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INNOVATION PERFORMANCE AS A SIGNIFICANT FACTOR IN THE CONVERGENCE PROCESS OF THE V4 COUNTRIES

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Abstract. Innovation constitutes a fundamental pillar of economic development, particularly within the framework of the knowledge-based economy, which prioritizes the creation of high added value through research and development (R&D). Within the European Union, innovation performance is increasingly acknowledged as a critical determinant of national competitiveness, economic prosperity, and regional convergence. This study examines the interrelationship between innovation performance—measured by the Summary Innovation Index (SII) and economic wealth, represented by GDP per capita and GDP per capita in purchasing power standards (PPS), across the Visegrad Four (V4) countries, all of which acceded to the European Union in 2004. Utilizing quantitative methods, primarily regression and correlation analyses, the research identifies statistically significant associations among innovation performance, R&D investment, and selected economic indicators. The findings reveal substantial disparities in innovation capacity among the V4 countries and highlight uneven progress in their convergence with the more established EU member states. Beyond the prevalence of declarative political commitments to fostering a knowledge economy, the results underscore the urgent need for targeted policy interventions aimed at enhancing innovation performance and accelerating the convergence trajectory of the V4 region.

Keywords: convergence; innovation; innovation performance; knowledge-based economy; research and development; Visegrad group countries

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JEL Classifications: O11, O30

1. Introduction

Explaining why some economies grow faster and become more prosperous than others has been a central concern since Solow's neoclassical growth model first formalized the role of factor accumulation over half a century ago. Subsequent research increasingly emphasizes that technological change and innovation, rather than capital deepening alone, are the decisive engines of sustained growth and convergence (González, Guimaraes & Diele-Viegas, 2025). In particular, the capacity of latecomer economies to absorb, adapt, and generate new technologies has been identified as a key determinant of catch-up, shifting attention from investment volumes to innovation capabilities (Fagerberg, 2010; Al-Omoush & Gomez-Olmedo, 2024; Ahmed, Piccinetti & Rezk, 2024).

Schumpeter framed innovation as the dynamic force of capitalism—new combinations introduced by entrepreneurs that transform production, organization, markets, and ultimately economic structures. His contribution underscores innovation as an economic process (not merely invention), highlighting its disruptive role and the entrepreneurial agency behind it (Schumpeter, 1934; Mirvis, 2024).

The Oslo Manual—jointly issued by the OECD and Eurostat—provides the international standard for defining and measuring innovation. The third edition (2005) crystallized the now-canonical four types of innovation (product, process, marketing, organizational), while the fourth edition (2018) broadened scope and updated concepts and guidance for cross-country comparability (OECD & Eurostat, 2005; OECD & Eurostat, 2018). Innovation can be understood as both a product/outcome (e.g., new goods, services) and a process (e.g., new production or delivery methods). Product innovations often differentiate firms and reshape market structures, while process innovations target cost, quality, and efficiency improvements—together enabling competitive repositioning and productivity gains (Lofsten, 2014; OECD & Eurostat, 2018; Li et al., 2024).

The European Innovation Scoreboard that is based on the Summary Innovation Index (SII) provides a comparative assessment of national innovation systems across the EU. Commonly merging indicators:

- Human resources in the area of science and technology (% of population)
- Participation in lifelong education (age of 25-64 years)
- Public expenses for research and development (% GDP)
- Company expenses for research and development (% GDP)
- Employment in medium-tech and high-tech production (% of overall work force)
- Employment in high-tech services (% of overall work force)
- Patents registered in The European Patent Office (per one m. citizens).

