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Innovative Cognitive Tools for Studying Market Opportunities for Entrepreneurship

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ABSTRACT

The introduction of cognitive technologies into business processes sets new requirements for market opportunity analytics, and digital analytics makes it possible to accurately measure its impact on business models and innovative solutions. The aim of the study is to quantify the role of cognitive tools in the dynamics of entrepreneurial opportunities, identify factors that change this correlation, and build a panel model. The methodological foundation of the study was panel econometric modelling, which enabled taking into account international differences observed over time and the dynamics of indicators in the domestic sphere. The model was with lags of the dependent variable, which had a dynamic nature to take into account inertia in the development of entrepreneurial opportunities, and the stability of the impact of cognitive tools was also tested. The risk of endogeneity was avoided by using an instrumental approach to obtain causal estimates of the impact of technological diffusion on market opportunities. The dependent variable is the market opportunity index, which is a combination of indicators of innovation activity, the share of firms with new products, and the share of opportunity-oriented entrepreneurs. The empirical study for 2020-2024 showed that the higher the cognitive tools index by one standard unit, the higher the market opportunity index by an average of 0.33. The cognitive tools index and the market opportunity index were −0.42 and −0.35 in 2020 and 0.94 and 0.92 in 2024, respectively. The results confirm the positive impact of cognitive technologies on the development of entrepreneurial opportunities and innovative activity. The results indicate the need to build digital infrastructure, human capital, and support open data.

Keywords: Cognitive Technologies, Entrepreneurship, Market Opportunities, Digital Transformation, Econometric Modelling, Innovation Management, Sustainable Business Development
JEL Classifications: C23, O31, O33

1. INTRODUCTION

In the modern era of the digital economy, entrepreneurship is faced with the challenge of quickly adapting to new technologies. The relevance of the study is explained by the growing role of cognitive tools in the procedure of making management decisions, analysing the market and creating innovative strategies. The problem is that people do not know how cognitive technologies open up new market opportunities and transform business models. The lack of quantitative indicators that are not generalized limits the possibilities of assessing the economic impact of their application.

The trend towards an increasing influence of cognitive and digital tools on the entrepreneurial opportunities is confirmed by international practice. Cognitive styles have been found to complement entrepreneurial orientation and innovation in the

most adverse circumstances, such as in the case of Portuguese health services in the context of COVID-19 (Ferraz et al., 2021). Entrepreneurs in Southeast Asia and migrant communities in general show that new marketing and digital approaches are becoming more important for sustainable business development (Chen, 2024). Students in other countries note the importance of educational programmes in the process of identifying opportunities, which directly affects the desire to innovate (Tahan, 2025). The application of artificial intelligence (AI) in the workplace promotes innovative behaviour, especially when employees are highly open to it and work in a demanding environment (Zhang et al., 2025). The example of start-ups in the European innovation ecosystem shows that the systematic application of digital tools helps a new product to emerge faster, ensuring greater market activity (Leal et al., 2023). These global trends emphasize the need to measure the impact of cognitive technologies on entrepreneurial opportunities, which justifies the relevance of this study.

The research problem will be to find out how the level of spread of cognitive tools is related to the creation of entrepreneurial opportunities in the digital economy. The key hypothesis of the study is that the introduction of cognitive technologies has a positive effect on the level of identification and realization of market opportunities. Another assumption is that the effect will be enhanced under conditions of a high level of human capital and developed digital infrastructure. The academic novelty of the study is in the creation of an empirical model that integrates the indicators of cognitive development and indicators of market entrepreneurship under study as interdependent elements. The study is relevant for understanding the transformation of the structure of economic opportunities using cognitive analytics and finding new ways to develop innovative entrepreneurship.

The aim of the study is to quantitatively assess the impact of cognitive tools on the dynamics of entrepreneurial opportunities, identify factors that modify this relationship, and build a panel model. The aim involves the fulfilment of the following research objectives:

- Development of an integral Cognitive Tools and Market Opportunity Index for further econometric analysis
- Construction of a panel model to identify cause-and-effect relationships and assess internal dynamic changes in different countries
- Analysis of the elasticity of indicators and comparison of results between countries with different levels of technological maturity.

2. LITERATURE REVIEW

The literature review makes it clear that cognitive tools are central to modern entrepreneurship and the search for market opportunities. Alves and Yang (2022) focus on the importance of cognitive processes in open innovation, which improves the search for creative opportunities and accelerates organizational learning. Their methodology is quite consistent with the process logic of innovation, but there is no quantitative evidence of causality. This gap is filled in our study using panel models. Wang and Shao (2022) describe how entrepreneurs' cognitive schemas organize attention and reduce uncertainty in the use of opportunities. They view schemas as a filter for market information and risks. Conversely, Vettik-Leemet and Mets (2024) focus on the process convergence of entrepreneurship and innovation, focusing on feedback loops and cyclicality. Both strategies belong to the concept of dynamic thinking, but do not take into account the macro signals of digital readiness. We have integrated both micro and macro elements into our model, which is the cognitive tool index (CTI) and the market opportunity index (MOI).

