects on entrepreneurial activity. This is a pooled analysis of all studied countries. In the second step, we conduct paired tests for each country separately and report the three-year differences between the pre-pandemic years (2017-2019) and the pandemic period (2020-2022).

Table 3 represents the results of econometric modeling. All models (Models 1-9) are statistically significant based on Chi-square significance tests, and they account for all introduced variables in Table 2. We observe statistically significant differences in all indicators across the studied countries, which supports the need to dive into the differences more in the second empirical approach. Yet, the overall effect of the pandemic on Central European entrepreneurship can

Figure 1. **Entrepreneurial Development across the Studied Countries**

Source: Author's own calculations based on Eurostat data (2023a; 2023b) in STATA 14 software.

be observed in the estimated coefficient of the variable *COVID-19 Pandemic*. The overall participation in self-employment increased by 0.9% in the post-pandemic period (Model 1), driven mostly by the rise of solo self-employment (Model 2) and insignificant changes in employer entrepreneurship (Model 3). Furthermore, we find no significant change in the retail segment (wholesale and retail trade; repair of motor vehicles and motorcycles, Model 4). On the contrary, in the remaining sectors (Models 5-9), all coefficients representing the pandemic provide us with positive and statistically significant coefficients, meaning that over the time of the pandemic and further on, the number of enterprises/businesses in these sectors were higher, compared to other years. The highest growth in absolute numbers is visible in the information and communications sector, increasing by an average of 32,541 operating companies and business organizations.

Despite the fact that Visegrád countries share a common history and structure of entrepreneurial and innovation activity (Sauka, Chepurenko, 2017; Zygmunt, 2018; Jabłońska, Fila, 2021; Vokoun, Dvouletý, 2022), our econometric analysis documents significant differences in its levels and the numbers of operating businesses. This is why we took a closer look at the post-pandemic differences to see if the observed changes for the whole region apply to each country. Table 3 reports the results of the conducted paired t-tests. It seems that the econometric results are mainly driven by Hungary and Poland, which provide more or less the same results as those visible in Table 2.

Table 1. **Summary Statistics of the Collected Variables Representing Entrepreneurial Activity**

Variable/indicator	Mean	Median	Minimum	Maximum	Number of Observations
Self-employment Rate	9.4	9.9	4.4	13.1	92
Solo Self-employment Rate	7.0	7.8	2.9	10.4	92
Employers' Rate	2.4	2.4	1.3	3.3	92
Wholesale and retail trade; repair of motor vehicles and motorcycles	248,177	178,516	23,697	579,582	60
Accommodation and food service activities	41,615	41,093	2,446	78,343	60
Transportation and storage	60,797	38,525	553	174,666	60
Manufacturing	122,787	118,128	8,044	244,319	60
Administrative and support service activities	44,272	39,176	3,949	101,162	60
Information and communications	50,378	37,531	935	193,213	60

Source: Author's own calculations based on Eurostat data (2023a; 2023b; 2023c; 2023d) in STATA 14 software.

Table 2. **Panel Regression Analysis**

Model number Independent variables / Dependent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
COVID-19 Pandemic	0.932^{+} (0.504)	1.091** (0.410)	–0.158 (0.105)	6762.8 (10694.0)	7083.8^{+} (4035.1)	10791.5** (4173.5)	17466.3* (8320.5)	18249.5*** (3139.8)	32541.8* (15549.8)
Hungary	–4.109*** (0.458)	–5.055*** (0.381)	0.946*** (0.0897)	–87208.3*** (4793.9)	–27025.2*** (1719.5)	–6095.7* (2761.0)	–124754.0*** (3597.1)	17079.5*** (2412.6)	–3002.3 (5771.4)
Poland	0.520 (0.378)	–0.0532 (0.298)	0.574*** (0.0930)	304543.8*** (7668.3)	11036.7*** (3121.2)	127140*** (2991.7)	52305.7*** (6147.7)	55235.2*** (2457.2)	89067.8*** (11264.5)
Slovakia	–1.601*** (0.355)	–1.461*** (0.284)	–0.140^{+} (0.0775)	–121050.3*** (5338.8)	–39697.7*** (1842.4)	–19485.2*** (2034.5)	–100063.8*** (3388.4)	6641.8** (2083.3)	–27162.5*** (6653.8)
Constant	11.27*** (0.443)	9.134*** (0.371)	2.135*** (0.0850)	219045.7*** (9765.0)	54808.3*** (3436.7)	35842.0*** (3374.6)	167633.8*** (7928.1)	26410.1*** (3297.2)	39307.2*** (9268.7)
R2	0.952	0.974	0.961	0.998	0.981	0.997	0.994	0.989	0.950
Akaike information criterion	43.68	34.72	–30.22	515.4	467.7	475.0	500.6	458.0	530.4
Bayesian information criterion	54.29	45.32	–19.62	526.0	478.3	485.6	511.2	468.6	541.0

Legend: (1) - Self-employment Rate; (2) - Solo Self-employment Rate; (3) – Employers' Rate; (4) - Wholesale and retail trade; repair of motor vehicles and motorcycles; (5) - Accommodation and food service activities; (6) - Transportation and storage; (7) - Manufacturing; (8) - Administrative and support service activities; (9) - Information and communications.

Notes: Robust Standard errors in parentheses, stat. significance is reported as follows: + p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001. Year Dummies included. Number of observations = 24. Prob > chi2 = 0. The reference group of countries is the Czech Republic.

Source: Author's own calculations based on Eurostat data (2023a; 2023b; 2023c; 2023d) in STATA 14 software.

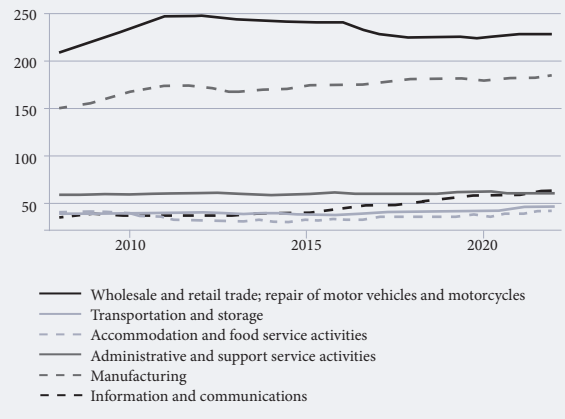
However, the Czech Republic and Slovakia have similar results only regarding the structural business statistics, and concerning individual engagement in self-employment, the main results differ. In the Czech Republic, we see a slight statistically significant decrease in self-employment and employer entrepreneurship rates, while Slovakia has positive differences, but these are not statistically significant. Otherwise, even this additional analysis shows the increased number of businesses operating in the information and communications industry and administrative and support service activities in all studied countries.

Concluding Remarks and Prospects for Future Development

Policymakers and practitioners were concerned about the impact of the COVID-19 outbreak on entrepreneurial activity, expecting significant declines in the overall levels of entrepreneurship and increased bankruptcy rates resulting from governmental restrictions and the decreased mobility of the population across the globe. As a response, significant financial resources were allocated in many countries to support the coverage of operational costs, bankruptcy moratoriums, or investment programs to provide firms with sufficient liquidity to maintain activity and employment (Ratten, 2020; 2021; Davidsson et al., 2021; Belitski et al., 2022).

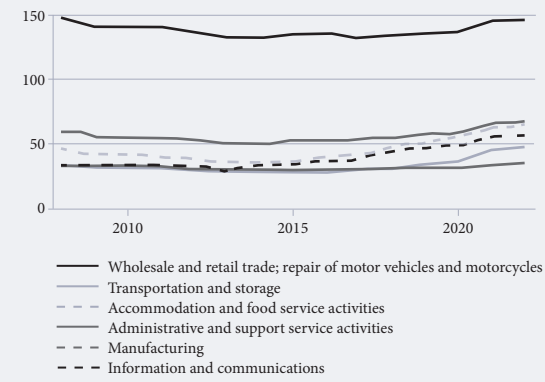
With the many forms of anti-crisis public policies implemented during the pandemic, we can now observe how entrepreneurship has changed at the macroeconomic level in the three years since its beginning. This study contributes to understanding this phenomenon by providing insight into entrepreneurial development in four Central European countries, namely the Czech Republic, Hungary, Poland, and Slovakia, united in the so-called Visegrád group, sharing a common socialist and communist history, which was represented by the lack of private ownership and almost no individual-level entrepreneurship and small businesses, until the 1990s, when the development of entrepreneurial activity experienced a rapid boost (Dvouletý, 2017; Sauka, Chepurenko, 2017). We can

Figure 2. **Development of the Number of Enterprises in the Czech Republic (*thousand units*)**



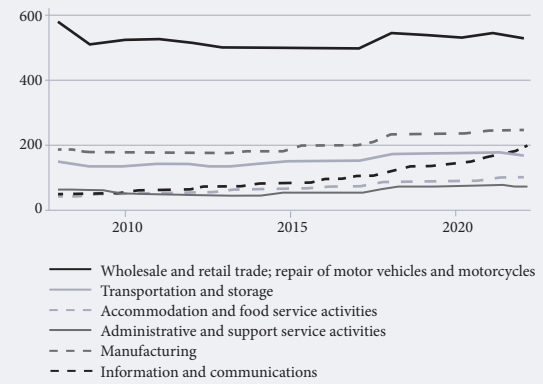
Source: Author's own calculations based on Eurostat data (2023c; 2023d) in STATA 14 software.

Figure 3. **Development of the Number of Enterprises in Hungary (*thousand units*)**



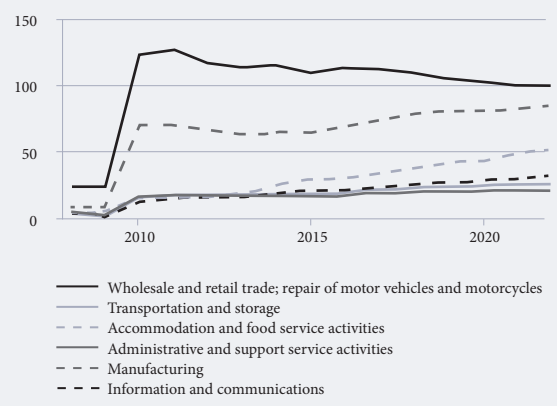
Source: Author's own calculations based on Eurostat data (2023c; 2023d) in STATA 14 software.

Figure 4. **Development of the Number of Enterprises in Poland (*thousand units*)**



Source: Author's own calculations based on Eurostat data (2023c; 2023d) in STATA 14 software.

Figure 5. **Development of the Number of Enterprises in Slovakia (*thousand units*)**



Source: Author's own calculations based on Eurostat data (2023c; 2023d) in STATA 14 software.

only speculate whether this historical milestone also impacted the adaptability of business owners to the new conditions of the market-driven economy and how participation on international markets has shaped their skills, resilience, and overall entrepreneurial culture in the region, but it might be the case that it did, and it helped entrepreneurs to promptly respond to the adverse times, such as those caused by a global pandemic and other adverse events.

An earlier article by Davidsson et al. (2021, p. 216) suggested that the COVID-19 pandemic might serve as an External Enabler (EE), i.e., "external, agent-independent, disequilibrating circumstance", that could benefit some business ventures despite its, in general, adverse nature. This was very clearly visible with the skyrocketing spread of online software tools (such as Zoom, Asana, Kissflow Digital Workplace, or GoogleWorkspace), allowing remote meetings and providing digital workspaces (Pratama, 2020) or remote physical training activities (Castoldi et al., 2023). The evidence from Central Europe is supportive in this direction as well. The overall picture of the collected statistical data and empirical analysis shows that entrepreneurial activity has risen in the region compared to its pre-COVID-19 levels. For all four studied countries, we show that the growth was driven especially by the higher number of businesses operating in the information and communications industry and administrative and support service ac-

Table 3. **Results of the Paired T-tests across the Studied Countries**

Variable/indicator	Czech Republic	Hungary	Poland	Slovakia
Self-employment Rate	–0.43*	1.54*	1.00*	0.19
Solo Self-employment Rate	–0.13	1.50*	0.99*	0.31
Employers Rate	–0.31*	0.04	0.01	0.01
Wholesale and retail trade; repair of motor vehicles and motorcycles	–299.7	8,351.7*	6,044.7	–7,747*
Accommodation and food service activities	218.3	2,588.7*	10,983*	1,095.7*
Transportation and storage	3,524.3*	12,045*	3,680.3	2,450*
Manufacturing	2,270.3	5,744.3*	17,888.3	5,434.7*
Administrative and support service activities	4,633.3*	13,933.7*	13,285*	10,271.7*
Information and communications	9,371.7*	10,861.7*	46,512.7*	5,068.7*

Notes: A paired t-test is calculated for each of the indicators separately, comparing years 2017-2019 vs 2020-2022. Statistically significant differences are indicated with * $p < 0.05$.

Source: Author's own calculations based on Eurostat data (2023a; 2023b; 2023c; 2023d) in STATA 14 software.

tivities, supporting the External Enabler framework. The regression analysis pointed out the increase in solo self-employment participation, which might be linked to the enhanced popularity and preference toward digital nomadism, providing opportunities to work online without having an explicitly stated office place and employer, providing services, for instance, via digital platforms or social networks (Sánchez-Vergara et al., 2023; Šímová, 2023). The actual details about the structure of self-employment activity, allowing for the incorporation of a definition of digital nomadism into the official statistics, is currently difficult to define and remains a recommendation for the representatives of the European statistical offices, as the proportions of individuals who are opting digital nomadism as a career choice, is still increasing (Demaj et al., 2021; Aroles et al., 2023) and is expected to shape the Central European entrepreneurship on a continuous.

On the other hand, we cannot neglect the adverse business effects brought on by the global pandemic, which at least temporarily affected entrepreneurs operating in retail, tourism, hospitality, culture, or sport. We need to remind ourselves of the closed restaurants, hotels, and considerable investments required to maintain the operation of retail stores (Dvorak et al., 2021; Betzler et al., 2021; Roncak et al., 2023). The three-year follow-up shows the number of businesses in the region in accommodation and food service activities has even increased (despite being insignificant in the Czech Republic in a separate analysis), which does not mean that there would not be closed businesses and entrepreneurs who would quit their occupations to find better options to earn a living, but the aggregate data inform us about the segment's overall development. One could thus only speculate on the intense competitiveness of the sector (new ones replaced closed businesses), the resilience of the entrepreneurs hoping to wait for better times, its overall dynamic development, or the effectiveness of the imposed anti-pandemic policies (Brown et al., 2020; Barbhuiya, Chatterjee, 2023). In this manner, we call for more micro-level evaluations, following the recent OECD (2023) Framework for the Evaluation of Entrepreneurship and SME policies, recommending that one implement the Evaluation Quality Score (EQS) and Six Steps approach to ensure that the evaluation results are sufficiently rigorous. Only rigorous evaluation studies can show which policies delivered the most influential impacts on the business's survival and growth during adverse times. This is a recommendation for ongoing studies, informing readers about the diverse effects of these public policies. One also cannot neglect the COVID-19 pandemic's effects, which were followed by the forthcoming energy crisis and Ukraine crisis, two ongoing events that have significantly affected both inflows of tourists to the region (in the negative direction) and, on the other hand, the high inflows of immigrants and refugees from Ukraine (Kříž et al., 2021; Kuckertz et al., 2023).

A recent study by the OECD (2022) reports on the best practices and key challenges associated with the segment's recovery. It is evident that the overall economic contributions of the industry to the gross domestic product (GDP) in all countries were affected negatively by the pandemic. Specifically, we use the OECD (2022) report to compare the contributions of the tourism economy to the GDP in the studied countries and to illustrate its downfall: Slovakia - 2019: 2.8%, 2020: 1.2%; Czech Republic - 2019: 2.9%, 2020: 1.5%; Hungary (measured as Gross Value Added) – 2019: 6.8%, 2020: 5.4%; Poland – 2018: 6.1%, 2020: 4.5%. Unfortunately, more novel comparable data for all countries are not available. Despite these harmful effects and the continuous recovery process, entrepreneurial activity does not seem to be showing such dramatic declines. The data up to 2022 shows that Central European entrepreneurs sustained and maintained business operations, and the data does not allow us to say the opposite. With that said, our main conclusion is that the COVID-19 pandemic has partially reshaped the structure of Central European businesses, which are now more inclined toward digitalization and information and communications, facing the challenges of the digital age, including artificial intelligence that could help us to understand further and expand sustainable business practices in the region (Cowls et al., 2021). A broader understanding of the adaption of these trends in the structure and size of the studied formerly communist economies thus remains a further challenge for ongoing research that could shed more light on the further adoption of sustainability and a digital agenda within the current EU policies, thus becoming one of the central pillars of doing business in Europe.

Applying the described methodological approach toward monitoring entrepreneurial activity and adapting new statistical operations might help in this direction and provide relevant insights for policymakers and stakeholders. The application of advanced statistical and econometric modeling techniques in the first year of the pandemic (Dvouletý, 2021) has already suggested that the overall effect on entrepreneurship might be positive, which was also supported by this study, looking at the data three years since the pandemic's beginning. Such a finding underlines the importance of timely ex-ante entrepreneurship and business cycle fluctuations forecasting (also called nowcasting when following short-term development and using real-time or high-frequency data) for policymakers' decision-making processes, despite its deviations from the real development, being determined ex-post (Carriero et al., 2020; Barbaglia et al., 2023). Other studies on the quantifying effects of the global pandemic, such as the recent contribution by Foroni et al. (2022), dove into the quantification of the recovery speed across the countries, allowing us to determine which countries have dealt with the consequences of the pandemic better and which experienced more significant (not only economic) dam-

ages, and thus experienced a slower recovery. This is another suitable recommendation for future research within the Central European context.

Ongoing monitoring of entrepreneurial development remains a key issue as the consequences of ongoing Black Swan events (e.g., Yousaf et al., 2022) reshape global economic and diplomatic powers, which opens up new tensions between established EU members and Russia, while awaiting the response of the remaining G20 superpower countries, such as China. If the European Union member states come to the point that they remain in isolation from international trade or lose their competitiveness due to the enhanced competitiveness of Asian countries and their technological advancement, even in traditional European industries there could be serious social and economic consequences (Berger et al., 2022; Vokoun, Dvouletý, 2022). Therefore, a key area of interest for European as well as Central European policymakers is to promote innovative solutions in the region, critically assess to what extent the current business population lags behind the global trends due to its regulatory framework, and to adapt rapid changes in enhancing the quality of the European entrepreneurial ecosystem, fostering ongoing international trade activities between Europe and other continents.

References

Apostolopoulos N., Ratten V., Petropoulos D., Liargovas P., Anastasopoulou E. (2021) Agri-food sector and entrepreneurship during the COVID-19 crisis: A systematic literature review and research agenda. *Strategic Change*, 30(2), 159–167. https://doi.org/10.1002/jsc.2400

Aroles J., Bonneau C., Bhankaraully S. (2023) Conceptualising "meta-work" in the context of continuous, global mobility: The case of digital nomadism. *Work, Employment and Society*, 37(5), 1261–1278. https://doi.org/10.1177/09500170211069797

Audretsch D.B., Belitski M. (2021) Towards an entrepreneurial ecosystem typology for regional economic development: The role of creative class and entrepreneurship. *Regional Studies*, 55(4), 735–756. https://doi.org/10.1080/00343404.2020.1854711

Barbaglia L., Frattarolo L., Onorante L., Pericoli F.M., Ratto M., Pezzoli L.T. (2023) Testing big data in a big crisis: Nowcasting under COVID-19. *International Journal of Forecasting*, 39(4), 1548–1563. https://doi.org/10.1016/j.ijforecast.2022.10.005

Barbhuiya M.R., Chatterjee D. (2023) Just Survive or Thrive? Effect of Psychological and Organizational Resilience on Adoption of Innovative Strategies by Hospitality Sector Post Covid-19. *Tourism Planning & Development*, 20(2), 188–211. https://doi.org/10.1080/21568316.2022.2121312

Belitski M., Guenther C., Kritikos A.S., Thurik R. (2022) Economic effects of the COVID-19 pandemic on entrepreneurship and small businesses. *Small Business Economics*, 58, 593–609. https://doi.org/10.1080/21568316.2022.2121312

Berger J., Hesjedal S.H., Hoefnagels J. (2022) *The European Economy in a New World Order*, Berlin: Themis Foresight.

Betzler D., Loots E., Prokůpek M., Marques L., Grafenauer P. (2021) COVID-19 and the arts and cultural sectors: Investigating countries' contextual factors and early policy measures. *International Journal of Cultural Policy*, 27(6), 796–814. https://doi.org/10.1080/10286632.2020.1842383

Blažková I., Svatošová V., Chmelíková G., Tamáš V., Svobodová E., Grega L., Miškolci S., Piecuch J., Ujj A., Hupková D., Puchala J., Bazsik I., Jancsovszka P., Pércsi K.N., Dobošová L. (2023) The effects of COVID-19 crisis on small family farms: Empirical evidence from Visegrad countries. *Agricultural Economics (Zemědělská ekonomika)*, 69(9), 366–374. https://doi.org/10.17221/217/2023-AGRICECON

Brändle L., Signer H., Kuckertz A. (2023) Socioeconomic status and entrepreneurial networking responses to the COVID-19 crisis. *Journal of Business Economics*, 93(1), 111–147. https://doi.org/10.1007/s11573-022-01120-w

Brown R., Rocha A., Cowling M. (2020) Financing entrepreneurship in times of crisis: Exploring the impact of COVID-19 on the market for entrepreneurial finance in the United Kingdom. *International Small Business Journal*, 38(5), 380–390. https://doi.org/10.1177%2F0266242620937464

Bruothová M., Hurný F. (2016) Selected characteristics of business environment in Visegrad region. *Central European Journal of Management*, 3(1), 23–35. https://doi.org/10.5817/CEJM2016-1-3

Burke A., Millán J.M., Román C., van Stel A. (2018) Exploring the impact of different types of prior entrepreneurial experience on employer firm performance. *Journal of Business Research*, 90, 107–122. https://doi.org/10.1016/j.jbusres.2018.05.004

Carriero A., Clark T.E., Marcellino M. (2020) *Nowcasting Tail Risks to Economic Activity with Many Indicators*, Cleveland, OH: Federal Reserve Bank of Cleveland.

Castoldi R.C., de Ângelo J.C., Pereira T.T., Dias R.M., Negrão F.J. (2023) Relationship between physical exercise and COVID-19 (SARS-CoV-2): Systematic review. *Sport Sciences for Health*, 19(1), 55–67. https://doi.org/10.1007/s11332-022-01028-6

Cieślik J., van Stel A. (2023) Solo self-employment – Key policy challenges. *Journal of Economic Surveys*, 38(3), 759–792. https://doi.org/10.1111/joes.12559

Cirera X., Cruz M., Davies E., Grover A., Iacovone L., Cordova J.E.L., Medvedev D., Maduko F.O., Nayyar G., Ortega S.R., Torres J. (2021) Policies to Support Businesses through the COVID-19 Shock: A Firm Level Perspective. *The World Bank Research Observer*, 36(1), 41–66. https://doi.org/10.1093/wbro/lkab001

Cowls J., Tsamados A., Taddeo M., Floridi L. (2021) The AI gambit: Leveraging artificial intelligence to combat climate change — opportunities, challenges, and recommendations. *AI & Society*, 38, 283–307. https://doi.org/10.1007/s00146-021-01294-x

Csákné Filep J., Martyniuk O.A., Wojtyra-Perlejewska M. (2023) The state of family business research in the Visegrád countries. *Journal of Family Business Management*, 14(3), 562–602. https://doi.org/10.1108/JFBM-04-2023-0057

Davidsson P., Recker J., von Briel F. (2021) COVID-19 as External Enabler of entrepreneurship practice and research. *Business Research Quarterly*, 24(3), 214–223. https://doi.org/10.1177/23409444211008902

Demaj E., Hasimja A., Rahimi A. (2021) Digital nomadism as a new flexible working approach: Making Tirana the next European hotspot for digital nomads. In: *The Flexible Workplace* (eds. M. Orel, O. Dvouletý, V. Ratten), Cham: Springer, pp. 231–257. http://dx.doi.org/10.1007/978-3-030-62167-4_13

Dvorak J., Komarkova L., Stehlik L. (2021) The effect of the COVID-19 crisis on the perception of digitisation in the purchasing process: customers and retailers perspective. *Journal of Entrepreneurship in Emerging Economies*, 13(4), 628–647. https://doi.org/10.1108/JEEE-07-2020-0260

Dvouletý O. (2017) What is the relationship between entrepreneurship and unemployment in Visegrad countries? *Central European Business Review*, 6(2), 42–53. http://dx.doi.org/10.18267/j.cebr.179

Dvouletý O. (2021) A First Year's Impact of the Pandemic on the Czech Entrepreneurial Activity. *Foresight and STI Governance*, 15(4), 52.

Dvouletý O., Fernandez De Arroyabe J.C., Mustafa M. (2021) Entrepreneurship during the times of COVID-19 pandemic: Challenges and consequences. *Journal of Entrepreneurship in Emerging Economies*, 13(4), 489–496. http://dx.doi.org/10.1108/JEEE-09-2021-461

Dvouletý O., Orel M. (2020) Determinants of solo and employer entrepreneurship in Visegrád countries: findings from the Czech Republic, Hungary, Poland and Slovakia. *Journal of Enterprising Communities: People and Places in the Global Economy*, 14(3), 447–464. https://doi.org/10.1108/JEC-04-2020-0052

Eurostat (2023a) *Population by sex, age, citizenship and labour status (1 000) [lfsa_pganws__custom_8886535]*. https://data.europa.eu/data/datasets/sgn9cpapwul832abajaibq?locale=en, accessed 04.12.2023.

Eurostat (2023b) *Self-employment by sex, age and occupation (1 000) [lfsa_esgais__custom_8886407]*. https://data.europa.eu/data/datasets/mcnfsen90pcsafjvbqjmxq?locale=en, accessed 04.12.2023.

Eurostat (2023c) *Annual enterprise statistics for special aggregates of activities (NACE Rev. 2) [sbs_na_sca_r2__custom_9050090]*. https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_SCA_R2/default/table?lang=en, accessed 04.12.2023.

Eurostat (2023d) *Enterprise statistics by size class and NACE Rev.2 activity (from 2021 onwards) [sbs_sc_ovw__custom_9049940]*. https://ec.europa.eu/eurostat/web/structural-business-statistics/database, accessed 04.12.2023.

Foroni C., Marcellino M., Stevanovic D. (2022) Forecasting the Covid-19 recession and recovery: Lessons from the financial crisis. *International Journal of Forecasting*, 38(2), 596–612. https://doi.org/10.1016/j.ijforecast.2020.12.005

Gerwe O. (2021) The Covid-19 pandemic and the accommodation sharing sector: Effects and prospects for recovery. *Technological Forecasting and Social Change*, 167, 120733. https://doi.org/10.1016/j.techfore.2021.120733

Gubik A.S., Farkas S. (2019) Entrepreneurial intention in the Visegrad countries. *Danube*, 10(4), 347–368. https://doi.org/10.2478/danb-2019-0018%0A

Henrekson M., Sanandaji T. (2020) Measuring entrepreneurship: Do established metrics capture Schumpeterian entrepreneurship? *Entrepreneurship Theory and Practice*, 44(4), 733–760. https://doi.org/10.1177/1042258719844500

Holienka M., Gál P., Kovačičová Z. (2017) Drivers of student entrepreneurship in Visegrad four countries: Guesss evidence. *Central European Business Review*, 6(2), 54–63. http://dx.doi.org/10.18267/j.cebr.180

Jabłońska M., Fila J. (2021) Conditions for Development of Entrepreneurship in Regions of Visegrad Group Countries. *Prague Economic Papers*, 30(4), 470–488. http://dx.doi.org/10.18267/j.pep.777

Kiviet J.F. (1995) On bias, inconsistency, and efficiency of various estimators in dynamic panel data models. *Journal of Econometrics*, 68(1), 53–78. https://doi.org/10.1016/0304-4076(94)01643-E

Koca Z. (2022) Government Responses to COVID-19: A Comparative Analysis of Visegrad Countries. *Central European Public Administration Review*, 20(1), 57–84.

Kříž Z., Urbanovská J., Brajerčíková S. (2021) Refugees, Energiewende and NATO Deterrence: Limits of German Leadership in Central Europe. *European Security*, 30(1), 137–158. https://doi.org/10.1080/09662839.2020.1795836

Kuckertz A., Brändle L. (2022) Creative reconstruction: A structured literature review of the early empirical research on the COVID-19 crisis and entrepreneurship. *Management Review Quarterly*, 72(2), 281–307. https://doi.org/10.1007/s11301-021-00221-0

Kuckertz A., Bernhard A., Berger E.S., Dvouletý O., Harms R., Jack S., Kibler E. (2023) Scaling the right answers – Creating and maintaining hope through social entrepreneurship in light of humanitarian crises. *Journal of Business Venturing Insights*, 19, e00356. https://doi.org/10.1016/j.jbvi.2022.e00356

Liñán F., Jaén I. (2022) The Covid-19 pandemic and entrepreneurship: Some reflections. *International Journal of Emerging Markets*, 17(5), 1165–1174. https://doi.org/10.1108/IJOEM-05-2020-0491

Meyer N., Meyer D.F. (2019) Examining the impact of entrepreneurial activity on employment and economic growth: The case of the Visegrád countries. *Polish Journal of Management Studies*, 20(1), 277–292. http://dx.doi.org/10.17512/pjms.2019.20.1.25

Muzaffar H. (2023) Pandemic silver lining: How the COVID-19 pandemic helped women to beat the „gender stereotypes pandemic" in entrepreneurship. *Gender in Management: An International Journal*, 38(1), 76–92. https://doi.org/10.1108/GM-10-2021-0316

OECD (2020) *OECD Economic Surveys*, Paris: OECD Publishing.

OECD (2022) *OECD Tourism Trends and Policies 2022*, Paris OECD. https://doi.org/10.1787/20767773

OECD (2023) *Framework for the Evaluation of SME and Entrepreneurship Policies and Programmes 2023*, Paris: OECD.

Pratama H., Azman M.N.A., Kassymova G.K., Duisenbayeva S.S. (2020) The Trend in using online meeting applications for learning during the period of pandemic COVID-19: A literature review. *Journal of Innovation in Educational and Cultural Research*, 1(2), 58–68. http://dx.doi.org/10.46843/jiecr.v1i2.15

Ratten V. (2020) Coronavirus (COVID-19) and entrepreneurship: Changing life and work landscape. *Journal of Small Business & Entrepreneurship*, 32(5), 503–516. https://doi.org/10.1080/08276331.2020.1790167

Ratten V. (2021) Coronavirus (COVID-19) and entrepreneurship: Cultural, lifestyle and societal changes. *Journal of Entrepreneurship in Emerging Economies*, 13(4), 747–761. https://doi.org/10.1108/JEEE-06-2020-0163

Roncak M., Scholz P., Linderová I., Masilka D., Hobza V., Vrabcová P. (2023) Positive Impacts of the COVID-19 Pandemic on Czech Hospitality Industry. *e-Review of Tourism Research*, 20(1), 176–201.

Sacio-Szymańska A., Kononiuk A., Tommei S., Valenta O., Hideg É., Gáspár J. (2016) The future of business in Visegrad region. *European Journal of Futures Research*, 4(1), 26. https://doi.org/10.1007/s40309-016-0103-3

Sánchez-Vergara J.I., Orel M., Capdevila I. (2023) Home office is the here and now. Digital nomad visa systems and remote work-focused leisure policies. *World Leisure Journal*, 65(2), 236–255. https://doi.org/10.1080/16078055.2023.2165142

Sauka A., Chepurenko A. (eds.) (2017) *Entrepreneurship in transition economies: Diversity, trends, and perspectives*, Cham: Springer. https://doi.org/10.1007/978-3-319-57342-7

Schøtt T., Gerschewski S., Meyer N., Dvouletý O. (2024) Guest Editorial: Entrepreneurship Responses to Disruptions, Crises, and "Black Swans" – A Cross-Country, Comparative Perspective. *European Journal of International Management*, 33(4), 509–520.

Storr V.H., Haeffele S., Lofthouse J.K., Grube L.E. (2021) Essential or not? Knowledge problems and COVID-19 stay-at-home orders. *Southern Economic Journal*, 87(4), 1229–1249. https://doi.org/10.1002/soej.12491

Šímová T. (2023) A research framework for digital nomadism: A bibliometric study. *World Leisure Journal*, 65(2), 175–191. https://doi.org/10.1080/16078055.2022.2134200

Urbano D., Aparicio S., Guerrero M., Noguera M., Torrent-Sellens J. (2017) Institutional determinants of student employer entrepreneurs at Catalan universities. *Technological Forecasting and Social Change*, 123, 271–282. https://doi.org/10.1016/j.techfore.2016.06.021

Urbanovics A., Sasvári P., Teleki B. (2021) Evaluation of the COVID-19 regulations in the Visegrad group. *Transforming Government: People, Process and Policy*, 15(4), 645–657. https://doi.org/10.1108/TG-08-2020-0228

van Stel A., van der Zwan P. (2020) Analyzing the changing education distributions of solo self-employed workers and employer entrepreneurs in Europe. *Small Business Economics*, 55, 429–445. https://doi.org/10.1007/s11187-019-00243-9

Vokoun M., Dvouletý O. (2022) International, national and sectoral determinants of innovation: evolutionary perspective from the Czech, German, Hungarian and Slovak community innovation survey data. *Innovation: The European Journal of Social Science Research*, 1–41 (ahead of print), https://doi.org/10.1080/13511610.2022.2158309

World Economic Forum (2019) *The Global Competitiveness Report 2019*, Geneva: World Economic Forum.

Yousaf I., Patel R., Yarovaya L. (2022) The reaction of G20+ stock markets to the Russia–Ukraine conflict "black-swan" event: Evidence from event study approach. *Journal of Behavioral and Experimental Finance*, 35, 100723. https://doi.org/10.1016/j.jbef.2022.100723

Zygmunt J. (2018) Entrepreneurial activity drivers in the transition economies. Evidence from the Visegrad countries. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 13(1), 89–103. https://doi.org/10.24136/eq.2018.005

The Digital Entrepreneurship Ecosystem in the Central Eastern European Countries

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Abstract

While the economic transition from a planned economy to a market economy seems to be over for most countries after 25 years, a socialist heritage could have long lasting effects. In this paper we aim to answer to the following two research questions: (1) How deeply have Central and Eastern European (CEE) countries proceeded in digital entrepreneurship? (2) Are there some specific digital entrepreneurship characteristics of the CEE countries that can be explained by their socialist heritage? We applied the Digital Entrepreneurship Ecosystem (DEE) Index methodology that relies upon a dataset for 170 countries to evaluate the former socialist CEE countries' performance in the development of a digital entrepreneurship ecosystem. The non-EU Western countries are the best performers in Europe, but Western EU member states are close behind. The Southern European country group's performance is close to the EU CEE country cluster, implying that these countries have caught up with most Southern European countries in their DEE development. The former SU country group and the non-EU Balkan country groups are very similar to each other. We also examined the four sub-indices and the twelve pillars and concluded that DEE scores vary significantly among European countries, but these differences can be explained by economic development and not the long-lasting effects of the socialist system. We also provided a detailed DEE profile for Russia, which explains Russia's modest performance in the development of a digital entrepreneurship ecosystem.

Keywords: Digital Entrepreneurship Ecosystem; DEE index; Central Eastern European region; Russia

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Introduction

Digital technologies have reshaped our world over the last few decades. Digitalization, as a general technology has affected all industries and all aspects of our lives (Chui et al 2023; Dwivedi, 2021). At the firm level, digitalization contributes to increasing sales, technology development, product innovation, and efficiency (Kreuzer et al., 2022). It also enhances new business creation and increases overall productivity (Zahra et al., 2023).

Digitalization and most importantly the internet have also changed the nature of entrepreneurship as (1) entrepreneurial processes become more fluid and less bounded and (2) entrepreneurial agency increasingly relies on a more diverse and frequently growing number of actors (Nambisan, 2017). Digitalization has contributed to the development of business processes, business resource and business model transformation that has led to the appearance and evolution of digital entrepreneurship ecosystems (Kraus et al., 2019; Kollmann et al., 2022; Paul et al., 2023). Digital innovations include not only technology development: Platformization has transformed how businesses are organized and contributed to the emergence of giant, multitrillion-dollar companies. Platforms, connecting the two sides of the market, have become the dominant form of business replacing traditional corporate organizations (Acs et al., 2021; Kenney, Zysman, 2016).

However, the spread of digitalization is not even, there are considerable differences. The first level of the digital divide refers to the groups of countries that do not have proper or equal access to digital tools (Van Dijk, 2017). The second level of the digital divide is associated with digital literacy, the lack of the "ability to efficiently and effectively find information on the Web" (Hargittai, 2002). A third degree of the digital divide was identified recently as inequality in the tangible outcomes of internet use (Scheerder et al., 2017). Therefore, the positive effects of digitalization are unevenly distributed across and within countries, calling for government involvement in shaping the widely interpreted environment of digital technology. At the same time, governments have limited power to influence the spontaneous evolution of the ecosystem, so instead of the direct interventions, indirect participation methods seem to be more useful. Nevertheless, government policy should be appropriately targeted to achieve the desired effects, which require the proper measure of digital technologies in their environment.

One way is to examine new digital technology creation capacity and the other is to examine to what extent countries are digitalized. While new technology innovation is mostly concentrated on a limited number of countries and regions[1], all countries are digitalized to a certain extent. The ecosystem approach provides us a useful way to conceptualize digitalization and examine it on a country level.

In this paper, we focus on a specific group of nations, the former socialist countries in Europe that transitioned from a planned to market economy system. While transition research was a popular topic in the 1990s and 2000s, interest had declined by the 2010s. Now these countries are viewed as variants of the capitalist system (Kitov, 2009, Dilli et al., 2018). However, current research shows that their socialist past has not passed without a trace (Havrylyshyn, 2009). Magyar and Madlovics (2020) claim that behind the formally transferred institutions, there are path-dependent 'stubborn structures' that exist with hidden, informal arrangements that undermine the formal institutions. Szerb and Trumbull (2016) found that Central and Eastern European (CEE) countries' cultural support for business creation lags behind Western European nations. In addition, CEE countries' performance is not uniform – there are considerable differences (Chepurenko, 2017). While the CEE EU members' handicaps are diminishing, Balkan countries are falling behind Western Europe significantly. These countries face a new challenge of digitalization, but digital technologies could also provide an alternative way to close the development lag. So, it is worth investigating how the CEE countries perform in a digital technology-fueled entrepreneurship.

In the following, we provide a short description of the evolution of digital entrepreneurship. Next, we explain the Digital Entrepreneurship Ecosystem (DEE) Index construction and methodology. With the help of the DEE, we analyze European country performances in the digital entrepreneurship ecosystem and their components by emphasizing the CEE nations. Unlike other approaches that interpret CEE countries as formerly socialist EU members (Brodny, Tutak, 2022; Huang, 2023; Trașcă et al., 2019) we consider all Central and Eastern European nations, including the Balkans and former Soviet Union (SU) successor states from Europe. Our highlighted case is Russia, the largest country in the CEE region with vast natural resources but a limited level of entrepreneurship (Obraztsova, Chepurenko, 2020; Szerb, Trumbull, 2018). Based on the Digital Entrepreneurship Ecosystem (DEE) Index, we provide a full picture of Russia's digital entrepreneurship ecosystem, its development, as well as strong and weak points over the 2020-2022 period.

The Evolution of Digital Entrepreneurship – from Digital Technology Creation to a Digital Ecosystem

The development of digital technologies has changed the business environment and ignited digital business. This in turn has breathed new life into traditional industries, enabling them to survive and adapt (Gao et al., 2013), and also enabled the creation of new businesses and digital start-ups that incorporate new technology as a core element of their business model and operations

[1] Like US (Silicon Valey, Seattle, Boston), China (Beijing, Hong Kong, Shanghai), India (Mumbai), Singapore, and the United Kingdom (London).

(Elia et al., 2020). Businesses nowadays are using information and communication technology (ICT) tools[2] to automate a variety of business activities that require significant human involvement (Paul et al., 2023). The impact of these technologies goes beyond incremental changes and challenges entrenched in business strategies, models, and processes (Bharadwaj et al., 2013).

These digital technologies in the entrepreneurial sphere take the form of three distinct but interrelated elements – digital artifacts, digital platforms, and digital infrastructure (Nambisan, 2017). A digital artifact is defined as a digital component, application, or media content that is part of a new product (or service) and offers a specific function or value to the end user (Ekbia, 2009; Kallinikos et al., 2013). Digital platforms are a complex mix of software, hardware, operations, and networks. Most importantly, they provide a common set of techniques, technologies, and interfaces for a wide range of users to build what they want. These platforms often upend the existing organization of economic activity by resetting the barriers to entry, changing the logic of value creation and capture, playing regulatory arbitrage, repackaging work, or repositioning power in the economic system (Kenney, Zysman, 2016). Digital infrastructure refers to digital technology tools and systems that provide communication, collaboration, or computing capabilities to support innovation and entrepreneurship (Nambisan, 2017). Kobzev et al (2020) have also found that the increase in productivity and competitiveness of industrial enterprises is directly related to the use of digital technologies. These digital technologies, like big data, new algorithms, and cloud computing are changing the nature of work and the structure of the economy. But as Kenney and Zysman (2016) highlight, the exact nature of this change will be determined by our social, political, and business choices.

As the world is moving toward digitalization, transforming into a virtual world, entrepreneurship is following digitalization trends to quietly transform into digital entrepreneurship (Paul et al., 2023). This is because digital technologies democratize entrepreneurship by reducing the barriers between invention and the creation of new businesses (Aldrich, 2014; Kelly, 2016). Digital entrepreneurship refers not only to the creation of new businesses but also the transformation of existing businesses by developing new digital technologies or experimenting with new uses of them (European Commission, 2015; Zhao, Collier, 2016; Shen et al., 2018). Nowadays, digitalization is widespread across most industries and business types, with only very traditional businesses not yet fully affected (Elia et al., 2020). According to Paul et al. (2023), typical traditional enterprises follow six steps on their way to digitalization: 1. Digital Knowledge Base Creation, 2. Digital Technology Adoption, 3. Digital Platform Readiness, 4. Digitalization Process, 5. Transition to Digital Ecosystem, and 6. Successful Digital Transformation of a Traditional Enterprise into a Digital Enterprise. Kraus et al. (2019) identified six research areas focusing on digital entrepreneurship: digital business models, digital entrepreneurship process, platform strategies, digital ecosystem, entrepreneurship education, and social digital entrepreneurship. Platform organization has become the new dominant business organization where digital technology fuelled network effects contribute to the emergence of giant digital enterprises (Acs et al., 2021).

