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COMPARATIVE ANALYSIS OF THE SCIENTIFIC AND TECHNOLOGICAL POTENTIAL OF THE EUROPEAN UNION AND ITS KEY COMPETITORS

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Abstract. The article covers the comparative analysis of the European Union's technological and scientific potential with its key competitors such as the United States, China and Russia. The study analyzes R&D share and brain drain problem through six indicators. Main methodologies include comparative analysis of the scientific and technological potential, as well as Keun Lee's Schumpeterian analysis. The European Union exibits a medium power in the ongoing geotechnological rivalry.

Key words: Technology, Horizon Europe, Fourth Industrial Revolution, investment, European brain, Brussels effect, innovation, breakthrough, rising power

INTRODUCTION

Technological and scientific indicators are important to assess state's geopolitical position. Technological supremacy of the Britain and the United States during the First and Second Industrial Revolutions was determing element of their role as global leader. In the period of the Fourth Industrial Revolution technologies are rebalancing the global order, reshaping power structures, becoming determinant to system changes, scientific and technological comparative analysis help to define state's role. A comparative analysis of the EU and its potential rivals such as the US, China, and the United Kingdom assists to determine position.

Western Europe was changed through the scientific knowledge production in the context of geopolitics and economics. Technological superiority and capital accumulation were interconnected that the First Industrial Revolution emerged in England and continuation of the Third and Fourth Industrial Revolutions prove the process. This historical understanding of the connection helps to conduct a research to analyze current tech and scientific opportunities of the EU.

The following problems are addressed further: main measurements of scientific and technological potential; technological innovations ecosystem analysis; R&D indicators; brain drain issue, Horizon Europe program.

THEORETICAL FRAMEWORK

Main methodologies include comparative analysis of the scientific and technological potential, as well as Keun Lee's Schumpeterian analysis and so on. According to Lee, there are three main stages of technological catch-up: foremost, establishing existing technologies in the relocation period; second, adapting adopted technologies to local environment - adaptation level; third, independent production of innovations at the creating stage. Rising power - China's case is practical model of Lee's analysis, and this also can be applied to analyze shortcomings and advantage capabilities of the EU.[1]

There are six main indicators of evaluating scientific and technological potential of states: first number of professionals in the rated fields per million people. Second indicator reflects how much state value innovations and ready to fund - R&D spending in relation to GDP. Third, number of tech companies and "unicorn" startups. Fourth, patent quality and granting. Fifth, developing important sectors such as biotechnology, AI and quantum technologies. Sixth, conducted scientific research volume with Nature Index and Web of Science indices.

MAIN ANALYSIS

According to WIPO Global Innovation Index report in 2025, top 20 innovative countries placed with the EU members, particularly Switzerland, Sweden, Denmark and Netherlands owe first places in the ranking while other non-EU countries also show high positions in the list that means in separate individual assessment of states gross decreasing. [2]

The EU Innovation Scoreboard report in 2025 details the R&D spending of the EU in the comparative position. Complete R&D spending was 2.22% of GDP or about €424 billion in 2024 - sufficiently lower than 3.3% in Japan, 3.5% in the US, 4.9% in South Korea and 5.4% in Israel.

OECD Science, Technology and Innovation Outlook report provides a fact that the US's total spending with $900 billion in 2024 closely double the EU's R&D spending. In the same year, China was the second global investor of the R&D with $738 billion. To deeply interpret the data it is obvious that in spite of the fact that the EU is behind in terms of absolute, stays competitive per capita terms. The nuance highlights that structural effectiveness is not sufficient rather than volume. [3]

However, R&D spending differs from among member states of the EU. This domestic structural issue raises from innovator countries till emerging innovative economies. Sweden with 3.5% of GDP, Finland and Austria 3.2%, Denmark 3.0% are innovation leaders closes to the US level. Yet, follower countries of innovation such as Hungary 1.8%, Greece 1.5%, Poland 1.4%,

[1] Lee, Keun. Schumpeterian Analysis of Economic Catch-up. Cambridge University Press, 2019, pp. 1–45.

[2] World Intellectual Property Organization. Global Innovation Index 2025. Geneva: WIPO, 2025

[3] OECD. OECD Science, Technology and Innovation Outlook 2025. Paris: OECD Publishing, 2025.

Romania 0.5% misbalances the distribution decreasing than average. In the result, single technological strategy could not be shaped until achieved necessary innovative capability. [4]

In the technological zone R&D spending plays an important role as first element of it - metropolis without technological sovereignty cannot form fully-completed technological zone - a core of academic and innovative startups to introduce to peripheries. In this case, in spite of the fact that the EU has separate technological hubs such as France, Germany and Netherlands, these hubs have not been united to a single technological zone - the internal issue of the EU.

Patenting process of scientific ideas should be unified with the capacity of commercializing these innovations. WIPO Global Innovation Index 2025 indicates that the first place was taken by more than 315,000 patent applications were filled out in the US in 2024. In parallel terms, China led with combination of internal and external applications 1.58 million in the same year. But according to patent quality indicators the US and Europe lead. [5]

In 2024, the European Patent Office granted approx. 188,000 patents. Leading countries are Germany, France, the Netherlands and Sweden. Structural problem can be seen through the patent activeness: the EU mainly grant patents in incremental -phased innovations - development in existing technologies rather than modifying innovations that serve to lead significant changes is lower than the US. The main cause of the issue is non-developing system of transfer mechanisms that connects research universities with funding ecosystem.