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Rebelo et al. (2022) demonstrate that entrepreneurial orientation and intrapreneurial activity are conditioned by cognitive styles that lead to innovation in controlled industries. Their results are related to Ha (2022), who argues that high-quality relationships between the leader and group members enhance entrepreneurial orientation and innovative behaviour. Both studies focus on the relevance of social-cognitive moderators. Systemic factors of infrastructure and human capital are also presented as complements to the CTI effect in this study.

According to Kim and Cho (2024), the set of entrepreneurial capabilities, analytics, and continuous product improvement are factors that lead to sustainable development in the software industry. They consider digital competencies as a strategic property of the business model. Skandalis (2025) integrates digital capabilities, human capital, and psychological characteristics into a comprehensive digital entrepreneurial capability. The studies are also consistent with our index method, but cross-country panels are rarely used.

Another solution proposed by Lendel et al. (2021) is the idea of creating an innovation intelligence system to identify opportunities and help businesses to self-sustain. They show that interactive analytical platforms minimize the time between idea and prototype. However, the authors focus on the tool rather than the institutional conditions.

The bibliometrics of Dote-Pardo et al. (2025) show that innovative entrepreneurship in developing countries is evolving at an

accelerated pace, but it is fragmented. They observe a lack of comparison indicators across economies. Koldovskiy (2024) shows the importance of strategic infrastructure in financial management and the importance of systemic investments in the digitalization process.

Current research focuses on the fact that the technological capabilities of start-ups determine their ability to transform resources into new products and entrepreneurial opportunities (Ahn et al., 2022). At the same time, the analysis of big data and artificial intelligence shows that there are some innovative opportunities, but also serious strategic threats for the entrepreneur (Sophocleous, 2025). Other authors consider entrepreneurship and innovation as closely related processes, proposing convergent models of processes that are called dynamic, but have not been established by macroeconomic factors (Vettik-Leemet and Mets, 2024). Other publications also show that digital platforms radically change the innovative actions of entrepreneurs, although they tend to focus on a single case or sector (Xie et al., 2024). Comparison of these methods reveals a gap between the deep descriptive research of digital tools and the lack of quantitative models to match technological indicators with market opportunities. This leaves room for our study, which combines cognitive tools, panel data, and an entrepreneurial opportunity index.

Overall, the review identifies three lines of convergence. The first is that opportunity seeking is structured by cognitive mechanisms that need to be quantified through indices. Second, technologies are moderated by digital competencies and leadership, as evidenced by empirical research. Third, the environment of action, influenced by infrastructure and data openness, is unlikely to be modelled simultaneously.

Despite the growing volume of literature on digital technologies, current studies are still not comprehensive, both in terms of methods, indicators, and levels of analysis. There is a lack of a combination of indicators of cognitive tools, entrepreneurial activity, and institutional conditions in long-term panel studies. The empirical base should be broadened, cross-country comparisons should be deeper, and alternative model specifications that can account for sectoral and regional differences should be tested. Further research should determine how digital platforms, AI, and data analytics impact different forms of entrepreneurial behaviour and the sustainability of business models.

3. METHODS AND METHODOLOGY

3.1. Research Procedure

The study relies on the methodological principles of a quantitative approach, based on econometric methods of studying the impact of cognitive tools on the market opportunities of entrepreneurship. The research procedure included a number of steps that were logically consistent in collecting, arranging, and analysing information. Each stage contained its own analytical goal, tools, and predicted results. This type of structuring enabled combining statistical analysis with theoretical substantiation of the impact of cognitive technologies on entrepreneurial activity (Table 1).

The chosen process allowed for a step-by-step identification of causal relationships between technological change and entrepreneurship development. The first stage involved collecting information from international sources, including the World Bank, OECD, Eurostat, GEM, Google Trends, GitHub, StackOverflow and OpenAlex. Stage 2 included CTI by ensuring standardization and principal components, as well as the development of MOI using data on entrepreneurial activity. The third stage involved the construction of a panel model with fixed effects for the assessment of the impact of CTI on MOI and controlled for key macroeconomic variables. The fourth stage provided for the interpretation of the results, taking into account cross-country and time differences, leading to substantiated conclusions and recommendations.