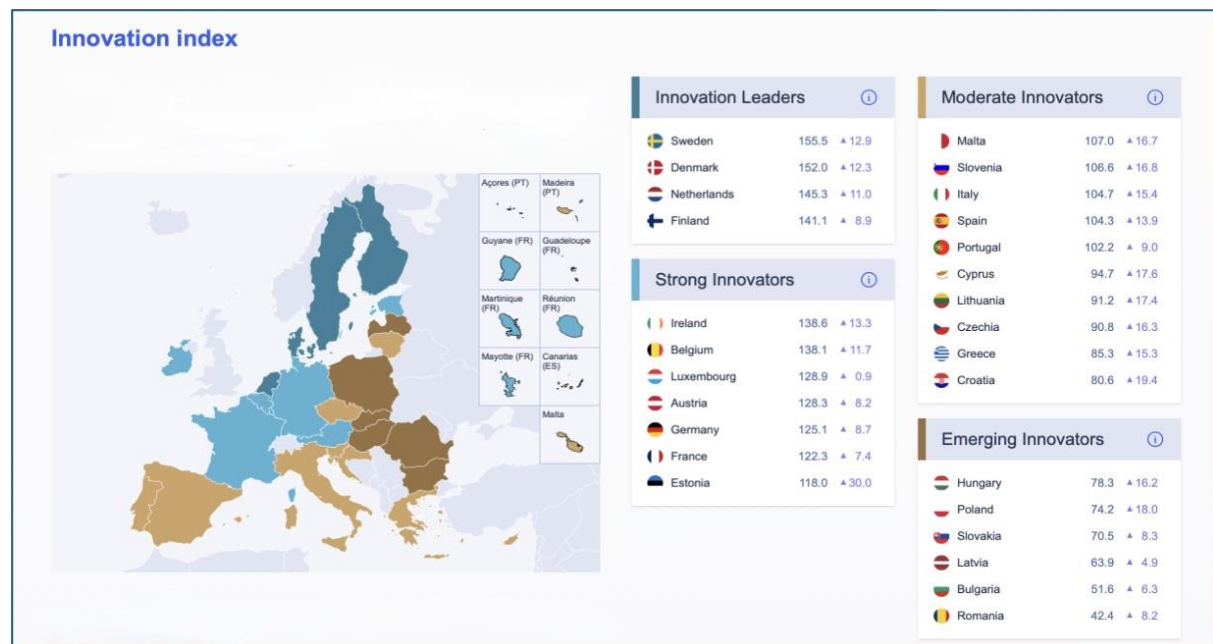


Fig. 1. Innovation performance of the European countries, 2025
Source: The European Innovation Scoreboard interactive tool (2025)

Figure 1 illustrates that the leading innovators within the European Union are predominantly Nordic countries, namely Sweden, Finland, Denmark, and the Netherlands. Hunady et al. (2022) perceive digital transformation as one of the essential sources of success of the Nordic countries. Digital innovations and e-knowledge deliver through the mechanism of digital infrastructure linkage and contribute to improved innovation performance (Janusz & Kowalczyk, 2022; Hussain, Jun & Radulescu, 2024). Within the Visegrad Group, only the Czech Republic attains the status of a moderate innovator, whereas the remaining member states are classified among the least innovative economies, categorized as emerging innovators.

In May 2004, Slovakia, Czech Republic, Poland, and Hungary joined the European Union as part of the largest enlargement in EU history, which integrated ten new Member States from Central and Eastern Europe. This accession marked a significant step toward political and economic integration, opening access to the single market and structural funds. From a convergence perspective, EU membership should accelerate the process

of real and nominal convergence, enabling these economies to narrow income and productivity gaps with older member states through increased trade, foreign direct investment, and institutional reforms aligned with EU standards. According to endogenous growth theory, innovation enhances productivity and accelerates structural transformation, enabling less developed economies to catch up with more advanced members. This article is focusing on the role of innovation performance in the economic convergence of Visegrad Four (V4) countries.

2. Literature review

In July 2022, the European Commission adopted the New European Innovation Agenda, which aims to position Europe at the forefront of deep-tech innovation and accelerate the scaling up of innovative companies. This agenda introduces five flagship areas—such as funding scale-ups, enabling innovation through experimentation, and fostering talent—and outlines 25 concrete actions to strengthen innovation ecosystems and address the innovation divide across the EU. It builds on previous strategies but reflects updated priorities like the green and digital transitions, resilience, and global competitiveness. Another important document is The European Industrial Strategy, updated in 2020 with recovery goals after the COVID pandemic. This document confirmed the Lisbon Strategic Aim to increase the investment ratio into science, research and innovation at least on the level of 3% GDP of the member countries.

To reach the set innovation goals the EU has proposed these following measures:

- 1) to continue in investments into innovation regardless of saving measures;
- 2) to improve the quality of Europe and individual state internal systems of research and innovation;
- 3) to modernize educational systems at all levels;
- 4) to use the EU research area for improving cooperation of innovators and researchers;
- 5) to simplify the approach towards European programs;
- 6) to commercialize innovations – improve the links among scientists and enterprises;
- 7) to dispose of the barriers restricting the introduction of new ideas into market – more functions for the SMEs sector;
- 8) to establish European partnerships this would support and accelerate the research, development and introduction of innovations to the market;
- 9) to improve innovations in the public sector;
- 10) to support the cooperation with international partners and open up the opportunity of the EU support programs.

