Artificial Intelligence: The Catalyst For New Industrial Revolution And Economic Development?

Cristian Romeo SPĂTARU, cspataru1970@gmail.com[1*],

Valer BOCAN, valer.bocan@upt.ro[2],

Cristian Constantin POPESCU, popescu@uaic.ro[3]

Abstract

Research-development-innovation drives economic growth and competitiveness. AI, a key element of Industrial Revolution 4.0 (transitioning to 5.0), transforms industries and society, offering innovation but also risks. This study reviews AI's role as a catalyst for industrial and economic change. Using multiple regression on EU27 data (2017–2022), it examines factors influencing "AI software development - Very High-impact AI projects (%)". The tested hypothesis states that talent availability and R&D investments shape AI project scope. Independent variables include R&D expenditure, venture capital in AI, researcher count, and the global innovation index. Results confirm that AI development depends on these factors. The findings provide insights for policymakers and industry leaders, highlighting the need for regulations to manage risks. Future research should address AI governance and long-term effects.

Keywords: AI projects, investments in AI, R&D, Global Innovation Index, researchers in R&D.

JEL Classification: O33, O38, C23, L86, M15

1. Introduction

Technological changes play an essential role in stimulating investments and driving economic growth (Romer, 1990; Aghion & Howitt, 1992). In turn, the ensemble of artificial intelligence (AI) technologies plays an essential role in the modern industrial revolution, bringing intelligent solutions that transform various sectors of activity. On the other hand, in the last decade, the significant economic and social impact of AI has led governments and international organizations to pay increased attention to regulating this field

[1] Department of Economics, The Doctoral School of Economics and Business Administration, "Alexandru Ioan Cuza" University of Iasi, Iași, Romania, e-mail address: cspataru1970@gmail.com

[2] Department of Computer and Information Technology, Faculty of Automation and Computers, POLITEHNICA University of Timisoara, Timișoara, Romania, e-mail address: valer.bocan@upt.ro.

[3] Department of Economics, Faculty of Economics and Business Administration, "Alexandru Ioan Cuza" University of Iasi, Iași, Romania, e-mail address: popescu@uaic.ro.

* Corresponding author.

to balance benefits with associated risks, specifically the results of technological innovation with the protection of fundamental rights and ensuring security.

AI is an interdisciplinary field dedicated to developing systems capable of performing tasks specific to human intelligence. Its first documented appearance was in 1956. Since then, AI has evolved significantly, having a major impact on industry and society (Howard, 2019; Jutel et al., 2023).

On the other hand, the United States, China, and the European Union, which are the main actors in the global governance of artificial intelligence, have distinct priorities. China emphasizes "research and application," the European Union focuses on "social impact," and the United States on "the role of government," but all three powers underscore the importance of institutions, respect for human rights, and promotion of scientific research (Wang et al., 2025). Managing AI challenges requires strengthened international cooperation, and the concept of "technological diplomacy" is proposed as a tool for aligning policies at the global level (Feijóo et al., 2020).

Given the trend of AI-aided development, the European Union will need to adopt strategic measures to support and accelerate the integration of AI in all sectors of sustainable development and strengthen its competitive position in the global market.

In the study, we will answer the research question derived from the paper's title. At the same time, in this period of digital and technological momentum, the present study focuses on the main determinants of AI projects at the level of EU member states. Through the multiple regression approach, our research aims to identify the impact of relevant predictors on the level of very high-importance AI projects.

2. Literature review

Industrial Revolution 4.0, a concept popularized by the founder of the World Economic Forum, Schwab (2016), describes an era in which advanced technologies merge to fundamentally transform society and the global economy. This revolution is characterized by the convergence of digital, physical, and biological technologies, having a significant impact on all economic and social sectors (Anderson, 2016; Li et al., 2017; Schiølin, 2020). These technologies include: *digitalization and hyperconnectivity* as a result of the central role of data (Bianchi & Labory, 2018), *Internet of Things (IoT)* which connects devices and machines for intelligent automation facilitating production processes (Xu, H., et al., 2018; Martinelli et al., 2020), *Artificial Intelligence (AI) and Machine Learning (ML)* optimize processes and facilitate advanced automation, for example autonomous vehicles and virtual assistants (Ross & Maynard, 2021) being essential in decision-making and reducing dependence on human intervention (Syam & Sharma, 2018), *Big Data and Cloud Computing* which allow analysis, scalability and efficient storage of data for informed decisions, along with inherent challenges and risks (Sandhu, 2021), *advanced robotics, industrial automation and wireless communication techniques* that increase efficiency and reduce production costs (Martinelli et al., 2020, Imran et al., 2020*), additive manufacturing* (3D printing) which supports product customization and production sustainability (Mohamed et al., 2024). All these technologies have a significant impact on how industries are managed and operated.

Industry increasingly dominates AI research, having control over computing power, large datasets and benefiting from the contribution of qualified researchers (Ahmed et al., 2023). AI is integrated into various fields, including healthcare, circular economy, supply chains, and management (decision-making), having a significant impact on business, social sciences, and exact sciences (Dwivedi et al., 2023).