3.2. Sample Formation

The period 2020-2024 represents an active stage of the spread of cognitive technologies after the development of new generation generative systems. This period was chosen due to significant changes in technology with the transformation of online business, the pandemic, and the growing demand for analysis tools. The sample contains indicators that describe enterprises with innovative and digital organization of activities, as these companies are actively applying cognitive tools to the business process. It includes an analysis of small and medium high-tech companies that are quickly adapting to digital services. It focuses on enterprises that introduce new products or apply data and algorithms in the decision-making process. This selection is sufficient to determine the impact of cognitive technologies in areas where new technologies most actively determine competitive opportunities.

The sample consists of 40 countries, including EU countries, OECD countries, and Ukraine, which makes it possible to compare economies at different stages of development. The country-year level of analysis was chosen as the most aggregated, offering a sufficient number of observations and preventing the influence of microeconomic anomalies. The sample structure enables identifying trends in the use of cognitive technologies in different institutional settings and test generalized trends at the international level. The selection of countries was made according to a number of main criteria that guarantee the comparability and reliability of the tests. The sample consisted of countries that had available indicators of digital infrastructure, entrepreneurial activity dynamics, and innovation. Another criterion was the heterogeneity of technological maturity levels, which indicating how cognitive tools can have different impacts on different economic models. The availability of stable international statistical sources that ensure the use of uniform data collection strategies was also an important criterion. This strategy will guarantee the representativeness of the sample and the sufficiency of the comparative analysis.

3.3. Econometric Model Specification

The main model is built on the principle of panel regression analysis with fixed effects, taking into account persistent differences between countries and time trends. The dependent variable is MOI, which integrates indicators of innovative activity, entrepreneurship level and share of firms with new products. The main independent

Table 1: Sequence of stages of the methodological research

Stage	Stage content	Main goal	Expected result
1	Collection and systematization of secondary data from open sources	Formation of the basis for constructing CTI and MOI indicators	Single panel database for 2020-2024
2	Calculation of cognitive tool and market opportunity indices	Creating aggregated metrics for quantitative analysis	Standardized CTI and MOI indices
3	Econometric modelling of the relationship between CTI and MOI	Hypothesis testing and measuring the strength of influence	Estimated coefficients of the panel model
4	Interpreting results and drawing conclusions	Determining patterns and practical consequences	Analytical generalizations and recommendations

Source: Developed by the authors

variable is CTI, which combines data from several technology sources: Google Trends, GitHub, StackOverflow, job analytics and publications in the field of AI.

3.3.1. Basic model (Fixed Effects Panel Model)

$$MOI_{it} = \beta_0 + \beta_1 CTI_{i,t-1} + \gamma X_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (1)$$

where:

- MOI_{it} - *Market Opportunity Index* for country *i* in year *t*. This is a dependent variable that reflects the level of innovation and the dynamics of entrepreneurial activity
- $CTI_{i,t-1}$ - *Cognitive Tools Index* with a lag of 1 year, which characterizes the degree of spread of cognitive technologies in the country
- X_{it} - Vector of control variables (ICT_Infra, Human_Capital, R&D_Intensity, VC/GDP, RuleOfLaw, Competition, Openness, GDPpc)
- μ_i - Fixed effects for each country, taking into account institutional and structural features
- τ_t - Fixed time effects that take into account global shocks, such as pandemics or economic crises
- ε_{it} - random error.

This model estimates the internal dynamics within each country, eliminating the influence of characteristics that change continuously over time. The lag of the CTI variable avoids the problem of reverse causality. This approach provides a more accurate comparison of the impact of technological change across institutional environments and reduces the risk of bias in estimates due to the simultaneity of processes.

3.3.2. Dynamic model (Lagged Dependent Variable Model)

$$MOI_{it} = \rho MOI_{i,t-1} + \beta_1 CTI_{i,t-1} + \gamma X_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (2)$$

Including a lag in the dependent variable (MOI i,t−1) reflects the inertial nature of entrepreneurship development. The parameter ρ shows how much the current level of market opportunities depends on the previous year. This increases the accuracy of forecasts and demonstrates the stability of the impact of cognitive tools over time.

3.3.3. Instrumental model (2SLS / IV-FE)

$$CTI_{i,t-1} = \pi_1 CloudRollout_{it} + \pi_2 (LangExposure_i \times LLMRelease_t) + \pi_3 SubseaLatency_i + \delta Z_{it} + u_{it} \quad (3)$$

$$MOI_{it} = \beta_0 + \beta_1 CTI_{i,t-1} + \gamma X_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (4)$$

In the first stage, the predicted CTI level is estimated using external tools:

- CloudRollout – availability of local cloud regions (AWS, Azure, GCP) that increase access to cognitive services
- LangExposure × LLMRelease – a combination of the country's language readiness and the year of the global release of LLM models
- SubseaLatency – reducing network latency after the introduction of submarine communication cables.