The digitalization activity of new businesses does not depend on a single firm, but on the entire entrepreneurial ecosystem (Zahra et al., 2023). Our approach is based on Sussan and Acs (2017), who define the digital entrepreneurship ecosystem as the integration of "the entrepreneurial ecosystem with its focus on agency and the role of institutions and the digital ecosystem with its focus on digital infrastructure and users" (p. 62). An entrepreneurial ecosystem can be described in terms of the actors and stakeholders involved, who contribute directly or indirectly to the achievement of the same ecosystem's goals through different roles and responsibilities (Elia et al., 2020). Levchenko and Konvisarova (2022) also stress that the digital economy is thus an important driver of economic development, offering innovative solutions to global problems, increasing the efficiency of public administration decisions, and promoting the active participation of businesses and civil society in shaping the country's economic well-being. Digitalization is changing society, creating new patterns of interaction and interdependence between technology and citizens, organizations and citizens, and technology and organizations (Stratu-Strelet et al., 2023).

The Digital Entrepreneurship Ecosystem (DEE) Concept

The DEE concept views digitalization via the lens of entrepreneurship. The DEE is built out of two ecosystems, namely, the digital ecosystem and the entrepreneurial ecosystem. The newly developed framework positions digital entrepreneurship within the wider context of digital infrastructure, users, institutions, and agents in such a way that users and agents constitute an individual agency, and the digital infrastructure and digital platforms form the external environment (Sussan, Acs, 2017). Song (2019) provides a refinement of the original DEE concept that helps us measure the DEE and its components.

The DEE Index was created to present a country-level measure of the DEE. The DEE Index consists of four sub-indices: Digital Technology Infrastructure (DTI), Digital User Citizenship (DUC), Digital Multisided Platforms (DMSP), and Digital Technology Entrepre-

[2] Such as artificial intelligence, chatbots, mobile applications (apps), social media platforms, cloud-based services, enterprise resource planning systems, big data and business analytics, web-based services, and a host of other internet-based technologies.

neurship (DTE). These sub-indices include the key economic, business, social, and policy issues: competition, privacy, innovation, and security, respectively. Each sub-index consists of three pillars and each pillar has two types of components, called variables. One variable always represents the entrepreneurship component and the other, that of the digital ecosystem (Sussan, Acs, 2017; Song, 2019; Szerb et al., 2020).

The twelve pillars are the central features of the DEE Index providing sufficient specifics about the configuration of the various DEE characteristics but not getting lost in the details. Table 1 provides a short description of the pillars.

Table 2 shows the structure of the DEE and provides a brief description of each variable. Each pillar is built from two to five indicators from various online sources such as GSMA Mobile Connectivity Index, UNCTAD, International Telecommunication Union, World Bank, Kaspersky, United Nations, and so on. The data collection covers the period of 2020-2022.

The Transition of the CEE Countries

Our focus countries from Central and Eastern Europe share partially common cultural and historical roots – most importantly a long lasting socialist, planned economy system (Brodny, Tutak, 2022). However, these countries have gone through different phases and development paths since they started their transition to a market economy (Dyba et al., 2018; Farkas, 2016). Half of these countries joined the European Union between 2004-2013, and Balkan countries also aim for accession to the EU. The former Soviet Union (SU) countries, with the exception of the Baltic states, chose other ways of development that deviate from the initially intended market economy and are often consider to have experience a backside transition (Gevorkyan, 2018; Chepurenko, Szanyi, 2022).

The transition from a planned economy to a market economy was a unique transformation experiment without previous historical examples and experiences (Blanchard, 1996; Blith, 2002). While it was believed that stabilization, the institutional reforms for the establishment of market-based institutions and privatization, and the dominance of private property at the cost of state ownership form the basis of the economic transition, the actual steps, their order, speed, and depth varied significantly between countries (De Melo et al., 1996; Kornai, 2006; Sachs, 1996). At the later stages of the transition, economic restructuring and the rise of productivity turned into the center of interest (Aghion et al., 1997). Capital shortages, the lack of proper management skills, and the low level of technology absorption capacities were the major obstacles impeding further development in this phase. Many transitional countries, most importantly the EU member CEE nations, supported export-oriented growth and foreign direct investment (FDI) (Csaba, 2005; Medve-Bálint, 2014; Szanyi, 2022). Albeit, to varying degrees, this policy has led to a dual-economy structure in many transitional countries, similar to other developing nations, with the presence of a high productive foreign and a low productive domestic sector (Farkas, 2016). In the Balkans and the former Soviet countries, the institutional reforms even reversed, which caused a transitional backslide phenomenon (Chepurenko, Szanyi, 2022).

Table 1. **Short Descriptions of Sub-indices and their Comprising Pillars**

Subindex	Pillars
The Digital Technology Infrastructure (DTI) subindex addresses the strengths and success of institutions in supporting digital technology infrastructure and its development.	*Digital Openness* pillar encompasses a nation's institutional effort to support the use and development of digital technology infrastructure.
	Digital Freedom pillar integrates the government regulation effort to freely use the internet with competition in the ICT sector.
	Digital Security pillar captures the success of laws and regulation to protect from piracy and cybercrime.
The Digital User Citizenship (DUC) subindex aims to describe the influence of institutions, both the explicit legitimization and the implicit social norms, on the users of digital technology.	*Digital Literacy* pillar refers to the ability of the country's population to use the digital tools and the effort of the government to support digitalization.
	Digital Access pillar measures how well citizens could access digital infrastructure and how well the institutions support it.
	Digital Rights pillar include the strength of the institutions in terms of fundamental rights, individual rights, and private property rights and how it supports citizens in the use of the digital infrastructure and how it protects their privacy.
Digital Multisided Platforms (DMSP) is where users of the digital ecosystem and agents of the entrepreneurship ecosystem interact. DMSPs can be viewed as an intermediary for trade and a medium for knowledge exchange.	*Networking* pillar aims to grasp the network effects of DMSPs. The network effect is a kind of externality when the value of the product or service depends upon the number of users.
	Matchmaking pillar applies in the case of two-sided platforms and aims to capture the value depending on the matching of a seller and a buyer.
	Financial Facilitation pillar includes platform-based alternative finance where users patronize businesses and financial technology firms provide alternative payment tools for users.
The Digital Technology Entrepreneurship (DTE) sub-index is comprised of those agents that partake in the alternative use and the development of digital technologies. It measures how entrepreneurial agents rely on digital technologies.	*Digital Tech Usage* pillar components reflect the entrepreneurial agents' basic ability to use digital technologies.
	Technology Adoption pillar measures how entrepreneurial agents can adopt existing digital technologies.
	Technology Diffusion pillar considers the capability of entrepreneurial agents not only to adopt but to diffuse these technologies.

Note: a full description of all 54 indicators can be found in the supplementary data to the article: https://foresight-journal.hse.ru/article/view/24109

Source: compiled by the authors

The transitional countries were affected by the 2008 global crisis very differently and their responses were also varied without one being able to generalize their responses (Biledeux, 2014). By the 2020s, divergent growth models emerged even in the EU member CEE countries with significant differences in terms of institutional development, the governments' expenditures (as percentage of GDP), innovation performance, human capital development, and financial conditions (EU transfer). As Győrffy (2022) reported, the most successful countries, the Czech Republic, Estonia, Lithuania, and Slovenia, demonstrate common characteristics with strong institutions, a knowledge focus, and favorable financial conditions. A lack of institutions characterizes Hungary and Romania, while Bulgaria, Croatia, and Slovakia face institutional/educational difficulties coupled with unfavorable finances.

Below we use the Bertelsmann Stiftung BTI Transformation Index to illustration the variations of the examined countries in terms of political, economic, and governance transitions. The BTI Index consists of the Status Index and the Governance Index based on 17 criteria and 49 questions. The Status Index reports on the countries based on the state of their democracy and market economy. The Governance Index gives details about the performance of the respective country's leadership. In 2024, there were 137 countries in the dataset (BTI, 2024). Table 3 contains the latest 2024 report data where we calculated the overall BTI score based on the average of the political, economic, and governance scores.

It is clear that the transitional scores in each sub-category coincide with the level of development, albeit the Baltic countries have higher scores than the other countries with the exception of the per capita GDP leader, Czech Republic. Hungary looks like an outlier in the EU member CEE group mostly because of governance performance. The Balkan countries have somewhat better performance than former Soviet countries that are not members of the EU, where Belarus and Russia are at the bottom. Out of the three main categories, governance, reflecting to quality of political management, has the lowest scores in all three country groups indicating that transition has not fully finished. As Győrffy (2022) claims, while the convergence of the EU member CEE countries continued in the 2010s, none of them could overcome the middle-income trap and reaching the average per capita GDP of the EU.

Table 2. **The Structure of the DEE Index for Digital Platform Economy**

Pillars	Variables (entrepreneurship / digital)	Variable content
Digital Technology Infrastructure		
Digital openness	Institutions	Capturing ICT and internet regulation,
	Technology	Network coverage and internet subscription
Digital freedom	Institutions	Business, world press, general freedom and internet competition combined with mobile tariffs
	Technology	Mobile tariffs and handset prices
Digital protection	Institutions	Measuring laws and regulations on cybercrime and cybersecurity
	Technology	Secure internet servers per million population, net infection ratio
Digital User Citizenship		
Digital literacy	Institutions	Human capital, the promotion of e-participation, tertiary education
	Users	Digital skills among the population
Digital access	Institutions	The existence of technical institutions, frameworks, policy coordination institutions, and strategies dealing with cybersecurity
	Users	Percentage of households with internet access
Digital rights	Institutions	Personal rights, fundamental rights, and property rights, internet privacy
	Users	Percentage of individuals using the internet, the gender gap in mobile ownership
Digital Multi-sided Platforms		
Networking	Agents	Language support of internet
	Users	Social media penetration
Matchmaking	Agents	E-government, locally developed apps, language accessibility of top apps
	Users	Mobile ownership
Financial facilitation	Agents	Access to finance, the number of financial technology businesses
	Users	Active mobile broadband subscription, the usage of digital financial solution
Digital Technology Entrepreneurship		
Digital Tech Usage	Agents	Computer software spending, skills, firms with a website
	Technology	Mobile speed, access to electricity
Digital Technology Adaptation	Agents	Industry capacity, adoption of emerging technology
	Technology	Generic top level domains, spectrum
Digital Technology Diffusion	Agents	Research & Development, number of researchers
	Technology	M2M mobile subscriptions, data centers

Source: authors, based on (Szerb, 2021).

Table 3. **The BTI Transformation Index: Political, Economic, and Governance Scores for the CEE Countries (2024)**

Country/region	Transformation			BTI score
	Political	Economic	Governance	
EU member CEE				
Bulgaria	7.20	7.64	5.65	6.83
Croatia	8.55	8.57	6.17	7.76
Czechia	9.20	9.21	6.87	8.43
Estonia	9.75	9.29	7.35	8.80
Hungary	6.30	6.82	3.79	5.64
Latvia	8.95	8.61	7.22	8.26
Lithuania	9.50	9.07	7.45	8.67
Poland	7.40	8.14	5.12	6.89
Romania	7.65	7.57	5.19	6.80
Slovakia	8.60	8.64	6.27	7.84
Slovenia	8.95	9.21	6.41	8.19
Average	**8.37**	**8.44**	**6.13**	**7.65**
Non-EU Balkan				
Albania	7.50	7.04	6.56	7.03
Bosnia and Herzegovina	5.55	6.29	3.64	5.16
Montenegro	7.10	7.14	5.93	6.72
North Macedonia	7.75	7.18	6.27	7.07
Serbia	6.05	6.64	4.43	5.71
Average	**6.79**	**6.86**	**5.37**	**6.34**
Non-EU, Former SU				
Belarus	3.47	5.04	2.22	3.58
Georgia	5.65	5.93	5.21	5.59
Moldova	6.70	6.04	5.69	6.14
Russia	3.43	4.93	2.55	3.64
Ukraine	7.05	5.96	6.04	6.35
Average	**5.26**	**5.58**	**4.34**	**5.06**

Source: authors, using BTI data (https://bti-project.org/en/downloads, accessed 27.07.2024).

In a highly cited paper, McMillan and Woodruff (2002) claimed that the success of transition ultimately depends on the performance of the country's entrepreneurs. The examined former socialist countries started the entrepreneurial transition from a disadvantaged position (Estrin et al., 2006). It was believed that supporting institutions would create productive entrepreneurship (Baumol, 1990). Over years, many transitional countries initiated entrepreneurship supporting programs while informal, culturally embedded institutional factors delayed the entrepreneurial transition, in particular in the new, formerly Soviet states (Estrin, Mickiewicz, 2011). Instead of a unified convergence to the Western, market economy countries, several strange forms of capitalist models have emerged, such as cronyism, oligarchy, clientelism, and nomenclature entrepreneurship frequently associated with the large role played by the state and state-owned enterprises (Bałtowski et al., 2022; Chepurenko, Szanyi, 2022; Ivlevs et al., 2021). While these characteristics mostly refer to the Baltic and the former SU countries, recently there are signs in Hungary and in Poland of the strengthening of patronage (rent seeking) entrepreneurship (Szanyi, 2022).

Digital Entrepreneurship in the CEE Context

The digitalization revolution reached the former socialist countries when the transition was nearly finished at least in the most advanced EU member CEE countries. Trașcă et al. (2019) find that CEE countries that are part of the EU lag far behind the leading countries in terms of digitization and are below the EU average. Brodny and Tutak (2022) show that, despite a common history of political and related economic transformations, there are large differences in the level of digitization between the CEE countries. However, this deviation can be explained more by their lower development levels than their socialist heritage (Lazar et al., 2019).

We examine the digital entrepreneurship ecosystem of the former socialist CEE countries grouped into three categories as EU member CEE countries (11 countries)[3], non-EU Balkan countries (5)[4], and non-EU former Soviet countries (5).[5] We also report three other groups' performances as Western EU (10 countries)[6], Southern EU (6),[7] and non-EU Western Europe (4).[8] As a country case, we will elaborate upon Russia's DEE profile.

We aim to answer to the following two research questions: (1) How deeply have CEE countries progressed in digital entrepreneurship? (2) Are there some specific digital entrepreneurship characteristics of the CEE countries that can be explained by their socialist heritage? Particularly, we are looking for specific DEE pillars that are significantly weaker or stronger than the other examined country groups. We examine the different levels of the digital entrepreneurship ecosystem including the super-index DEE score, its four sub-indices, twelve pillars, the entrepreneurship, and the digital components. In addition, by identifying the bottlenecks, we provide some policy recommendations based on improvements of the weak pillars.

First, we provide the basic ranking of the countries based on the overall DEE score. According to Appendix 1, developed countries lead the DEE ranking. Denmark is number one and Western European countries,

[3] Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.

[4] Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, Serbia. We have no data for Kosovo.

[5] Belarus, Georgia, Moldova, Russia, Ukraine.

[6] Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden.

[7] Cyprus, Greece, Italy, Malta, Portugal, Spain.

[8] Iceland, Norway, Switzerland, United Kingdom.

Table 4. **The DEE Index Score Development for the European Country Groups and Russia between 2020–2022**

Country group	DEE 2020	DEE 2021	DEE 2022	Development over 2020-2022 (%)	Development over 2020-2022
Non-EU Western Europe	75.8	77.5	80.3	5.9%	4.5
Western EU	72.3	74.1	77.2	6.9%	5.0
Southern EU	63.4	65.0	68.4	8.0%	5.1
EU member CEE	57.9	60.5	62.4	7.7%	4.5
Non EU-Former SU	41.6	43.0	43.8	5.1%	2.1
Non EU Balkan	36.2	37.5	39.9	10.0%	3.6
Russia	52.6	54.2	53.7	2.1%	1.1
Overall average	33.8	35.2	36.5	7.9%	2.7

Source: authors.

both EU members and non-EU members are not far behind the leader. Southern EU countries have similar scores as the best three CEE countries, Estonia, Slovenia, and the Czech Republic. The EU member CEE countries occupy the DEE Index ranking between 19th (Estonia) and 47th (Romania) out of the 170 countries. Only one non-EU former socialist country, Russia, has similar performance at 44th place. Other non-EU former SU countries include Georgia (56th), Ukraine (57th), Moldova (70th), and Belarus (73rd). Non-EU Balkan countries have a similar ranking as the previous former SU group, Serbia being the best (53rd) and Bosnia and Herzegovina the worst (87th).

By examining the development of the DEE Index scores over the 2020-2022 period (Table 4), we can see that there was notable development in the digital entrepreneurship ecosystem in Europe, a 7.9% increase on average. However, there are considerable differences among the countries and country groups. In relative terms, the most lagging non-EU Balkan countries progressed the most, followed by Southern EU nations. EU member CEE country DEE scores' increase was slightly below the EU average and the non-EU former SU countries are at the bottom with 5.1% increase in the DEE score. However, the differences between the leading nations and the CEE country groups increased in absolute terms. Russia performed worse than its group average, with 2.1% growth in its digital entrepreneurship ecosystem. In fact, Russia's DEE index score somewhat decreased from 2021 to 2022.

Table 5 goes further into the the DEE Index by showing the four sub-index values, the Digital Ecosystem (DE), and the Entrepreneurship Ecosystem (EE) scores in 2022.

According to Table 4, the ranking of the country groups for the four sub-indices mostly follow the DEE Index score ranking except for DTI, where the non-EU Western European countries are ahead of the Western EU country group. The differences between the EU member CEE countries and the other former socialist countries are significant, more than 50% in each sub-index, except DUC, so it seemingly pays off to be an EU member. The DE scores are higher than the EE ones in each country group indicating that the digital ecosystem is more advanced than the entrepreneurship ecosystem. The difference is high in the case of Russia, where DE scores exceed the EE scores by 19% implying significant inequalities between the two components.

Table 6 serves to present the twelve pillar values for our EU regions. We also show the lowest and the highest pillar values for each country group and the relative lag of the particular country group as compared to the leading group. The pillar values of the country groups mostly follow the previous rankings: Developed European countries, both EU members and non-EU mem-

Table 5. **The Four Sub-Index Scores and the DE and EE Scores of the European Country Groups and Russia (2022 data)**

Country	DTI score	DUC Score	DMSP score	DTE score	DE score	EE score	DE/EE ratio	DEE Index score
Non-EU Western Europe	79.3	83.2	79.1	79.9	92.2	83.9	1.099	80.3
Western EU	79.9	77.3	73.3	78.5	88.9	84.7	1.050	77.2
Southern EU	71.3	69.5	71.6	61.3	82.9	78.9	1.050	68.4
EU member CEE	67.9	63.2	62.2	56.1	80.3	74.7	1.075	62.4
Non EU-Former SU	44.2	46.1	47.1	37.6	70.0	59.4	1.178	43.8
Non EU Balkan	44.6	43.9	38.6	32.6	67.6	57.2	1.181	39.9
Russia	48.6	58.2	58.6	49.6	77.7	65.3	1.190	53.7
Overall average	38.1	35.8	36.2	36.0	57.5	52.9	1.088	36.5

Source: compiled by the authors

Table 6. **The Twelve Pillar Scores and the Gap between the European Country Groups and Russia (2022 data)**

DEE Direction (gap value in brackets)	Non-EU Western Europe	Western EU	Southern EU	EU member CEE	Non EU Former SU	Non EU Balkan	Russia	Overall average
Digital Access	84.1 (0.0%)	81.9 (2.6%)	**81.3** (3.3%)	68.2 (19.0%)	37.5 (55.4%)	51.7 (38.5%)	***34.8*** (58.6%)	37.0
Digital Freedom	84.1 (0.0%)	81.1 (3.6%)	61.6 (26.8%)	65.8 (21.7%)	36.9 (56.2%)	39.1 (53.5%)	37.5 (55.4%)	35.6
Digital Protection	76.9 (12.0%)	**87.4** (0.0%)	77.6 (11.1%)	**78.5** (10.1%)	**66.5** (23.9%)	**53.2** (39.1%)	**83.6** (4.3%)	48.3
Digital Literacy	85.6 (0.0%)	77.1 (9.9%)	69.4 (18.9%)	62.4 (27.1%)	54.5 (36.4%)	50.1 (41.5%)	68.9 (19.5%)	36.5
Digital Openness	88.2 (0.0%)	85.9 (2.7%)	77.4 (12.3%)	70.0 (20.6%)	51.9 (41.2%)	45.3 (48.6%)	79.1 (10.3%)	39.7
Digital Rights	84.9 (0.0%)	78.3 (7.8%)	66.3 (21.9%)	63.5 (25.2%)	39.3 (53.6%)	46.1 (45.7%)	40.5 (52.3%)	37.9
Networking	81.5 (0.0%)	75.8 (6.9%)	80.7 (1.0%)	66.4 (18.4%)	56.8 (30.3%)	45.2 (44.6%)	72.2 (11.4%)	39.5
Matchmaking	***73.3*** (0.0%)	***71.5*** (2.5%)	72.4 (1.3%)	65.5 (10.6%)	55.4 (24.5%)	45.0 (38.6%)	74.2 (-1.2%)	38.4
Financial Facilitation	**89.7** (0.0%)	79.4 (11.6%)	69.3 (22.7%)	59.7 (33.5%)	37.4 (58.3%)	32.2 (64.1%)	42.6 (52.5%)	37.4
Technology Usage	87.6 (0.0%)	81.7 (6.7%)	67.6 (22.9%)	57.7 (34.2%)	42.6 (51.4%)	43.3 (50.6%)	48.2 (45.0%)	41.9
Digital Adoption	78.6 (6.3%)	83.9 (0.0%)	59.6 (28.9%)	60.9 (27.4%)	***35.2*** (58.0%)	31.0 (63.1%)	46.3 (44.8%)	35.6
Technology Diffusion	81.2 (0.0%)	79.2 (2.5%)	***58.0*** (28.6%)	***51.8*** (36.2%)	37.3 (54.0%)	***26.5*** (67.4%)	58.2 (28.3%)	36.0

Legend: Bold letter: highest pillar; Bold and Italic letter: lowest pillar.
Source: compiled by the authors

bers, lead, followed by Southern EU and CEE countries. We also report a gap between the leading and other country groups for each pillar: Non-EU member Western countries lead in ten out of the twelve pillars, EU member Western countries lead in two cases (Digital Protection and Digital Adoption). In a surprising turn, Russia's Matchmaking value is higher than that of the non-EU Western country average. While the average gap between the non-EU and the EU Western countries is below 5%, Southern EU countries are behind by 17%, CEE countries by 23.7%, non-EU former SU countries by 45.3%, and non-EU Balkan countries by almost 50%, implying significant differences in digital entrepreneurship ecosystem development. Russia's average lag is 31.8%. Viewing the strong and weak pillars, there are, again, some alterations, however, there is only one case, Digital Protection, which seems to be the strongest pillar of former socialist countries. This pillar is particularly high in Russia, probably not independently from military applications. In the other cases, we do recognize any systematic differences that could be associated with socialist heritages.

Case Analysis of Russia

In a seminal study, Baumol (1990) posited that the level of entrepreneurship over time is about the same. However, the usefulness of entrepreneurial activity depends upon the institutional development. Under weak institutions, there are many non-effective and even destructive entrepreneurial events while strong and favorable institutions make the emergence of productive entrepreneurship possible. Baumol's idea proved to be particularly useful in explaining transitional countries' entrepreneurship. Many researchers concluded that Russia's low entrepreneurial activity and weak entrepreneurial performance is due to institutional deficiencies (Ageev et al., 1995; Aidis et al., 2008; Welter, Smallbone, 2017). Russia's institutional environment does not really support innovative startups (Veselovsky et al., 2017). Besides the institutional factors, the differences of actors, both businesses and individuals, regarding entrepreneurial skills, attitudes, and innovative behavior is also important. Szerb and Trumbull (2018) also highlight the importance of institutional development in Russia, but they called the attention to the individual factors that also explain why Russia is different than the transitional country group.

The shift to the digitalization of entrepreneurial activity have contributed to raising Russia's economic potential.[9] There are some positive examples of Russia's digital potential such as important tech-based companies – for example, ABBYY FineReader, Ngnix, Kaspersky, VK, and Yandex (Gritsenko et al., 2021). Despite this, the country is lagging behind global benchmarks (Levchenko, Konvisarova, 2022; Askerov et al., 2018). The growth of the high-tech sector in developed countries is accompanied by low efficiency in the Russian high-tech sector (Askerov et al., 2018). The discrepancies in digitization across Russian regions also underlines the need for tar-

[9] Of course, the downside, as for any other country, was an increase in the threats essential for the digital economy: complication of market control, data manipulation, information leakage, increase in fraud and deception, etc. (Makasheva, 2012).

Table 7. **The Development of Russia's DEE Index and the Four Sub-index Scores for 2017–2022**

Year	DTI	DUC	DMSP	DTE	DEE
2017	29.8	43.4	42.8	46.0	40.5
2018	30.5	47.5	44.6	45.9	42.1
2019	34.8	52.9	53.3	48.1	47.3
2020	49.5	59.4	51.8	49.5	52.6
2021	49.3	60.4	58.2	48.9	54.2
2022	48.6	58.2	58.6	49.6	53.7

Source: compiled by the authors

geted technology transition strategies (Zhulikov, Zhulikova, 2022).

The need to develop a digital economy was recognized as a national priority in Russia, expressed in a 2017 governmental order titled "Digital Economy of the Russian Federation". The project has ambitious aims to modernize Russia and to establish the digital economy ecosystem via the creation of the required institutional and infrastructural factors. The program targets the development of high-tech businesses as well as traditional industries and SMEs and an overall increase in the competitiveness of the Russian industries. This program emphasized digital security and the use of local software by federal and local governments and organizations (Abalakin et al., 2023). While the program highlights the micro level – markets and industries – and the environmental – institutional and infrastructural – factors, it does not deal with the digital platforms and technologies that are also vital for the entire digital entrepreneurship ecosystem (Lowry, 2022). Lukashov et al. (2021) also note that there are some contradictions between the program's ambitious goals and the its implementation.

Below, we use some of the digital economy program targets to evaluate the progress of Russia's digital economy.

Looking at Russia's digital entrepreneurship ecosystem development, we have shown previously that Russia ranked 44th in the DEE Index with a score of 53.7 (2022). With this performance Russia is leading its country group and precedes two EU-member CEE countries: Romania and Bulgaria. In 2022, DTI (48.6) proved to be the weakest and DMSP (58.6) was the best performing sub-index. DUC (58.2) and DTE (49.6) were between these two. In Table 7 we provide the development of Russia's DEE Index and its four sub-indices over 2017–2022.

Over the six years of 2017-2022, Russia's DEE Index scores increased from 40.5 to 53.7, which is a 33% increase. However, the improvement over 2020-2022 was only 2.1% as compared to the 7.9% average European increase. There was a decrease of the DEE Index scores from 2021 to 2022, one can say such a change was not independent of geopolitical tensions. It is also clear that the DTI scores, reflecting to the development of digital infrastructure, increased the most, by 63%, demonstrating the effectiveness of Russia's digital strategy implementation in this respect. While digital platform improvement was not in the strategy, DMSP proved to be the best sub-index for Russia over the entire period of 2017-2022. However, the DTE scores, expressing the entrepreneurship components, increased by only 8%. This means that Russian businesses' digitalization was very slow, despite the continuous government effort to improve SMEs' digital transition. This is also underlined by the fact that Russia's digital components (77.7) is much higher – by 12.4 points – than the entrepreneurship components (65.3).

Table 8 serves to further evaluate Russia's DEE profile. Viewing the twelve pillars and 24 variables, there are considerable differences. Russia's worst pillar is Digital Openness (34.8), followed by Digital Freedom (37.5). In both cases the main cause of the low values is the institutional weaknesses reflecting the deficiencies in ICT, e-commerce regulation, as well as some political problems and internet competition. Similar problems can be noticed in Digital Rights (40.5) where property rights and privacy seem to be problematic. In the case of Digital Openness, the quality of the digital ecosystem is also relatively low, showing obstacles to the population's use of G2–G5 networks and internet subscription. The improvement of broadband subscriptions and access to the internet was one of the main targets of Russia' digital strategy. The Digital Openness pillar's digital part increased only by 5.5% over 2017–2022, which is low by international standards.

On the brighter side, Russia's best pillars are Digital Protection (83.6), Digital Access (79.1), Matchmaking (74.2), and Networking (72.2). It is interesting that the higher parts in two of the four cases (Digital Access and Networking) are entrepreneurship ecosystem components. Cybersecurity regulation and language support for the internet are the strong points of Russia's entrepreneurship ecosystem, well reflecting the successful implementation of the digital strategy. Digital Literacy (68.9) and Technology Diffusion (58.2) are also at an acceptable level, again demonstrating a positive performance, according to the digital strategy.

Besides the components, ecosystems can be examined based on the ecosystem players/actors. Here we identified four types of actors as the governments representing the institutions, digital infrastructure developers, users, and agents (entrepreneurs). According to Table 8, Digital Technology Infrastructure (48.6) is the weakest component. Users (82.6) seem to be well prepared for changes brought on by the digital revolution, while entrepreneurs are also at an adequate level.

The DEE methodology makes it possible to provide policy recommendation based on the bottlenecks of the digital entrepreneurship ecosystem. Figure 1 shows how many additional resources would be optimally split among the twelve pillars to improve Russia's DEE Index score by ten percent. We report on only those pillars that require development.

According to Figure 1, Russia should improve six out of the twelve pillars to be able to improve its DEE score

Table 8. **Russia's Digital Entrepreneurship Ecosystem Profile (based on 2022 data)**

a) Pillars Scores

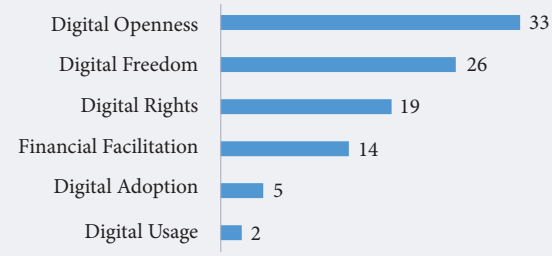
Pillar	Pillar score	Entrepreneurship ecosystem score	Digital ecosystem score
Digital Technology Infrastructure (DTI)			
Digital Openness	34.8	32.9	66.2
Digital Freedom	37.5	26.4	81.3
Digital Protection	83.6	85.8	88.3
Digital User Citizenship (DUC)			
Digital Literacy	68.9	75.6	87.6
Digital Access	79.1	94.6	80.5
Digital Rights	40.5	36.0	89.3
Digital Multi-sided Platform (DMSP)			
Networking	72.2	90.0	74.9
Matchmaking	74.2	81.7	86.2
Financial Facilitation	42.6	53.1	77.2
Digital Technology Entrepreneurship (DTE)			
Digital Usage	48.2	69.2	63.7
Digital Adoption	46.3	62.9	67.1
Technology Diffusion	58.2	75.8	69.8

b) Sub-indices Scores

Sub-index	Score
Users	82.6
Digital infrastructure	72.7
Agents	72.1
Digital Multi-sided Platform (DMSP)	58.6
Institutions (Government)	58.5
Digital User Citizenship (DUC)	58.2
Digital Entrepreneurship Ecosystem Index	53.7
Digital Technology Entrepreneurship (DTE)	49.6
Digital Technology Infrastructure (DTI)	48.6

Source: compiled by the authors

Figure 1. **Digital Platform Economy Optimization Analysis for Russia: the Distribution of Additional Resources for a 10% Increase of the DEE Index Score (2022 data)**



Source: compiled by the authors

by 10%. Most of the additional resources should be allocated toward Digital Openness (33%), Digital Freedom (26%), and Digital Rights (19%). All cases necessitate government involvement. The enhancement of Financial Facilitation (14%) requires relatively fewer resources, because entrepreneurs should be aiming to increase fintech startups. We have not dealt with Financial Facilitation. According to Abalakin et al. (2023), the financial technology market has been growing due to the spread of online payments and remittances and Fintech solutions providing digital services in insurance, lending, and investments. According to our results, the Fintech sector is a rather weak part of the Russian digital entrepreneurship ecosystem. Digital Adoption needs only 5% and Digital Usage 2% of the additional resources to achieve the desired goal.

Summary and Conclusion

In this paper we use the DEE Index methodology and scores to evaluate the performance of former socialist CEE countries with regard to their digital entrepreneurship ecosystems and identify some common features.

Since the start of the transition, former socialist countries have gone through significant changes. While initially these countries were handled as being one relatively homogeneous group, the unified, one-size-fits-all type of suggestions and policies proved to be only partially successful. The transition to a market economy caused a decline in per capita GDP as well as increased inequalities. The recovery was slower than expected, and the catch up with regard to developed countries has been unsuccessful even after 30 years. By the 2000s, most of the market economy institutions have been adopted, however, the institutional development was undermined by informal rules and corruption in many countries. The transitional literature called these alterations simply varieties of capitalism. The 2008 crisis also hit the transitional countries, and they selected different paths of recovery and development which led to increased divergencies. The different responses pinpointed the importance of path dependencies and the historical heritages that could explain the sluggish developments. These findings highlight the importance of analyzing these countries further not as a homogeneous group. Here we selected Russia as an example for such an individual case.

We grouped the transitional countries into three categories and included three groups of other developed European countries to examine their digital entrepreneurship ecosystem performance. To do so, we applied the DEE Index, which is a composite indicator, built from four sub-indices, twelve pillars, and 24 variables. Unlike other indices, the DEE has a solid theoretical basis and a large sample size of 170 countries that makes it possible to compare data from various countries.

While Denmark led the DEE Index 2022 rankings, the non-EU Western countries are the best performers in Europe. EU-member Western countries are close to

them. The Southern European country group performance is similar to that of the EU-member CEE country group, implying that the leaders of these former socialist countries – Estonia, Czech Republic, Slovenia, and Lithuania - have reached the level of most Southern European countries in their DEE development. The former SU country group and the non-EU Balkan country cluster are very similar to each other but with significantly lower DEE Index scores than the most advanced Western countries. However, the former SU countries perform slightly better than the Balkan countries. These finding reflect the developments of these countries and not the planned economy heritage – the Pearson correlation between the DEE Index scores and the per capita GDP was 0.90 based on the 2022 data. Over the 2020-2022 period, the non-EU Balkan countries decreased their arrears in a somewhat similar manner to the Southern European nations.

We consider the balanced performances in terms of the digital ecosystem and entrepreneurship ecosystem components, with the four subindices and the twelve pillars assessed as optimal. At the macro level, we have found that almost all European countries have better performance in the digital ecosystem as compared to the entrepreneurship ecosystem. The digital entrepreneurship component is significantly lower in the Balkan and former Soviet countries as compared to the EU member countries. This may imply that the entrepreneurs in these states still cannot fully exploit the potential of the digital ecosystem. Looking at differences at the sub-index level, it seems that the smallest lag between the leading group and the transitional countries was in terms of digital infrastructure (DTI) and the largest gap was observed for digital technology entrepreneurship (DTE). The underdevelopment of the entrepreneurial components could be explained, at least partially, by the socialist heritage, a period of time when entrepreneurship was restricted or even outright banned.

The weakest and strongest pillars vary across the six country groups with some surprises. Digital Adoption, Digital Diffusion, and Digital Literacy are the three weakest pillars in Europe, showing that there is room for improvement. The Western countries, both EU members and those outside the organization, have a relatively low level of the Digital Protection pillar.

Digging deeper at the pillar level, there are some country-group specific characteristics. We should highlight the Digital Protection pillar, which is the highest pillar for all former socialist countries. Similarly, a small lag can be noticed in the Matchmaking pillar showing that digital platforms are popular in these countries. The largest differences can be detected in Financial Facilitation, which is somewhat surprising given that fintech businesses flourish even in countries with poor infrastructure, such as some in Africa. Maybe regulation in the former socialist countries still favors classical finance and banks. The Digital Freedom and Digital Rights pillars also show significant differences between the leading country group and the transitional countries. These findings reflect some deficiencies in the political systems; however, such a situation does influence the smooth operation of the whole digital entrepreneurship ecosystem.

The usefulness of the DEE Index can be really seen when it is applied to a single country to explore that state's individual strengths and weaknesses. This type of investigation helps identify individual characteristics and provide tailor-made policy suggestions instead of bulk, group-specific recommendations. Our selected case was Russia. In the 2010s, Russia recognized its backwardness in the digital economy ecosystem and initiated a strategy with ambitious goals about the enhancement of Russia's digital economy. Based on the DEE Index approach, we could follow the strategy's implementation.

The DEE analysis puts Russia at 44th place in the DEE Index ranking with a score of 53.7, which reflects the development of the country. With this performance Russia is the best in the non-EU member country groups and ahead of Romania and Bulgaria. Over the examined six years – 2017–2022 – Russia has improved its DEE scores by 34%, however, this improvement slowed down in 2020–2022. Russia's digital entrepreneurship components are imbalanced: the digital component is almost 20% higher than the entrepreneurship ecosystem one. Based on the four sub-indices, Russia spent a lot of resources on improving its digital infrastructure, however, the enhancement of digital technology entrepreneurship has been lacking. The DMSP is Russia's best sub-index showing strengths in two out of its three pillars, Matchmaking and Networking. Russia's best pillar is Digital Protection, which is higher than many developed Western countries. Cybersecurity regulation and language support as well as the improvement of the population's digital literacy reflect the successful implementation of the digital strategy. However, there are some problematic points. Digital Openness, Digital Freedom, and Digital Rights show institutional deficiencies in regulation and internet competition. According to the bottleneck analysis, Russia should spend most of its additional resources for these three pillars and Financial Facilitation to increase its DEE Index scores by ten percent. Digital technology users are well prepared while institutions have the lowest values by far. This finding confirms the conclusions of the comparative economics literature about Russia's weak institutional development.

Finally, we should mention some limitations of our DEE Index and analysis. Like any other composite indicator, DEE Index is also based on available data. For 170 countries, it is very difficult to obtain data for many years. Besides that, we use 54 indicators, for which data can be lacking, mostly in the advanced application of digital technologies and their supporting environment. We did not go into detail about the country ranking, which might not reflect the general perception of the importance of the nation in digital technology development - especially China and India. Note that we used

country-level data and these countries have relatively small advanced regions, however, their overall development is still relatively low. Perhaps a regional analysis would be more appropriate especially when we aim to examine the creation of new technologies. However, our DEE Index is built to focus on the application and not the creation of these technologies. Moreover, the digital entrepreneurship ecosystem has been rapidly evolving with a roughly 5% yearly increase. Infrastructure developments are not continuous, and this causes sudden changes of country values and rankings. Therefore, policy suggestions might not reflect the situation by the time of data publication.

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References

Abalakin A.A., Yakovlev A.V., Akimenko V.A., Denisova E.V. (2023) Digital Entrepreneurship in Russia: Development during the Pandemic. *Bulletin of Kemerovo State University. Series: Political, Sociological and Economic sciences*, 8(2), 148–159 (in Russian). https://doi.org/10.21603/2500-3372-2023-8-2-148–159.

Acs Z.J., Song A.K., Szerb L., Audretsch D.B., Komlosi E. (2021) The evolution of the global digital platform economy: 1971–2021. *Small Business Economics*, 57, 1629–1659. https://doi.org/10.1007/s11187-021-00561-x

Ageev A.I., Gratchev M.V., Hisrich R. D. (1995) Entrepreneurship in the Soviet Union and Post-socialist Russia. *Small Business Economics*, 7, 365–376. https://doi.org/10.1007/bf01302737

Aghion P., Blanchard O.J., Carlin W. (1997) The economics of enterprise restructuring in Central and Eastern Europe. In: *Property Relations, Incentives and Welfare: Proceedings of a Conference held in Barcelona, Spain, by the International Economic Association* (ed. J. Roemer), London: Palgrave Macmillan, pp. 271–325.

Aidis R., Estrin S., Mickiewicz T. (2008) Institutions and entrepreneurship development in Russia: A comparative perspective. *Journal of Business Venturing*, 23(6), 656–672. https://doi.org/10.1016/j.jbusvent.2008.01.005

Aldrich H.E. (2014) *The democratization of entrepreneurship? Hackers, Makerspaces, and Crowdfunding*. Paper presented at the Academy of Management Annual Meeting, Philadelphia, PA. https://doi.org/10.5465/ambpp.2014.10622symposium

Askerov P.F., Medvedeva A.M., Rabadanov A.R., Bogdanova I.M., Zvezdichev G.J. (2018) Digital Economy as a priority direction for the development of modern innovative entrepreneurship in Russia. *Espacios,* 39(41), 30.

Bałtowski M., Kozarzewski P., Mickiewicz T. (2022) State capitalism with populist characteristics: Poland and Hungary. In: *The Oxford Handbook of State Capitalism and the Firm* (eds. M.Wright, G.T. Wood, A. Cuervo-Cazurra, P. Sun, I. Okhmatovskiy, A. Grosman), Oxford, New York: Oxford University Press, pp. 750–784.

Baumol W.J. (1990) Entrepreneurship: Productive, unproductive and destructive. *Journal of Political Economy*, 98(5), 893–921. http://www.jstor.org/stable/2937617?origin=JSTOR-pdf

Bharadwaj A., Sawy O.A.E., Pavlou P.A., Venkatraman N. (2013) Digital business strategy: Toward a next generation of insights. MIS Quarterly, 37 (2), 471–482. https://doi.org/10.25300/MISQ/2013/37:2.3

Bideleux R. (2014) Contrasting responses to the international economic crisis of 2008–10 in the 11 CIS countries and in the 10 post-communist EU member countries. In: *The International Economic Crisis and the Post-Soviet States* (eds. V. Feklyunina, S. White), New York: Routledge, pp. 4–29.

Blanchard O. (1996) Theoretical aspects of transition. *The American Economic Review*, 86(2), 117–122. https://www.jstor.org/stable/211810

Blyth M. (2002) *Great transformations: Economic ideas and institutional change in the twentieth century*, Cambridge: Cambridge University Press.

Brodny J., Tutak M. (2022) The Level of Digitization of Small, Medium and Large Enterprises in the Central and Eastern European Countries and Its Relationship with Economic Parameters. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(3), 113. https://doi.org/10.3390/joitmc8030113

BTI (2024) *BTI 2024 codebook for country assessment,* Gütersloh (GE): Bertelsmann Stiftung.

Chepurenko A. (2017) Entrepreneurial Activity in Post-Socialist Countries: Methodology and Research Limitations. *Foresight and STI Governance,* 11(3), 11–24. https://doi.org/10.17323/2500-2597.2017.3.11.24

Chepurenko A., Szanyi M. (2022) Parallel processes and divergent outcomes: The transformation of the economies of former Socialist countries. In: *The Routledge Handbook of Comparative Economic Systems* (eds. B. Dallago, S. Casagrande), New York: Routledge, pp. 411–432.

Chui M., Issler M., Roberts R., Yee L. (2023) *Technology Trends Outlook 2023,* Chicago, IL: McKinsey & Company.

Csaba L. (2005) *The New Political Economy of Emerging Europe,* Budapest: Akadémiai Kiad.

De Melo M., Denizer C., Gelb A.H. (1996) *From Plan to Market – Pattern of Transition*, Washington, D.C.: World Bank Publications.