The transition from Industry 4.0 based on digitalization, to Industry 5.0, represents an evolution based on the principles of the previous industrial revolution, plus personalized products, advanced communications, collaborative robots, new technologies – artificial intelligence of things (AIoT), with the main objective of production sustainability (Xiang et al., 2024), the approach being viewed from multiple perspectives - economic, ecological, and social. The last two perspectives require the adoption of a circular economy and orientation toward a human-centered industry (Möller et al., 2022). At the same time, from the specialized literature we also note that the transition to Industry 5.0 involves: *human-machine collaboration*, with emphasis on human integration and sustainability (Xu et al., 2018; Möller et al., 2022), *smart cities* through the development of autonomous and connected infrastructure (Ross & Maynard, 2021) and *renewable energy solutions* to reduce the negative impact on the environment (Mohamed et al., 2024).

Technological Impact of AI: Artificial intelligence (AI) is an essential factor of Industry 4.0, revolutionizing production processes and industrial design, contributing to automation and optimization, which leads to increased efficiency and reduced costs (Javaid et al., 2021; Malik et al., 2024). On the other hand, the integration of AI and robotics in high-precision tasks is revolutionizing the manufacturing industry, medicine, and agriculture. Thus, AI-based robotic systems, using advanced algorithms, machine learning, and real-time sensor data, achieve superior levels of precision, efficiency, and adaptability (Paköz, 2024). The development of self-learning and self-coding algorithms, recurrent neural networks (RNN), reinforcement learning, and pre-trained models are key aspects of AI progress in the last decade (Shao et al., 2022). As such, AI has the role of amplifying human activities and making us more efficient.

Technological Impact of AI on the Economy and Competitiveness: Investments in AI stimulate productivity, sales, employment, and company value through product innovations (Babina, et al., 2024). Additionally, AI stimulates innovation and influences productivity through task automation, simplifying operations, and reducing costs (Yi & Ayangbah, 2024; Chaudhary, 2024). AI contributes to economic growth in countries with strong national strategies and advanced infrastructure (Huy, et al., 2024), being essential in emerging economies (Fan & Liu, 2021). On the other hand, to maximize the benefits of AI, it is necessary to integrate this technology in emerging fields to enhance competitiveness (Shao, et al., 2022), as well as in governance systems (Saba & Ngepah, 2024). At the same time, to stimulate AI capacity, collaboration between the public sector, private industry, and educational institutions is important (Ozkaya & Demirhan, 2023). Artificial intelligence (AI) projects have a significant impact on economic growth, influencing productivity, innovation (Yuan et al., 2024), as well as the structure of the labor market, with the effect on the latter being bivalent. Thus, some jobs disappear, new, more qualified work tasks appear due to automation, but the replacement rate is slower; moreover, a slower increase in productivity compared to previous decades is also observed. Government correction measures are necessary in this context, as well as adjusting the educational curriculum in accordance with the new requirements of the labor market (Acemoglu & Restrepo, 2019). Artificial intelligence can be both an initiator and a facilitator of innovation, supporting the creation of new products and accelerating progress in the innovation process (Brem et al., 2021). AI projects are essential for economic development. Coherent national strategies and measures to combat AI risks are important for strengthening a nation's competitive advantage in the global market.

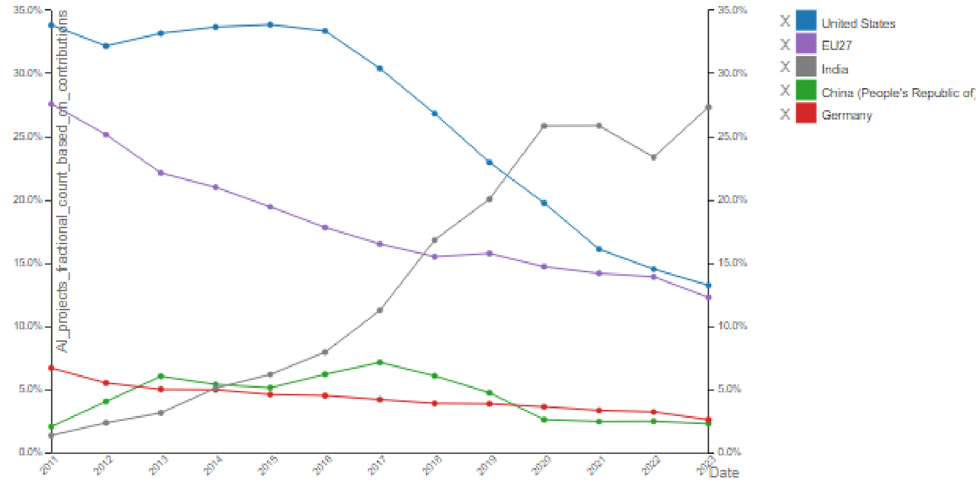
Impact of Research and Development Expenditures on AI Projects: The financial success of companies is due to focusing on AI technologies and increased R&D investments (Kumari et al., 2024), and revenues increase where the intensity of AI technology adoption is higher (Lee et al., 2022). R&D investments, especially when combined with AI, can enhance researcher productivity, accelerating the growth of innovations and implicit economic growth (Besiroglu et al., 2022). Conversely, AI promotes technological innovation by accelerating knowledge creation and technology transfer, improving learning capabilities, and increasing investments in R&D and talents (Liu, et al., 2020). At the same time, companies with intense R&D activities are more likely to adopt AI technologies (Kinkel, et al., 2021). The study by Xiao et al. (2024) shows that enterprises that adopt AI increase their R&D activity efficiency and performance indicators (revenue and market share).

Consequently, expenditures in research and development (R&D) oriented toward artificial intelligence (AI) projects can have a positive impact on development, technological innovation, and technological and financial progress.