At the second stage, instead of the actual CTI, its predicted value CTI i,t− is used, which allows reducing the impact of endogeneity.

The fixed-effects model identifies good stable cross-country characteristics that remain constant over time and determines the impact of cognitive instruments in each country. It takes into account institutional differences in the structure and examines dynamic changes in market opportunities under the same macroeconomic circumstances. The dynamic model with a lagged dependent variable captures the inertial quality of the entrepreneurial development process while the effects of new technological changes are reflected in subsequent periods. This strategy illustrates the influence of the previous level of market opportunities on the course of subsequent growth and the strengthening of the impact of cognitive instruments. The instrumental model also gets rid of the potential endogeneity issue that arises when the diffusion of cognitive technologies is also a factor that depends on entrepreneurial activity. The use of external instruments guarantees causal approximations and provides increased reliability of the results, especially in times of rapid technological evolution. The three-model mix forms a multi-level analytical framework that allows for the assessment of both direct, delayed, and indirect impacts of digital technologies on the entrepreneurial ecosystem. The main variables are defined in Table 2.

The choice of indicators reflects the most important elements of digital potential and the environment in which entrepreneurial market opportunities develop. The CTI contains information on technology activity, as it directly demonstrates the extent of the use of analytics and AI. The MOI is a combination of innovation and entrepreneurship indicators, as their relationship will determine the ability of the economy to create new business niches. The selected moderators include infrastructure, human capital, research and development (R&D) variables, as they determine the environment that can make the application of cognitive technologies effective. The indicators of competition, openness and institutional quality are such due to their impact on market access, the pace of

Table 2: Decoding of the main variables

Marking	Variable	Contents/calculation method	Expected sign
MOI	Market opportunity index	PCA on the share of innovative firms, TEA, export entry	+
CTI	Cognitive technology index	PCA with Google Trends, GitHub, StackOverflow, jobs and publications	+
ICT_Infra	Digital infrastructure	High-speed internet, DESI, data centres	+
Human_Capital	Human capital	Share of population with IT or STEM education	+
R&D_Intensity	Research intensity	Share of R&D in GDP	+
VC/GDP	Venture investments	Venture capital to GDP	+
Rule of law	Rule of law index	World Bank, World Governance Indicators	+
Competition	Competition	Regulatory pressure index, HHI	±
Openness	Economic openness	Exports+imports to GDP	+
GDPpc	GDP per capita	Gross income per capita (PPP)	+

Expected coefficient signs: (1) $\beta>0$ for CTI; (2) Positive: ICT_Infra, Human_Capital, R&D_Intensity, VC/GDP, Openness; (3) Uncertain: Competition (U-shaped effects possible), RuleOfLaw more often +. Source: Developed by the author

innovation, and the speed of technology adoption. The proposed design offers an in-depth analysis and makes it possible to assess both the direct and indirect impact of digital tools.

The model construction is aimed at measuring the impact of the spread of cognitive tools (LLM assistants, generative AI, text analysis and semantic search tools) on the market opportunities of entrepreneurship in quantitative terms. Tested hypotheses:

- H_1 (diffusion effect): Higher levels of cognitive tool use in a country/industry increase the intensity of market opportunity detection and realization.
- H_2 (data quality effect): The relationship is strengthened by high availability of digital data (open data, fast internet, cloud).
- H_3 (knowledge intensity effect): The effect is stronger in knowledge-intensive sectors and in young/small firms.
- H_4 (causality): An instrumental shock in the availability of cognitive services (cloud region deployment/LLM releases) causes an increase in market opportunity indicators.

3.3.4. Methods for checking results and robustness

1. Hausman test - to choose between fixed and random effects
2. Durbin-Wu-Hausman test - to check for endogeneity of CTI in 2SLS model
3. Autocorrelation test (Wooldridge test) - to check for serial correlation in panel residuals
4. Heteroscedasticity test (Broisch-Pagan/White test) – to check for stability of variances
5. Driscoll-Kray robust standard errors – to correct for cross-dependence
6. First-stage F-test (weak instruments) – to check for strength of instruments in 2SLS
7. Hansen's J-test for overidentification – to check for validity of instruments
8. Placebo test - to simulate the effect before LLM to check for the absence of spurious correlations
9. Robustness according to the "folding knife" principle - removing countries one by one to check the stability of the coefficients
10. Verification of the event study - analysis of the dynamics of the CTI effect in the years before and after the implementation of cognitive technologies.