It is important to note that the economies of the greatest innovators among European countries are strongly focusing in their key strategic documents on sustainable and “green” economic growth. Globocnik, Rauter and Baumgartner (2020) also emphasize the importance of the sustainability-related innovation orientation of the economy. Sustainable economy plays an important role of the covid-recovery financial help from the European Union – e.g., in Slovakia, the largest amount of financial support of the Covid-recovery plan will be used for support of the sustainable and “green” economy projects. Trainer (2022) however pointed out the practical unattainability of these green goals and their negative economic impact. Childs and Triantis (1999) examined different R&D investment policies and their success in fulfilling the goals – results could be also used as basics for evaluation of the sustainability-related innovation policies. Carboni and Medda (2020) offer tools for the evaluations of internal enterprises’ policies on the micro-level. Hafezali et al. (2020) modeled the impact of R&D expenditure on GDP growth in the EU under broad conditions of globalization. Regional development from the perspective of R&D expenditure was examined in the research made by Woo, Kim and Lim (2017). Hong (2017) in his research based on data from South Korea identified a link between the volume of R&D expenditure and the country's economic growth. Kamasak (2015) with other factors impacting innovation performance mentioned also R&D investments. Kučera and Fil'a (2022) confirmed a precondition that a higher % of expenditure into research and development increases also the innovation performance of an individual country. A typical example is Sweden which in long term spends on research and development in the comparison with the GDP the largest financial amount and so it represents the leader in innovation performance among the EU member states in long term. Albulescu and Draghici (2016) pointed out that higher business support alone does not mean higher innovation performance. From this perspective, it is crucial to support the R&D also by public funds and not only by private financial sources.

Wang and Thornhill (2010) are focusing on ways how the R&D development could be financed on micro-level. Among the innovation performance and wealthiness of the countries there is a precondition of correlation and therefore a higher innovation performance leads to higher wealth of the country (measured by the real GDP per capita). Endo and Ikeda (2021) focused in their research on ways how the wealthy countries are reaching the already mentioned sustainable development. The issue of wealth inequality between countries was well examined in the research made by Pfeffer and Waitkus (2021). Impact of the countries' wealth on happiness of the population was assessed by Senik (2014). Ketchen, Ireland and Snow (2007) examined different types of enterprises and their contribution to total wealth by using collaborative innovation. Azpitarte (2012) in addition to the countries' wealth also examined the impact on salaries. Hamilton and Hepburn (2014) mentioned in their research that GDP per capita should not be the only one indicator of wealth. Fessler and Schurz (2018) pointed out that welfare state and its higher expenditures from public funds in fact goes along with an increase of observed wealth inequality. Gok and Peker (2017), Rajapathirana and Hui (2018) in their research indicated the positive connection between market performance and innovation performance. Innovation policy of the EU is based on the support of enterprise sphere. This helps to contribute towards better industrial performance and so to support meeting broader social objectives such as industrial growth, increased employment rate and competitiveness of the industry within society and its sustainability. Fila (2017) perceives innovations as core of development of modern knowledge-based economy. Innovations in the born micro, small, and medium enterprises also contributes to sustainable economy growth (Mura et al., 2024; Hunková & Havierníková, 2024; Zainuri et al., 2025).

The economic growth theories indicate that GDP growth depends on capital increase, investments and from the increase of the workforce through population growth. Modern economic theories of the 20th century attributed the important role of GDP growth to technological progress (Solow's neoclassical growth model, Barro's and Romer's model). Romer (1993), within the endogenous growth theory, assumed that poor countries should adopt the technologies of better developed countries for faster economic growth. Higher R&D expenditures are a basic precondition for faster economic growth which is basically represented by GDP per capita. Technological progress has a significant impact on GDP and rapid/jump growth is not possible without innovation. The concept of convergence has been central to the European Union's (EU) integration process, serving as both a prerequisite for monetary union and a long-term objective for economic cohesion. Convergence in the EU context is multidimensional, encompassing nominal convergence, which refers to compliance with macroeconomic stability indicators, and real convergence, which denotes the gradual alignment of income levels and living standards across member states.

The Maastricht Treaty (1992) established the formal convergence criteria—commonly known as the Maastricht criteria—as conditions for adopting the euro. These criteria include: (i) price stability, measured by inflation rates not exceeding 1.5 percentage points above the three best-performing Member States; (ii) sound public finances, requiring a government deficit below 3% of GDP and public debt below 60% of GDP; (iii) exchange rate stability, demonstrated by participation in the Exchange Rate Mechanism (ERM II) for at least two years without severe tensions; and (iv) convergence of long-term interest rates, which should not exceed by more than 2 percentage points those of the three best-performing member states in terms of price stability. Nominal criteria were designed to ensure macroeconomic stability and prevent asymmetric shocks within the Economic and Monetary Union (EMU).

While nominal convergence is a legal and institutional requirement for euro adoption, real convergence—the process by which less developed economies catch up with more advanced ones in terms of GDP per capita—remains a broader economic goal. Real convergence is often assessed through two complementary concepts: β -convergence, which occurs when poorer economies grow faster than richer ones, and σ -convergence, which refers to a reduction in income dispersion across countries (European Central Bank (ECB), 2015). Empirical evidence suggests that while Central and Eastern European (CEE) countries have experienced significant real convergence since their accession to the EU, disparities persist, particularly among euro area members where structural rigidities and institutional weaknesses have hindered sustained convergence (ECB, 2015).

Solow (1956) stated that theoretical underpinnings of convergence trace back to the neoclassical growth model, which predicts conditional convergence based on diminishing returns to capital and technology diffusion.