Impact of the Number of Researchers vs. AI: Al-Marzouqi & Arabi (2024) found that global AI research has grown 26 times in 25 years, with China leading in publications and India showing rapid growth. While India ranks first in researcher count and R&D spending, Hong Kong and Singapore excel in top-tier journals, and Switzerland leads in citations per article. After normalizing indicators, Hong Kong, Singapore, and Switzerland, along with the USA, showed the highest economic impact via patent citations. The study suggests that AI impact depends not just on the number of researchers but on research quality, specialization, and applicability.

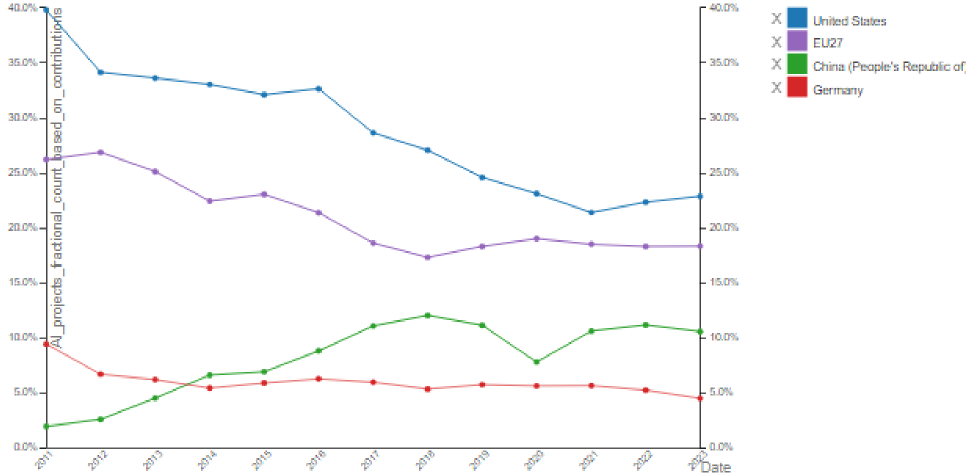
On the other hand, from OECD information, high-impact AI projects (6-100 forks, Fig. 2) and very high-impact projects (>100 forks, Fig. 3) bring to the forefront the USA, China, and the EU. India scores in quantity in total AI projects (Fig. 1), but we can infer from the figures presented that Indian AI projects are of a smaller scale.

Figure 1. *AI software development. Contributions to public and project impact. ALL AI projects (%)*



Source: OECD.AI

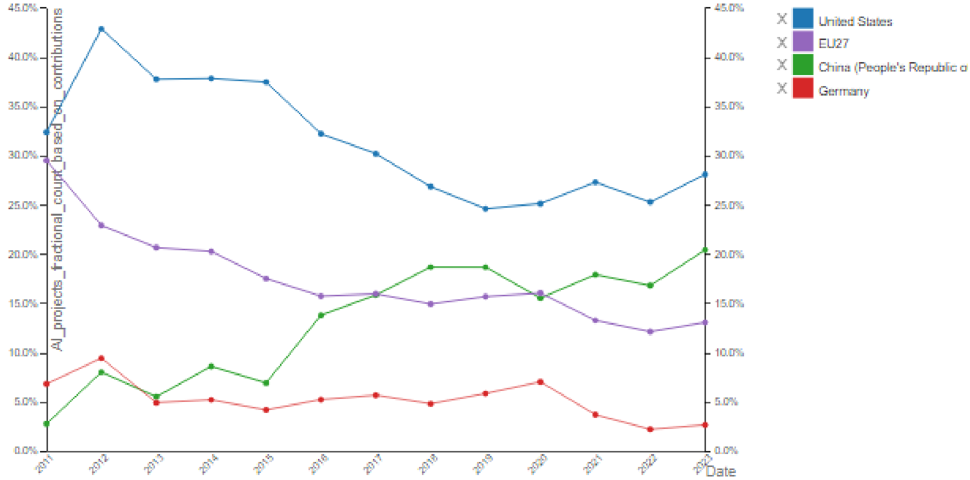
Figure 2. *AI software development.* *Contributions to public and project impact. High-impact (6-100 forks) AI projects (%)*



Source: OECD.AI

We take note from Fig. 2 that the EU occupies a reasonable position around high-impact AI projects (6-100 forks). We cannot note the same thing around very high-impact AI projects (Fig. 3).

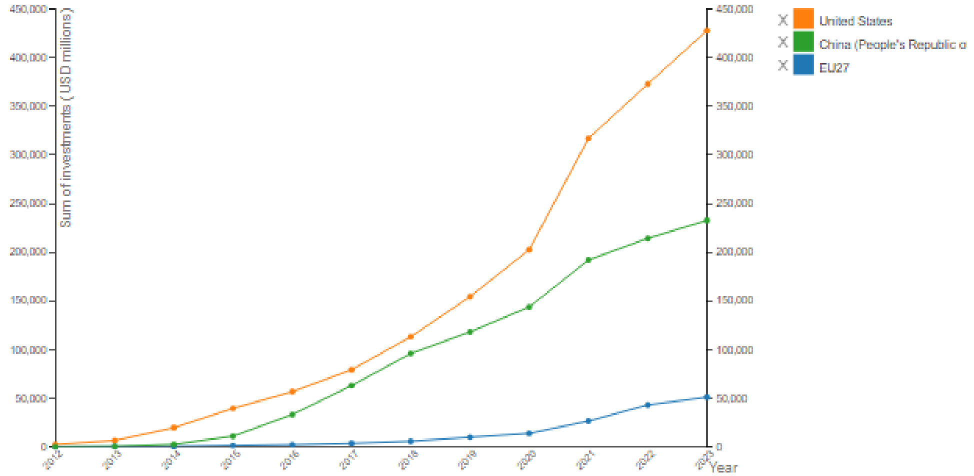
Figure 3. *AI software development.* *Contributions to public and project impact. Very High-impact (>100 forks) AI projects (%)*



Source: OECD.AI

These charts show the number of AI projects (i.e., AI-related GitHub 'repositories') as a fractional count based on the share of contributions (i.e. 'commits') by country and over time.