Dilli S., Elert N., Herrmann A.M. (2018) Varieties of entrepreneurship: exploring the institutional foundations of different entrepreneurship types through 'Varieties-of-Capitalism' arguments. *Small Business Economics*, 51, 293–320. https://doi.org/10.1007/s11187-018-0002-z

Dwivedi Y.K., Hughes L., Ismagilova E., Aarts G., Coombs C., Crick T., Duan Y., Edwards J., Eirug A., Galanos V., Ilavarasan P.V., Janssen M., Jones P., Kumar Kar A., Kizgin H., Kronemann B., Lal B., Lucini B., Medaglia R., Williams M.D. (2021) Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management,* 57, 101994. https://doi.org/10.1016/j.ijinfomgt.2019.08.002

Dyba W., Loewen B., Looga J., Zdražil P. (2018) Regional development in Central-Eastern European Countries at the beginning of the 21st century: Path dependence and effects of EU Cohesion Policy. *Quaestiones Geographicae,* 37(2), 77–92. https://doi.org/10.2478/quageo-2018-0017

Ekbia H.R. (2009) Digital artifacts as quasi-objects: qualification, mediation, and materiality. *Journal of the Association for Information Science and Technology*, 60(12), 2554–2566. https://doi.org/10.1002/asi.21189

Elia G., Margherita A., Passiante G. (2020) Digital entrepreneurship ecosystem: How digital technologies and collective intelligence are reshaping the entrepreneurial process. *Technological Forecasting and Social Change*, 150, 119791. https://doi.org/10.1016/j.techfore.2019.11979

Estrin S., Meyer K.E., Bytchkova M. (2006) Entrepreneurship in transition economies. In: *The Oxford Handbook of Entrepreneurship* (eds. M. Casson, B. Yeung, A. Basu, N. Wadeson), Oxford: Oxford University Press, pp. 693–725.

Estrin S., Mickiewicz T. (2011) Entrepreneurship in transition economies: The role of institutions and generational change. In: *The dynamics of entrepreneurship: Evidence from the global entrepreneurship monitor data* (ed. M. Minniti), Oxford: Oxford University Press, pp. 181–208. https://doi.org/10.1093/acprof:oso/9780199580866.003.0009

European Commission (2015) *Digital Transformation of European Industry and Enterprises,* Brussels: European Commission.

Farkas B. (2016) *Models of Capitalism in the European Union: Post-crisis Perspectives,* London: Palgrave Macmillan.

Gao J., Gruhn V., He J., Roussos G., Tsai W.T. (2013) Mobile cloud computing research-issues, challenges and needs. In: *Proceedings of the 2013 IEEE Seventh International Symposium on Service-Oriented System Engineering, 25-28 March 2013, Redwood City, California, USA*, Piscathaway, NJ: IEEE, pp. 442–453.

Gevorkyan A.V. (2018) *Transition economies: Transformation, development, and society in Eastern Europe and the former Soviet Union*, New York: Routledge. https://doi.org/10.4324/9781315736747

Gritsenko D., Kopotev M., Wijermars M. (2021) Digital Russia Studies: An Introduction. In: *The Palgrave Handbook of Digital Russia Studies* (eds. D. Gritsenko, M. Wijermars, M. Kopotev), Cham: Springer International Publishing, pp. 1–13. https://doi.org/10.1007/978-3-030-42855-6_1

Győrffy D. (2022) The middle-income trap in Central and Eastern Europe in the 2010s: Institutions and divergent growth models. *Comparative European Politics*, 20(1), 90–113. https://doi.org/10.1057/s41295-021-00264-3

Hargittai E. (2002) Second-level digital divide: Differences in people's online skills. *First Monday,* 7(4), 1–19. https://doi.org/10.5210/fm.v7i4.942

Havrylyshyn O. (2009) *Is the transition over?* (Queen's Economics Department Working Paper No. 1209), Kingston (CA): Queen's University.

Huang R. (2023) SDG-oriented sustainability assessment for Central and Eastern European countries. *Environmental and Sustainability Indicators*, 19,100268. https://doi.org/10.1016/j.indic.2023.100268

Ivlevs A., Nikolova M., Popova O. (2021) Former Communist party membership and present-day entrepreneurship. *Small Business Economics*, 57, 1783–1800. https://doi.org/10.1007/s11187-020-00364-6

Kallinikos J., Aaltonen A., Marton A. (2013) The ambivalent ontology of digital artifacts. *MIS Quarterly,* 37(2). https://doi.org/10.25300/MISQ/2013/37.2.02

Kelly K. (2016) *The Inevitable: Understanding the 12 Technological Forces That Will Shape Our Future,* New York: Penguin Books.

Kenney M., Zysman J. (2016) The rise of the platform economy. *Issues in Science & Technology,* 32(3), 61–69.

Kitov I.O. (2009) Modelling the evolution of real per capita during the transition from a socialist to capitalist economic system. *Journal of Applied Economic Sciences*, 4(4), 526–548.

Kobzev V., Izmaylov M., Skvortsov S., Capo D. (2020) *Digital transformation in the Russian industry: Key aspects, prospects and trends*. Paper presented at the International Scientific Conference - Digital Transformation on Manufacturing, Infrastructure and Service, November 18–19, 2020, Saint Petersburg, Russian Federation. https://doi.org/10.1145/3446434.3446451

Kollmann T., Kleine-Stegemann L., de Cruppe K., Then-Bergh C. (2022) Eras of digital entrepreneurship: Connecting the past, present, and future. *Business & Information Systems Engineering,* 64, 15–31. https://doi.org/10.1007/s12599-021-00728-6

Kornai J. (2006) The great transformation of Central Eastern Europe. *Economics of Transition,* 14(2), 207–244. https://doi.org/10.1111/j.1468-0351.2006.00252.x

Kraus S., Palmer C., Kailer N., Kallinger F.L., Spitzer J. (2019) Digital entrepreneurship: A research agenda on new business models for the twenty-first century. *International Journal of Entrepreneurial Behavior & Research*, 25(2), 353–375. https://doi.org/10.1108/IJEBR-06-2018-0425

Kreuzer T., Lindenthal A.K., Oberlaender A., Röglinger M. (2022) The Effects of Digital Technology on Opportunity Recognition. *Business & Information Systems Engineering,* 64(1), 47–67. https://doi.org/10.1007/s12599-021-00733-9

Lazar D., Minea A., Purcel A.A. (2019) Pollution and economic growth: evidence from central and eastern European countries. *Energy Economics,* 81, 1121–1131. https://doi. org/10.1016/j.eneco.2019.05.011

Levchenko T.A., Konvisarova E.V. (2022) Development of digital economy in Russia in context of global trends. *Vestnik of Astrakhan State Technical University. Series: Economics,* 2, 34-41 (in Russian). https://doi.org/10.24143/2073-5537-2022-2-34-41

Lowry A. (2022) Russia's Digital Economy Program: An Effective Strategy for Digital Transformation? In: *The Palgrave Handbook of Digital Russia Studies* (eds. D. Gritsenko, M. Wijermars, M. Kopotev), Cham: Springer International Publishing, pp. 53–75.

Lukashov N.V., Lukashova S.S., Latov Y.V. (2021) Paradoxes of the Russian digitalization programs. *Journal of Institutional Studies,* 13(1), 115–134. https://doi.org/10.17835/2076-6297.2021.13.1.115-134

Magyar B., Madlovics B. (2020) *The Anatomy of Post-Communist Regimes,* Budapest and New York: CEU Press.

Makasheva N.A. (2012) Economic science after the crisis: What will change? *Social Sciences and Modernity*, 6, 73–86.

McMillan J., Woodruff C. (2002) The central role of entrepreneurs in transition economies. *Journal of Economic Perspectives*, 16(3), 153–170. https://doi.org/10.1257/089533002760278767

Medve-Bálint G. (2014) The role of the EU in shaping FDI flows in Central Europe. *Journal of Common Market Studies,* 52(1), 35–51. https://doi.org/10.1111/jcms.12077

Nambisan S. (2017) Digital entrepreneurship: Toward a digital technology perspective of entrepreneurship. *Entrepreneurship Theory and Practice,* 41(6), 1029–1055. https://doi.org/10.1111/etap.12254

Obraztsova O., Chepurenko A. (2020) Entrepreneurial activity in Russia and its cross-regional differences. *Journal of the New Economic Association,* 46(2), 198–210. https://doi.org/10.31737/2221-2264-2020-46-2-12

Paul J., Alhassan I., Binsaif N., Singh P. (2023) Digital entrepreneurship research: A systematic review. *Journal of Business Research,* 156, 113507. https://doi.org/10.1016/j.jbusres.2022.113507

Sachs J.D. (1996) The transition at mid decade. *The American Economic Review*, 86(2), 128–133. http://www.jstor.org/stable/2118109?origin=JSTOR-pdf

Sahut J.M., Iandoli L., Teulon F. (2021) The age of digital entrepreneurship. *Small Business Economics,* 56, 1159–1169. https://doi.org/10.1007/s11187-019-00260-8

Scheerder A., van Deursen A., van Dijk J. (2017) Determinants of internet skills, uses and outcomes: A systematic review of the second- and third-level digital divide. *Telematics and Informatics,* 34(8), 1607–1624. https://doi.org/10.1016/j.tele.2017.07.007

Shen K.N., Lindsay V., Xu Y. (2018) Digital entrepreneurship. *Information Systems Journal,* 28 (6), 1125–1128. https://doi.org/10.1111/isj.12219

Song A.K. (2019) The Digital Entrepreneurial Ecosystem – A critique and reconfiguration. *Small Business Economics*, 53(3), 569–590. https://doi.org/10.1007/s11187-019-00232-y

Stratu-Strelet D., Gil-Gómez H., Oltra-Badenes R., Oltra-Gutierrez J.V. (2023) Developing a theory of full democratic consolidation: Exploring the links between democracy and digital transformation in developing eastern European countries. *Journal of Business Research*, 157, 113543. https://doi.org/10.1016/j.jbusres.2022.113543

Sussan F., Acs Z.J. (2017) The digital entrepreneurial ecosystem. *Small Business Economics,* 49(1), 55–73. https://doi.org/10.1007/s11187-017-9867-5

Szanyi M. (2022) The emergence of patronage and changing forms of rent seeking in East Central Europe. *Post-communist Economies*, 34(1), 122–141. https://doi.org/10.1080/14631377.2019.1693738

Szerb L., Ortega-Argilés R., Acs Z.J., Komlósi É. (2020) Optimizing entrepreneurial development processes for smart specialization in the European Union. *Papers in Regional Science,* 99(5), 1413–1458. https://doi.org/10.1111/pirs.12536

Szerb L., Trumbull W.N. (2016) The development of entrepreneurship in the European transition countries: Is transition complete? *Strategic Change,* 25(2), 109–129. https://doi.org/10.1002/jsc.2051

Szerb L., Trumbull W.N. (2018) Entrepreneurship development in Russia: Is Russia a normal country? An empirical analysis. *Journal of Small Business and Enterprise Development,* 25(6), 902–929. https://doi.org/10.1108/JSBED-01-2018-0033

Trașcă D.L., Ștefan G.M., Sahlian D.N., Hoinaru R., Șerban-Oprescu G.-L. (2019) Digitalization and Business Activity. The Struggle to Catch Up in CEE Countries. *Sustainability,* 11(8), 2204. https://doi.org/10.3390/su11082204

Van Dijk J.A. (2017) Digital divide: Impact of access. In: *The International Encyclopedia of Media Effects*, New York: Wiley, pp. 1–11. https://doi.org/10.1002/9781118783764.wbieme0043

Veselovsky M.Y., Izmailova M.A., Bogoviz A.V., Lobova S.V., Alekseev A.N. (2017) Business Environment in Russia and its Stimulating Influence on Innovation Activity of Domestic Companies. *Journal of Applied Economic Sciences,* 12(7), 1967–1981.

Welter F., Smallbone D. (2017) Entrepreneurship and enterprise strategies in transition economies: An institutional perspective. In: *Small Firms and Economic Development in Developed and Transition Economies* (eds. D. Kirby, A. Watson), New York: Routledge, pp. 95–113. https://doi.org/10.4324/9781315192451-7

Zahra S.A., Liu W., Si S. (2023) How digital technology promotes entrepreneurship in ecosystems. *Technovation,* 119, 102457. https://doi.org/10.1016/j.technovation.2022.102457

Zhao F., Collier A. (2016) Digital Entrepreneurship: Research and Practice. In: *9th Annual Conference of the EuroMed Academy of Business Proceedings*, Napoli: EuroMed Academy of Business, pp. 2173–2182.

Zhulikov S.E., Zhulikova O.V. (2022) Digital Development of Russian Regions. *Russia: Society, Politics, History*, 3(3), 124–141 (in Russian). https://doi.org/10.56654/ROPI-2022-3(3)-124-141

Appendix 1. **The Rank and Scores of the Countries in DEE (2022)**

Rank	Country	DEE 2022	Rank	Country	DEE 2022	Rank	Country	DEE 2022	Rank	Country	DEE 2022
1	Denmark	**89.9**	44	Russian Federation	**53.7**	87	Bosnia and Herzegovina	**30.9**	130	Pakistan	**15.9**
2	USA	**85.6**	45	Bulgaria	**53.4**	88	Egypt	**29.8**	131	Iraq	**15.6**
3	Norway	**85.4**	46	Turkey	**53.3**	89	Tunisia	**29.5**	132	Libya	**15.0**
4	Finland	**84.9**	47	Romania	**53.2**	90	Paraguay	**28.5**	133	Myanmar	**15.0**
5	Australia	**82.7**	48	Qatar	**50.8**	91	Jamaica	**28.2**	134	Uganda	**14.7**
6	Singapore	**82.0**	49	China	**50.4**	92	Fiji	**27.2**	135	Tanzania	**14.2**
7	Sweden	**79.4**	50	Bahrain	**48.2**	93	India	**27.2**	136	Zambia	**14.2**
8	Switzerland	**79.2**	51	Saudi Arabia	**48.2**	94	Maldives	**27.1**	137	Timor-Leste	**14.1**
9	Iceland	**79.2**	52	Argentina	**48.0**	95	Lebanon	**27.0**	138	Rwanda	**13.1**
10	Ireland	**78.5**	53	Serbia	**47.5**	96	Kyrgyzstan	**26.9**	139	Cameroon	**13.0**
11	Canada	**78.4**	54	Costa Rica	**46.7**	97	Sri Lanka	**26.7**	140	Benin	**12.5**
12	United Kingdom	**77.5**	55	Thailand	**45.7**	98	Belize	**26.5**	141	Papua New Guinea	**12.3**
13	Netherlands	**76.8**	56	Georgia	**45.7**	99	Botswana	**26.1**	142	Tajikistan	**12.3**
14	New Zealand	**76.5**	57	Ukraine	**45.6**	100	Saint Lucia	**26.1**	143	Gambia	**11.7**
15	Germany	**76.5**	58	Kuwait	**43.9**	101	Samoa	**25.7**	144	Zimbabwe	**11.4**
16	Spain	**75.0**	59	Mauritius	**43.0**	102	St. Vincent & Grenadines	**24.9**	145	Angola	**11.3**
17	France	**74.6**	60	North Macedonia	**42.6**	103	Uzbekistan	**24.8**	146	Mauritania	**10.9**
18	Luxembourg	**74.2**	61	Kazakhstan	**42.2**	104	Bhutan	**24.4**	147	Mali	**10.8**
19	Estonia	**73.8**	62	Mexico	**41.5**	105	Suriname	**23.8**	148	Togo	**10.7**
20	Belgium	**72.3**	63	South Africa	**41.2**	106	Cabo Verde	**23.7**	149	Sierra Leone	**10.5**
21	Korea, South	**71.7**	64	Oman	**40.7**	107	Bolivia	**23.6**	150	Liberia	**10.1**
22	Portugal	**70.3**	65	Vietnam	**39.7**	108	El Salvador	**23.2**	151	Burkina Faso	**9.1**
23	Japan	**69.7**	66	Montenegro	**39.6**	109	Venezuela	**22.9**	152	Sudan	**9.0**
24	Hong Kong	**69.2**	67	Panama	**39.1**	110	Tonga	**22.5**	153	Congo	**8.9**
25	Cyprus	**68.8**	68	Albania	**38.7**	111	Ghana	**22.1**	154	Malawi	**8.5**
26	Czech Republic	**68.8**	69	Colombia	**38.4**	112	Kenya	**20.8**	155	Solomon Islands	**8.5**
27	Italy	**68.8**	70	Moldova	**37.0**	113	Nepal	**20.5**	156	Haiti	**8.4**
28	Lithuania	**67.4**	71	Indonesia	**36.8**	114	Algeria	**19.8**	157	Yemen	**8.1**
29	Israel	**66.0**	72	Brunei Darussalam	**36.8**	115	Gabon	**19.5**	158	Guinea-Bissau	**8.0**
30	Austria	**65.3**	73	Belarus	**36.8**	116	Cambodia	**19.4**	159	Niger	**7.9**
31	Malta	**64.7**	74	Peru	**36.6**	117	Bangladesh	**18.7**	160	Guinea	**7.8**
32	Latvia	**64.4**	75	Armenia	**36.5**	118	Laos	**18.7**	161	Comoros	**7.6**
33	Slovenia	**63.3**	76	Barbados	**36.0**	119	Honduras	**18.3**	162	Ethiopia	**7.1**
34	Greece	**62.9**	77	Dominican Republic	**35.7**	120	Guyana	**18.2**	163	Madagascar	**7.1**
35	Slovakia	**62.3**	78	Ecuador	**34.5**	121	Nicaragua	**18.0**	164	Central Africa	**6.9**
36	Hungary	**62.1**	79	Mongolia	**34.5**	122	Guatemala	**17.5**	165	Mozambique	**6.9**
37	United Arab Emirates	**61.4**	80	Trinidad and Tobago	**34.2**	123	Vanuatu	**17.3**	166	Afghanistan	**6.3**
38	Poland	**59.9**	81	Bahamas	**33.7**	124	Senegal	**17.0**	167	Congo, D.R.	**5.2**
39	Chile	**57.6**	82	Jordan	**33.4**	125	Cote d'Ivoire	**16.8**	168	Burundi	**4.5**
40	Brazil	**57.4**	83	Azerbaijan	**31.9**	126	Eswatini	**16.7**	169	Chad	**4.4**
41	Croatia	**57.3**	84	Philippines	**31.9**	127	Nigeria	**16.7**	170	South Sudan	**3.7**
42	Uruguay	**55.6**	85	Morocco	**31.5**	128	Namibia	**16.0**			
43	Malaysia	**54.3**	86	Iran	**31.2**	129	Lesotho	**16.0**			

Legend: Light blue – Western EU, Brown – Southern EU; Green – Non-EU Western Europe; Yellow – EU member CEE; Blue – Balkan non-EU; Grey – Non-EU former SU countries

Source: authors.

Contextualizing the Notion of an Entrepreneurial University: A Reflective Framework

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Abstract

Developing academic entrepreneurship within a university entails a complex process of change. As internal and external contextual variables make the entrepreneurial journey of each university unique, finding a common "recipe" seems impossible. Therefore, having a reflective framework that allows each university to consider its entrepreneurial strategy and how it translates into more specific organizational measures may offer a path forward. In this paper, we discuss the content, process, and context of entrepreneurship at universities along the dimensions of anticipation, reflexivity, inclusion, and responsiveness. To inform our discussion, we rely upon the findings from the literature and examples from practice. In doing so we contribute to the debate on academic entrepreneurship across different contexts and provide both practical reflection points and future avenues for advancing research.

Keywords: entrepreneurial university; academic entrepreneurship; commercialization; developing economy

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Introduction

In recent decades, universities have been facing increasing pressure to become entrepreneurial (Hayter et al., 2018; Yusof, Jain, 2010) and take a leading role in creating entrepreneurial ecosystems (Schaeffer, Matt, 2016). An "entrepreneurial university" is one that effectively fulfills the "third mission" of stimulating economic development alongside education and research (Etzkowitz, 1983) and commercializes its knowledge through collaboration with industries, establishing technology transfer offices, and supporting start-ups, incubators, and science parks (Etzkowitz, 2003; Rothaermel et al., 2007; Tuunainen, 2005; Yusof, Jain, 2010). Yet, despite the decades of efforts, results remain mixed (Huyghe, Knockaert, 2015; Qiu et al., 2023).

While the economic impact of university entrepreneurship on regional and national performance can be significant (Etzkowitz et al., 2000; Schaeffer, Matt, 2016; Tijssen, 2006), the opposite is also true. Local economic, institutional, relational, and political factors influence the emergence and success of new academic ventures (Jevnaker, Misganaw, 2022; Schaeffer, Matt, 2016; Urbano, Guerrero, 2013). Most research even attributes the successful emergence of entrepreneurial universities to the systematic introduction of policies at the national level. For example, the US government's Bayh–Dole Act resulted in such poster ecosystems as Stanford University and the Massachusetts Institute of Technology (MIT). However, these policies have not produced the intended effects in other ecosystems (Mustar, Wright, 2010; Schaeffer, Matt, 2016). Nowadays, along with the classical American entrepreneurial university approach, research identifies other models of institutional development, such as those originating in Israel and China. Therefore, context is instrumental in understanding the development of academic entrepreneurship.

Furthermore, the process of embracing entrepreneurial activities can create tensions within the universities' internal environment. Among them, conflicts between old and new values, as well as between different activities and disciplines, exacerbated by the frequent lack of or inconsistent entrepreneurial role models within the university itself (Philpott et al., 2011; Qiu et al., 2023). The challenges that universities face fostering entrepreneurial cultures can be so profound that some question the place of entrepreneurship in academia altogether (Fuchs et al., 2023).

In this paper, we therefore offer a reflective framework that considers the content, process, and context of developing an entrepreneurial university. First, we adopt the four dimensions of governing responsible innovation: anticipation, reflexivity, inclusion, and responsiveness (Stilgoe et al., 2013). Responsible innovation is a dynamic concept enacted at multiple levels (see Fisher and Rip, 2013), and so is the governance of academic entrepreneurship. Second, to contextualize our analysis we consider the socio-cultural, spatial, and institutional boundaries of academic entrepreneurship (Chepurenko et al., 2024; Högberg, Mitchell, 2023). Both internal contextual variables such as university's history, tradition, resources, and organizational structure, as well as external contextual characteristics of the socio-economic system in which it exists, have a high impact upon its ability and willingness to engage in entrepreneurial activities (Riviezzo et al., 2019). Having the framework that guides reflection on how these internal and external variables impact the capacity of the university to anticipate, reflect, collaborate, and respond to the opportunities and challenges for academic entrepreneurship may have profound theoretical and practical implications. While far from proposing a normative solution, we seek to offer a novel lens on this complex issue and to contribute to the discussion on the embeddedness of entrepreneurship at different organizations and within various contexts (Wigren-Kristoferson et al., 2022).

Academic Entrepreneurship

Managing Academic Entrepreneurship

Academic entrepreneurship encompasses any activity that goes beyond traditional teaching and/or research, it is innovative, demands risk taking, and is associated with additional financial income for the academic entrepreneur and their organization (Abreu, Grinevich, 2013; Klofsten, Jones-Evans, 2000). These activities fall along a spectrum from "soft" to "hard" (Philpott et al., 2011), depending on the level of entrepreneurial sophistication (Klofsten, Jones-Evans, 2000). "Soft" activities include such activities as publications, conferences, consulting, and producing skilled graduates aiming to educate staff, students, and citizens about entrepreneurship, and creating networks with the entrepreneurial ecosystem around the university (Cohen et al., 2002, Philpott et al., 2011). "Hard" activities include patenting, licensing, and spin-off firm formation and are often managed by semi-autonomous technology transfer offices (TTOs) (Yusof, Jain, 2010). TTOs allow the entrepreneurial activity at a university to be concentrated in the hands of a few professionals, not necessarily active in research or education. While effective in stimulating knowledge transfer from universities, the TTO is nevertheless only one of the paths to channel the creations of academic spin-offs (Brantnell, Baraldi, 2022; Sansone et al., 2021). It is increasingly accepted that formal and informal interactions between (institutional) actors determine the development of the entrepreneurial ecosystem (Stam, 2015; Wurth et al., 2022).

Levels of and models for stimulating academic entrepreneurship and fostering entrepreneurial universities vary significantly. Stanford and MIT are well-known examples in the US, yet there is a considerable diversity in the entrepreneurial nature of universities as well. Other "country" models of institutional development include Israel (where the state fund of founda-

tions became the "anchor" founder of private venture funds, which included money from the diaspora) and mainland China (where newly created high-tech and development zones receive state support and include regional ecosystems of universities, businesses, and banks). In Europe, the development of entrepreneurial universities is generally less active and more heterogeneous. Yet here also there are notable exceptions such as Lund University and the Stockholm-Uppsala science cluster in Sweden, the Technical University of Delft and the University of Twente in the Netherlands, and Germany's WHU – Otto Beisheim School of Management and the Munich cluster (Technical University of Munich and Ludwig Maximilian University in Munich). Typically, such a "European model" involves collaboration among multiple universities to create regional clusters of innovative institutions and jointly develop the necessary infrastructure for fostering innovation. Public funding, rather than private investment, often supports these collaborations. These differences stem from varying systems of financing fundamental and applied sciences, with more reliance on public foundations and academies, and the predominance of public universities over private ones, especially in continental Europe.

Context

To contextualize our analysis and adapt the discussion to the development and governance of academic entrepreneurship, we further consider its socio-cultural, spatial, and institutional boundaries (Chepurenko et al., 2024; Högberg, Mitchell, 2023). Indeed, except for China, all the notable examples above stem from the developed economies. Yet, local economic, institutional, relational, and political factors influence the emergence and success of new academic ventures (Jevnaker, Misganaw, 2022; Schaeffer, Matt, 2016; Urbano, Guerrero, 2013).

The institutional environment of developing economies is often characterized by less developed and more fragile institutional infrastructure, unclear, inconsistent, or even inadequate government policies, disjointed infrastructure, and limited funding options (Manimala, Wasdani, 2015). These conditions lead to the poorer quality of entrepreneurial ideas that are biased toward necessity more than opportunity (Reynolds et al., 2003). In a context where entrepreneurial activities are more focused on necessity rather than opportunity, the boundaries for academic entrepreneurship need to be reconsidered from those of more established and prominent ecosystems (Chepurenko et al., 2024). Furthermore, Guerrero and Urbano (2017) suggest that along with the poor infrastructure and limited resources, entrepreneurs in developing countries may also face "dark institutional conditions" that include bureaucracy, taxes, lack of support, informal market dynamics, and even extortion by organized criminal groups. Recent evidence suggests that these conditions can pervade both the general economy and the university environment. For example, Chepurenko et al. (2024) describe how a university's administration appropriated the products and findings developed by one of the research groups in collaboration with students and industrial partners (p. 141). On the other hand, in some developing economies, such as India, China, or Brazil, the significant economic growth and market potential allow for opportunity-based entrepreneurship. For example, India is mentioned as the most rapidly growing entrepreneurial ecosystem by the World Economic Forum (2014), with 10,000 startups and 10 billion USD of investments in startups in 2015 alone[1].

Can and should we be talking about entrepreneurial university development and academic entrepreneurship stimulation in the context of a developing economy? To what extent are entrepreneurial ecosystems of developing economies unique? We assume that there are principles of responsible development and will develop a four-dimensional lens for this based on the work of Stilgoe et al. (2013).

The Four Dimensions of Responsible Governance at Academic Universities

Based on Stilgoe et al. (2013), we propose conceptualizing the governance of entrepreneurial universities through the lenses of anticipation, responsiveness, reflexivity, and inclusion. Originally developed to understand governing complex innovation processes in public spaces, this framework offers potential for analyzing entrepreneurial university settings (Fuchs et al., 2023).

Within the original framework, anticipation involves systematic thinking to foresee, comprehend, and shape desirable futures by aligning resources toward them (Stilgoe et al., 2013; Te Kulve, Rip, 2011). Reflexivity, at the level of institutional practice, means holding a mirror up to one's own activities, commitments, and assumptions (Stilgoe et al., 2013). Inclusion stands for engagement with stakeholders and the wider public, i.e., including lay members on scientific advisory committees, and employing hybrid mechanisms that attempt to diversify the inputs to and delivery of governance (Stilgoe et al., 2013). Finally, responsiveness requires adapting to emerging knowledge, perspectives, views, and norms, necessitating the ability to adjust course in response to changing stakeholder values and circumstances.

The dimensions of the framework "*do not float freely but must connect as an integrated whole*" (Stilgoe et al., 2013). They may both be mutually reinforcing and in tension with one another, generating conflicts. For

[1] https://www.statista.com/statistics/631967/share-of-startups-by-city-india/, accessed 16.02.2024.

example, anticipation can encourage wider inclusion, but may restrain responsiveness due to prior commitments (Stilgoe et al., 2013). In the coming sections we will introduce the dimensions in their application to the governance of entrepreneurial universities, followed by a discussion on the interdependence of these dimensions.

Anticipation

Successful anticipation requires understanding of the dynamics that shape technological futures in order to prioritize resource distribution toward the relevant areas of technological development, the provision of autonomy and slack resource pockets for experimentation, and an explicit recognition of the complexities and uncertainties of science and society's co-evolution (Stilgoe et al., 2013).

Anticipation in a University Context

In the context of a university this is often formulated in strategic documents, delineating the vision of the future the university sees and aims to engage with. For example, the University of Twente (UT) in their Shaping 2030 document states: "*In 2030, we will be living in a digitally mature society – an open world that continues to change. Those involved in creating and managing technologies will have new responsibilities, serving society sustainably as developers, analysts and improvers. … Many people will come to us for guidance: to learn what the future of technology means for society, and what the future of mankind requires from technology*."[2] Anticipation of the future should also be manifesting in the investments in identified directions, such as investments in R&D budgets as well as laboratory facilities and infrastructure for specific scientific disciplines. As such, the University of Groningen (UG) has just completed construction of 64,000 m^2 "Feringa building" that can house 1,400 students, 850 staff members, and 3 km of laboratory tables "*to continue contributing to important international research in fields such as chemical engineering, nanotechnology, material research and astronomy*"[3]. Meanwhile, the Moscow Institute of Physics and Technology (MIPT) committed itself in its development strategy to improving the campus, developing cross-disciplinary areas, and more than double the R&D budget aiming to enter the top 10 of the global ranking in physical sciences, the top 25 in computer science and mathematics, as well as take a leading position in the ranking of "entrepreneurial" universities in Russia. Furthermore, to address the complex challenges in society, these universities committed to the Sustainable Development Goals (SDG) mission (MIPT) by, creating interdisciplinary institutes focusing on societal transition areas (UG) and ensuring that SDGs serve as a guiding principle for at least 30% of the education and research, and that the university itself becomes a sustainable organization (UT). Hence, anticipation helps formulate the core positioning and development strategy of the university: how it sees the future and whether it aims to engage entrepreneurship in it.

Factors Stimulating the Anticipation of Innovation and Entrepreneurship

Anticipation prompts researchers and organizations to consider contingencies, reflect on what is known, what is likely, what is plausible, and what is possible (Stilgoe et al., 2013). Anticipation involves systematic thinking aimed at increasing resilience, while revealing new opportunities for innovation and the shaping agendas for socially robust risk research. Anticipatory processes need to be "*well-timed so that they are early enough to be constructive but late enough to be meaningful*" (Rogers-Hayden, Pidgeon, 2007; Stilgoe et al., 2013). Indeed, as Rip and Groen (2001) show, socio-technical development is a multi-level process over time in which technologies evolve from proving a principle that works in niches, to accepted as one of the regimes for certain functions up to becoming the dominant technology in a societal context. Anticipating which new knowledge to develop and "bet on" as a university to stimulate commercialization is therefore a difficult and uncertain process: "*whether expectations for new technologies will materialize, how they might be integrated into value chains, which regulatory measures may obtain, and the nature of broader societal acceptance*" (Te Kulve, Rip, 2011). Hence, universities need to act in anticipation of novel technological developments that require strong foresight capabilities of their top management and the scientific excellence of their staff that would inform the strategic foresight. Research highlights that scientific excellence is also a necessary first condition for successful industry-science links. In its turn, it depends upon the critical mass of faculty generating world-class research and the presence of star scientists (Clarysse et al., 2011; Colombo et al., 2010; O'Shea et al., 2005). Debackere and Veugelers (2005) further argue that industrial partners seek competence in both short-term R&D and in long-term strategic research.

Yet, in the context of universities, scientific excellence is connected to the competence of generating new original findings and approaches (Debackere, Veugelers, 2005). With the rapid advancement of AI tools, anticipation in scientific research is taking on new meanings. AI's capability to analyze complex biological, chemical, or physical processes at scales not accessible through experiments opens novel opportunities for discovery and application across traditional disciplinary boundaries (Wang et al., 2023). Incorporating AI in science (AI4Science) could lead to a less defined disciplinary

[2] https://www.utwente.nl/en/service-portal/topics/shaping2030/#embedding-shaping2030-in-teams, accessed 19.07.2024.
[3] https://www.rug.nl/groundbreakingwork/projects/feringa_building/?lang=en, accessed 05.06.2024.

focuses and faster technological development. It may also reshape research labs, increasing investments in computational scientists, methods, and cloud services, and fostering novel partnerships to support this progress (Wang et al., 2023).

Furthermore, anticipation requires infrastructural investments (Robinson et al., 2007). Strong science infrastructure allows, when in place and with enough capacity, for a variety of further work and product development (Robinson et al., 2007). If a university is considering engaging in an entrepreneurial mission and commercializing its knowledge, it needs to formulate not only the areas of development, but also, whether the infrastructure they invest in will be available for joint exploration and exploitation with industry, for strategic research, technology development, and maybe also product development. Sharing facilities, equipment, and skilled staff with partners in the ecosystem may be seen as a commitment to the entrepreneurial mission. Yet, it may also be a way to finance the envisioned future. For example, MESA+ at the UT is the largest nanotechnology institute in the Netherlands. They allow up to one third of their labs to be used by startups. Offering this facility led to dozens of startups. Furthermore, although the startups pay only a marginal rate of use per hour, this amounts to an important contribution to the costs of the labs.

Among the sources of funding for universities, there is government financing for long-term oriented fundamental research, industry contract research and collaborative R&D projects, as well as the competition-based public financing (Debackere, Veugelers, 2005). Endowment funds occupy a special place. Endowments are funds or assets donated to universities (or other institutions) to provide ongoing financial support. These assets are typically invested, and the returns are used to fulfill the organization's mission or support specific programs in perpetuity. Among the 20 wealthiest universities, the median endowment was a crisp $17.1 billion, increasing by an average of 1.9%. Only three institutions in the top 20 broke the 2023 average gain of 7.7%: the University of California system, John Hopkins University, and Duke University. John Hopkins had by far the highest jump at about 28%, and the UC system came behind with an almost 15% uptick[4]. This means that the university needs to be open to these different funding and collaboration activities, and be able to support the individual labs and scientists in obtaining, administrating, and reporting on these funds and activities.

Anticipation in the Context of Developing Economies

Anticipation requires a significant ability to invest in the future. However, in the context of developing economies, the absence of strong formal institutional mechanisms makes it challenging to safeguard investments. Here, more informal, trust-based connections can be relied upon, and a more distributed approach to funding may need to be considered. Business groups, as well as family businesses may be considered in the face of institutional voids and corresponding market failures in developing economies (Cao, Shi, 2021; Khanna, Palepu, 2000). For example, the Thapar Institute for Engineering and Technology (TIET) in northern India was founded in 1956 by the Thapar family to stimulate education, research, and the modernization of industry in the Indian Punjab. Nowadays this not-for-profit private university is teaching a few thousand engineers per year, conducts research that is often geared toward societal needs, and engages with the local ecosystem. It is also actively collaborating with leading international universities to contemporize education and research at a high speed. In India, TIET is ranked 20th among engineering institutions, and 22nd overall,[5] making it an example of how family endowment, reputation, and networks can provide stability and focus in a developing economy.

Furthermore, although the endowment system stems from US practice, we see this mechanism making a difference in the developing context as well. For example, there are more than 300 endowment funds in Russia.[6] Most endowments are created and operate in the interests of educational institutions of higher education (125 endowment funds). Endowments are also used in other social spheres, such as healthcare, social protection (support), science, culture, art, sports, and so on. The largest endowment funds in Russia are universities, as centers of strategic thinking and intellectual capital. An interesting example is the endowment fund of MIPT formed through alumni donations. Created in 2014, it has since become an important instrument in the strategic development of the university, amounting to more than $1 million offered by 780 people and targeting developmental programs, including student entrepreneurship. Furthermore, at MIPT, two funds have been created with the participation of major businessmen from among graduates: the ASH-NU Foundation and the Phystech.Pro Fund. Currently, the capital of the funds is 2 billion rubles; by 2030 it is planned to increase it to 100 billion rubles. Both funds are engaged in bringing MIPT's scientific developments to the market.[7]

Such "alternative" mechanisms of investments may counterbalance the impact of the otherwise crucial government support (Cao, Shi, 2021; Lazzeretti, Tavoletti, 2005). As government support is determined by the national development roadmaps, it may interfere with the anticipation at a more local and university level of development.

[4] https://universitybusiness.com/the-top-20-university-endowments-of-2023/, accessed 24.05.2024.
[5] https://www.nirfindia.org/2023/Ranking.html, accessed 09.01.2024.
[6] https://minobrnauki.gov.ru/about/deps/dep/funds/, accessed 23.05.2024.
[7] https://minobrnauki.gov.ru/press-center/news/novosti-ministerstva/82068/, accessed 23.05.2024.

Reflexivity

The second dimension, reflexivity, means holding a mirror up to one's own activities, commitments, and assumptions (Stilgoe et al., 2013). Building actors' and institutions' reflexivity means rethinking the conceptions about the division of labor within science and innovation (Swierstra, Rip, 2007). For academic entrepreneurship, this translates into asking a question about academic identity on an individual level, discussing the evaluation criteria on the level of the research group and institution, as well as establishing the prominence of entrepreneurship in the overall strategy of the university.

Entrepreneurial University Strategy

Universities can promote commercialization efforts by integrating entrepreneurial goals into their strategies and missions (Huyghe, Knockaert, 2015) and determining how exactly the knowledge generated within their walls is serving the society: whether "simply" made public, or pro-actively used to foster startups (Baglieri et al., 2018; Schaeffer, Matt, 2016). For example, between 1984 and 2009 UT had labeled itself as "The Entrepreneurial University". In all ranking efforts made in the Netherlands to establish the most entrepreneurial university UT has always held first place. Even today, after changing its motto to "High Tech. Human Touch" in 2009, entrepreneurship is one of the core themes of its mission. "Entrepreneur", "entrepreneurship" or "entrepreneurial" keywords are seen 29 times on the 16-page Shaping 2030 document. As a comparison, UG mentions entrepreneurship only five times across the 41 pages of its strategic plan for 2021-2026, it does so mostly in the context of fostering an "entrepreneurial spirit". This is also a notable change in the strategy of the university: back in 2016, the yearly report mentioned entrepreneurship 47 times, having the theme of knowledge valorization through commercialization and startup creation as its core strategy. The new strategy, however, established the role of the university in the advancement of complex societal transitions as a co-creator of impact in a broader sense. This resulted in the creation of four interdisciplinary schools focused on societal challenges and transitions as new value creating units were established between the 11 existing faculties. It also led to the closing of the entrepreneurship center as an integral unit of engaged scholarship (Van de Ven, 2007) that taught, researched, and stimulated entrepreneurship, transferring the support function to the Impact organization and dispersing education and research across faculties. The support function of academic entrepreneurship was then outsourced to other ecosystem partners.

University leaders, therefore, should be clear on the centrality and type of entrepreneurial strategy within the university to be able to establish its place and role in the organization. Coherence and coordination within the entrepreneurial university policy is directly related to the strategy and management structure of the university entrepreneurship support system/university entrepreneurship infrastructure. Lack of coherence within the entrepreneurial university policy can be detrimental to achieving functional links with not only industrial partners (Meissner et al., 2022), but also with internal stakeholders. In this context, primary attention is paid to the leader, the formal head of the entrepreneurship support infrastructure, who holds the position of either vice-rector or department head. The position of the university regarding its role in the commercialization process needs to be further operationalized through the organizational structures, the distribution of roles, as well as rewards and reinforcements.

Entrepreneurial Structures and Functions

To be a strong player on the knowledge market, a university should exploit the complementarities between teaching, basic research, and applied research (Debackere, Veugelers, 2005). Yet, universities find themselves at a curious crossroads: the prevailing share of income comes from educational activities, reputation, and status – from its research, and only a relatively small share of income or recognition comes from innovative entrepreneurial activities.

Traditionally, universities are considered to have an advantage in generating new technology, hence the role of universities was to develop technologies at a commercially feasible level and then transfer them to industrial partners in order to develop a business using those technologies (Takata et al., 2022). This perspective has given rise to TTOs' early activities targeted at connecting universities and industry (Debackere, Veugelers, 2005). While such centralized staff of experienced technology transfer offices manage the IP, contract and training issues are instrumental (Brantnell, Baraldi, 2022; Debackere, Veugelers, 2005), both for the role (Jevnaker, Misganaw, 2022) and business models (Baglieri et al., 2018) of TTOs, which have been redefined over the years (Takata et al., 2022). Several studies highlight that some TTOs consider their job to be funneling resources for research, while others focus on publishing and distributing that research; some TTOs support aspiring academic entrepreneurs while others act as CEOs instead (Baglieri et al., 2018; Brantnell, Baraldi, 2022; Jevnaker, Misganaw, 2022).

Other organizational arrangements have also been shown to impact the academic spin-off process, such as university startup incubators that often develop from an infrastructure supplier to a full support structure for competency development and access to markets and finance (Bruneel et al., 2012). University practice-oriented entrepreneurial education, business plan competitions, co-working spaces, and startup seed funds may facilitate the transition between knowledge generation and commercialization through an academic spin-off (Sansone et al., 2021; Shirokova et al.,

2018). If universities embrace the dispersed approach to stimulating academic entrepreneurship, they need to develop a portfolio of support services that complement each other and form a logical pipeline channeling entrepreneurial initiatives from different levels of the organization as well as focusing on different stages of technology and entrepreneurial readiness (Bruneel et al., 2012; Costa et al., 2020; Kirwan et al., 2006).

Becoming an entrepreneurial university, hence, shapes the dominant conception regarding "who" should be an academic entrepreneur – is it the student, the PhD candidate, the staff, or the actors out in the broader ecosystem of the university? For example, UG states in their mission that they aim to foster an entrepreneurial spirit –focusing on entrepreneurial education. MIPT takes a similar stand and invests in supporting a student technology park and business incubator. Yet, UT emphasizes the staff becoming academic social entrepreneurs. Not being at the center of a university's emphasis on entrepreneurial efforts does not mean "being excluded from entrepreneurship". For example, Chepurenko et al. (2024) show that universities that still operate as "an educational institution" or exclusively as a "fundamental research-oriented institution", find that entrepreneurial efforts may take on a deviant shape resulting in such types of entrepreneurs as silent investors, hybrid, and even destructive entrepreneurs. However, incentives and acknowledgement play a significant role. We mentioned earlier that UT labeled itself in the 1980s as an entrepreneurial university, allowing for and supporting reflexivity to anticipate entrepreneurial activities connected to an academic career. According to several studies (e.g. Clark, 1998; Lazzeretti, Tavoletti, 2005), this is an example of a highly entrepreneurial[8] and academically excellent[9] university that developed in a relatively underprivileged region since its start in 1961. Thus, the centrality of the entrepreneurial mission and its subsequent implementation through organizational structures, mechanisms, and performance indicators is of critical importance for the emergence of entrepreneurial university.