Romer (1993) by endogenous growth theories emphasized the role of innovation, human capital, and institutional quality in sustaining long-term convergence. Within the EU, economic integration—through the single market, structural funds, and cohesion policy—has been expected to accelerate convergence by facilitating capital flows, trade, and labor mobility (Alcidi, 2019). However, the global financial crisis and subsequent euro area debt crisis revealed that nominal convergence prior to euro adoption does not automatically guarantee real convergence, highlighting the importance of structural reforms and productivity growth (Bukowski, 2006; ECB, 2015). Beyond the EU, the notion of convergence has been widely studied in global economic literature. The hypothesis of absolute β -convergence posits that poorer countries grow faster than richer ones, leading to income equalization over time, while conditional β -convergence accounts for differences in structural characteristics such as savings rates, population growth, and institutional quality (Barro & Sala-i-Martin, 1992). Martinho (2023) confirmed partial convergence trends globally, though the pace and sustainability of convergence vary significantly across regions and periods.

In this context, overall, the literature underscores that convergence is neither automatic nor uniform. While EU policies and institutional frameworks have facilitated progress, persistent structural disparities and asymmetric shocks continue to challenge the objective of full economic cohesion. Achieving sustainable convergence requires not only adherence to nominal criteria but also long-term strategies that enhance innovation, innovation-driven productivity and institutional resilience.

3. Methodology

Regarding the identification of a possible relationship between the innovation performance (expressed by Summary Innovation Index – SII) and economic wealth of the V4 countries, represented by GDP per capita and GDP per capita in purchasing power standards (PPS), the set of hypotheses and goals shown below were set.

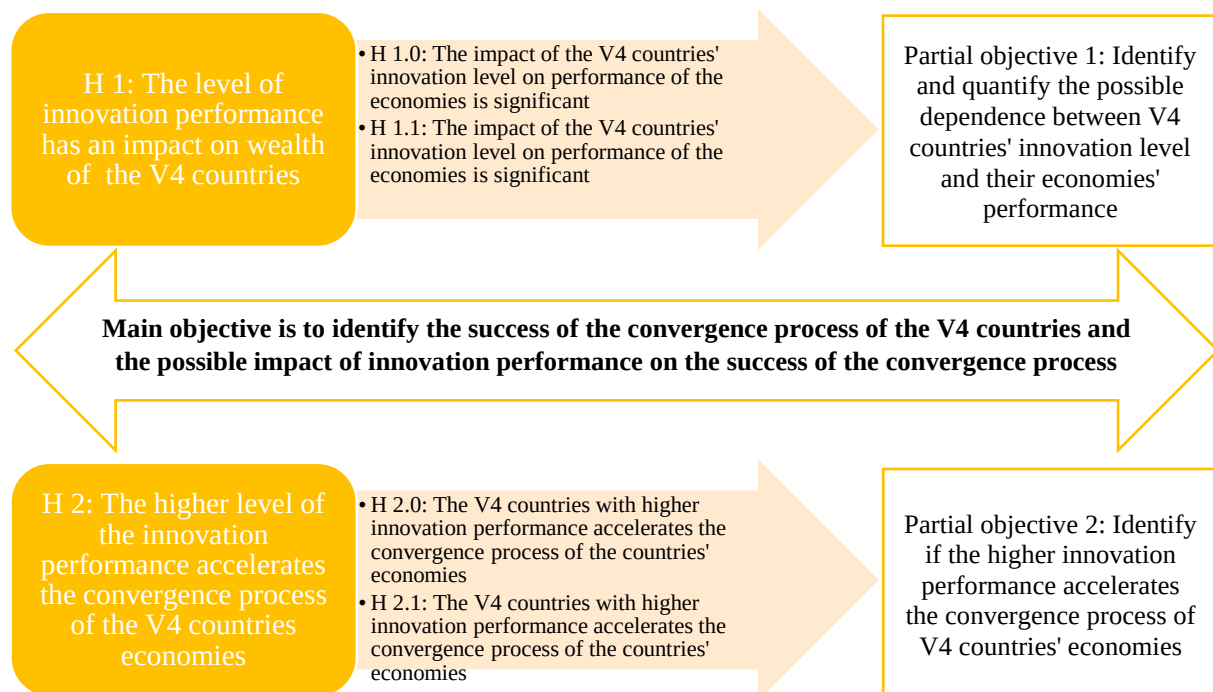


Fig. 2. A set of partial objectives and set hypotheses

Source: made by the author

The present study focuses on three core indicators: innovation performance, GDP per capita, and GDP per capita expressed in purchasing power standards (PPS) across the Visegrad Group (V4) countries. The primary objective is to assess whether innovation performance exerts a measurable influence on the economic prosperity of these countries and to determine the extent to which innovation performance contributes to accelerating the

convergence of V4 economies toward the European Union average, as reflected in GDP per capita and GDP per capita in PPS.