Figure 4. *Venture capital investments in AI, sum of investments (USD million)*



Source: OECD.AI

About the Venture capital investments in AI indicator (see Fig. 4), the USA holds supremacy with 427 billion USD, followed by CHINA with 232 billion USD, representing the aggregate amounts over the last 11 years (2012-2023). For this indicator, the EU in total aggregate value reaches only 50.8 billion EUR, far behind the main competitors.

3. Methodology

In this study, we used two research methods:

- Systematization of relevant literature (described in section 2) and
- Empirical analysis based on data, statistical methods, and techniques to test the working hypothesis H1: Available talent and the level of investments in research, development, and innovation significantly influence the scope of AI projects.

Specifically, the quantitative analysis consists of:

Multiple regression, to figure out the direction of relationships and connections between AI projects and their predictors

- Data used: Eurostat, OECD.ai, World Bank, IMD World Competitiveness
- Analysis period: 2017-2022. Number of observations = 28 (27 EU member states plus the EU average)

Definition of the model and variables subject to analysis:

The multiple regression equation is expressed by the formula below:

$$(AI\_projects)_i = \beta_0+\beta_1(RD\_GDP)_i+\beta_2(VC\_Invest)_i+\beta_3(Researchers)_i+\beta_4(GII)_i+\varepsilon_i \quad \textbf{(1)}$$

where:

- The dependent variable (acronym/name) is: AI_Very High Impact / *AI software development. Very High-impact (>100 forks) AI projects (%)* (Source: OECD.ai).
- Independent variables (predictors) are described in Table 1 (p. 9).
- β_0 = intercept, $\beta_1 \div \beta_4$ are regression coefficients, and $\mathcal{E}$ is residual error.

Statistical Methods and Techniques Used in Our Analysis:

- *Data Preparation and Cleaning*. We employed two approaches to handle predictors' missing data: calculating the average values (arithmetic mean neighboring values) and, in certain cases, utilizing Python-based predictive models for data imputation (linear regression or polynomial regression technique). EU-level values were calculated as weighted averages based on either population or GDP, depending on the case. • Data scaling/normalization (Z-score or min-max scaling). In this case, we applied standard normalization (Z-score), which transforms the data so that: Mean = 0 and Standard Deviation = 1. This allows the comparison of variables with different units on the same scale.
- *Preliminary Factor Analysis*. KMO Test (Kaiser-Meyer-Olkin) for measuring sampling adequacy (in other words, to evaluate the internal consistency of the selected variables). In theory, the KMO value must be between 0.5 and 1 (i.e., above 50%), indicating adequate sampling.
- *Multicollinearity Analysis*. To address the issue of multicollinearity and obtain more robust results, we applied the following solutions in our analysis: calculating the Variance Inflation Factor (VIF) and, when necessary, implementing regularization methods. In general, a VIF below 10 (preferably below 5) does not indicate severe multicollinearity issues. If VIF > 10, the appropriate regularization technique is applied: Ridge Regression, Lasso Regression, or Elastic Net (average between Ridge and Lasso).
- *Correlation Analysis*. This is a statistical technique that allows measuring the degree of interdependence between 2 studied variables and their statistical significance. To evaluate the intensity of relationships between variables, we used Pearson correlation coefficients (theoretical range: 0 – 1, preferred range: 0.50 – 0.95).
- *Regression Analysis*. In our case, multiple linear regression analysis. Regression analysis studies the relationship between the dependent variable and the rest of the independent variables, also called explanatory variables or predictors. The most important results of regression analysis

are the R coefficients, R Square (R^2), and the statistical significance level. In regression analysis, the coefficient of determination (R^2) is crucial as it shows that the independent variables explain the percentage of variation in the dependent variable. The statistical significance should ideally be below 0.05, indicating over 95% confidence. In current practice, values up to 0.1 are also accepted.

- *Analysis of Variance (ANOVA)*. In our case, multifactorial ANOVA is a statistical method that helps study the impact of explanatory factors on the dependent variable to certify the statistical significance of the model (< 0.05).
- *Validation and Interpretation of Results*

Table 1. *The independent variables selected in the analysis and their impact on the AI domain*