When analyzed by Robert Atkinson's approach in The Innovative Economy and Global Technological Competition the EU demonstrates several divergence to the US. According to Atkinson, successful innovative ecosystem not only relies on the funding amount of R&D, further it demands enterprise environment ready to risk, commercializing innovations in high rate and public-private partnerships.[6]

The EU's innovation ecosystem challenges were analyzed in Technological Sovereignty and European Competitiveness by Andrea Renda. Renda claims that without forming sufficient innovation ecosystem the EU could not achieve technological sovereignty goals. It ensures a phenomenon of the "Brussels paradox": the EU tries to be both regulator and producing force of technology simultaneously, but the first regulation environment can prevent innovative breakthrough climate driven by risk - shows two opposing sides of the situation.[7]

Human capital is most important element as it composes both innovator role and labor resource which is volatile problem for the EU in terms of technological and scientific potential. The

[4] European Commission. European Innovation Scoreboard 2025. Brussels: European Commission, 2025.

[5] WIPO. Global Innovation Index 2025. Geneva: WIPO, 2025.

[6] Atkinson, Robert. “Innovation Economics and Global Technological Competition.” ITIF, 2024.

[7] Renda, Andrea. “Technological Sovereignty and Europe’s Competitiveness.” CEPS, 2024.

UNESCO Science Report 2025 shows the number of 4.200 per million habitants that represent valuable measure globally. Human capital advantage of the EU is eroding by brain drain to the US.[8]

Main attracting country has been the United States- the EU's most talented experts and professionals according to "European Brain" report, particularly 40-50 percent of technologists with PhDs migrate other countries, especially to the US. High salaries with high risk-high reward culture in Silicon Valley keeps on attracting European scientists- this "brain drain" issue is structural problem to evaluate the EU's scientific and technological potential.

Systematic analysis of the problem of "brain drain" comes from Manuel Castells' theory of network society. According to Castells, "innovators" are "creators of self-programming workforce" which form the major value source in developed countries. Innovators are main drivers of network economy and prefer to work in high academic culture with high salaries and with prestigious working conditions. European Union fails in technological talent competition as cannot offer competitive salaries [9].

FINDINGS

There are two main confronted trends: first trend brain drain mainly in the spheres computer, engineering, second trend attracting experts and scientists in the fields of biotechnology and natural sciences from all over the world through the institutional mechanisms such as Marie Curie program and the European Research grants. So brain drain issue in the fields of cybersecurity, AI and semiconductors is very important in the technological rivalry.

According to the EIB Investment Report, the effectiveness of Horizon Europe program is its aiming at creating about €8-11 value for each invested €1. This program is one of the largest funding R&D with €95.5 billion during 2021-2027. There are three major routes: first, the European Research Council supports scientific research; second, the European Innovation Council improves innovation ecosystem and third, working out of global issues such as clime change, environmental pollution and etc.[10]

When Horizon Europe is compared to the US government R&D investments the evaluation shows that the program's gross volume is high but US's National Institute of Health and National Science Foundation's annual budget is approaching to the 7 years budget of the Horizon Europe. Overall budget for the Chinese "National Key Research Programs" and the "985 Project" is also in the volume that can surpass with EU's allocated R&D funding.

According to the European Investment Bank's Investment Report 2025, a key issue in the innovation investments: companies are dependent on external tech infrastructure, particularly to the US. A real case where leads to strategic dependent situation and impacts technological sovereignty of the EU is that AWS of Amazon, Google Cloud and Azure of Microsoft are cloud computing

[8] UNESCO. UNESCO Science Report 2025. Paris: UNESCO, 2025.

[9] Castells, Manuel. The Rise of the Network Society. Wiley-Blackwell, 2010, pp. 1–28.

[10] European Investment Bank. Investment Report 2025/2026. Luxembourg: EIB, 2026.

technological dominants in corporate environment and the US is leading in AI software industry is dominant in the EU. Control of data security and digital infrastructure show geopolitical characters of the issue rather than economic side.[11]

Geotechnological competition has a three significant sectors - AI, quantum computing and biotechnology - all is necessary to count every of them separately as it helps to understand prospects of geotechnological position of the EU through superiority or weak roles in these areas.