The analysis relies on secondary data drawn from the European Innovation Scoreboard (covering the period 2004–2025 for innovation performance across EU Member States) and complementary datasets from Eurostat (2004–2024 for GDP per capita and 2013–2024 for GDP per capita in PPS).

Empirical, exploratory, comparative and statistical methods of examining secondary data were used to meet the partial as well as main objectives of the research. The analytical tools used include the comparative analysis, the regression and correlation analysis. These analyses will allow us to confirm or refute the hypothesis. The regression analysis (in identified linear functions) examines a possible relationship between two variables, where we assume that:

- A. the value of the dependent variable (Y – GDP per capita) is affected by a change in the value of an independent variable (X – innovation performance). Regression formula is: $GDP_{pcit} = \beta_0 + \beta_1 \cdot SII_{it} + \varepsilon_{it}$
 - GDP_{pcit} : GDP per capita for country ii in year tt (in EUR).
 - β_0 : Intercept (baseline GDP per capita when $SII = 0$).
 - β_1 : Effect of SII on GDP per capita (change in EUR for a 1.0 increase in SII).
 - SII_{it} : Innovation performance index (0–1).
 - ε_{it} : Random error term (captures unobserved factors).
- B. the value of the dependent variable (Y – GDP per capita in PPS) is affected by a change in the value of an independent variable (X – innovation performance). Regression formula is: $PPS_{it} = \alpha_0 + \alpha_1 \cdot SII_{it} + u_{it}$
 - PPS_{it} : GDP per capita in Purchasing Power Standards (index, EU27 = 100).
 - α_0 : Intercept (baseline PPS index when $SII = 0$).
 - α_1 : Effect of SII on PPS index (change in index points for a 1.0 increase in SII).
 - SII_{it} : Innovation performance index (0–1).
 - u_{it} : Random error term (captures unobserved factors).

To build a 10-year projection of the innovation performance (SII) for each V4 country, by 2034, which could help reach the EU average level of GDP per capita indicator (GDP per capita in PPS is not suitable for the prediction because it is the normalized Eurostat index) a formula will be used (in simplified form):

$$SII = \frac{GDP_{pc}(EU\ 2034) - \alpha_c}{\beta_c}.$$

Not every innovation or type of innovation contributes equally to innovation performance or economic growth. From this point of view, we do not methodologically monitor the contribution of individual components of innovation or their number, but we monitor the contribution of the overall innovation performance of selected countries. The impact of innovation performance on the acceleration of convergence among the V4 countries will be assessed through a comparison of the values of innovation performance indicators and GERD investment, as well as GDP per capita and GDP per capita in PPS for the V4 countries and the EU average.

Limitations of the research made lies in the fact that the theory of economic growth is relatively complex, evolves over time and it is possible to express economic growth by many indicators or factors. This research abstracted from factors such as the quality of the environment, length of working time etc., and focus only on the basic key indicator expressing economic growth – the GDP per capita and GDP per capita in PPS.

4. Impact of the innovation performance on the wealth and convergence of the V4 countries

After the initial analysis through visual assessment using X to Y we chose a suitable mathematical function of which the curve best reflects the relationship between observed variables. In both cases – dependence between innovation performance and GDP per capita and GDP per capita in PPS, a linear function showed preferable, which suggests that both chosen wealth indicators rise with rising innovation performance in linear way. The sample has 80 country-year observations (4×20) – in the case GDP per capita 256 dependence and 44 country-year observations (4×11) – in the case GDP per capita in PPS dependence (see Table 1 below).

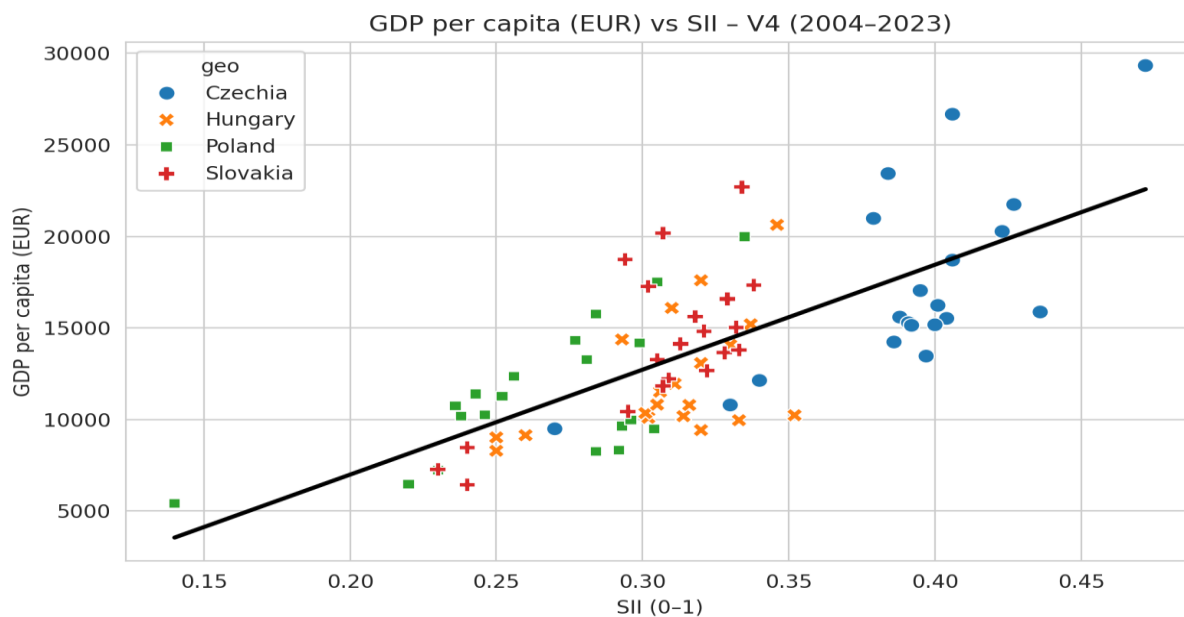
Table 1. Correlations (Pearson)