Entrepreneurial Academic Identity

Embracing entrepreneurial identity and having to add the norms and values of businesses to the already often conflicting roles of educators and researchers is a complex process as well (Giunti, Duberley, 2023). It is common to draw a distinction between "traditional" and "entrepreneurial" researchers – those who engage in collaboration with industry and have possibly started their own company. However, this dichotomy misrepresents the wide variety of perspectives on our campuses (Freel et al., 2019). Giunti and Duberley (2023) studied different types of academic entrepreneurs. They found that experience with entrepreneurship was one of the important distinguishing factors between those who did not consider entrepreneurship at all and those who successfully integrated it into their activities. It therefore requires business competency to understand the meaning of becoming an academic entrepreneur. One's attitude toward entrepreneurship was the other significant factor. However, attitude should not be understood as simply positive or negative. Giunti and Duberley (2023) showed that attitude could include curiosity as well as pragmatism, especially if included in the evaluation criteria for promotion.

Yet, the primary evaluation tools for promotion criterion for scholars continues to be research excellence with quantitative metrics (citation metrics, numbers of publications, or the amount of funding secured) being the dominant mode of evaluation (Fuchs et al., 2023). While research excellence can support anticipation, the research excellence-oriented academic career ladder assessed in terms of top journal publications is known to adversely affect academic entrepreneurial initiatives (Qiu et al., 2023). Thus, despite the crucial role of knowledge transfer in contributing to society in the missions of universities, and repeated calls for alignment between individual and organizational incentives for entrepreneurship in the last 20 years (e.g. Debackere, Veugelers, 2005), the KPIs for academic work lag behind.

While some universities incorporate educational career tracks, specific "commercialization" career tracks with incentives for researchers to get involved in joint projects with industrial partners – be they financial or in the form of performance evaluation indicators – are frequently absent or superficial (Qiu et al., 2023). To avoid potential conflicts of interest between being active in a spin off and being an academic, some universities even actively limit the scope of the academic participation in the startups and restrict the ownership one could have in the resulting company. Such conditions represent high opportunity costs for scientists, given that they miss both the time (or timeliness) for research and the ability to participate in the exploitation and value capturing stages of their intellectual property. Yet, several studies point to the risk that advanced knowledge-based ideas may fade away if the idea is separated from the creator or researcher (Jevnaker, Misganaw, 2022; Rasmussen, Borch, 2006), making it important for the overall result that the researcher stays involved in the invention.

Reflexivity in a the Context of a Developing Economy

While reflexivity requires embracing a specific identity and its systematic implementation across the different levels of the organization, developing economies are

[8] https://www.utwente.nl/business/meest-ondernemende-universiteit/, accessed 07.12.2023.
[9] https://www.timeshighereducation.com/world-university-rankings/university-twente, accessed 07.12.2023.

often characterized as dynamic and less predictable environments. If such environments require frequent and inconsistent changes in the strategy and, as a result, shifts in the structure and culture of the organization, this can be highly destructive for the motivation and trust of the actors previously involved in the entrepreneurship activities. Yet, the research also shows that in immature ecosystems, a university can trigger dynamics that lead to the concentration of the links among the ecosystem actors by becoming a hub organization (Schaeffer, Matt, 2016). Thus, a university can act as an anchor in a turbulent environment. In hierarchical structures, when entrepreneurship is among the direct tasks and responsibilities of the rector, who understands its strategic value and place in the overall development strategy of the university, results can be achieved more rapidly. For example, in 2014, the rector of the National Research University ITMO, Vladimir Vasiliev, included a transition to an entrepreneurial development model in the university's development strategy. Over the course of five years, an ecosystem of entrepreneurship was formed. The university became the leader of the federal project "5-100" in terms of the volume of R&D work per academic staff member, new international scientific laboratories, new science-intensive faculties and departments were created together with industrial partners, the research and teaching staff of the university was updated, and the education system at the university was transformed. However, when the university CEO does not see the value in entrepreneurship, there are plenty of opportunities to dismiss it, because, according to one academic entrepreneurship expert: "*The university in its essence, and this is stated in the charter, is an educational organization. The focus here is on education. … there is no focus on entrepreneurship. This means that the university devotes little attention, effort, and [money] to entrepreneurial activities*" (Chepurenko et al., 2024). Hence, in weaker institutional frameworks the role of the university leadership in establishing and maintaining the entrepreneurial identity of the university can be more pronounced.

Inclusion

Inclusion stands for engagement with stakeholders and members of the wider public who actively contribute to the joint development of governance (Stilgoe et al., 2013). In the context of a university, Clark (1998) called it "an expanded developmental periphery" referring to the way a university interacts with its environment, the type of organizational units and means, and the programs a university implements for those interactions. Indeed, as the previous sections have already described, an entrepreneurial university relies not only upon internal resources but also co-develops technological futures together with industry, the government, and other societal partners (Etzkowitz et al., 2000; Goldstein, 2010; Schmitz et al., 2017).

Ecosystem Perspective

Traditionally, an entrepreneurial university's developmental periphery was depicted through the notion of the Triple Helix model of university-industry-government relations. This model tries to capture the dynamics of both communication and organization by introducing the notion of an overlay of exchange relations that feeds back into the institutional arrangements (Leydesdorff, Meyer, 2003). The phenomenon of the triple helix system has been recognized widely (Sunitiyoso et al., 2012).

The modern understanding of the network of actors involved in the process of academic entrepreneurship has shifted towards an ecosystem perspective. The entrepreneurial ecosystem includes not only a top-class university, but also the presence of large firms and start-ups, top-level human resources at all start-up stages, venture capital, and the extensive participation of the government in shaping science and technology and an entrepreneurial culture (Matt, Schaeffer, 2018; O'Shea et al., 2007). A recent Dutch study shows that top entrepreneurial ecosystems can differ significantly (Hendricksen et al., 2024). For instance, Eindhoven, ranked among the top five regions, has strong industry players like ASML, Philips, VDL, and JUMBO. It also benefits from the presence of the Technical University of Eindhoven and several universities of applied sciences, along with strong public sector connections. On the other hand, Groningen, also in the top five regions, has smaller businesses or local branches of larger firms. However, it still ranks high due to its large university, a university of applied sciences, a major university hospital, and a substantial IT cluster mainly consisting of SMEs. Additionally, Groningen has well-established government networks, which contribute to its strong entrepreneurial ecosystem (Hendricksen et al., 2024). These two examples show that the mirror to use for reflexivity can be multi-faceted. Whatever the profile of the ecosystem, it is the access to critical expertise, networks, and knowledge (O'Shea et al., 2005; Saxenian, 1994) that stimulates voluntary and involuntary knowledge spillovers that favor open innovation strategies and generate fruitful opportunities for entrepreneurs to engage in value co-creation and participate in established industries (Nambisan et al., 2018). Knowledge infrastructure at the regional level is therefore of utmost importance: knowledge spillovers are spatially concentrated, benefiting entrepreneurial individuals and firms within close proximity to other actors (Crowley, Jordan, 2021). Robinson et al. (2007) describe two main routes of development of such infrastructure: co-creation or co-location. The first, the co-creation route, builds upon interrelated and interdependent networks, where technological opportunities and platforms are developed by being available at the same time. Usually, these are new and emerging fields far from technological finesse powered by the strong anticipation capacity of the knowledge-centered institutions. The second approach builds upon co-localized facilities and

scientific and technological competencies (geographic concentration), where the technology platforms are expansions of existing facilities that emerge around a university and later attract small and large companies (Robinson et al., 2007). Such networks are not limited to active commercialization partners only. An interesting example is the Wetsus – an excellence center for Water Technology in Leeuwarden in theNetherlands. This institute integrates societal partners and science as a core organizational principle. Wetsus organizes research themes that include groups of firms, professors from various universities, and central government support. Research is co-funded by firms, public research funds, and basic government support. Wetsus operates 12 research programs involving 60 PhD students, about 100 firms, and nearly 40 universities. Since 2007, it has engaged 48 professors, overseen 314 PhD projects, and produced 101 patents in sustainable water technologies. Many of these patents are commercialized through partner firms. To foster entrepreneurship, Wetsus encourages PhD students and professors to start businesses and collaborate with regional entrepreneurship support organizations.

Interactions, connections, and knowledge flows lie at the heart of ecosystems of innovation and entrepreneurship, where local and regional elements shape the aggregate capabilities of agents (Schaeffer et al., 2021). Informal contacts and human capital flows are ways of exchanging knowledge between enterprises and public research, which are more difficult to quantify, yet extremely important and often act as a catalyst for instigating further formal contacts. This once again highlights the necessity of spatial proximity in entrepreneurial ecosystems and not only based on the level of communication flows, but also through the multiplexity of the relationships necessary to build strong ties within the community leading to mutual trust (Burt, 2000). Yet, it should also be noted that a rich diversity of actors each pursuing their own institutional logic creates conditions for multiple divergences of interests and potential conflicts (Borah, Ellwood, 2022). Overall, the generation and diffusion of innovations, as well as entrepreneurial activity, are shaped by the local infrastructure, its externalities, specialized services, and levels of trust involved in the relationships between agents (Matt, Schaeffer, 2018).

Entrepreneurial Ecosystems in Developing Economies

In developing economies, entrepreneurial ecosystems are often characterized by a lack of good entrepreneurship support organizations and weak or small private institutions, yet they include the central role played by the government as the primary resource provider, together with foreign actors, and/or powerful established firms (Cao, Shi, 2021). For example, it is the government that acted as the main designer and coordinator for Chinese Silicon Valley (Li et al., 2017) as well as the industrial districts in Wenzhou, China (Liu et al., 2013). Similarly, in Russia, Skolkovo University was created with the prominent involvement of the presidential office and foreign contacts from MIT advising how to develop an entrepreneurial technical university (Chekanov, 2022). Yet, as McCarthy et al. (2014) argue, the early attempts of Russian government support for entrepreneurship failed to move beyond the stage of "idea creation" resulting in the tradition of "incomplete innovation" with a lack of support from informal cultural-cognitive institutions such as a culture that supports innovation and entrepreneurship.

Government involvement and funding may also impact entrepreneurial university development through national "development roadmaps". For instance, in 2021, Russia initiated the "University Technological Entrepreneurship Platform" to promote technological entrepreneurship among students, the university community, and investors. The project aims to introduce 30,000 technology entrepreneurs into the economy by 2030, all of whom are ready to launch new businesses. Objectives include involving students in technological entrepreneurship, creating a system for commercializing intellectual activity, and enhancing investment attractiveness in the research and development sector by establishing an entrepreneurial platform for startups. In 2023, 15 pilot startup studios were created, with plans to expand to 50 by 2030. The "Student Startup" grant support also provides up to 1 million rubles per project from the Foundation for Assistance to Small Innovative Enterprises (FASIE). Another state program, "Startup as a Diploma" has been implemented since 2021 at 40 Russian universities to involve talented students in developing the technological entrepreneurship ecosystem and supporting early-stage businesses. The final qualifying work is a real-life business project created by a student or team. In 2024, the Department of Technological Project Management at MIPT, co-financed by the Russian Venture Company, defended its first nine diplomas in the form of startups.[10]

These programs illustrate national policy commercialization efforts oriented toward student startups, potentially increasing support for student entrepreneurship even without deeply embedding this activity in the culture and identity of specific institutions. They also demonstrate some fundamental shortcomings of bureaucratic logic in nurturing academic entrepreneurship. For instance, they attempt to invest in the "supply" of academic entrepreneurship without any considerations for the role of the "demand" side (single business angels, a weak venture industry, low demand from the big industry actors for startups, etc.). Furthermore, developments initiated from the top down may lack consistency in their implementation. The volumes of allocated resources and the support program itself are such that they allow for fulfilling the plan in terms of quantity, involving the maximum number of universi-

[10] https://rvc-mipt.ru/chair/news/pervye-so-startap-kak-diplom-v-mipt/, accessed 17.06.2024.

ties, but at the same time with minimal funding, which does not allow for deep systemic work to implement educational programs in the field of entrepreneurship. For example, the state support framework defines the KPIs for entrepreneurship training in terms of thousands of students. To achieve such a scale of impact within the allocated budget, universities resort to one-day training sessions in entrepreneurship. However, these training sessions often create a misleading perception of how easily entrepreneurial skills can be acquired. The courses tend to be entertainment-oriented and are frequently led by instructors with inadequate qualifications. To boost attendance, organizers might cancel regular university classes to encourage students to participate in the training sessions, or they may offer additional incentives to motivate attendance.

Grant support programs from the Innovation Assistance Fund offer financial incentives that are particularly effective in regions with lower income levels compared to capital cities. Students compete for substantial grants, typically around 1 million rubles, but must establish a legal entity to qualify. This requirement can hinder the early stages of a startup, where forming a company might slow down the initial business launch. University startup studios globally are known for rapidly testing business ideas and fostering the mass creation of new companies within academic settings. The Russian Ministry of Science and Higher Education's 2022 initiative aimed to replicate this model, allowing for the systematic development of high-tech startups in material-based industries. However, implementing such a program in Russia faces challenges due to the lack of venture capital, experienced entrepreneurs, and successful venture exits required to support this venture financing-based model. Russian university startup studios, after one-and-a-half to two years, show mixed results. Some encourage collaboration with businesses, while others veer towards later-stage investments with minimal student involvement, resembling a holding model more than a venture model. State involvement in these studios, instead of being a co-investor, adds instead a bureaucratic layer that complicates approvals and introduces non-entrepreneurial management into startup operations. These conditions place a disproportionate amount of responsibility on the founders, outweighing the resources and benefits they receive. In addition, the main element that distinguishes a startup studio from a classic fund is missing - this is a mechanism for growing startups, which often simply does not exist. The most promising studios involve industrial partners who invest resources and expertise, fostering the growth of university-based startups. This partnership model offers a hopeful pathway for enhancing academic entrepreneurship, although substantial improvements are still needed in the broader framework.

Hence, although necessary, top-down government-led activities alone are not sufficient to build a sustainable innovation ecosystem (McCarthy et al., 2014). This is illustrated in one of the interviews in Russia: "*It seems as if all the elements are there, all the names are correct, managers have been appointed, KPIs have been formed, structures have been created (incubators, accelerators, startup studios and others), but they are not working or are extremely ineffective*" (Chepurenko et al., 2024). Indeed, behind the formal outline of an ecosystem structure, lies a myriad of informal contacts, gatekeeping processes, and industry-science networks on a personal base (Debackere, Veugelers, 2005). Together, these relations form an integrated entrepreneurial culture (Clark, 1998): an atmosphere of entrepreneurship and innovation that permeates every layer of the university and the organizations in the ecosystem.

To create this culture, companies may consider establishing their presence at the university not only on a project (e.g. PhD, product or technology development) basis, but in a rather more lasting manner. Consider the cooperation format between higher education institutions and industry, such as a "base" or "corporate" department. A corporate department is a structural unit within a university, initiated by a commercial organization or research institute. The first corporate departments were established at the MIPT in 1946. Unlike more established industrial departments, a corporate department is often located at an enterprise and facilitates cooperation between a university and a specific company or research institute, with the cooperation's scope individually defined. MIPT, the Higher School of Economics (HSE), and other universities have several dozen corporate departments. For example, the corporate department of the Russian Venture Company, established at MIPT in 2011, initially aimed to provide business education to MIPT students within a science and technology master's program. This program complemented their academic knowledge, enabling them to work effectively at the intersection of technology and business. The Russian Venture Company, as a development institution in the Russian Federation, focuses on training personnel for the venture market, including specialists and analysts for venture funds, which the company helped establish. Since the creation of the Russian Venture Company's corporate department, 264 master's students have been trained. These graduates work in various fields such as research and development, strategic and technological development, venture fund activities, technology startups, science, and consulting, both in Russia and globally.

Furthermore, the networked structure of the ecosystem incorporates an increasing number of international collaborations. As such, the Wetsus network actively works with China. Similarly, TIET is one of the first in India to invest in NVIDIA's latest units and build supercomputing capacity for AI development. This places them among the forerunners of AI technology adoption, along with, for example, UG that is also investing in the latest technology to serve as an AI hub, supported by EU, national, regional, and international businesses. Many universities foresee significant opportunities in AI technology and are collaborating

with various stakeholders to realize these opportunities. This brings us to the discussion on the responsiveness of entrepreneurial universities toward changing circumstances in the ecosystems.

Responsiveness

Responsible innovation requires the capacity to change the shape or direction of activities in response to stakeholder and public values and changing circumstances (Stilgoe et al., 2013). For responsible innovation to be responsive, it cannot overlook recent developments in society and policy at large. This may include nurturing transitions that advance complex solutions to the "grand challenges" (Lund Declaration, 2009), building upon environmental shocks such as Covid-19, which-brought changes to all spheres of life (Belousova et al., 2021), and overcoming the destruction brought on by military conflicts (Chepurenko et al., 2024). An analysis of ongoing societal and technological developments is necessary as well as some reduction of the complexity. Yet, as Kulve and Rip (2011) argue, this reduction of complexity "*needs to be open-ended to take the fluidity of the situation into account and to avoid biases regarding (the selection of) particular options*". To do so, it is important to "act locally, but think globally". For example, some universities are located in regions with particularly strong industries. As mentioned above, this goes for the region Eindhoven with their big partner AMSL. However, for ASML, TU-Eindhoven is not enough, and they actively work with other universities all over the world. TU-Eindhoven may also be very well connected to other partners elsewhere. One might also consider the University of Stavanger. Located in an oil and gas region, their strong collaboration with the leading company Equinor is not surprising. However, they actively collaborate internationally to explore other contexts.

The topic of responsiveness also naturally invites a reflection on the managerial approaches and the role of dynamic capabilities in academia (Klofsten et al., 2019). Managers, including university management, who face business environments challenged by volatility, uncertainty, complexity, and ambiguity cannot simply be efficient administrators if their organizations are to remain viable (Heaton et al., 2020). To address rapidly changing environments, organizations need to integrate, build, and reconfigure internal and external competencies, or, in other words, they need dynamic capabilities (Teece et al., 1997). Rasmussen and Borch (2006) suggest four categories of dynamic capabilities for entrepreneurial universities: capabilities that stimulate the exploration of new paths while reducing the path dependency of earlier strategic adaptation and resource bundling; capabilities to explore and map new valuable resources and complementary competences; capabilities that balance the present and the future interests of the organizational stakeholders, not the least protecting the new commercialization process from counteracting interests within the university organization; and, finally, they must possess the capabilities that reconfigure the available resources into a suitable exploitative pattern and link them together into a commercial venture.

As a reflexivity "muscle", strong dynamic capabilities govern a university's survival and growth. As Heaton et al. (2020) put it: "*Without adequate sensing capabilities, universities will be behind the curve in identifying opportunities of creating value for both their institutions and their constituents. For public universities, effectively seizing new entrepreneurial opportunities can generate nonstate funds that can be used to support disciplines, departments, programs, and activities that have limited potential to be self-funding. To take up their expanded roles, universities need to transform. Successful university leaders must provide the context for change.*"

Responsiveness in the Developing Context

In the developing contexts with their inherently more dynamic and less predictable environments, responsiveness may become one of the key dimensions of the development of an entrepreneurial university. Here, entrepreneurial development mechanisms like bricolage (Baker, Nelson, 2005) may be very important as improvisation and the need to make do with resources at hand are often the only way to start a business in such environment. Furthermore, as universities in developing economies are often more reliant on government support, there is a risk here that the university's involvement in the development of academic entrepreneurship may come down to only embracing some of the instruments sponsored by the government or achieving the more general KPIs set by the government rather than focusing on the immediate needs of the local ecosystems. With the strong presence of the government, the intermediary managers need to combine roles and skills at the interface of being a quasi-government official while assuming market-building activities (Cao, Shi, 2021). In such in multiple agency relationships embedded in different institutional logics, role and agency conflicts are also more likely to occur (Borah, Ellwood, 2022; Macho-Stadler et al., 2007). The capabilities of balancing the historic values and objectives of the academic research community with the new more commercially oriented focus is crucial for the entrepreneurial university (McCarthy et al., 2014).

Responsiveness requires not only navigating political changes, but technological trends as well. With the acceleration of technological change, the capacity of the TTO officers for scouting promising innovations may become overstretched. Having entrepreneurial activities "dispersed" (Birkinshaw, 1997) throughout the university may offer a solution by legitimizing more actors across the organization, such as students and staff, to be involved in entrepreneurial activities. It is, however, likely that coming from the lesser developed entrepreneurship ecosystem, the university is not involved beyond the proof-of-concept stage and an occasional product development, hence not having the

necessary business development competence among the staff – or in the surrounding ecosystem. It is, therefore, critical that the university defines its own roadmap of engaging different layers of the organization in entrepreneurship. For example, TIET started with the overall strategy of contemporizing their education by including entrepreneurship in the engineering curriculum of their students. To do so, they also educated 30 engineering faculty members in entrepreneurship through their international network, making them ambassadors for entrepreneurship across all programs and faculties. These faculty are both teaching the introductory entrepreneurship course as well as leading the Entrepreneurship Development Cell helping develop early-stage student and faculty startups. As the theme gained more traction, the university leadership also introduced the PhD student and faculty entrepreneurship courses and reinforced startup support through investing in co-creation and a VentureLab (business accelerator) space open for all students and faculty, as well as for external portfolio startups. It needs to be noted that this development has been going on for about 10 years and it is expected to continue for at least five years before a relatively stable situation is reached. Connections to alumni, government, local, and regional ecosystem partners are necessary to enable this ongoing development.

Integration and Tensions among the Dimensions

The discussion above examines the different mechanisms of governing an entrepreneurial university and contextualizes the discussion within the framework of developing economies. Finding a proper balance in managing the dimensions is central to making academic entrepreneurship governance possible. For this reason, institutional commitment to a strategic policy framework that integrates all four dimensions is vital. Yet, the analysis also identifies tensions and challenges.

A university's competitive advantage lies in its ability to produce top-class research, both fundamental and applied (Debackere, Veugelers, 2005). This has traditionally given research universities an edge in developing industry ties. However, a university's competitiveness is not solely determined by fundamental research, except when in competition with other universities for the funding of such research. In entrepreneurial contexts, market trajectories can vary significantly, necessitating a contextualized analysis. The discipline also influences competition strategies. For example, engineering often allows for shorter collaborations compared to physics or chemistry. Yet, this can change. For instance, in 2012, a scientific director of a nanoscience institute in The Netherlands claimed nanoscience had less commercialization potential than nanotechnology (Bruneel et al., 2012). Today, professors in nanoscience and nanotechnology win awards for both applied and fundamental research. Molecular precision medicine, for example, uses nanoscience for targeted drug delivery and nanotechnology for cancer distribution measurement. The same nanoscience institute has a new leader, and she is a member of a national "Top sector" industry committee and leads large grants in collaboration with industry such as the world's leading lithography company ASML. This institute now is actively involved in creating startups. This is an example of scientific excellence (anticipation) combined with responsiveness to the emerging scientific applications.

This, however, requires a strong reflexive perspective that includes entrepreneurship as part of the identity of the university, the department, and the scientist. For example, a UT nano-technology professor Albert van den Berg, Dutch Spinoza prize winner, author of dozens of patents and the inspiration behind multiple startups says[11]: "*The motivation for our research was both found in scientific questions and health- and sustainability related challenges.*"[12] This shows the importance of anticipation, reflexivity, and responsiveness working together: attracting and retaining top-class faculty capable of creating breakthrough research, translating it into industrial applications, and being willing and able to engage in commercialization through a startup journey. Planning for societal impact (e.g. through stressing the need for transitions outlined in the SDGs as opposed to expectations of short-term results) may be instrumental here. Yet, as the previous discussion shows, the dominant focus on assessing research excellence through the number and rank of publications may have detrimental effect upon engagement in the commercialization of university knowledge. Hence, research excellence may stimulate strong anticipation, but also lead to a reluctance to embrace an entrepreneurial identity.

Furthermore, efforts to increase the entrepreneurial spirit of a university often require funding and infrastructure that no university can derive from the first stream (student fees) money alone – and this is when inclusion "feeds" anticipation. We may even talk about a reinforcing spiral of development, where the first investment from either public or private investments can create interest in the expansion of infrastructural capacities, attracting more partners and allowing for broader development. Different origins (public or private) may require different management capabilities and have different trajectories of development (e.g., whether private partners join a government-financed technology program may differ according to country and grant conditions).

Inclusion may also be instrumental in creating a responsive system, especially if the potential for anticipation is limited. An example of distributed responsibility and co-creation is the creation of focused interdisciplinary research institutes where collaboration

[11] https://www.nwo.nl/en/node/38875, accessed 20.12.2023.
[12] https://www.utwente.nl/en/research/researchers/featured-scientists/berg/#nano-research-for-personalised-medicine, accessed 20.12.2023.

between universities and industry is maintained and enhanced, such as Wetsus which is recognized as a top-level institute warranting long-term government support as well.[13] Another example is UG offering scholarships for researchers to do work in the interdisciplinary Schools for Science & Society, named after famous Groningen scholars: energy transition and climate adaptation (Wubbo Ockels); healthy ageing (Aletta Jacobs); digital society, technology and artificial intelligence (Jantina Tammes); and sustainable development (Rudolf Agricola).[14] Setting up these schools as collaborative units outside the disciplinary schools is an interesting development to further research on its effect upon inclusiveness and anticipation of this university. Entrepreneurial ecosystems generate unique interactions in the sense that entrepreneurs do not gravitate toward entrepreneurial ecosystems in order to "learn the ropes" of a given industry or technology (Cao, Shi, 2021), but rather, they do so to become more effective in organizing their ventures for start-up and scale-up (Spigel, 2016). Depending on the strength of the entrepreneurial identity, culture and competence within the university, it is possible that the ecosystem around it will be functioning differently.

There is, therefore, a certain interdependency across the dimensions: due to a lack of anticipation, lacking financial resources from the university may be compensated through the inclusion mechanisms, while the lack of identity as an "entrepreneur" may be stimulated though the mobilization of responsiveness and anticipation of impact. Through engagement in entrepreneurial projects at the ecosystem level, university staff may have an opportunity to develop their capabilities and formulate their own attitude toward entrepreneurship, making it more likely for them to consider entrepreneurial activities in the future.

Discussion and Conclusion

Decades of efforts to include entrepreneurship as a third mission of universities have revealed many unresolved tensions (Qiu et al., 2023). In our examples, as well as in the literature, we see that this is not only so in developing economies – in countries such as Brazil, Russia, India, or China. In so-called developed economies like the Netherlands and elsewhere in Europe and America such variance and tensions occur in the realization of the third mission as well.

Answering questions that ensure anticipation, reflexivity, inclusion, and responsiveness in the decision-making processes of university strategy can help resolve some of them. However, these four dimensions of responsible academic entrepreneurship development need to be supplemented with theories on their respective content, such as entrepreneurship theories and models. Further exploration is needed to understand how these dimensions can guide university development, considering the multi-level characteristics of socio-technological developments (Rip, Groen, 2001). Furthermore, we showed that certain institutional and cultural issues may lead to dysfunctional processes in building the third mission. Not reflecting on these dysfunctional processes while developing policy will likely lead to failure of that policy.

Anticipation helps formulate the core positioning and development strategy of the university: how it sees the future and how it aims to engage in it. To effectively integrate entrepreneurship, universities should answer the policy questions that allow them to anticipate future technological developments: What areas are going to receive priority consideration and what resources can be devoted to their development? Which resources are becoming available? What is the horizon of planning? Which actors other than the university can gain benefits from this development in a legitimate way? Can these actors be involved in the process of university? If the answer is positive, this may lead to the institutional entrepreneurship of the university in its ecosystem.

Reflexivity requires asking questions regarding the centrality, type, and agents of entrepreneurial activities within the university. Are there sufficient opportunities to engage in applied research and eventually the application of the research and seeing that it makes its way onto the market? Did the university leadership ensure a portfolio of career opportunities across research, education, and commercialization? Do these criteria reflect the university strategy and policy? Are they aligned at the individual, department, and strategy levels? Oftentimes, academic entrepreneurship is evaluated using such indicators as the number of spin-offs and their performance indicators, such as sales or employment generated (Qiu et al., 2023). Yet, such evaluations are only properly reflecting the role of the academic institutions that are fully engaged in the commercialization process (Takata et al., 2022). Meanwhile, majority of the academic institutions will find themselves on the spectrum between the development of technology and participation in product development (Robinson et al., 2007). To develop the ability and willingness to act entrepreneurially, several activities forming a logical chain of events supporting the growing capabilities of the participants are needed (Costa et al., 2020) and must be evaluated separately.

Inclusion in its turn ensures shared agency and responsibility for the different stages of the technology, product, and business development required to commercialize the knowledge with the partners outside of the university walls. The high number of stakeholders within and around the university may represent a challenge as soon as resources are moved from one activity to another (Rasmussen, Borch, 2006). Hence, there is a need

[13] https://www.wetsus.nl, accessed 08.01.2024.
[14] http://www.rug.nl/about-ug/latest-news/news/archief2023/nieuwsberichten/1115-beurzen-rug-schools-uef?lang=en, accessed 09.01.2024.

for the clear integration of the different mechanisms of supporting entrepreneurship across the different stages of development (e.g., education, co-working spaces, incubators, lab facilities). The larger part of product and business development responsibilities lie on the shoulders of the ecosystem that is created around the universities. For the possibility of young startups to find their way toward the market, it is important that the ecosystem partners take active role in co-developing the technology toward the later readiness stages and its market introduction, even if the market is not in direct proximity (Fischer et al., 2022). In the specific processes of high-tech business development we see tensions (Groen et al., 2008), which may partly relate to the university. The question is, therefore, whether that can be compensated for by the entrepreneurship support officers of the where the ideas originated. Reflexivity and inclusion are key here: what part of the commercialization process is the university responsible for and how does it engage partners to take steps within and outside the university? How does the university navigate and stimulate these relationships? What sharing of value is to be expected for the university?

Finally, responsiveness makes the management ask questions about the sets of capabilities that are needed to manage both traditional and commercialization activities. In the context of a developing economy, it sometimes seems to be possible to jump generations of development. See the example of TIET – an Indian university collaborating with a globally leading company, NVDIA. This seems to allow the university to use the existing capabilities of staff in interactions with ecosystem partners and build stronger capabilities directly for research at the level of Industry 5.0, jumping over Industry 3.0 and 4.0, which took decades to evolve in developed countries.

In a developing economy, responsiveness is crucial for navigating both technological and political challenges. This requires strong leadership at the university itself and of the university in its local ecosystem. However, there are instances where university professors and leaders, despite adhering to accepted entrepreneurship principles, must concede significant benefits to the ruling elite of the country. This often occurs through the development of the university's third mission in a weak institutional framework that permits such dysfunctional processes.

The compensation effect can also be observed across the dimensions: the lack of financial or anticipation resources from the university may be compensated through the inclusiveness mechanisms, while the lack of an identity as an "entrepreneur" may be stimulated though the mobilization of responsiveness and attention to impact.

The current paper provides a framework that stimulates reflection on the functioning and governance of entrepreneurial universities, especially in the context of developing countries. This effort is not prescriptive or normative. Rather, we constructively inform an emerging debate on academic entrepreneurship across different contexts (Wigren-Kristoferson et al., 2022). Our framework draws upon the insights and experiences of responsibility and innovation as well as socio-technical theories and concepts (Stilgoe et al., 2013). Responsible innovation will inevitably be a dynamic concept implemented at multiple levels (Fisher, Rip, 2013), and so is the governance of academic entrepreneurship. While far from encompassing the whole literature, we rather seek to highlight and accentuate the issue of the embeddedness of entrepreneurship in different organizations and contexts. Seeing these processes through the lens of anticipation, reflexivity, inclusion, and responsiveness can help guide the needed alignment. Our analysis reveals that understanding the unique context of each university is critical in both developing and developed economies. While general mechanisms exist, their application varies significantly at a specific level. Recognizing examples of equifinality is crucial for advancing theory. The complexity of these processes allows for the same theoretical mechanisms to produce different outcomes in various situations. Meanwhile, different combinations of these mechanisms can lead to similar results, each providing a unique explanation for the observed outcomes. As such we call for further development of the complexity theory of social systems to better understand the equifinal pathways that generate socially productive entrepreneurial universities.

References

Abreu M., Grinevich V. (2013) The nature of academic entrepreneurship in the UK: Widening the focus on entrepreneurial activities. *Research Policy*, 42(2), 408–422. https://doi.org/10.1016/j.respol.2012.10.005

Baglieri D., Baldi F., Tucci C.L. (2018) University technology transfer office business models: One size does not fit all. *Technovation*, 76–77, 51–63. https://doi.org/10.1016/j.technovation.2018.05.003

Baker T., Nelson R. (2005) Creating Something from Nothing: Resource Construction through Entrepreneurial Bricolage. *Administrative Science Quarterly*, 50(3), 329–366. https://doi.org/10.2189/asqu.2005.50.3.329

Belousova O., Walsh S.T., Groen A.J. (2021) COVID-19 as Industry Forcing Function: Challenges for Entrepreneurship in the Post-Pandemic Future. *Foresight and STI Governance*, 15(4), 33–41.

Birkinshaw J. (1997) Entrepreneurship in multinational corporations: The characteristics of subsidiary initiatives. *Strategic Management Journal*, 18(3), 207–229. https://doi.org/10.1002/(SICI)1097-0266(199703)18:3%3C207::AID-SMJ864%3E3.0.CO;2-Q

Borah D., Ellwood P. (2022) The micro-foundations of conflicts in joint university-industry laboratories. *Technological Forecasting and Social Change*, 175, 121377. https://doi.org/10.1016/j.techfore.2021.121377

Brantnell A., Baraldi E. (2022) Understanding the roles and involvement of technology transfer offices in the commercialization of university research. *Technovation*, 115, 102525. https://doi.org/10.1016/j.technovation.2022.102525

Bruneel J., Ratinho T., Clarysse B., Groen A.J. (2012) The Evolution of Business Incubators: Comparing demand and supply of business incubation services across different incubator generations. *Technovation*, 32(2), 110–121. https://doi.org/10.1016/j.technovation.2011.11.003

Burt R.S. (2000) The network structure of social capital. *Research in Organizational Behaviour*, 22, 345–423. https://doi.org/10.1016/S0191-3085(00)22009-1

Cao Z., Shi X. (2021) A systematic literature review of entrepreneurial ecosystems in advanced and emerging economies. *Small Business Economics*, 57(1), 75–110. https://doi.org/10.1007/s11187-020-00326-y

Chekanov A. (2022) The Triple Helix in transition economies and Skolkovo: A Russian innovation ecosystem case. *Journal of Evolutionary Studies in Business*, 7(2), 160–183. https://doi.org/10.1344/jesb2022.2.j110

Chepurenko A.Y., Butryumova N.N., Chernysheva M.V., Sutormina A.Y. (2024) Entrepreneurship in and around academia: Evidence from Russia. *International Journal of Sociology and Social Policy*, 44(1/2), 130–154. https://doi.org/10.1108/IJSSP-04-2023-0101

Clark B.R. (1998) *Creating Entrepreneurial Universities, Organizational Pathways of Transformation,* Bingley (UK): Emerald.

Clarysse B., Tartari V., Salter A. (2011) The impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship. *Research Policy*, 40(8), 1084–1093. https://doi.org/10.1016/j.respol.2011.05.010

Colombo M.G., D'Adda D., Piva E. (2010) The contribution of university research to the growth of academic start-ups: An empirical analysis. *The Journal of Technology Transfer*, 35(1), 113–140. https://doi.org/10.1007/s10961-009-9111-9

Costa S., Belousova O., Ouendag A.M., Groen A.J. (2020) Venturelab Weekend: Developing entrepreneurial skills from idea to action. In: *How to Become an Entrepreneur in a Week: The Value of 7-Day Entrepreneurship Courses* (eds. H. Landstrom, L. Aaboen, R. Sørheim), Cheltenham (UK): Edward Elgar Publishing.

Crowley F., Jordan D. (2021) Do local start-ups and knowledge spillovers matter for firm-level R&D investment? *Urban Studies*, 59(5), 1085–1102. https://doi.org/10.1177/0042098021995105

Debackere K., Veugelers R. (2005) The role of academic technology transfer organizations in improving industry science links. *Research Policy*, 34(3), 321–342. https://doi.org/10.1016/j.respol.2004.12.003

Etzkowitz H. (1983) Entrepreneurial scientists and entrepreneurial universities in American academic science. *Minerva*, 31(3), 198–233. https://doi.org/10.1007/BF01097964

Etzkowitz H. (2003) Research groups as 'quasi-firms': The invention of the entrepreneurial university. *Research Policy*, 32(1), 109–121. https://doi.org/10.1016/S0048-7333(02)00009-4

Etzkowitz H., Webster A., Gebhardt C., Terra B.R.C. (2000) The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, 29(2), 313–330. https://doi.org/10.1016/S0048-7333(99)00069-4

Fischer B., Meissner D., Vonortas N., Guerrero M. (2022) Spatial features of entrepreneurial ecosystems. *Journal of Business Research*, 147, 27–36. https://doi.org/10.1016/j.jbusres.2022.04.018

Fisher E., Rip A. (2013) Responsible Innovation, Multi-level dynamics and soft intervention practices. In: *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (eds. R. Owen, J. Bessant, M. Heintz), Chichester: John Wiley & Sons, pp. 165–183.

Fisher E., Rip A. (2013) Responsible Innovation: Multi-Level Dynamics and Soft Intervention Practices. In Responsible Innovation (eds. R. Owen, J. Bessant, M. Heintz), New York: Wiley, pp. 165–183. https://doi.org/10.1002/9781118551424.ch9

Freel M., Persaud A., Chamberlin T. (2019) Faculty ideals and universities' third mission. *Technological Forecasting and Social Change*, 147, 10–21. https://doi.org/10.1016/j.techfore.2019.06.019

Fuchs L., Bombaerts G., Reymen I. (2023) Does entrepreneurship belong in the academy? Revisiting the idea of the university. *Journal of Responsible Innovation*, 10(1), 2208424. https://doi.org/10.1080/23299460.2023.2208424

Giunti G., Duberley J. (2023) Academic entrepreneurship: Work identity in contexts. *Entrepreneurship & Regional Development*, 35(5–6), 532–552. https://doi.org/10.1080/08985626.2023.2178676

Goldstein H.A. (2010) The 'entrepreneurial turn' and regional economic development mission of universities. *The Annals of Regional Science*, 44(1), 83–109. https://doi.org/10.1007/s00168-008-0241-z

Groen A.J., Wakkee I.A.M., De Weerd-Nederhof P.C. (2008) Managing Tensions in a High-tech Start-up: An Innovation Journey in Social System Perspective. *International Small Business Journal,* 26(1), 57–81. https://doi.org/10.1177/0266242607084659

Guerrero M., Urbano D. (2017) The Dark Side of Entrepreneurial Ecosystems in Emerging Economies: Exploring the Case of Mexico. *Academy of Management Proceedings*, 2017(1), 12941. https://doi.org/10.5465/AMBPP.2017.12941abstract

Hayter C.S., Nelson A.J., Zayed S., O'Connor A.C. (2018) Conceptualizing academic entrepreneurship ecosystems: a review, analysis and extension of the literature. *The Journal of Technology Transfer*, 43(4), 1039–1082. https://doi.org/10.1007/s10961-018-9657-5

Heaton S., Lewin D., Teece D.J. (2020) Managing campus entrepreneurship: Dynamic capabilities and university leadership. *Managerial and Decision Economics*, 41(6), 1126–1140. https://doi.org/10.1002/mde.3015

Hendricksen T., Stam E., van den Toren J.P. (2024) Entrepreneurial Ecosystem Index 2024: Stedelijke regio's versterken hun positie. Utrecht (NL): Utrecht University.

Högberg L., Mitchell C. (2023) Mixed embeddedness and entrepreneurship beyond new venture creation: Opportunity tensions in the case of reregulated public markets. *International Small Business Journal*, 41(2), 121–151. https://doi.org/10.1177/02662426221083827

Huyghe A., Knockaert M. (2015) The influence of organizational culture and climate on entrepreneurial intentions among research scientists. *The Journal of Technology Transfer*, 40(1), 138–160. https://doi.org/10.1007/s10961-014-9333-3

Jevnaker B.H., Misganaw B.A. (2022) Technology transfer offices and the formation of academic spin-off entrepreneurial teams. *Entrepreneurship & Regional Development*, 34(9–10), 977–1000. https://doi.org/10.1080/08985626.2022.2080867

Khanna T., Palepu K. (2000) The Future of Business Groups in Emerging Markets: Long-Run Evidence From Chile. *Academy of Management Journal*, 43(3), 268–285. https://doi.org/10.2307/1556395

Kirwan P., van der Sijde P., Groen A.J. (2006) Assessing the needs of new technology based firms (NTBFs): An investigation among spin-off companies from six European Universities. *International Entrepreneurship and Management Journal*, 2(2), 173–187. https://doi.org/10.1007/s11365-006-8683-1

Klofsten M., Fayolle A., Guerrero M., Mian S., Urbano D., Wright M. (2019) The entrepreneurial university as driver for economic growth and social change – Key strategic challenges. *Technological Forecasting and Social Change*, 141, 149–158. https://doi.org/10.1016/j.techfore.2018.12.004

Klofsten M., Jones-Evans D. (2000) Comparing academic entrepreneurship in Europe: The case of Sweden and Ireland. *Small Business Economics*, 14, 299–309. https://doi.org/10.1023/A:1008184601282

Lazzeretti L., Tavoletti E. (2005) Higher Education Excellence and Local Economic Development: The Case of the Entrepreneurial University of Twente. *European Planning Studies*, 13(3), 475–493. https://doi.org/10.1080/09654310500089779

Leydesdorff L., Meyer M. (2003) The Triple Helix of university-industry-government relations. *Scientometrics*, 58(2), 191–203. http://dx.doi.org/10.1023/A:1026276308287

Li W., Du W., Yin J. (2017) Digital entrepreneurship ecosystem as a new form of organizing: The case of Zhongguancun. *Frontiers of Business Research in China*, 11(1), 5. https://doi.org/10.1186/s11782-017-0004-8

Liu R., Weng Q., Mao G., Huang T. (2013) Industrial cluster, government agency and entrepreneurial development. *Chinese Management Studies*, 7(2), 253–280. https://doi.org/10.1108/CMS-Oct-2011-0085

Macho-Stadler I., Pérez-Castrillo D., Veugelers R. (2007) Licensing of university inventions: The role of a technology transfer office. *International Journal of Industrial Organization*, 25(3), 483–510. https://doi.org/10.1016/j.ijindorg.2006.06.001

Manimala M.J., Wasdani K.P. (2015) Emerging Economies: Muddling Through to Development. In: *Entrepreneurial Ecosystem: Perspectives from Emerging Economies* (eds. M.J. Manimala, K.P. Wasdani), Heidelberg, Dordrecht, London, New York: Springer, pp. 3–53. https://doi.org/10.1007/978-81-322-2086-2_1

Matt M., Schaeffer V. (2018) Building Entrepreneurial Ecosystems Conducive to Student Entrepreneurship: New Challenges for Universities. *Journal of Innovation Economics & Management*, 25(1), 9–32. https://dx.doi.org/10.3917/jie.025.0009

McCarthy D.J., Puffer S.M., Graham L.R., Satinsky D.M. (2014) Emerging Innovation in Emerging Economies: Can Institutional Reforms Help Russia Break Through Its Historical Barriers? *Thunderbird International Business Review*, 56(3), 243–260. https://doi.org/10.1002/tie.21619

Meissner D., Zhou Y., Fischer B., Vonortas N. (2022) A multilayered perspective on entrepreneurial universities: looking into the dynamics of joint university-industry labs. *Technological Forecasting and Social Change*, 178, 121573. https://doi.org/10.1016/j.techfore.2022.121573

Mustar P., Wright M. (2010) Convergence or path dependency in policies to foster the creation of university spin-off firms? A comparison of France and the United Kingdom. *The Journal of Technology Transfer*, 35(1), 42–65. https://doi.org/10.1007/s10961-009-9113-7

Nambisan S., Siegel D., Kenney M. (2018) On open innovation, platforms, and entrepreneurship. *Strategic Entrepreneurship Journal*, 12(3), 354–368. https://doi.org/10.1002/sej.1300

O'Shea R.P., Allen T.J., Chevalier A., Roche F. (2005) Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities. *Research Policy*, 34(7), 994–1009. https://doi.org/10.1016/j.respol.2005.05.011

O'Shea R.P., Allen T.J., Morse K.P., O'Gorman C., Roche F. (2007) Delineating the anatomy of an entrepreneurial university: The Massachusetts Institute of Technology experience. *R&D Management*, 37(1), 1–16. https://doi.org/10.1111/j.1467-9310.2007.00454.x

Philpott K., Dooley L., O'Reilly C., Lupton G. (2011) The entrepreneurial university: Examining the underlying academic tensions. *Technovation*, 31(4), 161–170. https://doi.org/10.1016/j.technovation.2010.12.003

Qiu H., Chreim S., Freel M. (2023) A tension lens for understanding entrepreneurship-related activities in the university. *Technological Forecasting and Social Change* 186(B), 122–167. https://doi.org/10.1016/j.techfore.2022.122167

Rasmussen E., Borch O. (2006) *The university and the spin-off process – A dynamic capability approach,* Turku (FI): European Council for Small Business and Entrepreneurship.