In the AI sector the US is complete leading country according to the number of global AI companies and venture investments value including Meta AI, Anthropic, ChatGPT, OpenAI and Google DeepMind. On the other hand, China is forming its AI ecosystem through Alibaba, Tencent, Huawei and Baidu and leading country in number of AI patents. To compare with the EU's main capital invested in AI startups was around $12-14 billion - a highly difference with $67 in the US in 2024. Meanwhile, the EU is an international leader in terms of AI legislation: the AI Act in 2026 is the first global AI regulation.[12]

The EU showcases potential competitive position in quantum technologies. The European Quantum Technology Flagship during 2018-28 years is aimed at conducting research in the relative fields like quantum sensing, quantum computing, quantum communication which funded with 1 € billion. The EU's independent scientific-technological potential can be seen through the following: France launch several startups towards quantum computing, Germany cooperates with Google and IBM while Netherlands has its QuTech center. Nevertheless, IBM, Baidu, Google and Honeywell companies by the US and China display leadership in technologies.[13]

Biotechnology is one of the most advancing fields in the EU. International biotechnology chain require the products by companies such as AstraZeneca of UK-Sweden, Novartis and Roche of Switzerland and BioNTech in Germany. One breakthrough was BioNTech-Pfizer vaccine in the Covid-19 period in the biotechnology industry. But main disadvantage is "dislocation of the corporative center not tech talents" to the US, as the US pharmaceutical companies are selling innovative startups.

Chinese strategy towards technological development can be analyzed through Schumpeterian method by Keun Lee. China has been gradually applying all three stages - transfer, adaptation, creation - of technological advancement at the same time. By 2027, China can be global leading actor in terms of patenting and can advance and reach to the US in AI researching publications. Important risk is about technological sovereignty of China as its rare earth materials and patents still need external technology.[14]

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[11] EIB. Investment Report 2025/2026. Luxembourg: EIB, 2026.

[12] OECD STI Outlook 2025; Reuters. “EU Seeks to Close Innovation Gap.” 2025.

[13] European Commission. Quantum Flagship Initiative. Brussels, 2024.

[14] Lee, Keun. Schumpeterian Analysis. Cambridge University Press, 2019.

Comparative analysis of the technological and scientific potential of the EU and China demonstrate the following results. Firstly, Chinese economic acceleration is in high speed during yet the EU's regulatory power, particularly in AI legislation and data transfer security system will obstacle technologies of China to access to the European market. Secondly, the EU leads in quality patent and scientific research, however lacks in R&D spending- €424 billion in the EU and $738 billion in China. Thirdly, strategic confrontation for sovereignty ambitions is in conflict with coopetition - competition-cooperation dynamics, so two sides should be balanced.

The European Innovation Scoreboard innovative indicators split of the EU countries into four groups: "innovation leaders", "strong innovators", "moderate innovators", and "emerging innovators". Economic difference can be reflection of technological disparity when observed domestic issue of structure: taxonomy among innovative leaders such as Finland, Belgium, Sweden, Denmark and Netherlands and emerging innovators such as Bulgaria, Latvia and Romania.[15]

Domestic policy of the EU faces several obstacles that prevent to create its own technological zone. It can be suggested that decreasing the gap among in two main parts: "innovative leading core" in Western- Northern Europe and "innovative periphery" in Eastern and Southern Europe would contribute to analyze the whole potential of the EU compared with the US and China. Moreover, internal divergence can be beneficial in the case of testing new technologies in low labor markets in "innovative periphery" countries.

There are observed several advantages of the EU. Firstly, scientific studies quality: occasionally high rankings by universities as Oxford, TU Munich, EHT Zurich. Indicators of Web of Science and Nature Index present that 30-35 percent of scientific knowledge production were by EU authors. Secondly, normative power: RePowerEU, AI Act, DMA - the EU sets global standards that coordinate strategic rivalry. Third, industrial technology and engineering: France leads in aerospace, Netherlands in ASML technology, Germany is known for engineering machinery.[16]

CONCLUSION

The analyzed literature gives several important conclusions through comparative assessment. Technological leapfrogging introduced by Keun Lee applied to the East Asian context can also be implemented to the EU. Institutional limitations as the issue of distribution of power among member states has not been counted despite the practical innovative analysis of Atkinson's approach. "Brussels paradox" introduced by Andrei Renda gives constitute analysis towards the EU but demands further empirical observations.

UNESCO, OECD, and WIPO reports add empirical data and evidence, however they have more descriptive and normative character and not fully refer to the geopolitical implications of the scientific and resource potential of the EU. Policy-related analysis was operational by the EIB report. Further Castells discusses network society theory and through it explains "brain drain" systematically till 2010, yet current AI century was not fully covered dynamically. So that the above analyzed literature was not sufficiently adequate to capture the scientific-technological

[15] European Commission. European Innovation Scoreboard 2025. Brussels, 2025.

[16] OECD STI Outlook 2025; Renda, Andrea. CEPS, 2024.

capability of the EU in the context of geotechnological competition and do not apply technological zone concept to analyze the position of the EU.

The EU exhibits a complicated landscape of scientific and technological resource potential through the above comparing analysis. While the EU has a regulatory power and global leaders in engineering, biotechnology, pharmaceutical industry and scientific work, it also lags behind the US, and China in investments, venture capital and capacity to discover "breakthrough" innovations in digital infrastructure and AI industry.

In conclusion, middle power is status that earned the EU in geotechnological rivalry as it means dual position weak in advanced digital technologies and strong in industrial traditional technologies. This allows to determine the EU's position as differentiated medium power. Therefore, competitive ecosystem was built on the research quality and hidden champions with engineering value, it lags behind the US in several spheres: AI funding through corporate venture capital, digital sector innovative scope.

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