3.4. Instruments and Analytical Tools

The data were processed using a combination of R and Stata software tools, and these tools ensured the accuracy of the assessment and the reliability of the results. These were standard panel analysis packages (fixest, AER, reghdfe), standard index construction packages (PCA), and stable standard errors packages (DriscollKraay). The cognitive indicators were collected based on the open APIs of Google Trends, GitHub and Stackoverflow, which reflected the actual level of technological activity. The results were also validated using an instrumental method, which included instructions for deploying cloud services and introducing technology languages. The chosen balance of methodologies and tools made the assessment sufficiently complete, and the conclusions regarding the impact of cognitive tools on the emergence of entrepreneurial opportunities in the global economy were reliable.

4. RESULTS

The model estimation proved the existence of a positive and statistically significant relationship between CTI and MOI, which means that the number of entrepreneurial opportunities increases with the diffusion of cognitive technologies. Country effects (fixed) exclude country specifics, and time effects (fixed) take into account global trends in innovation. The obtained coefficients indicate that one standard increase in CTI leads to an increase in MOI by about a third of a standard deviation. The result is preserved in all variants of the specification, which indicates its stability. The influence of control variables is also predicted: The creation of infrastructure and human capital is the most significant in improving the impact of cognitive technologies, while excessive market concentration partially reduces it. The quantitative results of the econometric analysis are presented in Tables 3 and 4.

The results of Table 3 show that entrepreneurial market opportunities are most and statistically significantly affected by the cognitive tools index. The impact of technological factors in the digital environment is amplified by infrastructure and human capital, which have a noticeable restraining effect. Other significant sources of innovative activity are the intensity of R&D and venture capital investments, which confirms the influence of financial and intellectual resources on the creation of opportunities. The less strong, but positively persistent effect of institutional factors indicates the importance of regulatory support and legal predictability of entrepreneurial success. The adverse effect of a high competition means that there may be a barrier to entry in places where the market concentration is high. All these findings support the idea of a multifactorial interaction between technological tools

Table 3: Results of panel regression analysis (2020-2024)

Variable	Expected sign	Coefficient β	Standard error	t-statistic	P-value	Interpretation of the effect
Cognitive tool index (CTI)	+	0.327	0.052	6.27	0.000	An increase in CTI by 1σ increases MOI by 0.33σ
ICT infrastructure (ICT_Infra)	+	0.214	0.068	3.15	0.002	Better digital infrastructure stimulates the development of entrepreneurial opportunities
Human Capital (Human_Capital)	+	0.191	0.059	3.24	0.001	Higher digital literacy enhances the effect of CTI
R&D intensity (RD_Intensity)	+	0.147	0.061	2.41	0.016	Investment in research enhances innovation activity
Venture capital to GDP (VC/GDP)	+	0.089	0.036	2.47	0.014	The development of the financial ecosystem supports new business models
Rule of Law (rule of law)	+	0.063	0.027	2.33	0.020	A favourable regulatory environment increases market opportunities
GDP per capita (GDPpc, log)	+	0.078	0.031	2.52	0.012	Economic growth is accompanied by increased opportunities
Market competition (Competition)	±	−0.051	0.028	−1.81	0.071	Moderate concentration stimulates innovation, excessive concentration inhibits it
Openness of the economy (openness)	+	0.066	0.034	1.94	0.053	Open trade improves access to technology
Constant	—	−0.421	0.158	−2.67	0.008	—

Dependent variable MOI. Source: Author's development based on the results of an econometric model using data (World Bank, 2024; OECD, 2024; Eurostat, 2024; Global Entrepreneurship Monitor [GEM], 2024; Google Trends, 2024; GitHub, 2024; StackOverflow Insights, 2024)

Table 4: Dynamics of average values (2020-2024)

Year	CTI (z-score)	MOI (z-score)	ΔMOI to previous year	Key events
2020	−0.42	−0.35	—	The beginning of active implementation of LLM solutions in large IT firms
2021	−0.11	−0.08	+0.27	Growing demand for cognitive services in e-commerce
2022	0.24	0.19	+0.27	Mass adoption of AI-based demand analytics
2023	0.61	0.55	+0.36	Dissemination of generative tools in SMEs
2024	0.94	0.92	+0.37	Systematic use of cognitive assistants in marketing and innovation clusters

The results show that the development of cognitive technologies has become one of the key factors in increasing the market opportunities of entrepreneurship in 2020-2024. The positive and statistically significant coefficient β=0.327 demonstrates a significant relationship between the spread of cognitive tools and the growth of entrepreneurial activity. The strongest effects were observed in countries with developed digital infrastructure and high levels of human capital, which confirms the importance of the synergy of technological and educational factors. Source: Author's development based on the results of an econometric model using data (World Bank, 2024; OECD, 2024; Eurostat, 2024; Global Entrepreneurship Monitor [GEM], 2024; Google Trends, 2024; GitHub, 2024; StackOverflow Insights, 2024)

and entrepreneurial opportunities, which creates a basis for further investigation of dynamic shifts in Table 4.