Pair	r
GDP per capita ↔ SII	0.720
GDP in PPS index ↔ SII	0.835

Source: made by the author

According to the Pearson's correlation coefficient and Cohen's interpretation of the correlation coefficient, there is:

1. a big positive dependence between the GDP per capita indicator and the level of innovation performance,
2. a big positive dependence between the GDP per capita in PPS indicator and the level of innovation performance.



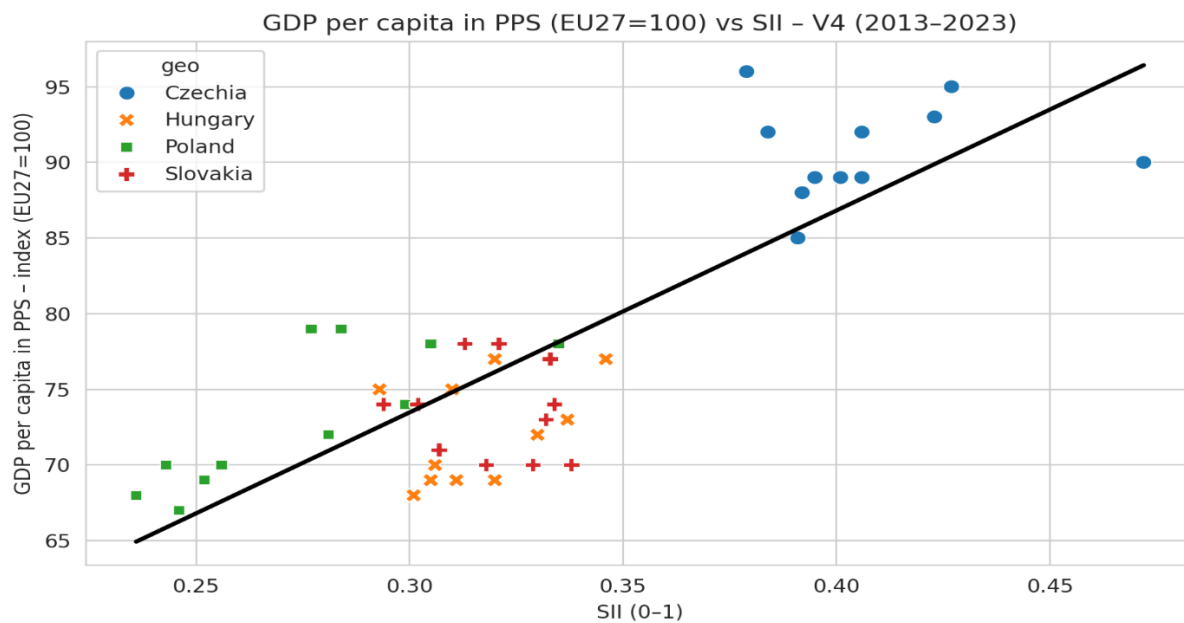


Fig. 3. Linear regression graphs
Source: made by the author

The Figure 3 shows linear regression graphs which illustrates the relationships between the GDP per capita and GDP per capita in PPS indicators with the level of innovation performance (represented by SII index).

In the case of the GDP per capita indicator, there is a strong positive slope: points trend upward—countries/years with higher innovation performance (SII) tend to show higher GDP per capita (EUR).

Country clustering:

- Czechia generally sits in the upper-right (higher SII, higher income).
- Poland and Hungary cluster mid-band and trend upward over time.
- Slovakia lags somewhat on both axes in several years, with visible progress but more volatility.

There is a dispersion around the line: The y-axis is nominal GDP per capita, so price inflation, exchange-rate swings, and cyclical shocks (e.g., COVID-19 pandemic 2020–2022) can pull points above/below the trend even when SII moves smoothly. Country-specific traits (tax structure, industrial mix) also shift points vertically.