Reynolds P., Bygrave W., Autio E., Cox L., Hay M. (2003) *Global Entrepreneurship Monitor: 2002 Executive Report*. https://doi.org/10.13140/RG.2.1.1977.0409

Rip A., Groen A.J. (2001) Many visible hands. In: *Technology and the Market Demand, Users and Innovation* (eds. R. Coombs, K. Green, A. Richards, V. Walsh), Cheltenham (UK): Edward Elgar Publishing, pp. 12–37. https://doi.org/https://doi.org/10.4337/9781843762867.00009

Riviezzo A., Santos S.C., Liñán F., Napolitano M.R., Fusco F. (2019) European universities seeking entrepreneurial paths: the moderating effect of contextual variables on the entrepreneurial orientation-performance relationship. *Technological Forecasting and Social Change*, 141, 232–248. https://doi.org/10.1016/j.techfore.2018.10.011

Robinson D.K.R., Rip A., Mangematin V. (2007) Technological agglomeration and the emergence of clusters and networks in nanotechnology. *Research Policy*, 36(6), 871–879. https://doi.org/10.1016/j.respol.2007.02.003

Rogers-Hayden T., Pidgeon N. (2007) Moving engagement "upstream"? Nanotechnologies and the Royal Society and Royal Academy of Engineering's inquiry. *Public Understanding of Science*, 16(3), 345–364. https://doi.org/10.1177/0963662506076141

Rothaermel F.T., Agung S.D., Jiang L. (2007) University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change*, 16(4), 691–791. https://doi.org/10.1093/icc/dtm023

Sansone G., Battaglia D., Landoni P., Paolucci E. (2021) Academic spinoffs: The role of entrepreneurship education. *International Entrepreneurship and Management Journal*, 17(1), 369–399. https://doi.org/10.1007/s11365-019-00601-9

Saxenian A. (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, MA: Harvard University Press.

Schaeffer P.R., Guerrero M., Fischer B.B. (2021) Mutualism in ecosystems of innovation and entrepreneurship: A bidirectional perspective on universities' linkages. *Journal of Business Research*, 134, 184–197. https://doi.org/10.1016/j.jbusres.2021.05.039

Schaeffer V., Matt M. (2016) Development of academic entrepreneurship in a non-mature context: the role of the university as a hub-organisation. *Entrepreneurship & Regional Development*, 28(9–10), 724–745. https://doi.org/10.1080/08985626.2016.1247915

Schmitz A., Urbano D., Dandolini G.A., de Souza J.A., Guerrero M. (2017) Innovation and entrepreneurship in the academic setting: A systematic literature review. *International Entrepreneurship and Management Journal*, 13(2), 369–395. https://doi.org/10.1007/s11365-016-0401-z

Shirokova G., Tsukanova T., Morris M.H. (2018) The Moderating Role of National Culture in the Relationship Between University Entrepreneurship Offerings and Student Start-Up Activity: An Embeddedness Perspective. *Journal of Small Business Management*, 56(1), 103–130. https://doi.org/10.1111/jsbm.12363

Spigel B. (2016) Developing and governing entrepreneurial ecosystems: the structure of entrepreneurial support programs in Edinburgh, Scotland. *International Journal of Innovation and Regional Development*, 7(2), 141–160. https://doi.org/10.1504/IJIRD.2016.077889

Stam E. (2015) Entrepreneurial Ecosystems and Regional Policy: A Sympathetic Critique. *European Planning Studies*, 23(9), 1759–1769. https://doi.org/10.1080/09654313.2015.1061484

Stilgoe J., Owen R., Macnaghten P. (2013) Developing a framework for responsible innovation. *Research Policy*, 42(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Sunitiyoso Y., Wicaksono A., Utomo D. S., Putro U. S., Mangkusubroto K. (2012) Developing Strategic Initiatives through Triple Helix Interactions: Systems Modelling for Policy Development. *Procedia – Social and Behavioral Sciences*, 52, 140–149. https://doi.org/10.1016/j.sbspro.2012.09.450

Swierstra T., Rip A. (2007) Nano-ethics as NEST-ethics: Patterns of Moral Argumentation About New and Emerging Science and Technology. *NanoEthics*, 1(1), 3–20. https://doi.org/10.1007/s11569-007-0005-8

Takata M., Nakagawa K., Yoshida M., Matsuyuki T., Matsuhashi T., Kato K., Stevens A.J. (2022) Nurturing entrepreneurs: How do technology transfer professionals bridge the Valley of Death in Japan? *Technovation*, 109, 102161. https://doi.org/10.1016/j.technovation.2020.102161

Te Kulve H., Rip A. (2011) Constructing Productive Engagement: Pre-engagement Tools for Emerging Technologies. *Science and Engineering Ethics*, 17(4), 699–714. https://doi.org/10.1007/s11948-011-9304-0

Teece D.J., Pisano G., Shuen A. (1997) Dynamic Capabilities and Strategic Management. *Strategic Management Journal*, 18(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7%3C509::AID-SMJ882%3E3.0.CO;2-Z

Tijssen R.J.W. (2006) Universities and industrially relevant science: Towards measurement models and indicators of entrepreneurial orientation. *Research Policy*, 35(10), 1569–1585. https://doi.org/10.1016/j.respol.2006.09.025

Tuunainen J. (2005) Contesting a hybrid firm at a traditional university. *Social Studies of Science*, 35(2), 173–210. https://doi.org/10.1177/0306312705047825

Urbano D., Guerrero M. (2013) Entrepreneurial Universities: Socioeconomic Impacts of Academic Entrepreneurship in a European Region. *Economic Development Quarterly*, 27(1), 40–55. https://doi.org/10.1177/0891242412471973

Van de Ven A.H. (2007) *Engaged Scholarship: A Guide for Organizational and Social Research*, Oxford: Oxford University Press.

Wang H., Fu T., Du Y., Gao W., Huang K., Liu Z., Chandak P., Liu S., Van Katwyk P., Deac A., Anandkumar A., Bergen, K., Gomes C.P., Ho S., Kohli P., Lasenby J., Leskove J., Liu T.-Y., Manrai A., Marks D., Ramsundar B., Song L., Sun J., Tang J., Veličković P., Welling M., Zhang L., Coley C.W., Bengio Y. Zitnik, M. (2023) Scientific discovery in the age of artificial intelligence. *Nature*, 620(7972), 47–60. https://doi.org/10.1038/s41586-023-06221-2

Wigren-Kristoferson C., Brundin E., Hellerstedt K., Stevenson A., Aggestam M. (2022) Rethinking embeddedness: A review and research agenda. *Entrepreneurship & Regional Development*, 34(1–2), 32–56. https://doi.org/10.1080/08985626.2021.2021298

Wurth B., Stam E., Spigel B. (2022) Toward an Entrepreneurial Ecosystem Research Program. *Entrepreneurship Theory and Practice*, 46(3), 729–778. https://doi.org/10.1177/1042258721998948

Yusof M., Jain K.K. (2010) Categories of university-level entrepreneurship: A literature survey. *International Entrepreneurship and Management Journal*, 6(1), 81–96. https://doi.org/10.1007/s11365-007-0072-x

Entrepreneurship in Russia: A Systematic Overview of Domestic Publications

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Abstract

Over the past three decades, entrepreneurship and related processes and institutions have been widely discussed in Russian academic literature. In order to understand the achievements, thematic gaps, and methodological problems that must be solved in subsequent studies, this article provides a systematic analysis of research papers on the topic of Russian entrepreneurship considering publications from leading Russian academic journals published in the period of 1991–2023. The analysis enabled the identification of the most elaborated topics, revealing the advances in the theoretical understanding of Russian entrepreneurship, as well as contradictions in research programs and empirical methods within publications on this topic in Russian and international journals. As a result of the analysis, promising scientific research areas for further investigation of entrepreneurship are proposed: (1) the reconceptualization of standard definitions/concepts of the theory of entrepreneurship, considering the Russian context; (2) building new theories and concepts of the middle level based on the investigation of unique phenomena and institutions in the Russian business environment.

Keywords: entrepreneurship; Russia; systematic literature review; structured literature review; reconceptualization; contextualization; twofold mixed embeddedness

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Introduction

In recent decades entrepreneurship has been one of the most popular research areas (Audretsch, 2012; Bosma et al., 2018; Kerr, Mandorff, 2023). Among many things, this was caused by political changes on the international arena at the turn of the 1980s and 1990s, when most territories in Eastern Europe and Southeast Asia started to shift from a state-controlled economy to a market economy. Business owners became the new chief social and economic agents in many countries, including Russia, which over time invented and reinvented its own approaches to establishing businesses, novel business practices, forms of interactions with other stakeholders, including the government, and amassed a significant number of scientific publications describing these changes. It is evident from international (Puffer, McCarthy, 2001; Aidis et al., 2008; Szerb, Trumbull, 2018 et al.) and Russian publications that analyzing the development of entrepreneurship and its main actors and strategies helps shape business ecosystems and regulatory mechanisms of small businesses.

The main trends in the international scientific studies of Russian entrepreneurship published during 1991–2021 have been thoroughly reviewed in the article (Shirokova et al., 2023). It concluded that majority of such studies were done by foreign researchers who have insufficient knowledge or understanding of the Russian context, for which they compensate by providing abstract reflections on how the situation must be. Although Russian journals remained outside the scope of that article, they have produced a plethora of works during the last 30 years about various aspects of the establishment and development of entrepreneurship, relevant market and government institutions, and business practices. This compilation of studies has not yet been subjected to a systematic review based on modern bibliometric methods and techniques. This paper attempts to fill this gap.

The following questions are examined: (1) what aspects and approaches were most often reflected in Russian journals when analyzing entrepreneurship in Russia? (2) what foreign ideas and theories that emerged in international research were then developed and improved in Russian journals? (3) what are the major differences in the features of Russian entrepreneurship as reflected by the international and Russian academic literature? (4) what are the theoretical and methodological prospects for studying the Russian business environment? To answer these, the authors performed a systematic review of relevant publications in Russian journals from 1991 to 2023, inclusive, with the help of bibliometric techniques. The five parts of the article include: the introduction; methodology of the research (journal sampling principles and analysis methods); description of the main results; promising areas for future research after the discussion; and finally, conclusions and the limitations of this study.

Methodology

To sum up the results of studies on entrepreneurship in Russian literature, a systematic review and bibliometric techniques were applied, which have proven their productivity in research (Wallin, 2012; Urbano et al., 2022). The retrieval and selection of publications were conducted in December 2023 in several stages. At the first stage, we used the eLibrary.Ru database for search queries affiliated with the Russian Science Citation Index (RSCI).

At the second stage, we used the terms "business* OR entrepreneur*" to search through publications, abstracts, and key words. Then, we selected only articles with full texts in leading scientific journals (taken from a list compiled by the HSE University[1]) which have been published in 1991–2023 in subject areas related to entrepreneurship: "Economics and management", "Sociology, demographics, and other social sciences", "Education", "Political science, international relations, public and municipal governance and regional studies", "Phycology and cognitive sciences", and "Development problems". The further selection among 108 journals was done based on the five-year RSCI impact factor as of 2022[2] not lower than 0.5. A lower impact factor means that those publications are cited less than in half of the relevant articles, and the journal itself is infrequently referenced in academia. In the end, 545 articles were selected.

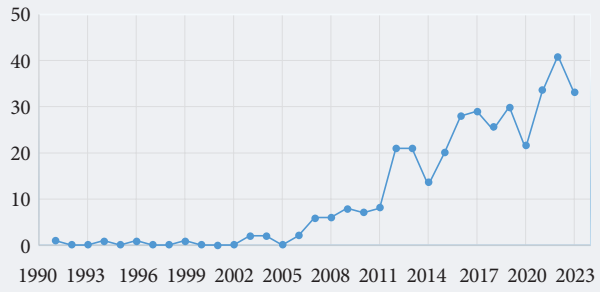
The third stage was the abstract analysis, where 185 papers were manually eliminated since they did not conform to the subject of the study and were, in our opinion, unscientific. After that, 360 articles were left. Figure 1 illustrates the yearly distribution with continuous growth in the number of publications about entrepreneurship in Russian scientific journals. In 2010–2023, 323 articles were published, 10 times more than in the previous decade. The greatest amount of publication activity occurred in 2022 (41 publications), in 2023 and 2021 (33 publications each), and in 2019 (30 publications). Such a dynamic reflects, firstly, the development of private entrepreneurship after its establishment in the 1990s (accumulating experience, practices, etc.), and secondly, the shaping of entrepreneurship analysis into a separate research program for Russian scientists (the accumulation of empirical data and methodological practices).

The conducted analysis helped to identify journals that published articles about entrepreneurship, as well as leading authors and their affiliations (Tables 1 and 2). The pool of authors included 611 Russian researchers, and the average number of publications per researcher was 0.59.

[1] We chose a list of journals by HSE University (https://www.hse.ru/en/science/scifund/an/spiski_all/), since it was compiled using strict academic standards and criteria (double-blind peer review, no publication fee, etc.), and its journals comply with research ethics guidelines.

[2] Since there are no data for some journals for 2022, a 5-year impact factor for the last available period was used.

Figure 1. **Number of Publications in the Sample by Year**

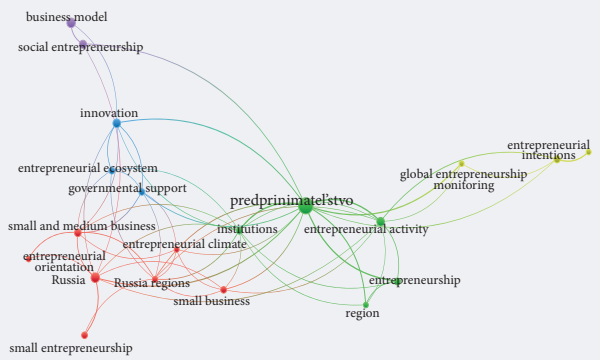


Source: compiled by the authors

As it was found by bibliometric studies (Anand et al., 2020), the main subjects in the literature can be figured out by key words — they reflect the most widely discussed topics at different times (Pesta et al., 2018). Therefore, we used keywords to systematize, group, and classify the articles and build a keyword co-occurrences map (Walsh, Renaud, 2017) to identify the relevant topics.

The final sample was compiled in two stages. At the first stage, the initial 360 articles were analyzed with quantitative methods. After they were uploaded into the system, the program identified 1,199 keywords. After that, we set the minimum frequency of six citations per term that helped capture all relevant keywords and reflect in the best way their interactions in articles. The threshold value was set at 20 keywords: articles that have none of them were excluded.

Figure 2. **Clustering of Publications about Russian Entrepreneurship Features in Leading Scientific Journals**



Source: compiled by the authors

The remaining 143 articles[3] were grouped into five clusters (Figure 2) that received the following placeholders according to their main content: 1) institutions and entrepreneurial climate in Russia (42 articles); 2) regional traits of entrepreneurial development (60 articles); 3) entrepreneurial ecosystem and innovation (25 articles); 4) entrepreneurial intentions and their role in shaping entrepreneurial activity (15 articles); and 5) business models in Russian entrepreneurship (26 articles). To identify the main topics and terms (Vrontis et al., 2021), we applied a qualitative text analysis, coded the articles in accordance with the methodology presented in the work (Grégoire et al., 2011), and synthesized them (Snyder et al., 2016; Kumar et al., 2020). Due to that, we eliminated some articles that were thematically irrelevant or not based on empirical data. Theoretical articles were eliminated in favor of better evidentiality and strictness of the research methodology. Some papers were manually redistributed between clusters for a better compliance. In the end, the final sample included 70 articles. Table 3 provides the descriptions of clusters, including keywords and the corresponding articles and topics. Then, we show the results of a qualitative analysis of articles in each cluster.

Analysis Results

Cluster 1. Institutions and entrepreneurial climate in Russia

The first cluster included 20 articles dedicated mostly to crisis response (2008–2009, 2014) strategies of Russian small and medium-sized enterprises (SMEs), their adaptation to external shocks (2020–2021, 2022), and the role of the government and its agencies in these processes. The authors most often characterize the Russian institutional environment as unfavorable for business development due to such barriers as the complexity and time consumption of administrative procedures, the absence of effective and consistent government support of entrepreneurship, high rent payments, expensive connection to energy infrastructure, corruption, and expensive bank loans (Verkhovskaya, Dorokhina, 2008; Verkhovskaya, Alexandrova, 2017; Zemtsov, 2020; Zemtsov, Baburin, 2019; Solodilova et al., 2016; Stolbov, Mosina, 2015; Cheglakova et al., 2023). To overcome these, it is suggested that administrative pressure be lowered on businesses, property rights protection be strengthened (Barinova et al., 2018), changing patenting mechanisms to promote the entrepreneurs' inventions on export markets (Bogoutdinov, 2016), and stimulating the SMEs' interactions with leaders of the innovation sector and major scientific institutions (Vlasov, 2020).

The results of several studies confirm the beneficial role of institutions for internationalization (Shirokova,

[3] Some articles were included in several clusters; the reflected figure does not include cross-references.

Table 1. **Publications by Journal and Institution**

	Publications by journal	Number	%
1.	Vestnik of Saint Petersburg University. Management	30	8.3
2.	Russian Management Journal	28	7.8
3.	Economy of regions	26	7.2
4.	Foresight and STI Governance	17	4.7
5.	Society and Economics	15	4.2
6.	Voprosy Ekonomiki	12	3.3
7.	Sever i rynok: formirovanie ekonomicheskogo poryadka	11	3.1
8.	Woman in Russian Society	10	2.8
9.	Journal of Applied Economic Research	10	2.8
10.	ECO	10	2.8
	Publications by institution	**Number**	**%**
1.	HSE University	77	21.4
2.	Saint Petersburg State University	49	13.6
3.	Lomonosov Moscow State University	22	6.1
4.	Ural Federal University	19	5.3
5.	Russian Residential Academy of National Economy and Public Administration	16	4.4
6.	Federal Center of Theoretical and Applied Sociology of the Russian Academy of Sciences	14	3.9
7.	Institute of Economics of the Ural Division of the Russian Academy of Sciences	13	3.6
8.	Far East Federal University	9	2.5
9.	Moscow State Institute of International Relations	9	2.5
10.	National Research Tomsk State University	9	2.5

Source: compiled by the authors

Zibarev, 2013) and the adoption of entrepreneurial orientation (Shirokova, Sokolova, 2013) by Russian SMEs, which is implemented only in a dynamic external environment (Shirokova et al., 2015). Ineffective institutions and uncertainty are, in turn, encouraging the development of informal entrepreneurship, whose level grows significantly during crises (Chepurenko, 2019). The ratio between entrepreneurs who became businessmen voluntarily and the ones who had to become businessmen due the external shocks is significantly shifting toward the latter due to their sensitivity to changes in the regulatory regime (Alexandrova, Verkhovskya, 2016). A resilient institutional environment is a necessary condition for entrepreneurial development, especially in times of economic turbulence.

During 2014–2023, a standalone research area shaped itself in the Russian literature. It was dedicated to the crisis management strategies of Russian entrepreneurs brought forth by external shocks, such as the COVID-19 pandemic or foreign sanction pressure. The article (Belyaeva et al., 2017) provides a theoretical and empirical analysis of the connection between strategical orientations and the results of SME activity during the 2014–2016 economic crisis, as well as assessments of access to financial services. The article (Krivosheeva-Medyantseva, 2022) uses in-depth interviews with businessmen to identify major institutional barriers that existed during the COVID-19 pandemic. Two unique studies are based on the data of a longitudinal SME study project of the Public Opinion Fund[4]

Table 2. **Top 10 Authors by the Number of Publications**

Author	Number of papers	Affiliation in the latest publication
Shirokova G.	21	HSE University (Moscow)
Chepurenko A.	14	HSE University (Moscow)
Malikov R.	11	Ufa State Petroleum Technological University (Ufa)
Bogatyryova K.	10	Saint Petersburg State University (St Petersburg)
Grishin K.	10	Ufa University of Science and Technology (Ufa)
Verkhovskaya O.	8	Saint Petersburg State University (St Petersburg)
Solodilova N.	7	Ufa State Petroleum Technological University (Ufa)
Zemtsov S.	6	Russian Residential Academy of National Economy and Public Administration (Moscow)
Aray Yu.	5	Saint Petersburg State University (St Petersburg)
Belyaeva T.	5	Skopai (Saint-Martin-d'Hères, France), KEDGE Business School (Marseille, France)

Source: compiled by the authors

Table 3. **Publications by Thematic Cluster**

Key words	Literature references
Cluster I. Institutions and entrepreneurial climate in Russia (20 articles)	
"small entrepreneurship", «small business", "small and medium-sized business", "entrepreneurial orientation", "entrepreneurial climate", "Russian regions", "Russia"	Aleksandrova, Verkhovskaya (2016); Barinova et al. (2018); Belyaeva et al. (2017); Bogoutdinov (2016); Verkhovskaya, Aleksandrova (2017); Verkhovskaya, Dorokhina (2008); Vlasov (2020); Egorova, Chepurenko (2022); Zemtsov (2020); Zemtsov, Baburin (2019); Zemtsov, Tsaryova (2018); Krivosheeva-Medyantseva (2022); Solodilova et al. (2016); Stolbov, Mosina (2015); Cheglakova et al. (2023); Chepurenko (2019); Chepurenko et al. (2023); Shirokova et al. (2015); Shirokova, Zibarev (2013); Shirokova, Sokolova (2013)
Cluster II. Regional traits of entrepreneurship development (11 articles)	
"entrepreneurship", "institutes", "entrepreneurial activity", "entrepreneurial management", "region"	Lu, Ruzhanskaya (2023); Antsygina et al. (2017); Vlasov (2020); Zazdravnykh (2019); Karelina (2015); Kozakov, Glukhikh (2011); Obraztsova, Chepurenko (2020); Osipova, Sidorenko (2007); Peshkova (2018); Staroverov (2010); Ushkin (2017).
Cluster III. Entrepreneurial ecosystem and innovation (14 articles)	
"government support", "innovation", "entrepreneurial ecosystem"	Albutova (2013); Zemtsov (2020); Zemtsov (2022); Zemtsov, Baburin (2019); Karacharovsky (2010); Malikov et al. (2022a); Meteleva (2021); Meteleva (2022); Obchinnikova, Zimin (2021); Ruzhanskaya et al. (2022); Saveliev, Turabaeva (2023); Solodilova et al. (2017); Chernysh (2018); Yakimova, Pankova (2023).
Cluster IV. Entrepreneurial intentions and their role in shaping entrepreneurial activity (12 articles)	
"global entrepreneurship monitoring", "entrepreneurial intentions", "student entrepreneurship"	Abid (2021); Aleksandrova, Verkhovskaya (2015); Belyaeva et al. (2016); Bogatyryova et al. (2021); Bogatyryova, Shirokova (2017); Butryumova, Golubeva (2018); Butryumova, Slepneva (2016); Verkhovskaya (2009); Verkhovskaya, Dorokhina (2013); Sibirskaya et al. (2018); Shafranskaya (2019); Shirokova et al. (2009).
Cluster V. Business models in Russian entrepreneurship (13 articles)	
"business model", "social entrepreneurship"	Aray (2018); Aray, Burmistrova (2014); Arif, Kuzminova (2021); Gavrilova et al. (2014); Kapustina et al. (2023); Klimanov, Tretyak (2014); Kusraeva (2017); Makushina et al. (2023); Markova (2023); Popov et al. (2018); Smirnov et al. (2021); Shatalov (2010); Shirokova, Ezhova (2012).

Source: authors.

(POF): the first is about factors which may affect the companies' resilience against external shocks (Egorova, Chepurenko, 2022), the second (Chepurenko et al., 2023) identifies their adaptation strategies and factors after the pandemic. This research area seems rather promising, considering how significantly the Russian business environment changed in 2022–2023.

It is evident from the analysis that a significant part of the works in this cluster are not based on the existing methodological and theoretical resources: authors of just five out of 28 of the reviewed sources used conceptual foundations (institutional (Scott, 1995) and resource theory (Barney, 1991) or effectuation theory (Sarasvathy, 2001)) when formulating hypotheses and building models. Although such concepts as entrepreneurial orientation (Covin, Slevin, 1989), resilience (Kantur, Say, 2015), or libertarian paternalism (Thaler, Sunstein, 2003) were used in some works, most papers did not have any sort of theoretical framework, and the results were obtained based on expert arguments, and not on the empirical evaluation of models. On top of that, a significant number of papers are narrative, with only several publications based on econometric data analysis and one — on qualitative data. But at the same time, it is the latter we use to make scientific breakthroughs, unlike qualitative studies that provide the incremental accumulation of knowledge (Edmondson, McManus, 2007).

Cluster 2. Regional traits of entrepreneurial development

This cluster includes 11 articles, most of which were published before 2020 and are based on desk studies. One of the important issues observed in the articles of this group is the spatial heterogeneity of the Russian Federation (Antsygina et al., 2017; Kozakov, Glukhikh, 2011; Obraztsova, Chepurenko, 2020), which creates a redress in the levels and configurations of barriers to enter and evolve in the chosen business activity. The regional traits of a considerable part of Russian territories include such factors as unemployment and low income levels for the population (Zazdravnykh, 2019; Kozakov, Glukhikh, 2011). The decisive factor is cultural norms in various regions of the country: the higher proclivity of the population to risk is in direct proportion to the level of entrepreneurial activity. On top of that, the level of SME development may not increase or even decrease as the region's economy continues to grow (Zazdravnykh, 2019).

Another research area studied by the authors of this cluster is the regional context of political business support mechanisms. Russian regions are categorized based on the existing differences in their institutional conditions and the level of economic development. For example, in regions that have a developed entrepreneurial system, the authorities are implementing "engaging" measures — incentives for SMEs, increased

[4] https://fom.ru/, accessed 22.04.2024 (in Russian).

financing of entrepreneurial universities, and facilitation of maintenance and development of industry-specific high value chains; in regions with low investment activity and socioeconomic welfare, regional and local authorities support micro-financing mechanisms and self-employment or create platforms that deploy small businesses (Obraztsova, Chepurenko, 2020). The business environment map of Russia developed in the cluster's articles reflects the main features of territories' business potential to help entrepreneurs make the decision to start a business, and public authorities — to optimize SME support programs (Antsygina et al., 2017). The authors describe the firms' opportunities (depending on the area of their activity, profitability, and the expenditure structure) to forecast the level of the tax burden and choose the taxation system (Osipova, Sidorenko, 2007), assess the prospects of lowering tax rates or receiving incentives (Ushkin, 2017), as well as participate in incentive programs and remuneration mechanisms by way of industrial competitions and professional fora (Vlasov, 2020).

The negative factors standing in the way of the entrepreneurial development in a specific region, include, according to researchers, the administrative barriers and non-effective channels of communications with authorities (Ushkin, 2017), crime rates (Staroverov, 2010), shortages or absence of integrated business structures on the region's territory (Karelina, 2015). The entrepreneurship activity of migrant workers is an independent factor. Kyrgyz workers, for example, show initiative in the largest Moscow agglomeration by exploiting kinship ties or connections in a foreign community (Peshkova, 2018). Other factors are more relevant for Chinese migrant workers: cross-cultural communication, available government support, and regulatory burdens (Lu, Ruzhanskaya, 2023).

An important achievement in studying Russian entrepreneurship was a comprehensive factor analysis of growth points in each region and the development of government support measures and mechanisms for various types of territories. The downside of this cluster's articles is the lack of input from foreign best practices on the heterogenic nature of factors that either stimulate or hinder entrepreneurial development on specific territories (see, ex., Delgado et al., 2010; Müller, 2016; Bosma, Schutjens, 2011) and a comparative analysis of historically defined differences of regional business landscapes (Fritsch, Storey, 2017).

Cluster 3. Entrepreneurial ecosystem and innovation

This cluster contains 14 articles that were published between 2000 and 2023, of which the most interesting are the papers dedicated to a poorly studied subject in the foreign literature (Audretsch et al., 2024): the features and categorization of regional entrepreneurial ecosystems and their input into sustainable entrepreneurship development. The article (Zemtsov, 2020) highlights how important the local conditions are to SMEs, since they have a direct access to local markets in a situation where local authorities do not have enough resources to support the business. Sociocultural barriers also pay a major role: distrust among entrepreneurs, the population, and the government as well as corruption. The acceleration of post-crisis development requires the rehabilitation of the business environment, the digital transformation of businesses and government services, and the maintenance of entrepreneurship and consulting training programs. To further develop these ideas, the article (Zemtsov, Baburin, 2019) suggested splitting Russian regions into three groups based on cluster density. Regions of the first (the most developed ecosystems) and the second (average development) types are recommended to focus on the support of rapidly growing companies, especially in technological sectors; regions of the third type (poor development) need to create cooperation ties between businesses and government agencies and extricate businesses from the informal economy. Finally, based on the econometric analysis (Ovchinnikova, Zimin, 2021), it was found that regions with mature entrepreneurial ecosystems have higher economic development rates.

External shock analysis that evaluates the shocks' effects on the sustainability of regional ecosystems became more relevant in recent years. For example, the article (Ruzhanskaya et al., 2022) used data from the Sverdlovsk Region to demonstrate that the decrease in the SME business activity, caused by the implementation of safety measures against COVID-19, turned out to be significantly lower than the forecasted level. The regional authorities have also been noticed to have different effects on SME activity depending on the entrepreneur's incorporation as a sole proprietor (SPs) or a legal entity: the government's participation in the region's economy turned out to be more important for SPs, and companies demonstrated a more prominent market orientation and strove toward economic freedom. The external shock fast-tracked the change of corporate business models and increased the role of business associations in facilitating cooperation between SMEs and government agencies.

Some articles illustrate the assessment methods that describe the potential of regional entrepreneurial ecosystems (REEs) or the classification (clusterization) of Russian regions by the type and condition of REEs. Thus, the article (Solodilov et al., 2017) introduced the term "institutional configuration of the business environment" and presented its parametric model by the administrative pressure on the entrepreneur criterium. These authors argue that the model helps calculate cooperation scenarios between the government and business structures in Russian regions depending on the business environment configuration. To study this approach further, the article (Malikov et al., 2022) used the data of the Republic of Bashkortostan to propose a method of assessing and forecasting REE productivity, i.e., the speed of reproducing "procreative entrepreneurship" on a specific territory within a specified amount of time. The hypothesis about a positive cor-

relation between REE productivity and the amount of government funding for businesses has been confirmed. Some publications (for example, the article (Meteleva, 2021; 2022) about the Russian regions of the Arctic) describe approaches to managing the formation of entrepreneurial networks based on measuring the human potential of the population and the readiness of large corporations to work as drivers of innovation development. Such an approach somewhat contradicts the established notion about entrepreneurship being a personal initiative in extremely unfavorable and harsh conditions of underpopulated regions.

The topics of several articles in the cluster under review are the establishment of institutions and practices of innovative entrepreneurship and studying the reasons why it is lagging in Russia. In one of the articles this is explained by the unpreparedness of large Russian capital cities for risky investments (Karacharovsky, 2010). After over 10 years, another author (Zemtsov, 2022) shifted the focus to the role of the business environment: to make technological startups into drivers of diversification, of a growing economy, and employment, one needs to balance environmental factors, including socio-cultural aspects, business agent networks, human capital, and available universities. The impetus to develop entrepreneurship in the last decade was the digitalization of the economy. By analyzing the panel data for Russian regions for 2018–2021, the authors of the work (Yakimova, Pankova, 2023) concluded that the number of rapidly growing companies and startups in the region is influenced by the presence of other gazelle companies, accelerators and incubators, scaled-out projects in areas of end-to-end technologies and investments in IT, a developed ICT sector, and its government support.

The role of several institutions in forming social entrepreneurship practices is reviewed in the article (Albutova, 2013). The author highlights that Russian social entrepreneurship was initially constructed to follow the American model, not European, as a financially stable type of business aimed at solving social issues. The paper (Saveliev, Turabaeva, 2023) shows that market players themselves think of it as a side business motivated by altruistic and image-building aspirations. The article (Chernysh, 2018) stands somewhat apart: it uses a Novosibirsk Region case of setting up a business incubator to analyze the formation of a government support system as a result of coordinating interests and views of various groups of actors.

Several articles in the cluster demonstrated significant progress in understanding the structural differences between entrepreneurial ecosystems of Russian regions, the reasons behind those differences, and their connection to building up the business and innovation potential. Almost all such works are based on the theory of entrepreneurial ecosystems that received wide dissemination in the foreign literature (Acs et al., 2017; Spigel, 2017). For the empirical verification of the hypotheses, some authors used advanced statistical and econometric data analysis methods or verified qualitative analysis methods. In other articles, task and goal setting is substituted with vague arguing, and the validation of conclusions is either absent or built upon an extremely scarce empirical base.

Cluster IV. Entrepreneurial intentions and their role in shaping entrepreneurial activity

This cluster consists of 12 articles, most of them were published after 2014, when the United States and European Union imposed sanctions on Russia and made the studies of factors influencing entrepreneurs' intentions, the business activity of the population, and their resilience relevant. Many foreign studies showed that external economic pressure serves as a driver of economic growth, increasing new jobs, innovation activity, and market competition (Linan et al., 2011; Herbane, 2010). Among the cluster's articles desk studies and quantitative research based on secondary source data prevail, first of all, the Global Entrepreneurship Monitoring (GEM) and the Russian part of the Global University Entrepreneurial Spirit Students Survey (GUESSS). Using this data allowed the authors to define the Russia-specific set of determinants of entrepreneurial intentions.

The cluster's articles demonstrate how specialized education and training (Belyaeva et al., 2016) and other engaging events (Butryumova, Golubeva, 2018; Butryumova, Slepneva, 2016), the positive image of a businessman in the media (Shafranskaya, 2019) and the perception of business from the society in general (Verkhovskaya, 2009), along with a developed institutional environment (Verkhovskaya, Dorokhina, 2013) increase the motivation of amateur entrepreneurs. Personal traits and factors, such as gender identity (Abid, 2021), the traits of the dark triad (Bogatyryova et al., 2021), confidence in one's own knowledge and skills (Aleksandrova, Verkhovskaya, 2015; Sibirskaya et al., 2018), and success (Sibirskaya et al., 2018) stimulate entrepreneurial intentions and ease their transfer into practical activities.

In addition to intentions, there are other factors that influence entrepreneurial activity. To assess them, the cluster's authors use quantitative analysis methods and neural networks. To confirm the results of foreign studies, it was established that getting acquainted with current entrepreneurs has a positive effect on business activity at the stage of creating a firm (Shirokova et al., 2009). The transfer from intention to action is also facilitated if the region's environment is well-developed for a potential launch, however if the amateur businessman has family members who are running a business, this decreases the possibility of him/her implementing business intentions in Russia (Bogatyryova, Shirokova, 2017), which goes against some conclusions by foreign authors (Arenius, Minniti, 2005).

Most of the cluster's papers that study entrepreneurial intentions are based on the planned behavior theory

(Ajzen, 1991). Their authors point out many internal (personal) and external factors of this process, however this subject of transforming intention into action requires further analysis following a number of international studies (Van Gelderen et al., 2015), including with Russian participation (Bogatyreva et al., 2019).

Cluster V. Business models in Russian entrepreneurship

This cluster covers 13 articles, most of which were published after 2010, i.e., when Russian entrepreneurs were speedily adapting to new challenges and limitations under the influence of economic crises and external shocks. The papers reflect the peculiarities of business models developing in Russia that are rooted in the sector of the economy where they operate (Kusraeva, 2017), the size of the company (Makushina et al., 2023), or the level of its involvement in the international business community (Kapustina et al., 2023). Based on the materials of the booming food service industry, various types of such models were identified and a statistically significant correlation between their characteristics and the results of the industry actors' activity has been provided (Shatalov, 2010). A comparative business model analysis was conducted with respect of two leading Russian IT companies that were formed after foreign competitors exited the Russian market (Markova, 2023). There are striking examples of international comparisons: a comparison of the business model features of 100 large Russian and foreign innovative companies (Smirnov et al., 2021); and an analysis of intrapreneurship as a tool of cultivating entrepreneurial initiatives from within an operating company (Shirokova, Ezhova, 2012). Such cases are extremely rare due to the labor-consuming nature of the comparative method that did not spread in entrepreneurship studies.

The papers (Aray, Burmistrova, 2014; Aray, 2018) categorized the business models of social entrepreneurship that have been shaping in Russia since the start of the 2010s. The authors identified three types of motivations behind non-commercial activity (in the interest of the business, to satisfy the personal needs of the entrepreneur, and in the name of corporate social responsibility (Arif, Kuzminova, 2021)), and describe institutional conditions for the development of social entrepreneurship in Russia; in particular, a close connection was established using a correlation analysis of several socioeconomic indices with a level of social entrepreneurial development in different groups of countries (Popov, 2018). In the article (Arif, Kuzminova, 2021), prosumerism is viewed as a specific form of social entrepreneurship. From the point of view of identifying country-specific business models, studying business practices by the size, type of economic and entrepreneurial activity, commercial or social, was proven to be productive. It helped establish a three-stage dynamic statistical approach to business model analysis — at the level of networks, interaction mechanisms of major network members and firms that create, assign, and distributes value (Klimanov, Tretyak, 2014).

The cluster has mostly desk studies and articles that are based on qualitative methods (interviews, case studies, discourse analysis); a rather small number of papers utilize big data from open sources and only a handful are written with the use of advanced quantitative analysis methods. When formulating research tasks and hypotheses, the authors rarely use intermediate theories described in foreign literature on entrepreneurship, such as an innovative business model of resilient business development (Schaltegger et al., 2012; Jolink, Niesten, 2015) or the social entrepreneurship theory (Santos, 2012).

Discussion

The analysis of Russian publications showed that during the reviewed period, Russian researchers made considerable progress in understanding the national specifics of entrepreneurship. The features of the Russian business context include: (1) instability, fast and often unpredictable changes in external conditions that force entrepreneurs to plan for higher uncertainty and risks in the business strategy; (2) a greater role of the government as the main customer (government procurement, etc.) and its gradual readjustment from funding entrepreneurs to managing their growth, through price and tariffs control mechanisms or by way of private public partnerships and regional ecosystems, where a central role is played by institutes and strategically important commercial banks; (3) considerable qualitative and structural heterogeneity of regional ecosystems that hinders not only the horizonal mobility of businesses, but the development of optimal government policy models with respect to entrepreneurship in different parts of Russia; (4) the advantages of a late launch into the market economy, due to which many infrastructural elements (online banking, e-commerce, etc.) are sometimes developed better than is some advanced countries; (5) comparatively high quality of human capital, favorable for such innovative organizational practices and models, such as intracorporate and social entrepreneurship.

Two topics prevailed in 1991–2023 publications: the regional features of entrepreneurial development and the role of the government and its agencies in forming a favorable environment for SMEs and creating new firms, which is likely to reflect territorial and economic peculiarities and the level of government involvement in the issues under the study. If the government institutions are paid enough significant attention throughout the reviewed period, the designs of regional entrepreneurship ecosystems and the meso-level agencies' roles are significantly less featured in the studies, although the intensity of publications on this topic grows every year. This is where we found a skew with the evolution of foreign studies about Russian

entrepreneurship, where, as evident from the article (Shirokova et al., 2023), initial (in the 1990s) attention was directed not only at the personal features of Russian entrepreneurs (Ageev et al., 1995), but also at the developing business environment (Cook, 1999). In the following decade (the 2000s; the 2008 crisis), other topics moved to the forefront, such as technology transfer (Sedaitis, 2000), corporate resources (Bruton, Rubanik, 2001), entrepreneurial networks (Batjargal, 2006), and the influence of institutes on business activity (Aidis et al., 2008). Finally, in the third decade (the 2010s; the 2014–2016 crisis), researchers were more often than not interested in high-tech entrepreneurship (Lau, Bruton, 2011), the business activity of new elites (Shurchkov, 2012), culture factors of business development (Rauch et al., 2012), the impact of crises (Shirokova et al., 2020), and the non-market strategies of firms (Belitski et al., 2021).

The analysis of Russian journal publications demonstrated that, firstly, as evident from the article distribution by year (Figure 1), data accumulation and scientific reflection do not happen simultaneously, they are time-consuming, and their peak levels coincided with crises and external shocks. In other words, upsurges in Russian publications about entrepreneurship are not proactive, they are reactive and caused by miscellaneous shocks. Secondly, the five clusters identified using machine algorithms intersect several subjects, which may be a sign of the complex nature of the phenomenon itself, or of the lack of depth in some Russian studies when it comes to working with keywords: the article terms do not always adequately reflect its main contents, which breeds considerable overlap in the topic with other publications.

Concepts that have firmly entered the scientific discourse in Russian research include: entrepreneurial orientation (Covin, Slevin, 1989), entrepreneurial ecosystem (Acs et al., 2017), resilience (Kantur, Say, 2015), and effectuation (Sarasvathy, 2001). At the same time, most publications lack theoretic rationale of the chosen models, i.e., there is no theoretical verification of the empirical test results or the assessment of the input in the entrepreneurship research development outside of Russia.