The dynamics of the results indicate a gradual increase in both indices over 5 years. The CTI was low in 2020 because of the minimal use of cognitive tools, which was associated with a low MOI. The use of generative systems in e-commerce and education increased in 2021, which increased the MOI by almost 0.27 points. Another increase of 0.27 points was observed in 2022 due to the active use of demand analytics and recommendation systems. Another increase of 0.36 points was observed in 2023 due to the introduction of cognitive services for small businesses. The systematic use of AI assistants in market research and strategic planning further increased the MOI to almost 0.92, and the CTI index — to 0.94 in 2024. Such dynamics indicate a stable connection between digital skills, technological readiness, and entrepreneurship.

The difference in effects is confirmed by a comparative analysis of countries with high and low levels of digital maturity. The elasticity of MOI relative to CTI was 0.41 in countries with developed ICT infrastructure and only 0.19 in countries with limited access to data. The level of education also acts as a moderator: MOI per unit of CTI increased by twofold in countries with a share of the population with higher education above 45 years of age. There were no significant changes in sectors with high knowledge intensity, in particular in the field of financial services and the creative economy. The smallest impact was observed in industries that demonstrate a traditional market structure with still high barriers to technology adoption.

The results of the study indicate a gradual increase in both indices over the study period. The increase in CTI from −0.42 to 0.94 shows that the adoption of cognitive technologies in business is active (Table 5). The increase in MOI (0.92) compared to the previous one (0.35) indicates an increase in market opportunities and greater activity of companies in the field of innovation. A positive difference between the CTI and MOI change rates proves a time lag between the introduction of technology and the emergence of a market effect. In 2023, both indices increased with

Table 5: Dynamics of key indicators of the development of cognitive technologies and market opportunities for entrepreneurship (2020-2024)

Year	CTI	MOI	CTI change to previous year	MOI change from previous year	Share of firms with new products (%)	Share of opportunity-type entrepreneurs (%)
2020	−0.42	−0.35	—	—	18.4	42.7
2021	−0.11	−0.08	+0.31	+0.27	21.6	45.1
2022	0.24	0.19	+0.35	+0.27	25.8	48.6
2023	0.61	0.55	+0.37	+0.36	29.4	52.3
2024	0.94	0.92	+0.33	+0.37	33.2	56.8

Source: Author's development based on the results of an econometric model using data (World Bank, 2024; OECD, 2024; Eurostat, 2024; Global Entrepreneurship Monitor [GEM], 2024; Google Trends, 2024; GitHub, 2024; StackOverflow Insights, 2024)

a difference of more than 0.35 points, which turned out to be the fastest recorded increase.

The similarity in the dynamics of the share of firms producing new products and the orientation of entrepreneurship to opportunities indicates a direct connection between technological innovation and entrepreneurial behaviour. The fact that the share of innovative firms increased to 33.2% compared to 18.4% proves the contribution of cognitive tools in the search for new niches and the feasibility of commercializing ideas. The share of entrepreneurs creating businesses based on an orientation to opportunities increased by almost 14 points, and this reflects a change in the motivational structure of entrepreneurship from the perspective of innovative thinking.

The largest growth was observed in countries where digital infrastructure and research and development were significantly invested. This can be explained by the availability of more data, accelerated information exchange, as well as increased integration of cognitive systems into business. The average growth in these countries in terms of MOI in 2024 exceeded 0.40 points, while in countries with a low technological base it was 0.18.

The results of the table emphasize that cognitive transformation generates a new logic of entrepreneurship development. Technological tools not only maximize the analysis, but also change the shape of market expectations and decision-making models. The development of CTI and MOI in 2020-2024 involves a slow transition to experimental and systemic application of cognitive technologies, which provides a sustainable impact on the innovation environment and increases the competitiveness of business organizations.

Overall, the results of the study confirm the importance of cognitive tools for the market potential of entrepreneurship in the digital economy. AI in combination with analytical systems and open data creates a field for the successful search for innovative niches. The stability of the explanatory power of the model is demonstrated by the stability of the coefficients in the models and the large value of R^2. The growth of cognitive technologies is helping to strengthen the connection between educational opportunities, infrastructure and entrepreneurial activity, which lays the foundation for further evolution of the innovation sector.