Independent Variable (acronym)	What it measures?	Relevance of the variable	Data source
1. Total expenditure for R&D, as percentage of GDP (R&D%GDP)	Measures the level of investment in research and development, % of GDP	R&D investments are essential for technological innovation, including AI development. Countries with high R&D expenditures tend to have more successful AI projects	World Bank & EUROSTAT
2. Venture capital investments in AI (VC_Invest_AI), % of GDP (VC_invest AI)	Measures the level of funding for companies developing AI technologies, % of GDP	This type of funding supports the development of AI projects and can influence the number of high-impact projects	Calculated by the authors based on OECD.ai data for the indicator Venture capital investments in AI, expressed in USD millions by country, as well as World Bank statistics for GDP values expressed in constant 2015 prices, USD millions
3. Total number of researchers in R&D per million people (Researchers)	Measures the density of researchers involved in R&D activities per 1 million inhabitants	A country with many researchers has the critical mass necessary to form a qualified workforce capable of generating innovations and contributing to successful AI projects	WORLD BANK (via UNESCO)
4. Global Innovation Index (GII), overall score: [0;100]	Measures the innovative ability and performance of countries	Countries with a higher GII score usually have more human resources (talents) and adequate infrastructure to support research and development, including in AI	WIPO

Source: authors' elaboration, March 2025

4. Results and discussions

Research Question: Could Artificial Intelligence (AI) be considered a catalyst for a new industrial revolution and economic development?
Answer: Following the systematization of relevant literature, the majority opinion is that AI enables automation and optimization of repetitive and complex processes, reducing costs and increasing efficiency and labor productivity. Moreover, robots and intelligent algorithms can replace or aid human labor in sectors such as industry, logistics, and services (finance, education, and health). AI will drop repetitive jobs but will generate (at a slower pace, according to Acemoglu) new jobs in areas such as algorithm development, AI ethics, and cybersecurity. Of course, professional retraining measures are necessary. The answer to the research question is that AI is a vector of the new industrial revolution, but its full success will depend on regulation, adequate education, and the adaptability of the labor market to new requirements.
For testing the statistical hypothesis H1, we present below the results of the empirical analysis: Kaiser-Meyer-Olkin (KMO) Test Results: Overall KMO Value: 0.6287 (62.9% shows moderate suitability for factor analysis).
VIF < 10 for all predictors. Regularization of coefficients is not needed, so we will proceed directly to correlation and regression analysis.

Table 2. *Correlation matrix_2017*

Variables	AI_Very High Impact	VC_Invest AI	R&D %GDP	Researchers	GII
AI_Very High Impact	1	0.6532	0.4287	0.3245	0.3102
VC_Invest AI	0.6532	1	0.2934	0.1876	0.1945
R&D %GDP	0.4287	0.2934	1	0.8456	0.6712
Researchers	0.3245	0.1876	0.8456	1	0.7234
GII	0.3102	0.1945	0.6712	0.7234	1

Source: authors' elaboration, March 2025

Table 3. *Regression Coefficients Table_2017*

Variable	Coefficient	Standard error	t-statistic	p-value
Intercept	-0.0002	0.0876	-0.0023	0.9982
VC_Invest AI	0.3876	0.1132	3.4238	0.0014
R&D %GDP	0.2654	0.1054	2.5183	0.0156
Researchers	0.1432	0.0965	1.4838	0.1456
GII	0.0765	0.1187	0.6445	0.5231

Source: authors' elaboration, March 2025

Figure 5. *Summary Model_2017*

Model Statistics

- **R-squared**: 0.6932
- **Adjusted R-squared**: 0.6612
- **F-statistic**: 21.3245
- **Probability (F-statistic)**: 0.0000

Source: authors' elaboration, March 2025

Table 4. *ANOVA Results_2017*

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*F-statistic*	*p-value*
Regression	*8.1243*	*4*	*2.0311*	*21.3245*	*0.0000*
Residual	*3.5678*	*36*	*0.0991*	-	-
Total	*11.6921*	*40*	-	-	-

Source: authors' elaboration, March 2025

Correlation Highlights (see Table 2)**:**

- Moderate positive correlation between AI Impact and VC Investments (65,32%)
- Weak positive correlation between AI Impact and R&D %GDP (42,87%)
- Strong positive correlation between Researchers and R&D %GDP (84,56%)
- Moderate positive correlation between Researchers and GII (72,34%)
- Moderate positive correlation between R&D %GDP and GII (67,12%)

Regression Analysis & Model Performance (see Table 3 – 4 and Fig. 5):

- VC Investments in AI remain the most significant predictor ($p = 0.0014 < 0.01$)
- R&D Expenditures also significant ($p = 0.0156 < 0.05$)
- The model explains 69.32% of AI Impact variance
- Globally significant model ($p = 0.0000$)

Table 5. *Correlation matrix_2022*

Variables	**AI_Very High Impact**	**VC_Invest AI**	**R&D %GDP**	**Researchers**	**GII**
AI_Very High Impact	1	0.7624	0.5203	0.4118	0.3946
VC_Invest AI	0.7624	1	0.3782	0.2647	0.2519
R&D %GDP	0.5203	0.3782	1	0.8234	0.6571
Researchers	0.4118	0.2647	0.8234	1	0.7312
GII	0.3946	0.2519	0.6571	0.7312	1

Source: authors' elaboration, March 2025

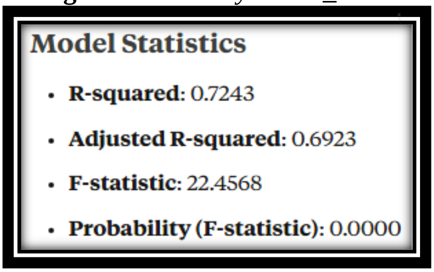
Kaiser-Meyer-Olkin (KMO): Test Results Overall KMO Value: 0.6542 (65,4% indicates moderate suitability for factor analysis).
VIF < 10 for all predictors. The regularization of coefficients is not required.