Among the analyzed papers, desk studies and the quantitative data analysis prevail. Qualitative studies are spread out much less, and their main empirical strategies are case studies or interviews, often not based on the existing methods (refer to, for example, (Gioia et al., 2013)), which diminishes the scientific value of achieved results. On top of that, the majority of papers do not make any attempts to adapt loan terms and concepts to the Russian business context. Even though entrepreneurship is a culturally and institutionally predefined construct, Russian researchers who study it often do not apply a critical approach to adopting theoretical ideas that were formulated using the data of developed economies of the United States and Europe (Filatotchev et al., 2021). These downsides promise to bring fruitful results in implementing new approaches to studying Russian entrepreneurship.

Conclusion

This study helped uncover the undeniable achievements of Russian researchers in studying the features of Russian entrepreneurship and reveal two systemic issues in this area: (1) insufficient knowledge and understanding of the theories and terms that have long been a part of the foreign mainstream (such as strategic entrepreneurship, dynamic abilities, entrepreneurial mindset (including effectuation), failures of and withdrawal from business, entrepreneurial finance, leadership, business culture and ethics, entrepreneurial networks, ethical entrepreneurship, etc.), and the underestimation of entrepreneurship's heterogeneity (differences between micro- and small businesses, hybrid entrepreneurship, family business, etc.); (2) the adoption of some concepts without appropriate contextualization, for example using the terms "social capital" or "social networks" and not correlating them with the Russian phenomena of "blat" or "administrative resources" rooted in Russian practice (Ledeneva, 1998; Rehn, Taalas, 2004).

At the same time, the Russian context opens great opportunities for the re-conceptualization of foreign theories and concepts (Bamberger, Pratt, 2010). In particular, the combination of high-quality human capital with relatively low business activity and the predominance of non-innovative spheres of business, a considerable imbalance of regional ecosystems and entrepreneurial practices, a low level of trust in the government, the spread of non-productive and even destructive entrepreneurship (Baumol, 1990), and other features that require a wider arsenal of applicable mid-level theories due to several concepts developed by the Russian school of institutional economics. Here, we talk about such ideas as "institutional traps" (Polterovich, 2004), "institutional matrix of economy development" (Bessonova, 2007), "forceful entrepreneurship" (Volkov, 2020), and so on.

On our end, as a methodological key to studying Russian entrepreneurship, we propose leaning on the concept of the "double mixed embeddedness". It is different from the actively promoted concept of "mixed embeddedness" (Högberg, Mitchell, 2023) in the foreign literature due to the inclusion of contexts at various levels (micro, meso and marco) that exist not only in a particular moment, but in different temporal regimes. Thus, the evolution of Russian entrepreneurship models is impossible to comprehend if we do not take into account their connection to institutes that were formed in previous historical eras (from wrestling for access to deficit resources in the late-Soviet economy to the institutional traps of privatization) and continue to influence the norms, customs, and practices of contemporary Russian entrepreneurship (for an example of implementing this approach, see, for example, the work (Chepurenko et al., 2024)).

The achieved results help outline the following areas for further Russian entrepreneurship studies:

(1) *at the macrolevel:* conduct comparative studies of entrepreneurial development in countries with similar macroeconomic and macrosocial conditions and entrepreneurial development features (for example, BRICS countries), and analyze the consequences of the new socioeconomic model that has been forming in Russia since 2022;

(2) *at the mesolevel:* analyze *intra-sectoral* and regional practices and institutes (competition and competitive cooperation, ecosystems), study how new formats of market presence (platforms, marketplaces) and technologies (online, artificial intelligence) affect them;

(3) *at the microlevel:* study intrapreneurship at large, influential companies and analyze behavior strategies, which affect innovation development and corporate output, adaptability to changing market conditions and innovative behavior;

(4) temporal *contextualization* of entrepreneurship research in Russia: analyze its evolution in light of previous developments and new macroeconomic and political realities;

(5) *re-conceptualization of universal terms/concepts* of entrepreneurial theory: business activity, strategic orientation, proactivity, risk appetite, innovativeness, business models, and so on;

(6) *creation of new theories and mid-level concepts* based on of the study of unique terms and institutes (administrative resource, networking, etc.), which play an important role in the Russian entrepreneurial environment.

Re-conceptualization deserves special attention. Its alternative is the quasi-replication method (Bettis et al., 2016), which helps one understand which factor specifically influences a change in the connection between constructs. However, despite the certain efficiency of this approach, it does not fully consider the uniqueness of the context (Tsui, 2004). Sometimes, to measure constructs, scientists use scales that were initially developed for the phenomena and processes in developed countries, but their use for different economic systems and the validity of such studies' results is questionable (Barkema et al., 2015). Re-conceptualization (Tsui, 2000) is something that helps solve this problem by placing the existing concept in a specific context (Welter, 2011) and the national culture (Hayton et al., 2002) as a system of norms, values, institutes, and so on (Bruton et al., 2018). At the initial stage, the very term of "entrepreneurship" in the Russian context may be studied through the lens of re-conceptualization. Its results are likely to differ from the mainstream definitions (Shane, Venkataraman, 2000) and reflect another level of possibilities that are being opened by entrepreneurship and the ins and outs of putting them into action (Baumol, 1990).

Finally, for the progressive development of entrepreneurship research in Russia, it is necessary to create specific institutional conditions: several high-quality journals, scientific conferences, and large interuniversity projects that promote specialized research communities.

This paper has several limitations. Firstly, the selection process was based on a list of HSE University's journals, and we could miss some that have valuable and relevant studies. Secondly, we used a keyword search method to analyze the articles, which identified clusters based on terminological co-occurrence. Unfortunately, some journals do not use keywords or started doing so only recently. Finally, the text of some articles became unavailable in Russian citation databases, which also limited the opp of analysis.

Despite these limitations, we dare to hope that this study will serve as a stimulus to revise approaches have been applied in the Russian entrepreneurship research for the last 20 years and will bring new innovative works that consider the unique historical context, where this phenomenon occurs.

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References

Abid U. (2021) Gender asymmetry of entrepreneurial intentions of students in Russia and China. *Journal of Applied Economic Research*, 20(1), 133–147. https://doi.org/10.15826/vestnik.2021.20.1.006

Acs Z.J., Stam E., Audretsch D.B., O'Connor A. (2017) The lineages of the entrepreneurial ecosystem approach. *Small Business Economics*, 49, 1–10. https://doi.org/10.1007/s11187-017-9864-8

Ageev A.I., Gratchev M.V., Hisrich R.D. (1995) Entrepreneurship in the Soviet Union and post-socialist Russia. *Small Business Economics*, 7(5), 365–376. https://doi.org/10.1007/BF01302737

Aidis R., Estrin S., Mickiewicz T. (2008) Institutions and entrepreneurship development in Russia: a comparative perspective. *Journal of Business Venturing*, 23(6), 656–672. https://doi.org/10.1016/j.jbusvent.2008.01.005

Ajzen I. (1991) The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Albutova A.I. (2013) Social entrepreneurship in Russia: Key players and formation potential. *Economic Sociology,* 14(3), 109–132 (in Russian).

Alexandrova E.A., Verkhovskaya O.R. (2015) Entrepreneurial intentions in Russia: An empirical analysis. *Russian Journal of Management*, 13(2), 3–28 (in Russian).
Alexandrova E.A., Verkhovskaya O.R. (2016) Motivation for entrepreneurial activity: The role of the institutional environment. *Bulletin of St. Petersburg University. Management*, 3, 107–138 (in Russian).
Anand A., Argade P., Barkemeyer R., Salignac F. (2021) Trends and patterns in sustainable entrepreneurship research: a bibliometric review and research agenda. *Journal of Business Venturing*, 36(3), 106092. https://doi.org/10.1016/j.jbusvent.2021.106092
Antsygina A.L., Zhukov A.N., Sypchenko A.E. (2017) Macroeconomic determinants of entrepreneurial activity at different phases of the business cycle: regional level. *Regional Economics*, 13(4), 1095–1106. https://doi.org/10.17059/2017-4-10 (in Russian).
Arai Yu.N. (2018) Business models in social entrepreneurship: a typology approach. *Russian Journal of Management,* 16(2), 253–272. https://doi.org/10.21638/spbu18.2018.205 (in Russian).
Arai Yu.N., Burmistrova T.A. (2014) Specifics of business models in social entrepreneurship. *Russian Journal of Management*, 12(4), 55–78 (in Russian).
Arenius P., Minniti M. (2005) Perceptual variables and nascent entrepreneurship. *Small Business Economics*, 24, 233–247. https://doi.org/10.1007/s11187-005-1984-x
Arif E.M., Kuzminova T.A. (2021) Non-profit activity of young entrepreneurs of St. Petersburg in the craft sector. *Journal of Social Policy Research*, 19(1), 55–68. https://doi.org/10.17323/727-0634-2021-19-1-55-68 (in Russian).
Audretsch D. (2012) Entrepreneurship research. *Management Decision*, 50(5), 755–764. https://doi.org/10.1108/00251741211227384
Audretsch D.B., Rocha H., Aggarwal S., Bramanti A. (2024) Do entrepreneurial ecosystems foster sustainable development? *International Entrepreneurship and Management Journal*, 20, 1–37. https://doi.org/10.1007/s11365-023-00916-8
Bamberger P.A., Pratt M.G. (2010) Moving forward by looking back: Reclaiming unconventional research contexts and samples in organizational scholarship. *Academy of Management Journal*, 53(4), 665–671. https://doi.org/10.5465/amj.2010.52814357
Barinova V.A., Zemtsov S.P., Tsareva Yu.V. (2018) Entrepreneurship and institutions: is there a connection at the regional level in Russia? *Voprosy Ekonomiki,* 6, 92–116. https://doi.org/10.32609 /0042-8736-2018-6-92-116 (in Russian).
Barkema H.G., Chen X.P., George G., Luo Y., Tsui A.S. (2015) West meets East: New concepts and theories. *Academy of Management Journal*, 58(2), 460–479. https://doi.org/10.5465/amj.2015.4021
Barney J. (1991) Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120. https://doi.org/10.1177/014920639101700108
Batjargal B. (2006) The dynamics of entrepreneurs' networks in a transitioning economy: the case of Russia. *Entrepreneurship and Regional Development*, 18(4), 305–320. https://doi.org/10.1080/08985620600717448
Baumol W. (1990) Entrepreneurship: Productive, Unproductive, and Destructive. *Journal of Political Economy*, 98(5), 893–921. http://dx.doi.org/10.1086/261712
Belitski M., Desai S., Godley A. (2021) Small business and poverty: Evidence from post-Soviet cities. *Regional Studies*, 55(5), 921–935. https://doi.org/10.1080/00343404.2020.1826037
Belyaeva T.V., Laskovaya A.K., Shirokova G.V. (2016) Entrepreneurship education and the formation of students' entrepreneurial intentions: the role of national culture. *Russian Journal of Management,* 14(1), 59–86 (in Russian).
Belyaeva T.V., Shirokova G.V., Gafforova E.B. (2017) Firm performance during the economic crisis: the role of strategic orientations and financial capital. *Russian Journal of Management,* 15(2), 131–162. https://doi.org/10.21638/11701/spbu18.2017.201 (in Russian).
Bessonova O.E. (2007) The phenomenon of the theory of institutional matrices: Restoration of an outdated paradigm. *Economic Science of Modern Russia*, 2, 23–33 (in Russian).
Bettis R.A., Helfat C.E., Shaver J.M. (2016) The necessity, logic, and forms of replication. *Strategic Management Journal*, 37(11), 2193–2203. https://doi.org/10.1002/smj.2580
Bogatyreva K., Edelman L.F., Manolova T.S., Osiyevskyy O., Shirokova G. (2019) When do entrepreneurial intentions lead to actions? The role of national culture. *Journal of Business Research*, 96, 309–321. https://doi.org/10.1016/j.jbusres.2018.11.034
Bogatyreva K., Shirokova G. (2017) From entrepreneurial intentions to creating a business: the experience of Russian students. *Foresight and STI Governance*, 11(3), 25–36. https://doi.org/10.17323 /2500-2597.2017.3.25.36
Bogatyreva K.A., Laskovaya A.K., Klemina T.N., Orekhova Yu.A. (2021) "The Good, the Bad and the Ugly"? The influence of the "dark triad" of personality on the formation of entrepreneurial intentions. *Bulletin of St. Petersburg University. Management*, 20(3), 293–325 (in Russian).
Bogoutdinov B. (2016) Small business in Russia: Profitability analysis and support measures. *Society and Economics*, 6, 97–108 (in Russian).
Bosma N., Content J., Sanders M., Stam E. (2018) Institutions, entrepreneurship, and economic growth in Europe. *Small Business Economics*, 51, 483–499. https://doi.org/10.1007/s11187-018-0012-x
Bosma N., Schutjens V. (2011) Understanding regional variation in entrepreneurial activity and entrepreneurial attitude in Europe. *The Annals of Regional Science*, 47, 711–742. https://doi.org/10.1007/s00168-010-0375-7
Bruton G.D., Rubanik Y. (2002) Resources of the firm, Russian high-technology startups, and firm growth. *Journal of Business Venturing*, 17(6), 553–576. https://doi.org/10.1016/S0883-9026(01)00079-9
Bruton G.D., Zahra S.A., Cai L. (2018) Examining entrepreneurship through indigenous lenses. *Entrepreneurship Theory and Practice*, 42(3), 351–361. https://doi.org/10.1177/1042258717741129
Butryumova N.N., Golubeva N.V. (2018) Study of entrepreneurial intentions and activity of schoolchildren in Nizhny Novgorod. *Bulletin of Moscow University. Series 6: Economics*, 4, 166–186 (in Russian).

Butryumova N.N., Slepneva Yu.N. (2016) Involving students in innovative entrepreneurship: the experience of Niu Vshe - Nizhny Novgorod. Bulletin of St. Petersburg University. Management, 1, 91–124 (in Russian).
Cheglakova L.M., Bataeva B.S., Melitonyan O.A. (2023) Environmentally responsible behavior: SMEs' perceptions. *Economic Issues,* 5, 106–130. https://doi.org/10.32609/0042-8736-2023-5-106-130 (in Russian).
Chepurenko A. (2015) Entrepreneurship theory: New challenges and prospects. *Foresight and STI Governance*, 9(2), 44–57. https://doi.org/10.17323/1995-459X.2015.2.44.57 (in Russian).
Chepurenko A.Y., Butryumova N.N., Chernysheva M.V., Sutormina A.Y. (2024) Entrepreneurship in and around academia: evidence from Russia. *International Journal of Sociology and Social Policy*, 44 (1/2), 130–154. https://doi.org/10.1108/IJSSP-04-2023-0101
Chepurenko A.Yu. (2019) Flexibility of organizational structure and typology of informal small business in Russia. According to a longitudinal study (2013–2015). *Economic Sociology,* 20(4), 39–69. https://doi.org/10.17323/1726-3247-2019-4-39-69 (in Russian).
Chepurenko A.Yu., Galitsky E.B., Oslon A.A. (2023) Adaptation of Russian small businesses to the shocks of the COVID-19 pandemic: First data from a longitudinal study. *Social Sciences and Modernity,* 2, 90–110. https://doi.org/10.31857/S0869049923020065 (in Russian).
Chernysh A.V. (2018) Institutionalization of rules for state support of innovation activities in Russia in the 2000s. using the example of a business incubator in the Novosibirsk region. *Economic Sociology,* 19(1), 25–61. https://doi.org/10.17323/1726-3247-2018-1-25-61 (in Russian).
Cook L.D. (1999) Trade credit and bank finance: Financing small firms in Russia. *Journal of Business Venturing*, 14(5–6), 493–518. https://doi.org/10.1016/S0883-9026(98)00026-3
Covin J., Slevin D. (1989) Strategic management of small firms in hostile and benign environments. *Strategic Management Journal*, 10(1), 75–87. https://doi.org/10.1002/smj.4250100107
Delgado M., Porter M.E., Stern S. (2010) Clusters and entrepreneurship. *Journal of Economic Geography*, 10(4), 495–518. https://doi.org/10.1093/jeg/lbq010
Edmondson A.C., McManus S.E. (2007) Methodological fit in management field research. *Academy of Management Review*, 32(4), 1155–1179. https://doi.org/10.5465/amr.2007.26586086
Egorova A.I., Chepurenko A.Yu. (2022) Factors of elasticity of small businesses in conditions of external shocks in Russia (according to a longitudinal study). *Russian Journal of Managemen*t, 20(2), 172–197. https://doi.org/10.21638/spbu18.2022.202 (in Russian).
Filatotchev I., Ireland R.D., Stahl G.K. (2021) Contextualizing management research: An open systems perspective. *Journal of Management Studies*, 59(4), 1036–1056. https://doi.org/10.1111/joms.12754
Fritsch M., Kristalova M., Wyrwich M. (2020) *Regional trajectories of entrepreneurship: The effect of socialism and transition* (Jena Economic Research Paper No. 2020-010), Jena: Friedrich Schiller University Jena.
Fritsch M., Storey D.J. (2014) Entrepreneurship in a regional context: Historical roots, recent developments and future challenges. *Regional Studies,* 48(6), 939–954. https://doi.org/10.1080/00343404.2014.892574
Gavrilova T., Alsufyev A., Yanson A.S. (2014) Modern notation of business models: Visual trend. *Foresight-Russia*, 8(2), 56–70.
Gioia D.A., Corley K.G., Hamilton A.L. (2013) Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, 16(1), 15–31. https://doi.org/10.1177/1094428112452151
Grégoire D.A., Corbett A.C., McMullen J.S. (2011) The cognitive perspective in entrepreneurship: an agenda for future research. *Journal of Management Studies,* 48(6), 1443–1477. https://doi.org/10.1111/j.1467-6486.2010.00922.x
Hayton J.C., George G., Zahra S.A. (2002) National culture and entrepreneurship: A review of behavioral research. *Entrepreneurship Theory and Practice*, 26(4), 33–52. https://doi.org/10.1177/104225870202600403
Herbane B. (2019) Rethinking organizational resilience and strategic renewal in SMEs. *Entrepreneurship & Regional Development*, 31(5–6), 476–495. https://doi.org/10.1080/08985626.2018.1541594
Högberg L., Mitchell C. (2023) Mixed embeddedness and entrepreneurship beyond new venture creation: Opportunity tensions in the case of reregulated public markets. *International Small Business Journal: Researching Entrepreneurship,* 41(2), 121–151. Advance online publication. https://doi.org/10.1177/02662426221083827
Jolink A., Niesten E. (2015) Sustainable development and business models of entrepreneurs in the organic food industry. *Business Strategy and Environment*, 24, 386–401. https://doi.org/10.1002/bse.1826
Kantur D., Say A.I. (2015) Measuring organizational resilience: A scale development. *Journal of Business Economics and Finance*, 4(3), 456–472.
Kapustina L.M., Izakova N.B., Korovina E.I. (2023) Strategies for transforming business models of road construction equipment manufacturers in the context of competition with foreign companies. *Bulletin of Moscow University. Series 6: Economics*, 1, 164–190 (in Russian).
Karacharovsky V. (2010) Business and innovative activity in the Russian economy. *Society and Economics*, 12, 13–32 (in Russian).
Karelina M.G. (2015) Empirical analysis of the integration activity of business structures in the regions of Russia. Regional Economics, 4(44), 54–68. https://doi.org/10.17059/2015-4-5 (in Russian).
Kerr W.R., Mandorff M. (2023) Social networks, ethnicity, and entrepreneurship. *Journal of Human Resources*, 58(1), 183–220. https://doi.org/10.3368/jhr.58.3.0719-10306R2
Klimanov D.E., Tretyak O.A. (2014) Business models: Main directions of research and searches for the substantive foundation of the concept. *Russian Journal of Management*, 12(3), 107–130 (in Russian).
Kozakov E.M., Glukhikh P.L. (2011) Assessing the influence of organizational aspects of entrepreneurial activity on the socio-economic development of highly specialized territories. *Regional Economics*, 1(25), 123–130 (in Russian).

Krivosheeva-Medyantseva D. (2022) Adaptive behavior of small business owners during the COVID-19 pandemic. *Journal of Institutional Research*, 14(4), 122–138. https://doi.org/10.17835/2076-6297.2022.14.4.122-138 (in Russian).
Kumar A., Paul J., Unnithan A.B. (2020) 'Masstige'marketing: A review, synthesis and research agenda. *Journal of Business Research*, 113, 384–398. https://doi.org/10.1016/j.jbusres.2019.09.030
Kusraeva O.A. (2017) Features of business models of Russian agricultural companies. *ECO,* 1(511), 63–71 (in Russian).
Lau C.M., Bruton G.D. (2011) Strategic orientations and strategies of high technology ventures in two transition economies. *Journal of World Business*, 46(3), 371–380. https://doi.org/10.1016/j.jwb.2010.07.011
Ledeneva A.V. (1998) *Russia's economy of favours: Blat, networking and informal exchange*, Cambridge (UK): Cambridge University Press.
Linan F., Santos F.J., Fernández J. (2011) The influence of perceptions on potential entrepreneurs. *International Entrepreneurship and Management Journal*, 7, 373–390. https://doi.org/10.1007/s11365-011-0199-7
Lu J.J., Ruzhanskaya L.S. (2023) Factors influencing Chinese migrants' entrepreneurial activity in Russia: A case study of Sverdlovsk region. *R-Economy*, 9(2), 187–206. https://doi.org/10.15826 /recon.2023.9.2.012
Makushina E.Yu., Malofeeva T.N., Koziorova O.I., Andreeva Yu.A. (2023) Non-financial factors of efficiency of pharmaceutical companies in Russia. *Bulletin of Moscow University. Series 6: Economics*, 1, 135–163 (in Russian).
Malikov R., Grishin K., Sultangareev D. (2022) On forecasting the productivity of regional entrepreneurial ecosystems. *Society and Economics,* 4, 14–24. https://doi.org/10.31857/S020736760019576-2 (in Russian).
Markova V.D. (2023) The ecosystem is moving away: the case of the Russian companies 1C and Galaktika. *ECO,* 4(586), 74–92. https://doi.org/10.30680/ECO0131-7652-2023-4-74-92 (in Russian).
Meteleva M.A. (2021) Design and management of business networks: assessment of the network potential of the population of the territories of the Arctic zone of the Russian Federation. *The North and the Market: Shaping Economic Order,* 24(4), 172–187. https://doi.org/10.37614/2220-802X.4.2021.74.013 (in Russian).
Meteleva M.A. (2022) Design of entrepreneurial networks: development of a methodology for assessing the network potential of corporations in the Arctic zone of the Russian Federation. *The North and the Market: Shaping Economic Order,* 25(3), 19–35. https://doi.org/10.37614 /2220-802X.3.2022.77.002 (in Russian).
Müller S. (2016) A progress review of entrepreneurship and regional development: what are the remaining gaps? *European Planning Studies*, 24(6), 1133–1158. https://doi.org/10.1080/09654313.2016.1154506
Obraztsova O.I., Chepurenko A.Yu. (2020) Entrepreneurial activity in Russia and its interregional differences. *Journal of the New Economic Association,* 2(46), 198–210. https://doi.org/10.31737/2221-2264-2020-46-2-12 (in Russian).
Osipova A.A., Sidorenko O.V. (2007) Stimulating the development of small businesses in the region. *Spatial Economics*, 2, 61–76 (in Russian).
Ovchinnikova A.V., Zimin S.D. (2021) Assessing the connections between entrepreneurial ecosystems and the level of economic development of Russian regions. *Journal of Applied Economic Research,* 20(3), 362–382. https://doi.org/10.15826/vestnik.2021.20.3.015 (in Russian).
Peshkova V.M. (2018) Entrepreneurial activity of foreign labor migrants in Russia. Using the example of Kyrgyz migrants in Moscow and the Moscow region. *Economic Sociology,* 19(5), 11–40. https://doi.org/10.17323/1726-3247-2018-5-11-4
Pesta B., Fuerst J., Kirkegaard E.O. (2018) Bibliometric keyword analysis across seventeen years (2000–2016) of intelligence articles. *Journal of Intelligence*, 6(4), 46. https://doi.org/10.3390/jintelligence6040046
Polterovich V.M. (2004) Institutional traps: is there a way out? *Social Sciences and Modernity,* 3, 5–16 (in Russian).
Popov E., Veretennikova A., Kozinskaya K. (2018) Institutional environment of social entrepreneurship in the global space. *Society and Economics,* 5, 97–114 (in Russian).
Puffer S.M., McCarthy D.J. (2001) Navigating the hostile maze: A framework for Russian entrepreneurship. *Academy of Management Perspectives*, 15(4), 24–36. https://doi.org/10.5465/ame.2001.5897647
Rauch A., Frese M., Wang Z.M., Unger J., Lozada M., Kupcha V., Spirina T. (2013) National culture and cultural orientations of owners affecting the innovation-growth relationship in five countries. *Entrepreneurship and Regional Development*, 25(9–10), 732–755. https://doi.org/10.1080/08985626.2013.862972
Rehn A., Taalas S. (2004) 'Znakomstva I Svyazi' (Acquaintances and connections) – Blat, the Soviet Union, and mundane entrepreneurship. *Entrepreneurship & Regional Development*, 16(3), 235–250. https://doi.org/10.1080/0898562042000197108
Ruzhanskaya L.S., Fonova N.G., Yakimova E.A. (2022) The response of small and medium-sized businesses to the coronavirus crisis: The influence of the authorities of the constituent entities of the Federation. *Regional Economics,* 18(3), 653–672. https://doi.org/10.17059/ekon.reg.2022-3-3 (in Russian).
Santos F.M. (2012) A positive theory of social entrepreneurship. *Journal of Business Ethics*, 111(3), 335–351. https://doi.org/10.1007/s10551-012-1413-4
Sarasvathy S.D. (2001) Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. *Academy of Management Review*, 26(2), 243–263. https://doi.org/10.5465/amr.2001.4378020
Savelyev I.I., Turabaeva A.M. (2023) Network approach to social entrepreneurship: Preliminary results of an empirical study. *Bulletin of Moscow University. Series 6: Economics,* 4, 147–164. https://doi.org/10.55959/MSU0130-0105-6-58-4-7 (in Russian).
Schaltegger S., Lüdeke-Freund F., Hansen E.G. (2012) Business cases for sustainability. The role of business model innovation for corporate sustainability. *International Journal of Innovation and Sustainable Development*, 6, 95–119. https://doi.org/10.1504/IJISD.2012.046944
Scott R. (1995) *Institutions and Organizations*, Thousand Oaks, CA: Sage.
Sedaitis J. (2000) Technology transfer in transitional economies: A test of market, state and organizational models. *Research Policy*, 29(2), 135–147. https://doi.org/10.1016/S0048-7333(99)00056-6

Shafranskaya I.N. (2019) Can entrepreneurship be taught: factors shaping students' entrepreneurial intentions. *University Management: Practice and Analysis*, 23(3), 79–93. https://doi.org/10.15826/umpa.2019.03.021 (in Russian).
Shane S., Venkataraman S. (2000) The promise of entrepreneurship as a field of research. *Academy of Management Review*, 25, 217–226. https://doi.org/10.5465/amr.2000.2791611
Shatalov A.I. (2010) The relationship between a business model and a company's performance (based on materials from Russian companies in the public catering industry). *Bulletin of St. Petersburg University. Management,* 2, 24–54 (in Russian).
Shirokova G., Beliaeva T., Manolova T.S. (2023) The role of context for theory development: Evidence from entrepreneurship research on Russia. *Entrepreneurship Theory and Practice*, 47(6), 2384-2418. https://doi.org/10.1177/10422587221138226
Shirokova G., Bogatyreva K., Belyaeva T. (2015) Entrepreneurial orientation of Russian firms: The role of the external environment. *Foresight and STI Governance,* 9(3), 6–25. https://doi.org/10.17323/1995-459X.2015.3.6.25.
Shirokova G., Osiyevskyy O., Laskovaia A., Mahdavi M.H. (2020) Navigating the emerging market context: Performance implications of effectuation and causation for small and medium enterprises during adverse economic conditions in Russia. *Strategic Entrepreneurship Journal,* 14(3), 470–500. https://doi.org/10.1002/sej.1353
Shirokova G.V., Arepyeva M.A., Molodtsova M.Yu. (2009) The influence of social networks at different stages of development of an entrepreneurial firm: results of analysis of data from the Global Monitoring of Entrepreneurship in Russia. *Bulletin of St. Petersburg University. Management*, 3, 3–31 (in Russian).
Shirokova G.V., Ezhova Y.S. (2012) The formation of intra-company entrepreneurship in a Russian company: formation, development and prospects. *Russian Journal of Management*, 10(1), 117–140 (in Russian).
Shirokova G.V., Sokolova L.S. (2013) Formation of entrepreneurial orientation in Russian small and medium-sized businesses: the role of the institutional environment. *Russian Journal of Management,* 11(2), 025–050 (in Russian).
Shirokova G.V., Zibarev I.A. (2013) Internationalization of entrepreneurial firms from emerging economies: The Russian experience. *Bulletin of St. Petersburg University. Management,* 1, 69–109 (in Russian).
Shurchkov O. (2012) New elites and their influence on entrepreneurial activity in Russia. *Journal of Comparative Economics,* 40(2), 240–255. https://doi.org/10.1016/j.jce.2011.12.003
Sibirskaya E.V., Oveshnikova L.V., Makhova O.A. (2018) Statistical analysis of entrepreneurial activity. *Issues in Statistics,* 25(10), 47–60 (in Russian).
Smirnov S.A., Bobrova S.V., Arenkov I.A., Salikhova Y.Yu. (2021) Sustainable combinations of distinctive business model features of innovative firms. *Bulletin of St. Petersburg University. Economics,* 37(1), 62–83. https://doi.org/10.21638/spbu05.2021.103 (in Russian).
Snyder H., Witell L., Gustafsson A., Fombelle P., Kristensson P. (2016) Identifying categories of service innovation: A review and synthesis of the literature. *Journal of Business Research*, 69(7), 2401–2408. https://doi.org/10.1016/j.jbusres.2016.01.009
Solodilova N.Z., Malikov R.I., Grishin K.E. (2016) The influence of administrative regulation on the efficiency of business activity in the region. *Regional Economics,* 12(4), 1001–1013. https://doi.org/10.17059/2016-4-3
Solodilova N.Z., Malikov R.I., Grishin K.E. (2017) Institutional configuration of the regional business environment. *Economic Policy,* 12(3), 134–149. https://doi.org/10.18288 /1994-5124-2017-3-05 (in Russian).
Spigel B. (2017) The relational organization of entrepreneurial ecosystems. *Entrepreneurship Theory and Practice*, 41(1), 49–72. https://doi.org/10.1111/etap.12167
Staroverov V.V. (2010) Raiding – hostile takeover of enterprises. *Monitoring Public Opinion: Economic and Social Changes*, 1(95), 49–62 (in Russian).
Stolbov A.G., Mosina E.A. (2015) Features and conditions for the development of small businesses in the Murmansk region. *The North and the Market: Shaping Economic Order*, 4(47), 23–29 (in Russian).
Szerb L., Trumbull W.N. (2018) Entrepreneurship development in Russia: Is Russia a normal country? An empirical analysis. *Journal of Small Business and Enterprise Development*, 25(6), 902–929. https://doi.org/10.1108/JSBED-01-2018-0033
Thaler R.H., Sunstein C.R. (2003) Libertarian paternalism. *American Economic Review*, 93(2), 175–179. https://doi.org/10.1257/000282803321947001
Tsui A.S. (2004) Contributing to global management knowledge: A case for high quality indigenous research. *Asia Pacific Journal of Management*, 21(4), 491–513. https://doi.org/10.1023/B:APJM.0000048715.35108.a7
Tsui A.S. (2006) Contextualizing in Chinese management research. *Management and Organization Review*, 2(1), 1–13. https://doi.org/10.1111/j.1740-8784.2006.00033.x
Urbano D., Turro A., Wright M., Zahra S. (2022) Corporate entrepreneurship: A systematic literature review and future research agenda. *Small Business Economics*, 1–25. https://doi.org/10.1007/s11187-021-00590-6
Ushkin S.G. (2017) "Easy" business, or what problems do entrepreneurs face in the regions? *Sociological Research*, 3(395), 144–149 (in Russian).
Van Gelderen M., Kautonen T., Fink M. (2015) From entrepreneurial intentions to actions: self-control and action-related doubt, fear, and aversion. *Journal of Business Venturing*, 30(5), 655–673. https://doi.org/10.1016/j.jbusvent.2015.01.003
Verkhovskaya O.R. (2009) Factors in the formation of emerging entrepreneurship: Features of Russia. *Bulletin of St. Petersburg University. Management*, 2, 32–52 (in Russian).
Verkhovskaya O.R., Aleksandrova E.A. (2017) Entrepreneurial activity in Russia: results of the project "Global Monitoring of Entrepreneurship" 2006-2016. *Russian Journal of Management*, 15(1), 3–26. https://doi.org/10.21638/11701/spbu18.2017.101 (in Russian).
Verkhovskaya O.R., Dorokhina M.V. (2008) Entrepreneurial activity in modern Russia. *Russian Journal of Management*, 6(1), 25–52 (in Russian).
Verkhovskaya O.R., Dorokhina M.V. (2013) Entrepreneurial firms and job creation in Russia: Empirical evidence. *Russian Journal of Management*, 11(1), 19–40 (in Russian).

Vlasov M.V. (2020) Policy of innovative behavior of small and medium-sized enterprises in an old industrial region. *Regional Economics*, 16(4), 1335–1347. https://doi.org/10.17059 /ekon.reg.2020-4-22 (in Russian).

Volkov V.V. (2020) *Power entrepreneurship, 21st century: Economic and sociological analysis*, Saint-Petersburg: Autonomous non-profit educational organization of higher education "European University in St. Petersburg" (in Russian).

Vrontis D., Makrides A., Christofi M., Thrassou A. (2021) Social media influencer marketing: a systematic review, integrative framework and future research agenda. *International Journal of Consumer Studies,* 45(4), 617–644. https://doi.org/10.1111/ijcs.12647

Wallin M.W. (2012) The bibliometric structure of spin-off literature. *Innovation,* 14(2), 162–177. https://doi.org/10.5172/impp.2012.14.2.162

Walsh I., Renaud A. (2017) Reviewing the literature in the IS field: two bibliometric techniques to guide readings and help the interpretation of the literature. *Systèmes d'information et Management*, 22(3), 75–115. https://doi.org/10.3917/sim.173.0075

Welter F. (2011) Contextualizing entrepreneurship — conceptual challenges and ways forward. *Entrepreneurship Theory and Practice*, 35(1), 165–184. https://doi.org/10.1111/j.1540-6520.2010.00427.x

Yakimova V.A., Pankova S.V. (2023) The influence of digital environment factors on the development of entrepreneurial ecosystems in Russian regions. *Journal of Applied Economic Research,* 22(3), 600–629. https://doi.org/10.15826/vestnik.2023.22.3.025 (in Russian).

Zazdravnykh E.A. (2019) Historical effects of regional entrepreneurial activity. *Russian Journal of Management*, 17(1), 97–120. https://doi.org/10.21638/spbu18.2019.105 (in Russian).

Zemtsov S.P. (2020) Institutions, entrepreneurship and regional development in Russia. *Journal of the New Economic Association*, 2(46), 168–180. https://doi.org/10.31737/2221-2264-2020-46-2-9 (in Russian).

Zemtsov S.P. (2022) Technological entrepreneurship as a factor in the development of Russia. Journal of the New Economic Association, 1(53), 212–223 (in Russian).

Zemtsov S.P., Baburin V.L. (2019) Entrepreneurial ecosystems in Russian regions. *Regional'nye issledovaniya,* 2(64), 4–14 (in Russian).

Zemtsov S.P., Tsareva Yu.V. (2018) Entrepreneurial activity in Russian regions: how spatial and temporal effects determine the development of small businesses. *Journal of the New Economic Association*, 1(37), 145–165 (in Russian).

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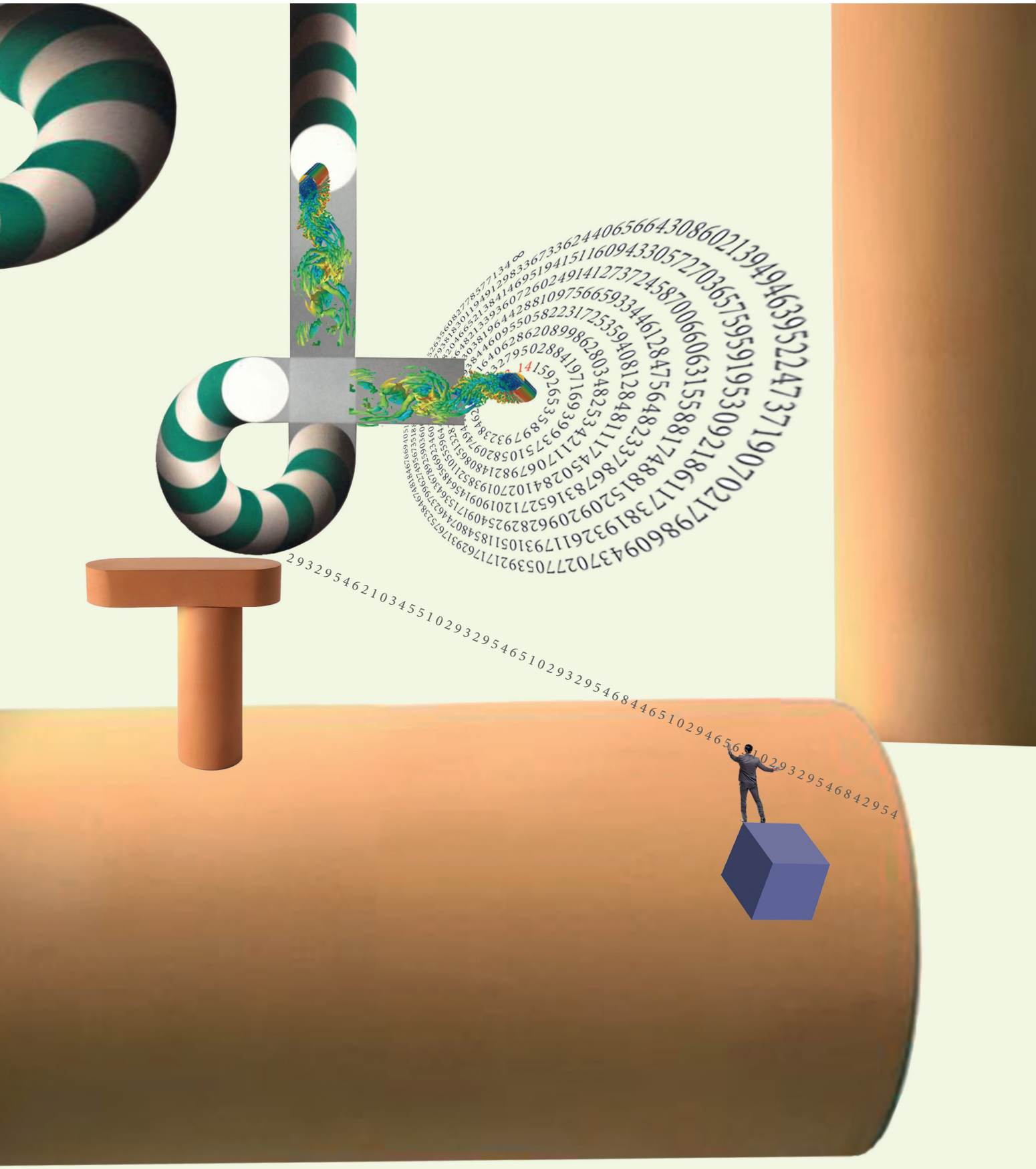
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The Evaluation of GenAI Capabilities to Implement Professional Tasks

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Abstract

Generative AI (GenAI) or large language models (LLMs) have been running the world since 2022, but despite all the trends surrounding the use of generative models, these cannot yet be used professionally. While they are most valued for 'knowing everything', nonetheless GenAI models cannot explain and prove. In this way we conceptualize the most recent problem of LLMs as the general trend of mistakes even in the core of knowledge and non-causality of mistake via the complexity of question, as the mistake can be named as an accident and be everywhere as the most limitation of professionalism. At their current stage of development, LLMs are not widely used in a professional context, nor have they replaced human workers. They do not event extend workers' professional abilities.. These limitations of GenAI have one general: non-repayment. This article seeks to analyze GenAI's professional viability by examining two models (GigaChatPro, GPT-4) in three fields of knowledge (economics, law, education) based on our unique Bloom's taxonomy benchmark. To prove our assumption concerning the low possibility of its professional usage, we test three hypotheses: 1) the number of parameters of models have low elasticity regarding difficulty and taxonomy with even the right answer; 2) difficulty and taxonomy jointly have no effect on the correctness of an answer, 3) multiple choice is a factor that decreases the number of right answers of a model. We also present the results of GPT-4 and GigaChat MAX on our benchmark. Finally, we suggest what can be done about the limitations of GenAI's architecture to reach at least a quasi-professional use.

Keywords: professionalism; generative artificial intelligence; professional use of language models; graphs of knowledge; orchestration; Bloom's taxonomy

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Introduction

Generative artificial intelligence (GenAI) technologies based on large language models (LLM) have become widespread in the last few years, especially with the emergence of ChatGPT. Such tools are mainly used for the quick retrieval of reference information, writing and translating texts, and creating images and videos. As an assistant, they are in demand in various fields, including education, economics, finance, law, medicine, and pharmaceuticals (Table 1).

The generative AI market is expected to experience a great boost in the years up to 2030. The industry stood at just under $67 billion at the end of 2024, nearly triple the size of 2022. The Statista forecast[1] says it may reach nearly $207 billion (see Figure 1). In Russia, according to the ISSEK sociological survey[2], organizations using AI technologies spend about 15% of total expenditures on digital technologies on them.

According to a report by the consulting company International Data Corporation (IDC) (IDC, 2024), the economic impact of artificial intelligence (AI) technologies around the world will amount to $19.9 trillion by 2030 and will account for 3.5% of global GDP.[3] The IDC study notes that by 2030, every $1 billion of corporate AI investment will generate $4.6 billion for global GDP with direct and indirect impacts.

The overall trend for GDP development is slow. Global GDP growth will slow to 2.7% in 2024 from 2.9% in 2023, according to the Organization for Economic Cooperation and Development (OECD) (OECD, 2024). The indicator's expected value next year will be the lowest since 2020 during the Covid-19 pandemic. The slowdown in growth in the forecast of the organization has been called a direct consequence of the tight measures conducted by the central banks of developed countries and a contraction in business activity, along with generally weakened trade. That is, GDP growth due to AI is a new event, which generally breaks from the existing trend, which is slowing down and focused on stable export-import flows. Is this expectation justified and rational? How we can illustrate those prospects?

Capabilities and Limitations of LLMs

In order to assess expectations surrounding AI's ability to solve problems and stimulate economic growth, it is useful to outline a notional scale of technological potential. For this purpose, let us provide two historical analogies.

The first refers to the alchemical practices of the Middle Ages, associated with attempts to obtain gold from other metals with the help of the Philosopher's Stone. It is noteworthy that in the 20th century it was possible to experimentally convert mercury into gold by means of nuclear reaction, but this method of production turned out to be extremely expensive and has no prospects for payback.[4] In other words, the "philosopher's stone" can refer to technologies characterized by increased labor intensity and financial costs, but are never realized in reality, despite the high expectations associated with them. They become the first reference point on our scale.