The cross-section + time pooled relationship is clearly positive: higher SII goes hand-in-hand with higher income levels across the V4 timeline. Within a single country, the year-to-year income response to SII can be masked by macro shocks and price effects—so the tightness of the cloud is not uniform across countries/periods.

In the case of the GDP per capita in PPS indicator the cloud is typically tighter and more linear than the previous one. As SII rises, the PPS index also rises. Country placement is similar (Czechia toward the upper-right), but the spread around the line is smaller. Why this plot is tighter because the PPS index removes cross-country price-level differences and dampens inflation/exchange-rate shocks, so it aligns more closely with structural productivity.

Innovation performance is closely aligned with GDP per capita in PPS Even after stripping out country idiosyncrasies and common year shocks, improvements in SII tend to coincide with higher GDP per capita in PPS within countries over time in 2013–2023.

Table 2. Regression output – predictions

TERM	COEF.	ROBUST (HC3)	SE	P VALUE
DEPENDENT VARIABLE: GDP PER CAPITA (EUR) — PREDICTOR OF INTEREST: SII				
SII (0–1)	39,565.21	7,896.87		5.44×10^{-7}
DEPENDENT VARIABLE: GDP PER CAPITA IN PPS (EU27 = 100) — PREDICTOR OF INTEREST: SII				
SII (0–1)	85.51	16.22		1.36×10^{-7}

Source: made by the author

For both models, as it is shown on the Table 2, the p-values are extremely small ($p < 0.001$), which means the probability of observing such strong associations by random chance is less than 0.1%. This provides very strong statistical evidence that innovation performance (SII) is positively associated with both nominal GDP per capita and GDP per capita in PPS in the V4 countries. Interpretation of coefficients:

- **GDP per capita (EUR)**
A 0.10 increase in SII (on a 0–1 scale) is associated with an increase of about **3,957 €** in GDP per capita, holding other factors constant.
- **GDP per capita in PPS**
A 0.10 increase in SII corresponds to an increase of about **8.6 index points** in PPS, which is a substantial improvement compared to the EU average.

As previously indicated, there is a logical and direct relationship between innovation performance and investments in R&D. Over the long term, the Czech Republic has consistently allocated the highest percentage of its GDP to R&D. Poland, however, has also steadily increased its investment volume over time, followed by Hungary and the Slovak Republic. The following graph illustrates the evolution of resources invested in R&D since the accession of the V4 countries to the European Union.

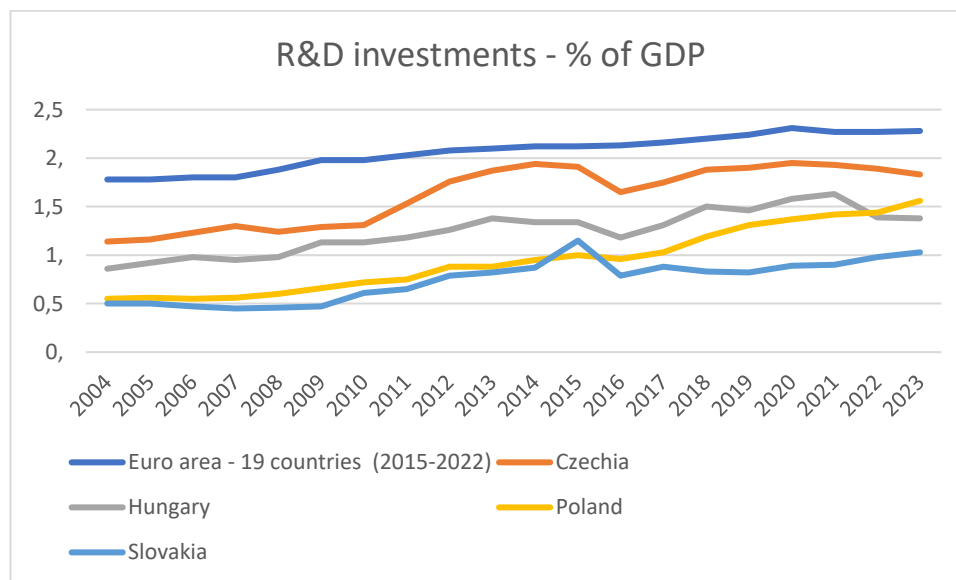


Fig. 4. R&D investments covering the year period 2004-2023

Source: made by the author based on EUROSTAT data sets

The Czech Republic is the leader among the V4 countries in terms of innovation performance and the volume of resources invested in research and development (% of GDP). It is also the country that has achieved the greatest convergence toward the EU average in living standards since its accession, as measured by GDP per capita and GDP per capita in PPS indicators. The table below presents the percentage values of innovation performance, the volume of resources invested in research and development, GDP per capita, and GDP per capita in PPS relative to the average of the original EU member states in selected years.