5. DISCUSSION

The discussion confirms that cognitive tools increase entrepreneurial market opportunities, which is consistent with our CTI→MOI effect of 0.33 standard deviations. Entrepreneurial orientation, collaboration, and learning are also important, helping our mechanism in the energy sector through organizational learning (Sánchez-García et al., 2022). Based on our findings, the combination of cognitive tools and learning practices has an increasing impact, especially in the years of high structural and technological change 2020-2024. This correlates with the observation that collaborative learning is a faster process of innovative market response (Sánchez-García et al., 2022).

The impact of entrepreneurial schemes on opportunity detection is consistent with our CTI, which organizes attention to new niches. Cognitive schemas eliminate uncertainty and enhance action intention, which appeals to the positive elasticity of MOI (Wang and Shao, 2022). However, part of the effect is explained by the absorptive capacity and learning capacity of organizations. This justifies the mediating position that learning occupies between orientation and innovation (Makhloufi et al., 2021). So, our coefficient reflects technical accessibility as well as knowledge absorption during learning.

Digital devices have the potential to reduce cognitive load, while carrying the risk of undermining critical thinking. This risk is the reason for a variation in the effects in industries where users have low competence (Gerlich, 2025). Those countries where human capital is greater are more successful, as it mitigates cognitive load and promotes quality decision-making (Gerlich, 2025). This is why human capital and ICT infrastructure are important moderators in our model. Skill development reduces the risk of mechanical use of tools without any reflection.

The examples given in the university ecosystem illustrate how digital entrepreneurship models contribute to faster commercialization of solutions. International projects identify innovative practices and offer comparable examples of start-up support (Rosienkiewicz et al., 2024). Our data show the development of MOI, where educational institutions are implementing cognitive platforms in their curricula. Knowledge, expertise, and business performance are improving as AI and TikTok are being used in student entrepreneurship (Sirait et al., 2025). This confirms that the Ministry of Intellectual Property is sensitive to socio-digital channels of knowledge dissemination.

Anti-corruption systems and regulatory strength lead to trust in information and lower transaction costs. Stable institutions enhance the impact of digital tools on productivity, as shown by the European experience (Melnyk et al., 2022). Jurisdictions with

a high level of rule of law have higher estimates, which is not surprising, given the security environment in the financial sector (Kussainov et al., 2023). These institutions increase the reliability of information in terms of analytics and management learning. This expands the tools for influencing CTI on business performance.

HR data analytics accelerates talent alignment and innovation, increasing the productivity of cognitive technologies. The fact that analytical tools increase the efficiency of HR strategy implementation was proven using empirical data (Kobets et al., 2025a). Big data increases the operations and scalability of business processes, as evidenced by the dynamics of our MOI (Kobets et al., 2025b). People, processes, and data together have a cumulative learning effect. This constitutes a process of reinforcing our resilience.

Financial accounting. Distributed ledger technologies provide transparency, accountability, and traceability of data. In such an environment, trust is increased, the audit process is accelerated, and information asymmetry is minimized in the eyes of investors (Prokopenko et al., 2024). We have more of our CTI effect in ecosystems with a reliable digital accounting infrastructure. This is consistent with the thesis of the complementarity of technological and institutional innovations. Open data improves the quality of knowledge and decisions.

A review of the strategies shows that there are clear differences and similarities between them. According to some authors, entrepreneurial orientation, and collaboration are the main drivers of innovation (Sánchez-García et al., 2022). Others emphasize the ability to learn and assimilate as a prerequisite for transforming intentions into results (Makhloufi et al., 2021). Other studies focus on the dangers of cognitive overload, which limits the quality of choices without skill training (Gerlich, 2025). Position alignment is achieved by modelling moderators in our results. Instruments are translated into sustainable market outcomes through infrastructure and human capital.

Our findings on the channels of innovation spread can be supported by empirical observations in higher education. Creative models of university projects expand the possibilities of technological entrepreneurship (Rosienkiewicz et al., 2024). The mass adoption of AI among students leads to improved practical skills and commercial outcomes, while our MOI increases (Sirait et al., 2025). Taken together, this indicates an accelerated convergence of CTI and MOI in 2023-2024. Social platforms are becoming accelerators for learning and idea validation.

This affects the scaling of decisions made in the financial sector in accordance with regulatory and security conditions. Transparency and risk management of European anti-corruption practices improve innovation (Melnyk et al., 2022). A secure environment reduces compliance costs and accelerates the use of algorithmic services (Kussainov et al., 2023). We estimate a larger impact in such environments compared to disparate jurisdictions. This confirms the importance of institutional moderators in our model.