The second analogy concerns a development that arose almost by accident, at the intersection of two dominant technologies that have proven useful and cost effective. This refers to the invention of steam locomotives and the formation of railroad infrastructure, processes that resulted from a successful attempt to equip coal transportation vehicles with a steam engine that was originally designed for other purposes (Turnock, 1998). This development had a very simple applied and observable purpose – to accelerate the logistics process with a tangible, measurable result – the speed of doing something. Now railways bring great profits for each country – both direct (for its use and operation and as a huge sector of labor) and indirect – on savings from transaction costs.[5] Technologies with such attributes will be labeled a "steamroller" on our notional scale.

The process of creating the Philosopher's stone also had an applied cost: obtaining gold with minimal costs. However, what does one with this gold if the process of its extraction becomes almost cost-free? No one could give an answer. The other result is obvious – gold would have been devalued. Today, it is seen as an unconditional "currency" - a pledge of stability for the financial marketplace.[6] The Philosopher's stone was never invented – this is due to the unrealistic (and not obvious) way of using the results of this development given that if it were to spread hypothetically, the financial market would lose stability very quickly.

It is difficult to assess which investments were made in both discoveries (or lack of discoveries), and it is not related to the aims of our study. It is, however, worth paying attention to the expectations of returns on these two developments. Where are we and GenAI at this point in our history – closer to a steam locomotive or a philosopher's stone? Do we know which applied tasks, expressed in specific operations and in specific profits,

[1] https://www.statista.com/forecasts/1474143/global-ai-market-size, accessed 27.09.2024.

[2] https://issek.hse.ru/news/981416418.html, accessed 13.11.2024.

[3] Just for comparison, in 2022, the share of agriculture in the global gross domestic product was 4.27%. https://www.statista.com/statistics/256563/share-of-economic-sectors-in-the-global-gross-domestic-product/, accessed 11.10.2024.

[4] https://www.ixbt.com/live/offtopic/pravda-li-chto-mozhno-sdelat-zoloto.html, accessed 17.10.2024 (in Russian).

[5] For example, the latest year (April 2022 to March 2023) saw passengers contribute £8.6 billion of fares income in UK (ORR, 2023).

[6] Now the price of the December gold contract on the Chicago Mercantile Exchange (CME) increased by 0.77%, rising to $2,750.9 per ounce, according to trading data as of the end of October 2024, the price of the precious metal rose above $ 2,750 per ounce for the first time in history. https://www.barchart.com/futures/quotes/GC*0/profile, accessed 22.11.2024.

Table 1. **Prospective Applications for GenAI**

Field	Assisting functions of GenAI	Literature
Education	Teacher or students assistants which can be used to decrease routines	Al-Zahrani, Alasmari, 2024; Ogunleye et al., 2024; Al-Zahrani et al., 2023; Gill et al., 2023; Chu et al., 2022; Dai, Ke, 2022; Hassan et al., 2022
Economics and finance	Financial consultants	Shapira et al., 2024
Law	Copilot lawyer who performs basic tasks under the very strict supervision via prompts – e.g., summarize the huge document as an Act	Alimardani, 2024; Lai et al., 2023
Medicine	Helping with diagnoses	Chen, Esmaeilzadeh, 2024
Pharmaceuticals	Construction of new formulas	Choi at al., 2024; Mortlock, Lucas, 2024

Source: compiled by the authors

we can solve with it? We will attempt to answer following the literature review and author's experiment.

Before analyzing the prospects for the professional use of large language models, let us outline what is meant by the term "professionalism". In this case we define professionalism as the ability to select the optimal solutions within the conditions of uncertainty in keeping with knowledge and resisting the most common, secular knowledge if such information contradicted the true empirically stated knowledge. The LLMs, on the contrary, usually operate according to common knowledge (Strachan et al., 2024). LLMs can operate the basic routine operations such as solving basic knowledge operations and other human routines what can help to simplify operations in these fields (Cheung, 2024; Han et al., 2023). However, such functions are routine, whereas professional activity also implies creativity and work with novelty. Since generative models in most cases rely on superficial knowledge and information from low-quality sources, there is an increased risk that they will give an erroneous answer to even elementary questions, which is regarded as an unsatisfactory outcome.

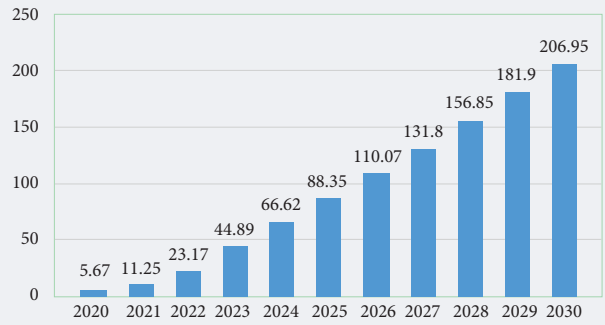
Hence, this is the main limitation for the full-scale delegation of professional tasks to language models. Increasing the number of customization parameters does not eliminate the overall problem, which is further illustrated by statistical hypothesis testing. Thus, when using GenAI for work tasks, it is not yet possible to do without close human supervision. As will be shown empirically, the tested language models GigaChat Pro and GPT-4 make up to 50% errors in the theoretical foundations of law, education, and economics because they lack basic professional knowledge. All known methods of pre-training cannot yet offer an optimal solution. Entrusting professional work to an incompetent "assistant" can be fraught with not only financial but also reputational losses for companies. Therefore, no clear strategy for GenAI productivization has yet been developed.

Another constraint to the expansion of the professional application of LLMs is the lack of empirical analysis of the effects of their implementation in business, education, and other applied fields (McKnight et al., 2024; Sohail et al., 2023). As a consequence, no generative model is currently being used as a professional work product (Noever, Ciolino, 2023). Amidst the expectations associated with their development, there are obvious risks of not satisfying needs, as evidenced by sociological observations. According to Thomson Reuters, almost 60% of lawyers surveyed are not sure that GenAI will have an impact on the value creation of legal services. At least 70% of respondents said they see the greatest risks of using LLMs as being low response accuracy, and 57% ethical impropriety to such tools (Thomson Reuters, 2024). A McKinsey & Company survey shows a similar picture (Figure 2) - organizations are concerned about the low quality and incorrectness of answers generated by AI (56%). Such an indicator obviously does not meet the criteria of professionalism.

We also highlight the lack of empirical studies about LLM implementations to the business, education, or other applied fields and the absence of research describing the practices surrounding LLM use (McKnight et al., 2024; Sohail et al., 2023). As a result, no LLM tool is used completely independently of human oversight in a professional setting (Noever & Ciolino, 2023). There is empirical evidence of the risks of using LLMs. According to a Thomson Reuters survey almost 60% of legal professionals do not believe GenAI will impact the rates they charge clients. More than 50% of respondents stated that LLMs generally have inaccurate responses (70%); poorly comply with laws and regulations (60%); and have a lot of dangerous ethical issues and possibly do not meet criteria for responsible usage (57%) (Thomson Reuters, 2024). Let us also pay attention to the GenAI-related risks that global organizations consider relevant according to a McKinsey & Company poll (see Figure 2) which proves the thesis about the main constraint of LLM usage – the low quality of answers (56%) and inaccuracy, which hinders professionalism.

Thus, the results of AI work require control by means of special procedures - prompting (adjusting queries), fine-tuning of response parameters, and so on. Moreover, LLMs have other limitations (Borji, 2023) because of a number of biases: gender (Borji, 2023),

Figure 1. **Generative Artificial Intelligence (GenAI) Market Size Worldwide from 2020 to 2030 (*billion USD*)**



Source: https://www.statista.com/forecasts/1474143/global-ai-market-size, accessed 18.10.2024.

linguistic (Zhang et al., 2024; Zhang et al., 2021), objectivity (Anthis et al., 2024), and lack of logic (Nguyen et al., 2023; Wan et al., 2024). Thus, generative artificial intelligence models did not bring obvious profit and were not massively productized as professional assistants (Cheung, 2024), nor do they have a level of performance to operate professionally. The final hypothesis we prove in this article via an empirical analysis in the fields of economics, law, and education. This shows that the humans still cannot trust the answers of LLM models professionally, and that we have unjustified expectations from AI.

What have we done to realize the professional usage of LLM and what can be done? Generative AI models have already begun to move toward productization, although they have also done so indirectly. The new "color of the season" is training the model so that it has an increased ability to reason – to use a chain of thoughts (Wei et al., 2022; Liu et al., 2023). In this matter we must declare a limitation of our study – in the moment that we publish this, the new models GPT-4o1 and GigaChat MAX were launched. We have tested these as well, but not in an as statistically rigorous way as we did their predecessors. However, we can note two relevant points based on the newer models. Based on the overall accuracy of the generated responses, it can be noted that GigaChat MAX generally shows a larger gain on our benchmark (Pro vs. MAX +10%) against +5% for GPT-4o1 compared to GPT-4 (see below).

To continue the topic of discussion of which methods are usually used to improve the quality of models, we can name the method of using knowledge graphs (Xu et al., 2024; Luo et al. 2023; Sun et al., 2023) within the framework of RAG (Retrieval Augmented Generation) or KAG (Knowlegdge Augmented Generation), which received a "boom" in the second quarter of 2024 and are quite successful for further training models in the fields of creative thinking (Sanmartin, 2024; Liang et al., 2024), reasoning, and logic (Mirzadeh et al., 2024). They are even employed to improve the quality of responses to customer queries within individual modules of the model (Xu, 2024). The mixture of Experts (MoE) method is also quite popular, but its optimal use has not yet been identified (Cai et al., 2024; Zhong et al., 2024; Antoniak et al., 2023), although attempts have been underway, strictly speaking, since the time before the advent of transformer models. It should also be noted that there is a great need to increase the level of proficiency in mathematical operations through orchestration techniques (Zhou et al., 2024), for which success has been confirmed (Rasal, 2024).

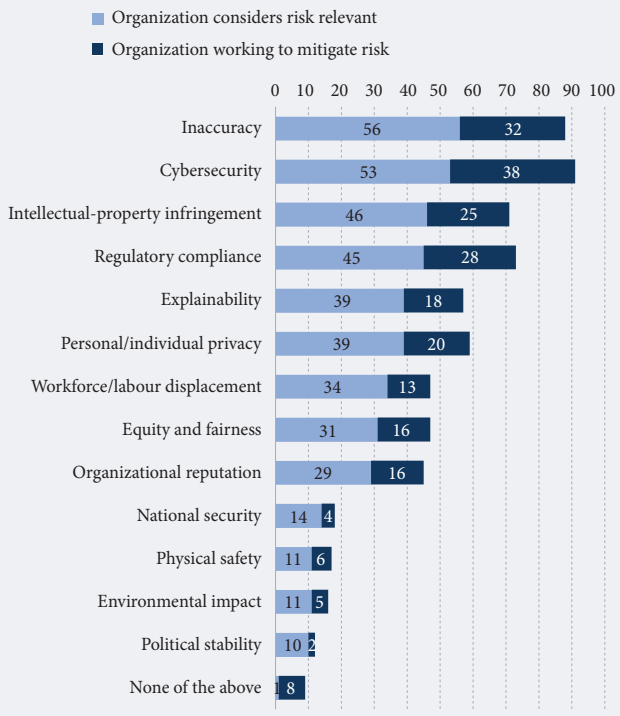
All these strategies can only be called an indirect attempt to achieve the professional use of such models, since these techniques are aimed only at generally improving the ability of the model to respond, which is expressed in the risk of increasing errors and profanity in responses. Such outcomes are unacceptable for a professional, as we have already emphasized earlier. Why is this happening contrary to the expectations of productization? We do not have an established method for "teaching" LLMs, we can only improve upon them.

According to ISSEK (HSE, 2024), the majority (70.1%) of students in AI programs in Russia study within the fields of Engineering, Technology and Technical Sciences; about a quarter (27.2%) are in "Mathematical and Natural Sciences" departments. Still, only 1.5% study as part of "Social Sciences" programs. Why is this dangerous for the productivity of models? Modelers often set themselves the goal of "growing" models, seeking to increase the number of hyperparameters, and then test them on benchmarks that have nothing to do with checking the level of professionalism. Meanwhile, the product departments of companies have clear intentions for the model to perform specific, professionally oriented tasks. According to the results of several empirical experiments, which we will describe in the next section, an increase in the number of hyperparameters of the model does not have a direct impact on improving the abilities of the model.

In this case we can say that the risk of not meeting professional standards cannot be answered without an academic approach to the term 'teaching' (we will conceptualize the academic approach in the methodological section of this paper). We state that professional teaching of LLMs should be based on the concept of the knowledge's core, which was created as one of the key concepts of positivism by Kuhn and Lakatos (Kuhn, 1977; Lakatos, 1963; Lakatos, 1970a; Lakatos, 1970b). The key for teaching LLMs this core tenant is finding a way to restrict the possibility of errors and mistakes in the basic knowledge.

For professional usage we need to align the process of 'boosting' and rethink the core of knowledge, the connection of subject areas with one another to create the clean datasets, the relevant RAG techniques, etc., and these tasks can be done only by professional academics in the relevant fields (recall the example of Arizona State University and OpenAI).

Figure 2. **Risks that Organizations Worldwide Consider Relevant While Using LLMs**



Source: McKinsey & Company. https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year, accessed 17.10.2024.

Moreover, we need not only 'teach' but also evaluate the results of this 'teaching' in a professional way. Global trends in the development of benchmarks (Wang, 2024) show that professional complication of issues is one of the new turns in the development of benchmarks in general. In this regard, this paper presents a new approach to benchmarking professionalism and testing the actual versions of LLMs on this.

To summarize, in this section of article we have attempted to highlight the problem of not using LLM models professionally, and the lack of opportunities to use them according to some observed facts, both concluded sociologically or via the relevant literature. In the next section, we prove empirically why our corollary about the actual, non-professional level can be stated as real and we further describe our methodology for this experiment.

The Empirical Evaluation of the Degree of Professionalism of LLMs

To test our main hypotheses of the models' inability to act professional, we conducted an experiment using our own benchmark in three fields (domains): economics, law, and pedagogy & education. A detailed presentation of the benchmark methodology was outlined in our earlier study (Kardanova et al., 2024).

To explain it in brief (see Figure 3), the testing process was conducted in accordance with an academic approach, in which the test tasks were prepared based on the principles of:

- scientific criteria – not checking the model's ability to state the facts, but verifying its ability to demonstrate fundamental knowledge and an ability to solve the practice cases needed to have this kind of knowledge.
- taxonomy and difficulty criteria – each question was assigned (by an expert) to the basic Blooms' criteria (Bloom, 1956) of taxonomy: to remember, to understand, and to apply[7]; also, the level of difficulty was assigned to each question: easy, moderate, difficult.[8]
- collectivity (collegiality) – the mixture of independent experts' opinions.
- iterativity – a staged process to check each question for the all the criteria.

Within the framework of these principles, each of the tasks were created by an expert (a professional academic specialist) for each domain and subsequently checked by a psychometrician to prove compliance with the classical measurement theory. Finally, each question was also validated by three independent experts afterwards (see Figure 3).

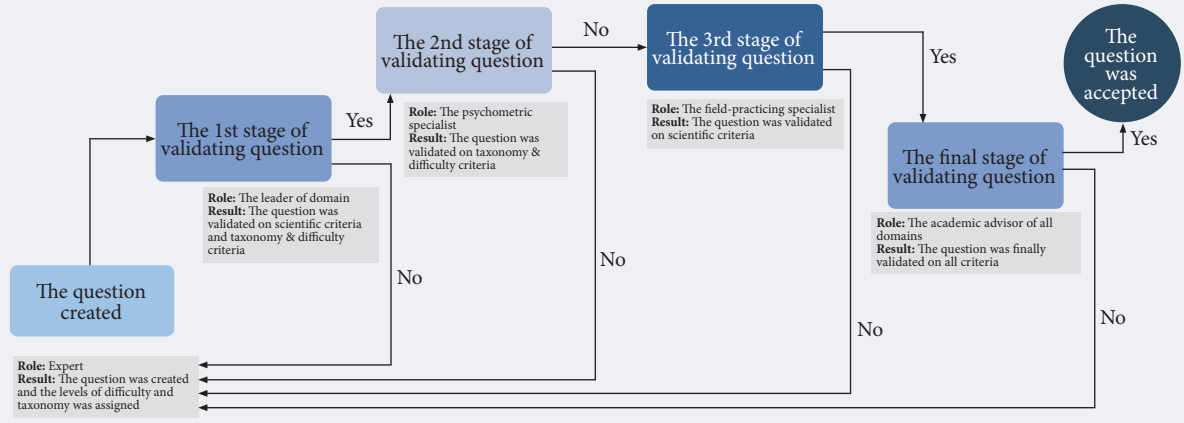
The questions created within the framework of the benchmark are based on the principle that the versatility and responsiveness of knowledge is one of the most important criteria of a professional. The questions test both fundamental knowledge and the possibility of applying this knowledge in various contexts, often non–trivial ones. The tasks were of varying complexities to test the model from different scientific sides. The questions have a certain level of complexity, set by an expert, and can measure the depth of the model's knowledge.

The questions vary in taxonomy levels to test the model's abilities in different contexts. The questions have multiple levels of taxonomy, set by an expert, and can measure the breadth of knowledge of the model and its ability to combine knowledge from different sources in different contextual situations. Taxonomy is the basis for creating any assessment tool for both people (exams) and large language models (benchmarks). However, a separate or unique taxonomy for checking the level of large language models has not yet been developed, which makes the current assessment biased toward psychometric patterns of checking people. Given

[7] Each level was assigned expertly. The level of remembering means that the student can reproduce the main points of the theory. The level of understanding means that the student can relate theory and a practical task. The level of applying means that the student can apply the relevant theory in the right way.

[8] Each level was assigned expertly. A task is considered easy if more than 70% of undergraduate students can solve it. The task is considered moderate if from 30% to 70% undergraduate can solve it. A task is considered difficult if less than 30% of undergraduate can solve it.

Figure 3. **Algorithm of Expert Validation of Test Questions**



Source: compiled by the authors

the increase in the number of model parameters, only in 20% or less of the cases for all domains would the questions contain the need to verify knowledge about the fact or theory (an easy task).

In total, more than 13,000 unique MLUU-type original questions were created. Given the very high risk of leakage of a benchmark (and mixing with pre-train[9]), we cannot make public even one of these questions to show an example. We tested models with chain-of-thoughts (CoT) and without them to show the difference in the results if a model "thinks" before answering (in the case of CoT) or not.

All questions were assigned a level of taxonomy and difficulty. Generally, the results of testing GPT-4 and GigaChat Pro (with chain-of-thoughts and without) using these questions shows the impossibility of using these models in a professional setting as they must be evaluated by a person. We state that the impossibility of usage of GenAI in a professional context is highly correlated with fact that the model can make mistakes when answering the simplest questions. To prove this thesis, we provide three hypotheses (all of which were confirmed):

Hypothesis 1: The number of parameters of models have a low elasticity to difficulty and taxonomy even when providing the right answer.

Hypothesis 2: Difficulty and taxonomy jointly have no effect on obtaining a correct answer

Hypothesis 3: Multiple choice is a way to decrease the number of correct answers of a model.

Before statistically proving the hypotheses, we should pay attention to the average level of accuracy (see Table 2). All tests were run with a temperature equaling 1.[10]

Based on results of testing, we can conclude that GPT-4 did not create a serious competition for the GigaChat Pro model. In its current state, neither GigaChat Pro nor GPT-4 can be used for professional purposes without the supervision of a specialist (specific prompting, tuning, etc.). Both models are insufficiently stable and do not show a level above satisfactory - an overall low level is observed (no more than 50% of correct answers). This means that the possession of a theoretical basis (i.e. a broad and valid pre-training base with a stable significance of the subject core) is fundamentally important for further training of both models.

Moreover, as we can highlight the same low correlation of difficulty and taxonomy levels for GigaChat Pro as for the GPT-4. Below we prove that statistically.

Table 3 shows that at all levels of remembering, the best results are observed for all levels of difficulty. This means that for GigaChat Pro, ceteris paribus, it is not difficult to reproduce the theory. However, this does not allow it to "understand" the theory or successfully use it – this can be seen if we turn to the level of understanding and application. Moreover, the model has significant difficulties in understanding which theory to use in a particular case. When the model is tasked with applying the theory – without reflecting on the understanding of the correspondence of theory to practice – it copes generally better, although the gap is no more

[9] Pre-train is a stage of machine learning that consists in forming a knowledge base. The greatest difficulty lies in selecting the most useful information from the "infinite" stream of Internet data, where a paradox arises. On the one hand, if you train the model every time you make a new update to the dataset, this process will be too resource-intensive and slow. On the other hand, if training is carried out after accumulating a "critical array" of updates, the risks of incorrect training track and, as a consequence, a drop in the quality of generated answers increase. Therefore, working with pretrain is a peculiar art of balancing. Source: https://habr.com/ru/companies/yandex/articles/759306/, accessed 20.10.2024 (in Russian).

[10] Temperature is a fine-tuned randomness parameter for language model output, measured on a scale from 0 to 1. Lowering its value leads to predictable and "traditional" responses to the user's query. On the contrary, the higher the value of this indicator, the more creativity and variety should be expected in the output. For example, a lower temperature level can be used for factual responses, while an increase in temperature is useful for creative tasks. Source: https://learn.microsoft.com/ru-ru/ai-builder/prompt-modelsettings, accessed 21.10.2024 (in Russian).

Table 2. **Comparative Indicators of the Share of Correct Answers for the Tested Language Models (%)**

Model	CoT	Non-CoT
GigaChat Pro	34	38
GPT-4	45	46

Source: compiled by the authors

Table 3. **The Conjugacy of the Percentage of Correctly Completed Tasks of Different Difficulty Levels and Taxonomy for GigaChat Pro (share of right answers, %)**

Taxonomy/ Difficulty	Easy	Moderate	Difficult
To remember	44.8	37.1	40.3
To understand	43.3	34.0	31.7
To apply	41.9	33.6	33.7

Source: compiled by the authors

Table 4. **The Conjugacy of the Percentage of Correctly Completed Tasks of Different Difficulty Levels and Taxonomy for GPT-4 (share of right answers, %)**

Taxonomy/ Difficulty	Easy	Moderate	Difficult
To remember	54.4	46.4	45.8
To understand	52.7	44.5	40.8
To apply	49.2	45.3	44.3

Source: compiled by the authors

than 1.5% on average for the levels of application and understanding (in favor of application).

Thus, two significant conclusions can be drawn. In general, the low level of theory proficiency (less than 50%) does not allow the model to put into practice the knowledge that exists in the pre-training. A significant gap in the levels of "reproduction-application" means that the data available in the pretraining is simply not enough to apply them in professional or academic situations.

If the level of understanding is the most difficult for the model, then the model does not have relevant mechanisms to correlate a theory, but the relevant theory in the pre-train correlates it with the practical situation. This was the case for GigaChat Pro. For GPT-4, all patterns are the same (see Table 4).

As we state in Hypothesis 1, the number of parameters of models have a low elasticity regarding difficulty and taxonomy even when the right answer is obtained. Using the results of regression analysis (OLS model specification) we find that this hypothesis can be confirmed (see Model 1, Table 5). The dependent variable shows the status (right or wrong answer to a question), the covariates show the level of difficulty and taxonomy.

Table 5. **Model Parameters for Testing Hypothesis H1**

Dependent variable (status – 0/1)	GPT-4		GigaChat Pro	
	non CoT	CoT	non CoT	CoT
Intercept	0.52***	0.51***	0.45***	0.4***
Difficulty	-0.04***	-0.05***	-0.05***	-0.04***
Taxonomy	-0.01	-0.01	-0.02**	-0.01*
Observations	13225	13225	13225	13225
AIC	1.665e+04	1.665e+04	1.665e+04	1.665e+04
BIC	1.669e+04	1.669e+04	1.669e+04	1.669e+04

Note: Status: 0 — wrong answer; 1 — right answer. * — $p < 0.05$, ** — $p < 0.01$, *** — $p < 0.001$.

Source: compiled by the authors.

The intercepts, which show the general level of accuracy if the other parameters are equal to 0, for both models (with CoT and without) have no more than 11% of variance. It should be noted that the GPT-4 model has almost 2 trillion parameters while GigaChat Pro has only 40 billion. This highlights a plateau in the development of large language models by simply boosting the number of parameters and the insufficiency of such a technique for the professional improvement of models (the ability to solve professional problems).

For GPT-4, we can observe similar trends (see Table 4), only with the 5%-10% best results. Again, this result can be highlighted as a great prospect for GigaChat Pro, drawing attention to the great gap of hyperparameters numbers. Practically, this means that both models do not have mechanisms for comparing theory and practice yet, which is unacceptable for professional use in general. Moreover, for both models we can see that the results without CoT is better.

We also found that the relationship "difficulty vs the chance of answering correctly", although statistically significant, is insignificant – all other things being equal, an increase in the difficulty level only reduces the chance of answering correctly by 4%-5% for all models. The taxonomy factor is statistically significant only for GigaChat Pro, but the number is negligible (1%).

Test model 1 has the following formula:

$$Status_i = \beta_0 + \beta_1 * Difficulty_i + \beta_2 * Taxonomy_i + \epsilon_i \quad (1)$$

where: β – constant (the value of the equation provided that all variables are equal to 0); $Difficulty_i$ –difficulty level; $Taxonomy_i$ – taxonomy element; ϵ_i – standard error (deviation of the predicted value from the real value of the variable).

As we stated in the Hypothesis 2, models can have mistakes in as many easy tasks as difficult ones, also the same can be said for different taxonomies. We checked the hypothesis with Model 2 (Table 6).

$$Status_i = \beta_0 + \beta_1 * Difficulty_i + \beta_2 * Taxonomy_i + \beta_3 * (Difficulty_i * Taxonomy_i) + \epsilon_i \quad (2).$$

Table 6. **Model Parameters for Testing Hypothesis H2**

Dependent variable (status – 0/1)	GPT-4		GigaChat Pro	
	non CoT	GPT-4 CoT	non CoT	GigaChat Pro CoT
Intercept	0.54***	0.54***	0.47***	0.41***
Difficulty	-0.06***	–0.1***	–0.07***	–0.05***
Taxonomy	–0.03**	–0.03**	–0.03*	–0.02*
Difficulty* Taxonomy	0.02*	0.03**	0.02	0.01
Observations	13225	13225	13225	13225
AIC	1.665e+04	1.665e+04	1.665e+04	1.665e+04
BIC	1.669e+04	1.669e+04	1.669e+04	1.669e+04

Note: Status: 0 — wrong answer; 1 — right answer. * — p < 0.05, ** — p < 0.01, *** — p < 0.001.

Source: compiled by the authors.

Table 7. **Model Parameters for Testing Hypothesis H3**

Dependent variable (status – 0/1)	GPT–4		GigaChat Pro	
	non CoT	CoT	non CoT	CoT
Intercept	0.58***	0.61***	0.58***	0.47***
Difficulty	–0.05***	–0.07***	–0.05***	–0.04***
Taxonomy	–0.03**	–0.03**	–0.03**	–0.02*
Taxonomy* Difficulty	0.01	0.02**	0.01*	0.002
Multiple	–0.23***	–0.41***	–0.24***	–0.35***
Observations	13225	13225	13225	13225
AIC	1.665e+04	1.665e+04	1.665e+04	1.665e+04
BIC	1.669e+04	1.669e+04	1.669e+04	1.669e+04

Note: Status: 0 — wrong answer; 1 — right answer. * — p < 0.05, ** — p < 0.01, *** — p < 0.001.

Source: compiled by the authors.

As we see from Model 2 (the same specification as Model 1, but the interaction variable of taxonomy and difficulty was added), the interaction of taxonomy and difficulty is not significant. This means that for each question, ceteris paribus, there is a joint, but tiny influence of taxonomy and complexity, and it is positive (significant only for GPT-4). This may be a consequence of the fact that the level of understanding for a moderate level of complexity is the most problematic for the GPT-4 model to solve. Generally, the coefficients for GPT-4 being insignificant with regard to the joint effect of taxonomy and difficulty in GigaChat Pro allow us to confirm Hypothesis 2 and conclude that the models nowadays produce errors both in simplest questions where remembering is all that is necessary as well as the difficult prompts of applying or understanding (the process, the theory, etc.).

Table 8. **Results of Preliminary Testing of New Model Versions of GigaChat and GPT-4**

Language model (testing mode)	Share of right answers	Share growth in relation to previous versions
GigaChat MAX (non-CoT)	49%	+10% to GigaChat Pro
GPT-4o1 (non-CoT)	51%	+5% to GPT-4

Source: compiled by the authors

Finally, the Hypothesis 3 states that multiple choice prompts significantly decrease the number of correct answers of a model (Table 7).

$$Status_i = \beta_0 + \beta_1 * Difficulty_i + \beta_2 * Taxonomy_i + \beta_3 * (Difficulty_i * Taxonomy_i) + \beta_4 * Multiple_i + \epsilon_i \quad (3),$$

where $Multiple_i$ is the factor of multiple choice.

Model 3 shows a statistically significant and negative relationship between the multiple-choice factor and the likelihood of answering correctly for all models. The coefficient indicates that the previously stated assumption that the model copes worse with multiple choice produces error rates between 23% and 41%, while the GigaChat Pro copes better than the GPT-4 using CoT. Interestingly, including the factor of multiple-choice means that GPT-4 starts performing better with the CoT than without. This can be explained by the fact that GPT-4 performs better with simple operations and CoT helps it. The corollary of this is the fact that the more diverse task is, the worst results we get. On the contrary, a strong professional should and must deal with complex situations.

While this article was being written, new models were released – GPT-4o1 and GigaChat MAX. We did therefore run our test using these versions as well (Table 8).

We can only prove our hypothesis about the potential of the smaller model (in this case GigaChat) to more significantly.

Conclusion

This article illustrates the current quality of GenAI. In fact, such models as GPT-4 and GigaChat can be successfully used for translating, summarizing, content-making for non-professional tasks. However, today's models definitely need a supervisor, and they are not ready to go beyond the co-pilot in use. We see that the models are mistaken in the core of knowledge, imitating the behavior of Ostap Bender[11], they "adapt" to the context, without highlighting the scientific truth. Imagine that you have hired a law assistant who makes unpredictable mistakes in interpreting Constitutional provisions, an economist who cannot calculate the Pareto optimum, or a teacher's assistant who cannot distinguish tutoring from developmental teaching methods. At the same time, you do not know exactly where

[11] Ostap Bender is the hero of I. Ilf and E. Petrov's novel The Twelve Chairs. Ostap Bender is the hero of the novel "The Twelve Chairs" by Ilf and Petrov, characterized by his ability to over-invent, adjust to any interlocutor, and reproduce false facts. In foreign literature, the closest analog of such a character can be considered Baron Munchausen.

your assistant will have fewer mistakes: in light routine tasks or complex applied ones. All you know is that these errors will occur. And these errors will be, strictly speaking, regardless of the level of general "knowledge" of the assistant.

These conclusions were confirmed by three regression models in this paper and found additional validation on the primary results of the new GPT-o1 and GigaChat MAX models. We would especially like to emphasize that increasing the parameters of the model has a negligible effect on the ability of the model to perform professional tasks. We believe that a new word in the development of generative artificial intelligence lies in the orchestration of models (Zhou et al., 2024), in the use of knowledge graphs to increase connectivity of knowledge an imitate the human cognition (Jin et al., 2023; Zhu et al., 2024; Wen et al., 2023; Yang et al., 2023) and in what can be called the development of special glossaries (what brings the terminology of the core of knowledge into a clear form for LLMs), but these are prospects for description in future publications.

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References

Alimardani A. (2024) Generative artificial intelligence vs. law students: An empirical study on criminal law exam performance. *Law, Innovation and Technology*, 2392932, 1–43. https://doi.org/10.1080/17579961.2024.2392932

Al-Zahrani A., Alasmari T. (2024) Exploring the impact of artificial intelligence on higher education: The dynamics of ethical, social, and educational implications. *Humanities and Social Sciences Communications*, 11(1), 912. https://doi.org/10.1057/s41599-024-03432-4

Al-Zahrani A.M. (2024) From Traditionalism to Algorithms: Embracing Artificial Intelligence for Effective University Teaching and Learning. *IgMin Research*, 2(2), 102–112. https://doi.org/10.61927/igmin151

Anthis J., Lum K., Ekstrand M., Feller A., D'Amour A., Tan C. (2024) *The impossibility of fair LLMs* (ArXiv paper 2406.03198). https://doi.org/10.48550/arXiv.2406.03198

Antoniak S., Krutul M., Pióro M., Krajewski J., Ludziejewski J., Ciebiera K., Król K., Odrzygóźdź T., Cygan M., Jaszczur S. (2023) *Mixture of Tokens: Continuous MoE through Cross-Example Aggregation* (ArXiv paper 2310.15961). https://doi.org/10.48550/arXiv.2310.15961

Bloom B.S., Engelhart M.D., Furst E.J., Hill W.H., Krathwohl D.R. (1956) *Taxonomy of Educational Objectives: The Classification of Educational Goals* (Handbook 1: Cognitive Domain), Ann Arbor, MI: Edwards Bros.

Borji A. (2023) *A categorical archive of Chat GPT failures* (ArXiv paper 2302.03494) https://doi.org/10.48550/arXiv.2302.03494

Cai W., Jiang J., Wang F., Tang J., Kim S., Huang J. (2024) *A Survey on Mixture of Experts* (ArXiv paper 2407.06204). https://doi.org/10.48550/arXiv.2407.06204

Chen Y., Esmaeilzadeh P. (2024) Generative AI in Medical Practice: In-Depth Exploration of Privacy and Security Challenges. *Journal of Medical Internet Research*, 26, e53008. https://doi.org/10.2196/53008

Cheung M. (2024) *A Reality check of the benefits of LLM in business* (ArXiv paper 2406.10249). https://doi.org/10.48550/arXiv.2406.10249

Choi J., Palumbo N., Chalasani P., Engelhard M.M., Jha S., Kumar A., Page D. (2024) *MALADE: Orchestration of LLM-powered Agents with Retrieval Augmented Generation for Pharmacovigilance* (ArXiv paper 2408.01869). https://doi.org/10.48550/arXiv.2408.01869

Chu H.C., Hwang G.H., Tu Y.F., Yang K.H. (2022) Roles and research trends of artificial intelligence in higher education: A systematic review of the top 50 most-cited articles. *Australasian Journal of Educational Technology*, 38(3), 22–42.

Dai C-P, Ke F. (2022) Educational applications of artificial intelligence in simulation-based learning: A systematic mapping review. *Computers and Education: Artificial Intelligence*, 3, 100087. https://doi.org/10.1016/j.caeai. 2022.100087

Gill S.S., Xu M., Patros P., Wu H., Kaur R., Kaur K., Fuller S., Singh M., Arora P., Kumar A.P., Stankovski V., Abraham A., Ghosh S.K., Lutfiyya H., Kanhere S.S., Bahsoon R., Rana O., Dustdar S., Sakellariou R., Uhlig S., Buyya R. (2023) Transformative Effects of ChatGPT on Modern Education: Emerging Era of AI Chatbots. *Internet of Things and Cyber-Physical Systems*, 4, 19–23. https://doi.org/10.1016/j.iotcps.2023.06.002

Han S.J., Ransom K.J., Perfors A., Kemp C. (2023) Inductive reasoning in humans and large language models. *Cognitive Systems Research,* 83, 1–28. https://doi.org/10.1016/j.cogsys.2023.101155

Hassan R., Ali A., Howe C.W., Zin A.M. (2022) Constructive alignment by implementing design thinking approach in artificial intelligence course: Learners' experience. *AIP Conference Proceedings*, 2433(1), 0072986. https://doi.org/10.1063/5.0072986

Hendrycks D., Burns C., Basart S., Zou A., Mazeika M., Song D., Steinhardt J. (2020) Measuring Massive Multitask Language Understanding (ArXiv paper 2009.03300). https://doi.org/10.48550/arXiv.2009.03300

HSE (2024) *Training of highly qualified personnel in the field of artificial intelligence* (ed. L.M. Gokhberg), Moscow: HSE University (in Russian).

IDC (2024) *The Global Impact of Artificial Intelligence on the Economy and Jobs*, Needham, MA: IDC Corporate.

Jin B., Liu G., Han C., Jiang M., Ji H., Han J. (2023) *Large Language Models on Graphs: A Comprehensive Survey* (ArXiv paper 2312.02783). https://doi.org/10.48550/arXiv.2312.02783

Kardanova E., Ivanova A., Tarasova K., Pashchenko T., Tikhoniuk A., Yusupova E., Kasprzhak A.G., Kuzminov Y., Kruchinskaia E., Brun I. (2024) *A Novel Psychometrics-Based Approach to Developing Professional Competency Benchmark for Large Language Models* (arXiv paper 2411.00045). https://doi.org/10.48550/arXiv.2411.00045

Kuhn T.S. (1977) *The Essential Tension*, Chicago: University of Chicago Press.

Lai J., Gan W., Wu J., Qi Z., Yu P.S. (2023) *Large Language Models in Law: A Survey* (ArXiv paper 2312.03718). https://doi.org/10.48550/arXiv.2312.03718
Lakatos I. (1963) Proofs and Refutations (I). *British Journal for the Philosophy of Science,* 14(53), 1–25.
Lakatos I. (1970a) Falsification and the Methodology of Scientific Research Programmes. In: *Criticism and the Growth of Knowledge* (eds. I. Lakatos, A. Musgrave), Aberdeen: Cambridge University Press, pp. 91–195.
Lakatos I. (1970b) History of Science and Its Rational Reconstructions. *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association*, pp. 91–136.
Liang L., Sun M., Gui Z. et al. (2024) KAG: Boosting LLMs in Professional Domains via Knowledge Augmented Generation. ArXiv paper 2409.13731, 1–33. https://doi.org/10.48550/arXiv.2409.13731
Liu N.F., Lin K., Hewitt J., Paranjape A., Bevilacqua M., Petroni F., Liang P. (2023) *Lost in the Middle: How language models use long contexts* (ArXiv paper 2307.03172). https://doi.org/10.48550/arXiv.2307.03172
Luo L., Li Y.F., Haffari G., Pan S. (2023) *Reasoning on Graphs: Faithful and Interpretable Large Language Model Reasoning* (ArXiv paper 2310.01061). https://doi.org/10.48550/arXiv.2310.01061
McKnight M.A., Gilstrap C.M., Gilstrap C.A., Bacic D., Shemroske K., Srivastava S. (2024) Generative Artificial Intelligence in Applied Business Contexts: A systematic review, lexical analysis, and research framework. *Journal of Applied Business and Economics*, 26(2), 7040. https://doi.org/10.33423/jabe.v26i2.7040
Mirzadeh I., Alizadeh K., Shahrokhi H., Tuzel O., Bengio S., Farajtabar M. (2024) *GSM-Symbolic: Understanding the limitations of mathematical reasoning in large language models* (ArXiv paper 2410.05229). https://doi.org/10.48550/arXiv.2410.05229
Mortlock R., Lucas C. (2024) Generative artificial intelligence (Gen-AI) in pharmacy education: Utilization and implications for academic integrity: A scoping review. *Exploratory Research in Clinical and Social Pharmacy,* 15, 100481. https://doi.org/10.1016/j.rcsop.2024.100481
Naveed H., Khan A.U., Qiu S., Saqib M., Anwar S., Usman M., Akhtar N., Barnes N., Mian A. (2023) *A comprehensive overview of large language models* (ArXiv paper 2307.06435). https://doi.org/10.48550/arXiv.2307.06435
Nguyen H., Fungwacharakorn W., Satoh K. (2023) *Enhancing logical reasoning in large language models to facilitate legal applications* (ArXiv paper 2311.13095). https://doi.org/10.48550/arXiv.2311.13095
Noever D., Ciolino M. (2023) *Professional Certification Benchmark Dataset: The first 500 jobs for large language models* (ArXiv 2305.05377). https://doi.org/10.48550/arXiv.2305.05377
OECD (2024) *OECD Economic Outlook* (Interim Report, September 2024), Paris: OECD.
Ogunleye B., Zakariyyah K.I., Ajao O., Olayinka O., Sharma H. (2024) A Systematic Review of Generative AI for Teaching and Learning practice. *Education Sciences*, 14(6), 14060636. https://doi.org/10.3390/educsci14060636
ORR (2023) *Rail industry finance (UK): April 2022 to March 2023,* London: Office of Rail and Road.
Rasal S., Hauer E.J. (2024) Navigating Complexity: Orchestrated Problem Solving with Multi-Agent LLMs (ArXiv paper 2402.16713). https://doi.org/10.48550/arXiv.2402.16713
Sanmartin D. (2024) *KG-RAG: Bridging the gap between knowledge and creativity* (ArXiv paper 2405.12035). https://doi.org/10.48550/arXiv.2405.12035
Shapira E., Madmon O., Reichart R., Tennenholtz M. (2024) *Can LLMs replace economic choice prediction labs? The case of language-based persuasion games* (ArXiv paper 2401.17435). https://doi.org/10.48550/arXiv.2401.17435
Sohail S.S., Faiza Farhat F., Himeur Y., Nadeem M., Madsen D.O., Singh Y., Atalla S., Mansoor W.. (2023) Decoding ChatGPT: A taxonomy of existing research, current challenges, and possible future directions. *Journal of King Saud University – Computer and Information Sciences*, 35(8). https://doi.org/10.1016/j.jksuci.2023.101675
Strachan J., Albergo D., Borghini G., Pansardi O., Scaliti E., Gupta S., Saxena K., Rufo A., Panzeri S., Manzi G., Graziano M.S.A., Becchiol C. (2024) Testing theory of mind in large language models and humans. *Nature Human Behaviour,* 8(7), 1285–1295. https://doi.org/10.1038/s41562-024-01882-z
Sun J., Xu C., Tang L., Wang S., Lin C., Gong Y., Ni L.M., Shum H.Y., Guo J. (2023) *Think-on-Graph: Deep and responsible reasoning of large language model on knowledge graph* (ArXiv paper 2307.07697). https://doi.org/10.48550/arXiv.2307.07697
Thomson Reuters (2024) *2024 Generative AI in Professional Services*, Toronto: Thomson Reuters Institute.
Turnock D. (1998) *An Historical Geography of Railways in Great Britain and Ireland* (1st ed), New York: Routledge.
Wan Y., Wang W., Yang Y., Yuan Y., Huang J., He P., Jiao W., Lyu M.R. (2024) $A \wedge B \Leftrightarrow B \wedge A$: *Triggering logical reasoning failures in large language models* (ArXiv paper 2401.00757). https://doi.org/10.48550/arXiv.2401.00757
Wang Y., Ma X., Zhang G., Ni Y., Chandra A., Guo S., Ren W., Arulraj A., He X., Jiang Z., Li T., Ku M., Wang K., Zhuang A., Fan R., Yue X., Chen W. (2024) *MMLU-Pro: A more robust and challenging Multi-Task Language Understanding benchmark* (ArXiv paper 2406.01574). https://doi.org/10.48550/arXiv.2406.01574
Wei J., Wang X., Schuurmans D., Bosma M., Ichter B., Xia F., Ed H., Quoc C.V., Zhou L.D. (2022) *Chain-of-Thought Prompting Elicits Reasoning in Large Language Models* (ArXiv paper 2201.11903). https://doi.org/10.48550/arXiv.2201.11903
Wen Y., Wang Z., Sun J. (2023) *MindMap: Knowledge Graph prompting sparks graph of thoughts in large language models* (ArXiv paper 2308.09729). https://doi.org/10.48550/arXiv.2308.09729
Xu Z., Cruz M.J., Guevara M., Wang T., Deshpande M., Wang X., Li Z. (2024) *Retrieval-Augmented Generation with Knowledge Graphs for Customer Service Question Answering* (ArXiv paper 2404.17723). https://doi.org/10.48550/arXiv.2404.17723
Yang L., Chen H., Li Z., Ding X., Wu X. (2023) *Give Us the Facts: Enhancing Large Language Models with Knowledge Graphs for Fact-aware Language Modeling* (ArXiv paper 2306.11489). https://doi.org/10.48550/arXiv.2306.11489
Zhang Y., Ding H., Shui Z., Ma Y., Zou J., Deoras A., Wang H. (2021) *Language models as recommender systems: Evaluations and limitations*. Paper presented at the NeurIPS 2021 Workshop on I (Still) Can't Believe It's Not Better.
Zhang Y., Sun R., Chen Y., Pfister T., Zhang R., Arik S.O. (2024) *Chain of Agents: Large language models collaborating on Long-Context Tasks* (ArXiv paper 2406.02818). https://doi.org/10.48550/arXiv.2406.02818
Zhong Z., Xia M., Chen S., Lewis M. (2024) *Lory: Fully Differentiable Mixture-of-Experts for Autoregressive Language Model Pre-training* (ArXiv paper 2405.03133). https://doi.org/10.48550/arXiv.2405.03133
Zhou J.P., Luo K.Z., Gu J., Yuan J., Weinberger K.Q., Sun W. (2024) *Orchestrating LLMs with Different Personalizations* (ArXiv paper 2407.04181). https://doi.org/10.48550/arXiv.2407.04181
Zhu Y., Wang X., Chen J., Qiao S., Ou Y., Yao Y., Deng S., Chen H., Zhang N. (2023) *LLMS for Knowledge Graph Construction and Reasoning: Recent Capabilities and Future Opportunities* (ArXiv paper 2305.13168). https://doi.org/10.48550/arXiv.2305.13168

Applying the Industry 4.0 Maturity Models to the Aerospace Sector

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Abstract

The aerospace industry is a sector with primary demand for mastering cutting-edge technologies and innovations. It has the potential to pull other sectors to previously unattainable levels. Its current transformations and emerging new vectors are of key importance for a wide range of areas in the economy and society. Currently, companies in this sector are faced with the challenges of mastering Industry 4.0 technologies. The article examines the main trends and technological achievements in the global aerospace industry. Based on the presented picture, the authors propose an adapted model for assessing the technological maturity of the aerospace sector, tested on the example of Brazil. Pilot testing of the companies included in it, using this model, showed that for most of the aspects considered, the level of technological readiness does not exceed the second (with a scale of five levels), and this is despite the fact that the products of the Brazilian aerospace sector are in high demand in many countries, including developed ones. The presented model can be adapted to assess the technological maturity of other sectors of the economy.