Table 6. *Regression Coefficients Table_2022*

Variable	Coefficient	Standard error	t-statistic	p-value
Intercept	-0.0001	0.0892	-0.0013	0.9990
VC_Invest AI	0.4237	0.1154	3.6721	0.0009
R&D %GDP	0.2918	0.1076	2.7120	0.0095
Researchers	0.1654	0.0987	1.6753	0.1022
GII	0.0932	0.1243	0.7496	0.4578

Source: authors' elaboration, March 2025

Figure 6. *Summary Model_2022*



Source: authors' elaboration, March 2025

Table 7. *ANOVA Results_2022*

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*F-statistic*	*p-value*
Regression	*8.4521*	*4*	*2.1130*	*22.4568*	*0.0000*
Residual	*3.2198*	*36*	*0.0894*	-	-
Total	*11.6719*	*40*	-	-	-

Source: authors' elaboration, March 2025

Correlation Highlights (see Table 5)**:**

- Strong positive correlation between AI Impact and VC Investments (76,24%)
- Moderate positive correlation between AI Impact and R&D %GDP (52,03%)
- Moderate positive correlation between Researchers and GII (73,12%)
- Strong positive correlation between Researchers and R&D %GDP (82,34%)
- Moderate positive correlation between R&D %GDP and GII (65,71%)

Regression Analysis & Model Performance (see Table 6 – 7 and Fig. 6):

- VC Investments in AI remain the most significant predictor (p = 0.0009 < 0.01)
- R&D Expenditures are also significant (p = 0.0095 < 0.01)
- Weak predictor: Researchers (p = 0.1, indicating 90% confidence)
- The model explains 72.43% of AI Impact variance
- Globally significant model (p = 0.0000)

5. Conclusions

The current industrial revolution, known as Industry 4.0 (evolving towards Industry 5.0), is characterized by advanced technologies that profoundly modify current socio-economic and industrial systems, with AI occupying an important place in these transformations.

On the other hand, AI projects are essential for enhancing national competitiveness, having a significant impact on technological and economic capabilities. Strengthening the competitive advantage of organizations and implicitly of nations in the global market requires integration of scientific knowledge, development of appropriate national strategies, and addressing challenges specific to artificial intelligence.

Artificial Intelligence (AI) can be considered a catalyst for socio-economic progress and the new industrial revolution, but its full success will be conditioned by an efficient regulatory framework and an adequate educational system capable of adapting to new labor market requirements.

Although this paper did not aim to address the risks associated with AI (unethical use, loss of low-skilled jobs, amplification of social inequalities, and loss of control), these will require special attention from legislators through regulation and strict control.

The results of the empirical analysis indicate that the development of very large-scale artificial intelligence projects is closely correlated with the level of investment in research and, especially in AI, while the influence of the total number of active researchers in the research and development (R&D) sector is lower. Intuitively, it can be argued that the essential difference is determined by the quality and expertise of researchers rather than their number. Moreover, according to the latest available data, countries best positioned in the area of very important AI projects (Fig. 3) have, according to WB statistics (via UNESCO), a total number of researchers working in the R&D sector, per 1 million inhabitants, of approximately 4,500 (USA) and 1,700 (China), compared to countries at the top with 9,100 (Korea) or > 8,000 (Sweden), and India with only 260 researchers, which is a leader in small projects (Fig. 1 – ALL AI projects).

The multiple regression econometric model proposed in the empirical analysis is valid, and the dependency hypothesis, "Available talents and the level of investment in research, development, and innovation significantly influence the scale of AI projects," has been confirmed by the statistical results obtained.

The results of this study contribute to an in-depth understanding of the determinants of the development of artificial intelligence projects with significant impact at the level of EU27 member states. In this context, countries that allocate substantial financial resources in the field of research, development, and innovation, especially in the sphere of artificial intelligence, can anticipate considerable economic benefits. At the same time, the European Union cannot afford the risk of losing the global technological competition with its main rivals, the USA and China, especially in terms of progress in the field of artificial intelligence.

To strengthen its position in the field of artificial intelligence and increase its global competitiveness, the European Union should adopt a series of strategic measures:

- Increasing R&D Investments: Allocate more funds for AI projects through dedicated programs and encourage public-private partnerships for innovation.
- Fostering a Competitive AI Ecosystem: Promote collaboration between universities, research institutes, and industry to accelerate knowledge and technology transfer.
- Creating a Supportive Legal Framework: Implement clear, flexible regulations that foster innovation while safeguarding ethics and rights in AI use.
- Enhancing Digital Skills: Boost workforce competitiveness by offering educational and training programs for AI specialists.
- Supporting Start-ups and SMEs: Improve access to financing and markets for AI companies to enhance their global competitiveness.
- Building Advanced Digital Infrastructure: Develop high-performance computing networks, cloud infrastructure, and shared AI databases.
- Promoting International Cooperation: Establish strategic alliances to access advanced technologies and make a contribution to the development of global AI standards.

Regarding the study's limitations, future research may consider, but is not limited to, the inclusion of additional indicators and/or countries, the examination of longer periods (depending on data availability), the exploration of risks associated with digitalization and AI, along with strategies for their mitigation or elimination, and the formulation of new hypotheses or research questions related to the topic.

References

Acemoglu, D. and Restrepo, P., 2019. Automation and new tasks: How technology displaces and reinstates labor. *Journal of Economic Perspectives*, 33(2), pp.3-30.