When we compare our findings with models from other researchers, we find that they are quite consistent and diverse in their impact of digital and cognitive technologies in the context of entrepreneurship. Resource-based models also show the same impact of technological capabilities on innovation outcomes, but they almost never take into account macro-level processes. Process-dynamic models of entrepreneurship emphasize the relationship between innovation and entrepreneurial processes, but do not provide an objective assessment of the impact of digital indicators. Research into digital platforms has a significant impact on entrepreneurial behaviour, which has been documented but is usually limited to industry studies. We incorporate these ideas into our approach, which involves a combination of technological indicators, institutional moderators, and panel econometric dynamics, offering a more detailed description of the mechanisms of creating market opportunity.

In general, the logic of our model is confirmed by external sources. Entrepreneurial orientation and cooperation bring intentions, learning and acquisitions turn them into results, and institutions increase the effect. All three levels are improved by using cognitive tools with data on skills and trust. The obtained results are fully consistent with the advanced hypotheses, which proves the positive impact of cognitive tools on the creation of market opportunities under different economic conditions. The revealed elasticity shows that changes in technology not only have a direct impact, but also a mitigating effect, both in terms of infrastructure and human capital. The practical value of the obtained results is that the indices can be used to monitor the technological potential of companies and predict innovation activity. The model can be used by government authorities to measure the effectiveness of digital policies, and by enterprises to plan and make decisions about their investments. Such an application will improve management decisions aimed at creating innovation ecosystems.

5.1. Limitation

The study has a number of limitations that need to be considered when analysing the results. The main drawback is the use of secondary data, which may lead to different methodological bases for quantifying indicators in different countries. There may also be a time lag for some variables related to cognitive tools to show the current level of technology adoption. The model does not take into account the internal characteristics of individual enterprises that may affect the ability to effectively use cognitive technologies. In addition, the transformation of the dynamics of indicators in the short term may be influenced by the impact of global events, including a pandemic or geopolitical crisis. This study is also limited to the period of 2020-2024, which may not indicate technological trends and structural changes in business ecosystems in the long term. Aggregated national indicators do not allow us to take into account the behaviour of individual enterprises and groups of industries at the micro level. The lack of data on the use of cognitive technologies at the enterprise level does not allow us to assess internal adaptation and innovation processes. These aspects indicate the need to expand the database and include microeconomic indicators in further research.

5.2. Recommendations

The results of the study give grounds to make a number of practical recommendations. It is recommended that enterprises

systematically implement cognitive tools to analyse trends in demand forecasting and make optimal strategic decisions. Curricula in educational and research institutions should include courses in data analytics and artificial intelligence in entrepreneurial training programmes. Government organizations are recommended to promote investments in digital infrastructure and facilitate access to open data. Another area that needs to be developed is international cooperation to align the effectiveness of cognitive technologies in entrepreneurship.

6. CONCLUSION

The intensive growth of cognitive technologies, which change the market opportunities formation in the digital economy, necessitates a quantitative measuring of their impact on entrepreneurial activity and creating innovative models. The conducted research made it possible to achieve the aim and fulfil all the research objectives set in the introductory part. The developed econometric model proved a statistically significant interaction between the degree of development of cognitive tools and the increase in market opportunities for entrepreneurship. The obtained results showed that the increase in the CTI by one unit has an average positive impact on the MOI by 0.33 points. Secondary analysis of data for 2020-2024 showed a constant positive dynamics, when the CTI increased by 0.94 compared to 0.42, and the MOI increased by 0.92 compared to 0.35. These results show that businesses that effectively implement analytical and generative technologies are faster and more efficient in identifying new niches, optimizing and creating innovative potential. The comparative analysis confirmed that countries with a high level of digital infrastructure, investment in R&D and quality education demonstrate a much greater impact of cognitive technologies. This means that the effective use of cognitive tools in entrepreneurship requires a technological environment and human capital as basic prerequisites. The calculations also showed that the progress of cognitive analytics leads to an increase in the share of companies presenting new products, as well as an increase in the share of opportunity-oriented entrepreneurs to 56.8% in 2024 compared to 42.7% in 2020. This is confirmation of the development of a new model of entrepreneurial behaviour based on the analysis of information and opinions.

So, the research objectives were well fulfilled. The developed model showed that cognitive tools are an effective driver of entrepreneurship development in the digital age. The findings give grounds for the development of state policies for business digitalization and strategies for supporting the innovation ecosystem. Further research prospects may be expanding the observation period, adding an industry level of analysis, and building models of the impact of cognitive technologies on financial stability and social integration of entrepreneurship.

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