Keywords: global value chain transformation; innovation; aerospace industry; technological transformation; Industry 4.0; manufacturing technologies; technological maturity; national sectoral innovation systems

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Introduction

The aerospace sector a priori applies to those strategic, high-tech industries which, on the one hand, are drivers of scientific and technological progress, and on the other hand, make a significant contribution to increasing the mobility of society. The industry consists of three main industrial segments: the aviation industry (produces airplanes and helicopters), the space industry (creates space platforms, spacecraft, provides related services), and the defense industry (produces missiles, combat aircraft and works with other aviation and space technologies related to the military sphere). Its most characteristic feature is that the technologies, products, and processes are highly complex, while the military segment is usually ahead of the civilian segment in terms of the level of innovation (Bravo-Mosquera et al., 2022).

In recent years, this area has been developing dynamically, the developing market opens many opportunities that both investors and professionals respond to. There is an increased interest in the development of companies specializing in satellite technologies. The main focus is on the production of compact devices that can comprehensively analyze the Earth's surface, provide communications between highly protected servers, the operation of the global Internet of Things, and broadband communications for civil and military purposes.[1] Digital technologies are radically transforming production and industry models, changing the ways of providing services.

According to a Deloitte study on Industry 4.0, 84% of aerospace and defense executives are considering the new generation of digital technologies as one of the significant forces for achieving competitive advantages.[2] To study their transformation potential and the industry's readiness to master them, we apply a tool – an assessment of technological maturity (*technology maturity)*.

Based on this, we set out to explore existing methods for assessing technological maturity in the context of Industry 4.0. Using the example of the Brazilian aerospace sector, we demonstrate the model we have developed – the process of its formation, structure, and content. Current maturity models are poorly suited to a rapidly changing and increasingly complex context, as they are primarily theoretically focused, making them inflexible and unable to offer effective solutions to the problems at hand (Barata, Cunha, 2017).

After a comprehensive overview of technological trends in the global aerospace sector, we move on to describe the Brazilian context and then present a technological maturity model.

The Soft Transformation of the Global Aerospace Industry

To describe the evolution in the sector under consideration, we can use the term soft transformation, which, of course, does not exclude high levels of complexity and stress. A favorable, dynamic climate results from a successful combination of various factors: past developments, constant and growing demand for services and products, and orders for innovations. Large-scale investments (both public and private) are concentrated here, high standards of personnel, products and services training are observed, and innovations are continuously introduced and are aimed at increasing the efficiency of the sector, both in the production of products and in its management.

The aforementioned aspects, on the one hand, determine the relative well-being of the industry and increase its potential, and on the other hand, "make it feasible" only for a few countries.[3] Largely due to research and development (R&D), which, by definition, requires both a historical and competence-based background, namely, a solid scientific base. However, this does not mean that the industry does not face serious challenges.

The aerospace industry is becoming increasingly knowledge-intensive, with rising costs for specialization (Gkotsis, Vezzani, 2022). Patents, know-how, and new knowledge are driving the transformation of the sector, increasing the competitiveness of its companies. According to Deloitte, in 2023, the aerospace industry saw continued strong demand for products, particularly for new aircraft, due to the increase in transportation (Deloitte, 2024). In comparison to many sectors, the aerospace industry showed sustained positive dynamics (World Bank, 2020). The value of aerospace intermediate good exports grew by about 6% per year, increasing over the period from $272 billion in 2007 to about $536 billion in 2018. (Caliari et al., 2023).

The composition of the exported goods has also changed as the importance of intermediate production phases (particularly pre-assembly) has grown relative to the final goods. This trend reflects the fact that countries other than those where the main contractors are located are increasingly involved in aerospace value chains and can use their innovation and manufacturing capabilities to get closer to final markets.

Companies are able to maintain their leading positions by relying on economies of scale and intensive investments in R&D . Table 1 lists the main players in the aerospace industry according to their turnover.

Most of the companies are based in the US and Europe, with some of their activities related to the defense sec-

[1] https://www.boyden.com/media/aerospace-and-defense-industry-outlook-perspectives-on-future-6979750/, accessed 21.05.2024.

[2] https://www2.deloitte.com/th/en/pages/financial-services/articles/the-industry-4-paradoxes-the-challenge-of-digital-transformation-en.html, accessed 18.06.2024.

[3] The key players in the aerospace industry are related, first of all, to G7 countries (USA, Japan, Germany, France, United Kingdom, Canada, Italy) as well as China and Russia..

Table 1. **Major Players in the Global Aerospace Industry in 2020**

Company	Country	Annual turnover (million dollars)	Number of employees	Investments in R&D (million dollars)	R&D intensity (%)***
Lockheed Martin Corp.	USA	65 398.0	114 000	1157.2	1.8
Airbus	EU	61 409.0	131 349	3491.0	5.7
Boeing Company	USA	58 656.0	141 000	2674.9	4.6
Raytheon Technologies Corp.	USA	56,587.0	181 000	2683.8	4.7
General Dynamics Corp.	USA	37 925.0	100 700	414.8	1.1
China ASIC Limited **	China	37 075.2	–	–	–
Northrop Grumman Corp.	USA	36 799.0	97 000	–	–
Honeywell International Inc	USA	32 637.0	103 000	–	–
Bae Systems Plc	United Kingdom	26 161.0	81 000	283.8	1.1
Safran	France	21 635.0	78 892	1171.0	5.4
Thales	France	20 908.5	80 702	918.6	4.4
Leonardo SPA	Italy	17 060.4	49 882	1496.0	8.8
Rolls-Royce Holdings Plc	United Kingdom	15 867.8	48 200	1305.8	8.2
Bombardier Inc	Canada	15 462.0	16 000	387.2	2.5
Parker Hannifin Corp.*	USA	14 347.6	54 640	–	–
Avic Airborne System Co. Ltd.**	China	13 496.0	–	137.7	1.0
Textron Inc	USA	11 651.0	33 000	575.9	4.9
L3 Technologies Inc **	USA	10 244.0	31 000	–	–
Almaz-Antey**	Russia	9657.0	–	–	–
Huntington Ingalls Industries **	USA	8899.0	–	–	–

Note: Due to data availability, turnover figures may refer to 2021 (*) or 2019 (**). *** - R&D Intensity calculates as share of R&D investments in total annual turnover.

Source: authors, adapted from (Caliari et al., 2023).

tor. Airbus, Boeing, and Raytheon Technologies Corporation significantly exceed $2 billion in annual R&D investments. The national innovation system is an important asset in developing productsion capacities in this industry (Alberti, Pizzurno, 2015). Improving national capabilities is often seen as a government-oriented strategy, with governments committed to science and innovation (Lee, Yoon, 2015) and using industrial policies based on subsidies and public procurement (McGuire, 2014). The intellectual property factor is of high importance for the formation of national production as well as scientific and technological potential. The previously noted positive industry dynamics are reflected in the increase in the number of patents filed. Thus, during the period under review, according to statistics from the US Patent Office (US Patents and Trademarks Office) it grew fourfold (from 2,225 to 9,494). At the same time, the number of patent applications increased by about 20%, and the number of countries of origin of the applicants increased from 36 to 63 (Caliari et al., 2023).

Despite the described positive dynamics of demand, it is becoming increasingly difficult to meet it. One of the limiting factors is the shortage of highly qualified specialists capable of working with great complexity, both in the technological and managerial dimensions. Therefore, aerospace companies are in fierce competition with other industries for valuable personnel.

Another factor is the increasing complexity and vulnerability of supply chains.

The Changing Nature of the Aerospace Supply Chain

The aerospace industry is a high value-added sector, characterized by the strong role of national governments, linked to issues of sovereignty and efforts to implement strategies to promote industrial and technological capabilities. This is complicated by the fact that many different technologies contribute to the final products (Landoni, Ogilvie, 2019). The different stages of production in the aerospace industry are usually characterized by a multi-tiered supply chain structure.

Moving down the value chain, products exhibit a higher degree of technological content, become more industry-specific, and require greater innovation capabilities as well as closer relationships with leading companies. From a relatively low level of complexity to an intermediate level, which consists of integrating different components into subsystems, which in turn are used by primary contractors to produce the final products.

The relationship between countries' competitiveness and innovation systems depends largely on the product, but innovation capabilities generally become increasingly important as one moves along the value chain from basic components to final products embodying different technologies. The positioning of countries along the value chain is more closely related to the strength of the innovation system. There is a positive relationship between qualitative advantages in the innovation system and participation in the most sophisticated and valuable segments of the aerospace

value chain. Countries that are better positioned to export products at the lower end of the supply chain (closer to the market) also have more developed and high-quality IP.

In terms of challenges for all industry segments, the most unifying one is the unprecedentedly complex and turbulent reconfiguration of global supply chains, making the implementation of diversification and transparency in the chain extremely problematic, but necessary.

These are points of vulnerability where delays in the delivery of necessary resources, slowdowns in production, higher prices for materials, and so on can potentially occur. Turbulence is observed at all stages of the chain - from raw material suppliers to manufacturers of equipment, semiconductors, microelectronics, and other key components. The search for raw materials, especially for rare earth minerals - a key component of electronics, is a unique problem, since their reserves are concentrated in only a few countries. There is no short-term alternative to them, most likely, this will only become possible in the distant future. Thus, enterprises are required to be especially insightful, inventive, and flexible in order to combine current developments with emerging ones, build up a strategic resource base for the production of critical products, and participate in the creation of new supply chain options. Recently, a new model of cross-border production relations has emerged – friendshoring.[4] In such conditions, companies can take an advantageous position in the supply chain, provided that they maintain strategic reserves of raw materials, ensure bulk purchases of goods with long lead times, and explore alternative supply channels.

Participation in global alliances provides opportunities for large aerospace companies to reduce production costs, fully utilize partners' technologies, and optimally allocate resources in favor of focusing on high-value-added production segments such as aircraft design, assembly, and marketing (Bamber et al., 2016; Niosi, Zhegu, 2005; 2010). The authors of the article (Caliari et al., 2023) analyzed the participation of countries at different stages of the value chain using data on the exports of products of different levels of complexity, as well as the effectiveness of their innovation systems, based on statistics about patents registered in the United States. Data on 38 countries for the period 2007–2018 were analyzed. A close relationship was found between the strength and sophistication of the innovation system and involvement in supply chains, and patterns of specialization of countries at different stages were traced. At the stages with high added value in the chains, there are countries whose innovation systems rely on the diversity and high quality of products, rather than on production intensity and quantitative indicators. Therefore, to maintain competitiveness, countries must make a greater contribution to the modernization of supply chains by improving their innovation systems, integrating different actors into it, and diversifying the knowledge base.

Key contractors are increasingly focusing on their core competencies, delegating *greater* responsibility to large suppliers to share risks with corresponding revenue distribution. The bulk of secondary functions are delegated to participants at lower levels of the supply chain, producing less complex products. Such a management structure allows for the organic linking of different stages in order of ascending added value. Key contractors operate at all stages of the chain, from R&D and design to providing high-level after-sales service.

"Low complexity" companies design parts for after-sales replacement, while "high complexity" manufacturing plants located closer to the end user place orders for them (Caliari et al., 2022).

The more complex the level of production, the greater is the contribution of the company to the creation of added value. This is also an indicator of the changed nature of aerospace value chains, where the traditional vertically integrated and geographically localized structures are being replaced by a specialization model with a translocal hierarchical structure, distributed along the links of the supply chain (Turkina et al., 2016).

The relationship between innovation and participation in value chains has two main characteristics: the importance of differentiated intellectual property (diversification among actors and technologies) and the role of prime contractors (Niosi, Zhegu, 2010). The industry relies on a system of scientific and technological organizations with different and complementary capabilities, as well as on the leadership of prime contractors, with traditionally key contributions from nation states.

The most successful countries tend to combine prime contractors and a strong innovation system, with strong public policy support. The United States, France, and Germany combine prime contractors and a large number of companies operating at high complexity levels (Landoni, Ogilvie, 2019; Robinson, Mazzucato, 2019). A counter-example is Brazil, which, despite having a world-class prime contractor (Embraer), has failed to use economies of scale and scope to develop a network of globally competitive local suppliers and strengthen its innovation system (Caliari, Ferreira, 2022). For countries specializing in sub-assemblies, the options for entering more complex global value chain (GVC) segments may be different. When the development of an innovation system is too complex, the capabilities offered to suppliers from GVCs can be decisive (Cooke, Ehret, 2009; Rebolledo, Nollet, 2011). However, the risk of lock-in at low GVC stages should be avoided. Mexico, Morocco, and the Philippines have managed

[4] Friendshoring is the practice of limiting the reach of supply chain networks to allies and friendly countries in order to minimize potential threats to business processes.

to achieve a relevant international position at the subassembly stage, but they have not developed technological capabilities at the same pace; this hinders their further improvement (Bamber et al., 2016).

Singapore has built competitive advantages in both components and subassemblies, coupled with significant growth in its industry-specific technological capabilities, putting the country in a stronger position in the aerospace sector.

It appears that the real challenge for developing countries that have established themselves in the production of low-complexity products through the fragmentation of aerospace value chains is to improve their technological capabilities to enter more complex stages of the value chain. Government policies should both guarantee access to the potential offered by participation in the chains and improve local capabilities. This, in turn, may impact IP through local suppliers' demand for an improved system (Lema et al ., 2019). The hierarchical governance structure of this industry is dominated by leading companies that maintain stable control over the value chain and its knowledge flows.

Technologies and Materials

Technologies. Among the industry's digital management technologies, digital twins are becoming increasingly popular, making processes occurring in supply chains as transparent and predictable as possible. This, in turn, optimizes production at all stages, increasing efficiency and quality standards. Digital twins can also be used to track the operation of parts and mechanisms throughout their entire service life.

Other important areas are the creation of engines that run on alternative fuels as well as supersonic and hypersonic aircraft. To solve these problems, it is extremely important to develop new materials that will reduce the weight of aircraft, which will reduce fuel consumption and increase overall strength.

In the defense segment, new geopolitical challenges and the task of modernizing the technical base have driven demand for next-generation innovations. For example, the United States is developing new-generation fighters based on adaptive engine technology. The possibilities of ensuring silent flight at supersonic speeds by reducing the intensity of the sonic boom are being studied. However, so far, these developments are only at an early stage. In addition to supersonic aircraft, the demand for defensive hypersonic technologies is growing. Due to the accelerating digitalization of the entire industry, cybersecurity issues are becoming increasingly relevant.

Materials. Aerospace product design today is dominated by high-strength composites and alloys of titanium, aluminum, steel, and carbon-reinforced polymers. These materials have advanced the industry in many ways. Their use allows aircraft to be lighter, save fuel, and carry more passengers and cargo, reduce noise and vibration, and improve thermal insulation. Modern composite materials are at the forefront of aerospace innovation. Research in this area is aimed at creating new composites with improved properties that promise super-strength, flexibility, and resistance to extreme conditions.

Additive manufacturing (3D printing) has become a radical innovation that facilitates the production of parts of particularly complex shapes compared to traditional technologies. At the same time, the total time and number of iterations of the production process are reduced many times over, and resources are saved.[5]

Another transformative direction for the sector is the use of "smart" materials. Their production actively uses bio-imitation principles, that is, the reproduction of the properties of various natural structures. They have the potential for self-healing, adaptation to changing weather conditions and increased functionality. Numerous sensors are built into them, allowing for the monitoring of structural integrity, stress, temperature, and other critical parameters of aircraft components in real time.

New technologies are paving the way for the industry to reach a new level. The fusion of smart materials and breakthrough technologies is taking the aerospace industry into areas of innovation previously thought unachievable. Artificial intelligence (AI) and machine learning have penetrated deep into the aerospace industry, analyzing massive amounts of data and running complex simulations to identify the most efficient design options.

Thus, it can be said that the industry in question has made significant progress in recent decades, largely due to progress and innovation in the field of structural and engine materials.

Space Business

The picture would not be complete without mentioning the main areas in the aerospace industry, where new companies are most actively created. More than 60,000 patents, over 10,000 implemented R&D grant projects[6], and high investment activity is noted. The largest investors are Fidelity, Geely, and BlackRock. Companies are developing reusable launch vehicles to further reduce the cost of launching rockets. An increase in space travel is expected, in connection with which the relevance of space traffic management systems and the development of clearing services in near-Earth space will increase. For example, a joint project Slingshot is being implemented in this area. The Defense Advanced Research Projects Agency (DARPA) is devel-

[5] For example, the General Electric plant in Brazil has managed to reduce the manufacturing process for some parts from two months to one day.

[6] https://www.startus-insights.com/innovators-guide/spacetech-startups/, accessed 16.07.2024.

oping a new system for detecting anomalous satellites.[7] Its task will be to serve several large satellite constellations of more than 10,000 spacecraft being formed by international government and commercial space operators. The system will be built on machine learning technologies based on more than 60 years of data. The system is highly adaptable and scalable, which gives it a wide range of potential applications outside the space industry, such as genomics, biomedicine, agriculture, and utility management. New space communication systems based on laser and quantum technologies are also being developed, providing higher data rates and better data security compared to traditional radio frequency systems.

Aerospace Industry in Brazil

Brazil is one of the few countries with a developed aerospace industry with strong potential, which is of strategic importance to the national economy. It creates jobs, stimulates R&D, and generates export earnings, which significantly contributes to economic growth and strengthens national security. This sector catalyzes innovation and high-value-added production, increasing Brazil's competitiveness in the global aerospace sector.

Leading national aerospace company Embraer (Empresa Brazil de Aeronáutica) is one of the world's leading manufacturers of regional aircraft, producing a variety of commercial, military, and utility aircraft, including the popular E-Jet series. Military aircraft (the AMX fighter and the super turboprop aircraft Tucano) are exported even to developed countries.[8] The national space program focuses on satellite development, space research, remote sensing, and telecommunications.

The Brazilian aerospace science and technology complex plays a decisive role in the development of the sector. The innovative ecosystem formed around it includes the following actors: the government, the army, the defense industry, funding and educational institutions, and accreditation bodies (Reis et al., 2021).

For example, in 2023, the Brazilian Ministry of Science, Technology and Innovation allocated BRL 1B from the National Fund for Scientific and Technological Development for five priority innovative initiatives to develop new satellites, with the participation of local universities and research institutes.[9]

It is planned build the Aerospace Technology Park to stimulate the innovative industry system. It will operate in four key areas: space, defense, aeromobility, and commercial aeronautics. In particular, the following sub-areas will be implemented: advanced flight and air traffic control systems, aerospace engineering systems, new energy and propulsion technologies, and aerospace cybersecurity.[10]

Close partnerships at two levels contribute to the development of innovation: nationally – between universities, research institutes, and industry, and internationally – in inter-country aerospace programs.

Brazil has managed to build a robust supply chain to support its aerospace industry, including the production of components and systems, which will allow it to fully exploit its potential in the coming years, in particular in expanding its market share in regional aircraft, leveraging its expertise in military aviation and exploring advances in space technology.

Development of a Technological Maturity Model

The presented literature review contains a sufficient knowledge base for the development of a technological maturity model in Industry 4.0 and its adaptation to the Brazilian aerospace sector.[11] The concept of "maturity" is characterized by a quantitative assessment and the assignment of a certain status in the development of a particular technology in terms of its applicability in the sector under consideration and the degree of integration into the industry strategy (Figure 1).[12]

In Figure 2, the relationship between the Industry 4.0 concept, maturity models, and the aerospace sector is reflected. The overlapping circles are the location of the proposed method, reflecting its synthetic nature. The stages of creating the proposed model are illustrated in Figure 3. Part of it was the development of a realistic and reliable questionnaire, therefore, in addition to studying the literature, a survey was conducted with the aim of obtaining reverse communications from specialists (from the scientific field and business).

Different maturity models presented in the literature were compared. Their key attributes were studied and those that the proposed model should consist of were identified, including the completeness and meaningfulness of the assessment questions, applicability to the specifics of the sector under consideration, and ease of use.

[7] https://www.slingshot.space/news/slingshot-darpa-agatha-ai, accessed 07.08.2024.

[8] https://latamfdi.com/aerospace-industry-in-brazil/, accessed 12.08.2024.

[9] https://www.gov.br/aeb/pt-br/assuntos/noticias/empresas-brasileiras-celebram-investimento-de-r-1-bilhao-para-inovacao-no-setor-espacial, accessed 24.09.2024.

[10] https://gizmodo.uol.com.br/brasil-vai-ganhar-novo-parque-aeroespacial-veja-o-que-ja-se-sabe/l, accessed 24.09.2024.

[11] According to the Web of Science database on January 1, 2023, with the keywords "Industry 4.0" AND "maturity", 409 results were obtained. The publications started in 2015 with four publications, increasing over time, and in 2022, 116 papers were published. In comparison with the keyword "Industry 4.0", which has approximately 26,000 published works (only 1.6% of the total number of Industry 4.0 publications), leading to the conclusion that there are few publications on maturity in Industry 4.0.

[12] https://www.industria40.ind.br/artigo/19931-maturidade-para-industria-40-avaliacao-quantitativa-e-qualitativa-do-nivel-de-tecnologia-gestao-e-pessoas-para-implantacao-da-digitalizacao, accessed 24.09.2024.

At the initial stage of the model creation, existing approaches were analyzed, taking into account concepts related to aerospace sector. A total of 36 dimensions were identified. Similarities between them and the possibilities were identified. Synthesis within the questionnaire was ensured in such a way as to optimize the time spent by respondents on filling it out and at the same time not omit key aspects. It turned out that most existing models are dominated by issues of strategic planning and human resource management. For this reason, the first of the two basic dimensions of our model was "Strategy and People". The strategic component is vital for any organization or project, establishing the potential for long-term success, since it allows for the coordinated management of a diversity of available resources, processes, tools, practices, and behavioral models, which contributes to the achievement of the fundamental goal (Heerkens, 2007). The human component is important, since with changing market needs and technological developments, the requirements for competencies will change (Bonilla et al., 2019).

The second basic dimension of the model was the "Intelligent Factory" as a specific attribute of Industry 4.0. Smart factories are defined as the collection of machines, systems, and processes across the supply chain that form an interconnected ecosystem based on advanced technologies such as: AI, machine learning, big data analytics, Internet of Things, robotics, and automation.

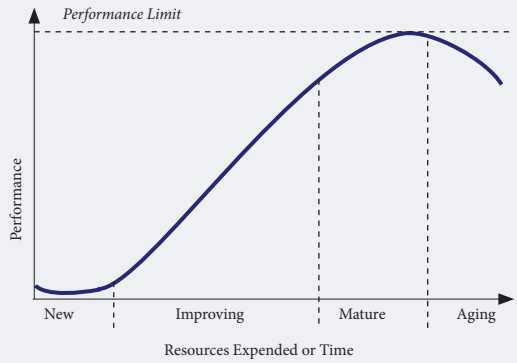
The block of questions for the first dimension contains 19 questions and the second is comprised of 16 (see Appendix).

We then moved on to defining the evaluation criteria. To convert the answers into a quantitative point assessment in maturity models, the Likert[13] scale is used most often. A five-point version of the scale was adopted, with the following levels of technology proficiency identified: 1 - "beginner", 2 - "learner", 3 - "intermediate", 4 - "specialist", and 5 - "top specialist". The company's maturity level is calculated as the average of these values (Figure 4).

In the "Strategies and People" block, calculations are based on 19 questions, and in the "Smart Factory" block, they are basedon 16. We implemented the maturity model in the form of online tools - a questionnaire with questions on two dimensions ("Strategies and People" and "Smart Factory"), a calculator, a dashboard, and monitoring.

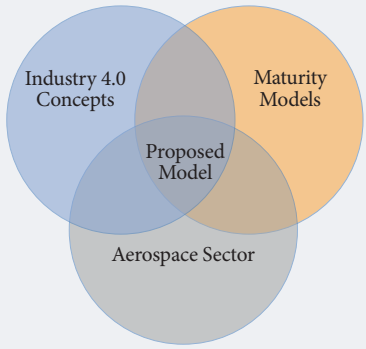
An adapted scenario was created for analyzing the survey responses and their targeting as well as receiving feedback (an example is given in Table 2). Then a panel was formed for tools, which was designed to display all the key indicators obtained from the analysis of questionnaires on one screen (Few, 2006). At the beginning,

Figure 1. Technology Maturity



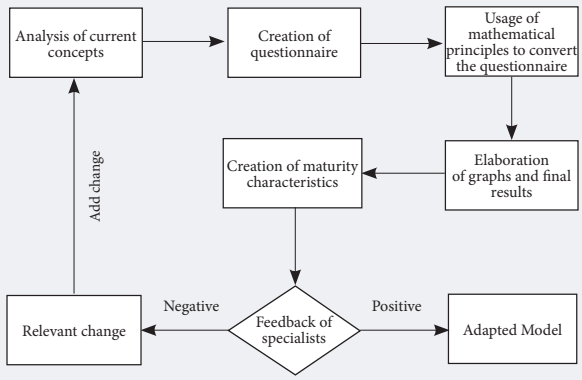
Source: compiled by the authors

Figure 2. Venn Diagram



Source: compiled by the authors

Figure 3. Steps in the Model Building Process



Source: compiled by the authors

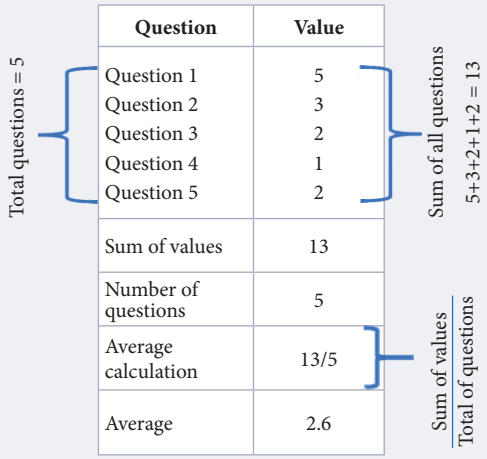
[13] See, for example, the works (Schumacher et al., 2016; Xavier et al., 2020), dedicated to the Business Intelligence Maturity Model, adopted by Hewlett - Packard.

Table 2. Examples of Questionnaire Prompts with Answer Options

Question	Answer options
9 – Have you created a roadmap with objectives related to Industry 4.0 at the organization?	A. No. B. There are studies underway to implement this. C. It is currently being implemented D. It is used in some projects. E. Yes
10 – Has the organization's decisions been based on data?	A. No. B. A few decisions C. Half of the decisions D. More than half of the decisions E. All the decisions

Source: compiled by the authors

Figure 4. Calculation of the Average Level



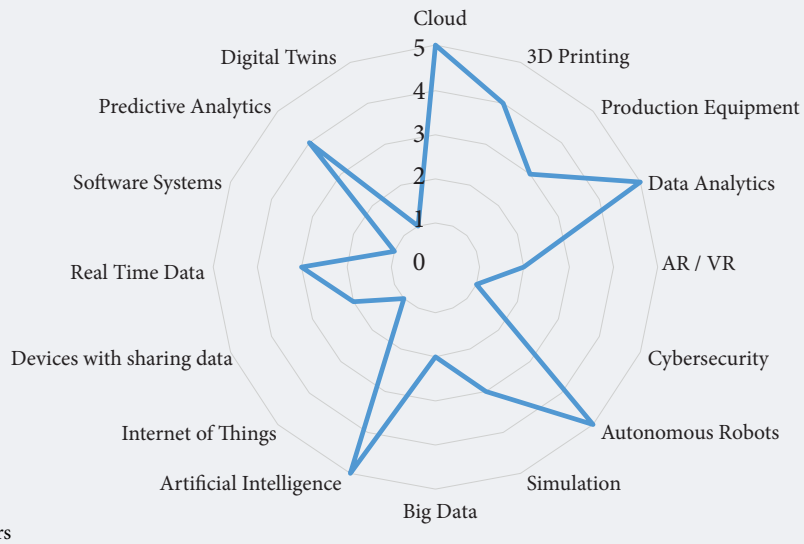
Source: compiled by the authors

Table 3. Survey Results

Components	Meaning	Proficiency level
Strategy and People		
Strategy Implementation	2.3	Learner
Partners	2.2	Learner
Investments	2.7	Learner
Data analysis	2.3	Learner
Employee skills	2.5	Learner
Development Areas	2.3	Learner
Indicators	2.2	Learner
Roadmap	2.7	Learner
Decisions using data	2.7	Learner
Agile methodologies	2.5	Learner
Multidisciplinary teams	2.7	Learner
Continuous improvement	2.3	Learner
Innovation management	2.3	Learner
Zero paper	2.3	Learner
Technology watch	1.5	Beginner
Leadership	2.3	Learner
Smart Factory		
Cloud	2.5	Learner
Data analytics	2.3	Learner
Cybersecurity	2.5	Learner
Simulation	2.2	Learner
Artificial intelligence	1.5	Beginner
Data sharing	2.4	Learner
Predictive analysis	1.5	Beginner
3D printing	2.4	Learner
Equipment	1.5	Learner
Virtual / augment reality	2.7	Learner
Autonomous robots	2	Beginner
Internet of things	2	Learner
Real time analysis	2.5	Learner
Software	2	Learner
Digital twins	1.5	Beginner
Average of both dimensions	2.23	LEARNER

Source: compiled by the authors

Figure 5. Smart Level Radar Chart



Source: compiled by the authors

one of five levels of proficiency in a particular technology is displayed (from beginner to top specialist).

The second part of the dashboard contains a variety of visualizations (in the form of radars, tree structures, and bar and pie charts). They reflect the current picture of the organization's level of mastery of certain technologies (Figure 5).

Tree maps provide an opportunity to study and select the most optimal option for managing these assets from a variety of available methodologies (for example, Scrum, lean manufacturing, Kanban, Crystal Family, hybrid methods). In general, the data panel can be flexibly configured and display the level of maturity of the company, both in general and in individual aspects. A "traffic light gradation" is provided when visualizing the assessment indicators, showing which aspects need more attention. To implement the presented tool in the Brazilian aerospace sector, invitations were sent to its constituent companies for pilot testing. Responses were received from 20% of those organizations. The results are presented in Table 3. It can be seen that in none of the aspects, according to the questionnaire prompts, did the companies achieve even an average level of competence. The lowest level (beginner) is observed in relation to technological monitoring, autonomous robots, AI, predictive analysis, and digital twins (all of which are included in the dimension «Smart Factory»).

Conclusion

Like most sectors, the aerospace industry is transforming and modernizing through the adoption of new production technologies and management methods. Given the sector's primary need for advanced technologies to ensure the maximum quality and safety of its products, all companies have found themselves among the first to face the challenges of mastering Industry 4.0 technologies. Technological maturity assessment models are being created to effectively manage these processes. The objective of this study was to develop such a tool, applicable to the specifics of the Brazilian aerospace sector, and to pilot it among relevant organizations. According to 2019 data, only 4% of the national economy's sectors could be considered to have adapted to Industry 4.0 (FIESP, 2019). In terms of the sector in question, our pilot survey of companies showed that they could be considered "learners" in most respects (average level - 2.23). In some aspects, mainly concerning Industry 4.0 technologies, only a starting level of maturity has been established, therefore, there is an urgent need to improve upon performance. There is sufficient potential for this, since Brazil ranks second in terms of the number of publications on maturity in Industry 4.0, and also it has the largest number of start-ups among all Latin American countries. Based on the above, it can be concluded that the country is moving quite dynamically toward the development of Industry 4.0, however, it is necessary that certain tools be employed to facilitate an increase in the country's technological maturity.

Our research can only be considered as initial contribution to understanding the maturity level of the Brazilian aerospace sector in relation to Industry 4.0 technologies and the prospects for its improvement. In this direction, continuous and in-depth expert work is required, taking into account the latest scientific and technological achievements. The interest in the process of assessing technological maturity in Brazil is growing, including from companies and universities related to the sector in question, which determines the relevance of the model we have developed.

References

Alberti F.G., Pizzurno E. (2015) Knowledge exchanges in innovation networks: Evidences from an Italian aerospace cluster. *Competitiveness Review*, 25(3), 258–287. https://doi.org/10.1108/CR-01-2015-0004

Bamber P., Gereffi G., Frederick S., Guinn A. (2016) *Costa Rica in the Aerospace Global Value Chain: Opportunities for Entry & Upgrade*, Durham, NC: Duke Center on Globalization, Governance & Competitiveness.

Barata J., Cunha P.R. (2017) *Climbing the maturity ladder in industry 4.0: A framework for diagnosis and action that combines national and sectoral strategies*. Paper presented at the 23rd Americas Conference on Information Systems, Boston, United States 10–12 August 2017.

Bonilla S.H., Silva H.R., Silva M.T, Franco G.R., Sacomano J.B. (2018) Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, 10(10), 3740. https://doi.org/10.3390/su10103740

Bravo-Mosquera P.D., Catalano F.M., Zingg D.W. (2022) Unconventional aircraft for civil aviation: A review of concepts and design methodologies. *Progress in Aerospace Sciences,* 131, 100813. https://doi.org/10.1016/j.paerosci.2022.100813

Caliari T., Ferreira M.J.B. (2022) The historical evolution of the Brazilian aeronautical sector: A combined approach based on mission-oriented innovation policy (MOIP) and sectoral innovation system (SIS). *Economics of Innovation and New Technology,* 32(5), 682–699. https://doi.org/10.1080/10438599.2021.2011258

Caliari T., Ribeiro L.C., Pietrobelli C., Vezzani A. (2023) Global value chains and sectoral innovation systems: An analysis of the aerospace industry. *Structural Change and Economic Dynamics*, 65, 36–48, https://doi.org/10.1016/j.strueco.2023.02.004

Cooke P., Ehret O. (2009) Proximity and procurement: A study of agglomeration in the Welsh aerospace industry. *European Planning Studies,* 17(4), 549–567. https://doi.org/10.1080/09654310802682115

Deloitte (2024) *2024 Aerospace and Defense Industry Outlook*, London: Deloitte. https://www2.deloitte.com/us/en/insights/industry/aerospace-defense/aerospace-and-defense-industry-outlook.html

Few S. (2006), Stephen. Information Dashboard Design: The Effective Visual Communication of Data. 223p, 2006. North Sebastopol, CA: O'Reilly Media, Inc.

FIESP (2019) *Sondagem Fiesp de Indústria 4.0,* São Paulo: Federação das Indústrias do Estado de São Paulo.

Gkotsis P., Vezzani A. (2022) The price tag of technologies and the 'unobserved' R&D capabilities of firms. *Economics of Innovation and New Technology,* 31(5), 339–361. https://doi.org/10.1080/10438599.2020.1799141

Heerkens G. (2007) *Introducing the revolutionary strategic project management maturity model (SPM3)*. Paper presented at Project Management Institute (PMI) Global Congress 2007, North America, Atlanta, GA.

Landoni M., Ogilvie D.T. (2019) Convergence of innovation policies in the European aerospace industry (1960–2000). *Technological Forecasting and Social Change*, 147, 174–184. https://doi.org/10.1016/j.techfore.2019.07.007

Lee J.J., Yoon H.A. (2015) Comparative study of technological learning and organizational capability development in complex products systems: Distinctive paths of three latecomers in military aircraft industry. *Research Policy,* 44(7), 1296–1313. https://doi.org/10.1016/j.respol.2015.03.007

Lema R., Pietrobelli C., Rabellotti R. (2019) Innovation in global value chains. In: *Handbook On Global Value Chains* (eds. S. Ponte, G. Gereffi, G. Raj-Reichert), Chelteham: Edward Elgar Publishing, pp. 370–384.

McGuire S. (2014) Global value chains and state support in the aircraft industry. *Business and Politics,* 16(4), 615–639. https://doi.org/10.1515/bap-2014-0014

Niosi J., Zhegu M. (2005) Aerospace clusters: Local or global knowledge spillovers? *Industry and Innovation*, 12(1), 5–29. https://doi.org/10.1080/1366271042000339049

Niosi J., Zhegu M. (2010) Multinational corporations, value chains and knowledge spillovers in the global aircraft industry. *Institutions and Economies,* 2(2), 109–141.

Rebolledo C., Nollet J. (2011) Learning from suppliers in the aerospace industry. *International Journal of Production Economics*, 129 (2), 328–337. https://doi.org/10.1016/j.ijpe.2010.11.008

Reis M., Wehmann C., Martinez M., Reis P. (2021) Mapeamento Patentário Sobre as Tecnologias Aeroespaciais das Instituições de Pesquisa e das Empresas Brasileiras. *Cadernos de Prospecção*, 14(4), 1219–1235. https://doi.org/10.9771/cp.v14i4.42426

Robinson D.K.R., Mazzucato M. (2019) The evolution of mission-oriented policies: Exploring changing market creating policies in the US and European space sector. *Research Policy,* 48(4), 936–948. https://doi.org/10.1016/j.respol.2018.10.005

Schumacher A., Erol S., Sihn W. (2016) A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP, 52, 161–166. https://doi.org/10.1016/j.procir.2016.07.040

Soni R., Verma R., Garg R.K., Sharma V. (2023) A critical review of recent advances in the aerospace materials. *Materials Today: Proceedings*, 12.08.2023. https://doi.org/10.1016/j.matpr.2023.08.108

Turkina E., van Assche A., Kali R. (2016) Structure and evolution of global cluster networks: Evidence from the aerospace industry. *Journal of Economic Geography,* 16(6), 1211–1234. https://doi.org/10.1093/jeg/lbw020

World Bank (2020) *World Development Report 2020: Trading for Development in the Age of Global Value Chains*, Washington, D.C.: World Bank.

Xavier A., Reyes T., Aoussat A., Luiz L., Souza L. (2020) Eco-innovation maturity model: A framework to support the evolution of eco-innovation integration in companies. *Sustainability,* 12(9), 3773. https://doi.org/10.3390/su12093773

Appendix 1. **Questionnaire Contents***

1. The Strategy and People dimension

1- How would you describe the status of implementation of the industry 4.0 strategy in the organization?
2 – Does the organization have partners encouraging development in industry 4.0?
3 – Are these technologies being invested in the organization?
4 – In which dimensions do employees have skills for industry 4.0?
5 – How important is the use of data analysis in the organization?
6 – How many % does the organization need development work in relation to industry 4.0?
7 – Is there any action to obtain the missing skills (abilities)? (updates, seminars, courses, etc.)
8 – Are indicators and schedules being used for the implementation of industry 4.0?
9 – Was a roadmap created with objectives related to industry 4.0 in the organization?
10 – Does the organization make decisions based on data orientation?
11 – Does the organization use any agile methodology?
12 – Are the organization's teams multidisciplinary?
13 – Is any continuous improvement methodology being used in the project?
14 – Are innovation management tools used in the organization?
15 – Does the organization operate using the concept of zero paper – for documentation, data, etc?
16 – Is the organization familiar with the concept – technology watch?
17 – Is there collaboration (universities, companies, agencies, etc.) to prepare the project?
18 – On a scale of 1 to 5, which grade would you choose in relation to leadership of your organization (data-driven decisive – disruption driver – talent champion and social super)
19 – Do employees have the autonomy and freedom to manage their tasks, give opinions and change something?

2. Smart Factory dimension

1 – What is the level of use of 3d printers in the organization?
2 – Does the organization use cloud services?
3 – How advanced is the digitalization of your production equipment (sensors, iot connection, digital monitoring, control, optimization and automation?)
4 – Is data analytics (autonomous data examination) used in the organization?
5 – Are virtual reality and/or augmented reality used in the organization?
6 – Which of the following services does your organization use in relation to cyber security?
7 – Are autonomous robots used in the organization?
8 – Is adaptive robotic simulation used in the organization?
9 – Is data management and analysis done in real time?
10 – Is artificial intelligence (autonomous and flexible processes – pattern recognition) used in the organization?
11 – Is the internet of things (IoT) used in the organization?
12 – Can machines provide data and send it to computers in real time, which employees can communicate and connect with the devices?
13 – Is there integration of information sharing between departments in the organization?
14 – Does the organization use these systems for management? (example: PPS- production planning system, CAD – computer-aided design, PLM – product lifecycle management)
15 – The organization performs forecasting by analyzing different variables (predictive analysis)
16 – Does the organization use the concept of digital twins?

* Respondents have the opportunity to choose several answer options.

Source: compiled by the authors

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