Aghion, P. and Howitt, P., 1992. A model of growth through creative destruction. Econometrica, 60(2), pp.323-351. https://doi.org/10.2307/2951599 [accessed March 2025].

Ahmed, N., Wahed, M. and Thompson, N., 2023. The growing influence of industry in AI research. *Science*, 379, pp.884-886. https://doi.org/10.1126/science.ade2420 [accessed March 2025]

Al-Marzouqi, A. and Arabi, A., 2024. A comparative analysis of the performance of leading countries in conducting artificial intelligence research. *Human Behavior and Emerging Technologies*. https://doi.org/10.1155/2024/1689353 [accessed March 2025]

Anderson, K., 2016. Fond remembrances of past futures. *Journal of Business Anthropology*, 5, pp.77-88. https://doi.org/10.22439/JBA.V5I1.5216 [accessed March 2025]

Babina, T., Fedyk, A., He, A. and Hodson, J., 2024. Artificial intelligence, firm growth, and product innovation. *Journal of Financial Economics*. https://doi.org/10.1016/j.jfineco.2023.103745 [accessed March 2025]

Besiroglu, T., Emery-Xu, N. and Thompson, N., 2022. Economic impacts of AI-augmented R&D. *Research Policy*. https://doi.org/10.1016/j.respol.2024.105037 [accessed March 2025]

Bianchi, P. and Labory, S., 2018. *Industrial policy for the manufacturing revolution: Perspectives on digital globalisation*. Edward Elgar Publishing.

Brem, A., Giones, F. and Werle, M., 2021. The AI digital revolution in innovation: A conceptual framework of artificial intelligence technologies for the management of innovation. *IEEE Transactions on Engineering Management*, pp.1-7. https://doi.org/10.1109/TEM.2021.3109983 [accessed March 2025]

Chaudhary, S., 2024. Artificial intelligence and its impact on economic growth. *Shodh Sari-An International Multidisciplinary Journal*. https://doi.org/10.59231/sari7676 [accessed March 2025]

Dwivedi, Y. et al.., 2023. Evolution of artificial intelligence research in Technological Forecasting and Social Change: Research topics, trends, and future directions. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2023.122579 [accessed March 2025]

Fan, D. and Liu, K., 2021. The relationship between artificial intelligence and China's sustainable economic growth: Focused on the mediating effects of industrial structural change. *Sustainability*. https://doi.org/10.3390/su132011542 [accessed March 2025]

Feijóo, C. et al., 2020. Harnessing artificial intelligence (AI) to increase wellbeing for all: The case for a new technology diplomacy. *Telecommunications Policy*, 44, pp.101988-101988. https://doi.org/10.1016/j.telpol.2020.101988 [accessed March 2025]

Howard, J., 2019. Artificial intelligence: Implications for the future of work. *American Journal of Industrial Medicine*. https://doi.org/10.1002/ajim.23037 [accessed March 2025]

Huy, T., Hong, T., Thanh, C. and Tran, P., 2024. AI innovation and economic growth: A global evidence. *WSB Journal of Business and Finance*. https://doi.org/10.2478/wsbjbf-2024-0017 [accessed March 2025]

Imran, M. et al., 2020. Wireless automation as an enabler for the next industrial revolution. https://doi.org/10.1002/9781119552635 [accessed March 2025]

Javaid, M., Haleem, A., Singh, R. and Suman, R., 2021. Artificial intelligence applications for Industry 4.0: A literature-based study. *Journal of Industrial Integration and Management*. https://doi.org/10.1142/s2424862221300040 [accessed March 2025]

Jutel, M. et al., 2023. The artificial intelligence (AI) revolution: How important for scientific work and its reliable sharing. *Allergy*, 78. https://doi.org/10.1111/all.15778 [accessed March 2025]

Kinkel, S., Baumgartner, M. and Cherubini, E., 2021. Prerequisites for the adoption of AI technologies in manufacturing – Evidence from a worldwide sample of manufacturing companies. *Technovation*. https://doi.org/10.1016/j.technovation.2021.102375 [accessed March 2025]

Kumari, S., Shaikh, R., Bhayo, M., Devi, S. and Cao, S., 2024. Optimizing financial success: The synergistic impact of artificial intelligence and R&D investments in U.S. firms. *Journal of Infrastructure, Policy and Development*. https://doi.org/10.24294/jipd.v8i9.6985 [accessed March 2025]

Lee, Y., Kim, T., Choi, S. and Kim, W., 2022. When does AI pay off? AI-adoption intensity, complementary investments, and R&D strategy. *Technovation*. https://doi.org/10.1016/j.technovation.2022.102590 [accessed March 2025]

Li, G., Hou, Y. and Wu, A., 2017. Fourth industrial revolution: Technological drivers, impacts and coping methods. *Chinese Geographical Science*, 27, pp.626-637. https://doi.org/10.1007/s11769-017-0890-x [accessed March 2025]

Liu, J., Chang, H., Forrest, J. and Yang, B., 2020. Influence of artificial intelligence on technological innovation: Evidence from the panel data of China's manufacturing sectors. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2020.120142 [accessed March 2025]

Malik, S., Muhammad, K. and Waheed, Y., 2024. Artificial intelligence and industrial applications revolution in modern industries. *Ain Shams Engineering Journal*. https://doi.org/10.1016/j.asej.2024.102886 [accessed March 2025]

Martinelli, A., Mina, A. and Moggi, M., 2020. The enabling technologies of Industry 4.0: Examining the seeds of the fourth industrial revolution. *Economics of Innovation eJournal*. https://doi.org/10.2139/ssrn.3726922 [accessed March 2025]

Martinelli, A., Mina, A. and Moggi, M., 2021. The enabling technologies of Industry 4.0: Examining the seeds of the fourth industrial revolution. *Industrial and Corporate Change*. https://doi.org/10.1093/ICC/DTAA060 [accessed March 2025]

Mohamed, M., Ibrahim, O., Hamed, H. and Abdelnaby, S., 2024. Engineering's next leap: How fourth industrial revolution is shaping the future of the industry. *ERU Research Journal*. https://doi.org/10.21608/erurj.2024.245917.1086 [accessed March 2025]

Möller, D., Vakilzadian, H. and Haas, R., 2022. From Industry 4.0 towards Industry 5.0. *2022 IEEE International Conference on Electro Information Technology (eIT)*, pp.61-68. https://doi.org/10.1109/eit53891.2022.9813831 [accessed March 2025]

Ozkaya, G. and Demirhan, A., 2023. Analysis of countries in terms of artificial intelligence technologies: PROMETHEE and GAIA method approach. *Sustainability*. https://doi.org/10.3390/su15054604 [accessed March 2025]

Paköz, B., 2024. AI and robotics in precision research. *Human Computer Interaction*. https://doi.org/10.62802/0j3aqk28

Paschek, D., Mocan, A. and Draghici, A., 2019. Industry 5.0 – The expected impact of the next industrial revolution, pp.125-132.

Romer, P. M., 1990. Endogenous technological change. *Journal of Political Economy*, 98(5), pp. S71- S102. http://www.jstor.org/stable/2937632 [accessed March 2025]

Ross, P. and Maynard, K., 2021. Towards a 4th industrial revolution. *Intelligent Buildings International*, 13, pp.159-161. https://doi.org/10.1080/17508975.2021.1873625 [accessed March 2025]

Saba, C. and Ngepah, N., 2024. The impact of artificial intelligence (AI) on economic growth in BRICS: Does the moderating role of governance matter?. *Research in Globalization*. https://doi.org/10.1016/j.resglo.2024.100213 [accessed March 2025]

Sandhu, A., 2021. Big data with cloud computing: Discussions and challenges. *Big Data Min. Anal.*, 5, pp.32-40. https://doi.org/10.26599/bdma.2021.9020016 [accessed March 2025]

Schiølin, K., 2020. Revolutionary dreams: Future essentialism and the sociotechnical imaginary of the fourth industrial revolution in Denmark. *Social Studies of Science*, 50, pp.542-566. https://doi.org/10.1177/0306312719867768 [accessed March 2025]

Schwab, K., 2016. *The fourth industrial revolution*. NY: Crown Business.

Shao, Z., Zhao, R., Yuan, S., Ding, M. and Wang, Y., 2022. Tracing the evolution of AI in the past decade and forecasting the emerging trends. *Expert Systems with Applications*, 209, 118221. https://doi.org/10.1016/j.eswa.2022.118221 [accessed March 2025]

Syam, N. and Sharma, A., 2018. Waiting for a sales renaissance in the fourth industrial revolution: Machine learning and artificial intelligence in sales research and practice. *Industrial Marketing Management*, 69, pp.135-146. https://doi.org/10.1016/J.INDMARMAN.2017.12.019 [accessed March 2025]

Wang, S., Zhang, Y., Xiao, Y. and Liang, Z., 2025. Artificial intelligence policy frameworks in China, the European Union and the United States: An analysis based on structure topic model. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2025.123971 [accessed March 2025]

Xiang, W., Yu, K., Han, F., Fang, L., He, D. and Han, Q., 2024. Advanced manufacturing in Industry 5.0: A survey of key enabling technologies and future trends. *IEEE Transactions on Industrial Informatics*, 20, pp.1055-1068. https://doi.org/10.1109/TII.2023.3274224 [accessed March 2025]

Xiao, L., Xiao, Y. and He, R., 2024. The research and development investment management in technology enterprises under artificial intelligence. *IEEE Access*, 12, pp.190936-190944. https://doi.org/10.1109/ACCESS.2024.3518070 [accessed March 2025]

Xu, H., Yu, W., Griffith, D. and Golmie, N., 2018. A survey on industrial internet of things: A cyber-physical systems perspective. *IEEE Access*, 6, pp.78238-78259. https://doi.org/10.1109/ACCESS.2018.2884906 [accessed March 2025]

Xu, L., Xu, E. and Li, L., 2018. Industry 4.0: State of the art and future trends. *International Journal of Production Research*, 56, pp.2941-2962. https://doi.org/10.1080/00207543.2018.1444806 [accessed March 2025]

Yi, Z. and Ayangbah, S., 2024. The impact of AI innovation management on organizational productivity and economic growth: An analytical study. *International Journal of Business Management and Economic Review*. https://doi.org/10.35409/ijbmer.2024.3580 [accessed March 2025]

Yuan, C., Tang, J., Cao, Y., Wei, T. and Shen, W., 2024. The impact of artificial intelligence on economic development: A systematic review. *International Theory and Practice in Humanities and Social Sciences*. https://doi.org/10.70693/itphss.v1i1.57 [accessed March 2025]