Table 3. Percentage of the EU average in the selected set of indicators from 2004 until now

R&D	2004	2023
Czechia	64,04%	80,26%
Hungary	48,31%	60,53%
Poland	30,90%	68,42%
Slovakia	28,09%	45,18%
SII	2004	2023
Czechia	61,36%	87,73%
Hungary	56,82%	67,66%
Poland	31,82%	63,38%
Slovakia	54,55%	63,38%
GDPpc	2004	2024
Czechia	36,58%	66,79%
Hungary	31,96%	48,93%
Poland	20,89%	51,18%
Slovakia	24,79%	54,45%
GDPpc PPS (measured from 2013)	2013	2024
Czechia	78,70%	87,50%
Hungary	62,96%	74,04%
Poland	62,04%	75,96%
Slovakia	71,30%	72,12%

Source: made by the author

Table 3 above presents the percentage share of selected indicators for the V4 countries relative to the average of the original EU member states. More than 20 years have passed since the V4 countries joined the European Union, yet none of them has managed to reach the average values of the original member states.

However, it was demonstrated that higher investments in R&D—and consequently higher innovation performance—enable an accelerated convergence process. Estonia also joined the European Union in May 2004. It has continuously and significantly increased its R&D investment from 0.8% of GDP in 2004 to 2.3% in 2011, and to the current level of 1.8%. It is the only post-socialist country that has reached the ‘strong innovators’ category, thereby substantially accelerating its convergence.

Among the V4 countries, the Czech Republic is the convergence leader, as it has consistently invested the highest proportion of its GDP in R&D and is the only country classified as a ‘moderate innovator’; the others remain in the ‘emerging innovators’ category. Poland, thanks to its continuous increase in R&D investment, is expected to move into the ‘moderate innovator’ category in the near future.

Table 4. Outputs of the innovation performance raise prediction for the V4 countries

Country	SII 2024	SII needed for GDP Selected 2034	SII in 2034	Growth of the SII per year	Prediction GDP pc in 2034
Czechia	0.472	0.712	0.712	+0.024	47,969
Hungary	0.364	0.774	0.774	+0.041	47,969
Poland	0.341	0.787	0.787	+0.045	47,969
Slovakia	0.341	0.635	0.635	+0.029	47,969

Source: made by the author

Table 4 above indicates that all V4 countries must significantly raise their innovation performance (SII) to reach the projected EU average levels of GDP per capita by 2034. Hungary and Poland require the largest annual SII increases (around +0.04–0.05 per year), while Czechia and Slovakia need slightly smaller but still substantial

improvements. If these innovation targets are met, each country is expected to converge to the EU-level GDP benchmark within the next decade. This highlights that sustained innovation growth is a critical driver for economic convergence in the region (see Table 5 below).

Table 5. Summary of correlation and regression analysis output

HYPOTHESES	CONFIRMATION / REFUSAL	RESULTS
H1	YES	The impact of the V4 countries' innovation level on performance of the economies is significant. A 0.10 increase in SII (on a 0–1 scale) is associated with an increase of about 3,957 € in GDP per capita. A 0.10 increase in SII corresponds to an increase of about 8.6 index points in GDP per capita in PPS, which is a substantial improvement compared to the EU average.
H 1.0	YES	
H 1.1	NO	
H2	YES	The V4 countries with higher innovation performance accelerate the convergence process of the countries' economies. The Czech Republic is the leader among the V4 countries in terms of innovation performance and also selected convergence indicators – GDP per capita and GDP per capita in PPS.
H 2.0	YES	
H 2.1	NO	

Source: made by the author

Table 5 summarizes the outputs of the analytical part and links them to the hypotheses and goals of the methodological part in Figure 2. The outputs of the regression analysis confirmed that the level of innovation performance has an impact on wealth of V4 countries and also that this impact is significant (0.10 increase in SII is associated with an increase of about 3,957 € in GDP per capita and with an increase of about 8.6 index points in GDP per capita in PPS, which is a substantial improvement compared to the EU average). The outputs of the analytical part also confirmed that the higher level of the innovation performance accelerates the convergence process of the V4 countries' economies and therefore the V4 countries with higher innovation performance accelerates faster the convergence process of the countries' economies (The Czech Republic is the leader among the V4 countries in terms of innovation performance and also selected convergence indicators).

Conclusions

This research provides empirical evidence that innovation performance is a critical determinant of economic prosperity and convergence within the V4 countries. The analysis confirmed a strong positive correlation between the Summary Innovation Index (SII) and both GDP per capita and GDP per capita in purchasing power standards (PPS). Specifically, a 0.10 increase in SII is associated with an approximate rise of €3,957 in GDP per capita and an increase of 8.6 index points in PPS, underscoring the significant role of innovation in accelerating economic convergence (see Table 2).

The study is unique in its comprehensive focus on the V4 countries over almost a two-decade period, combining innovation performance indicators with economic convergence metrics. Unlike previous studies that often-examined innovation or convergence in isolation, this research integrates both dimensions and provides a forward-looking projection of innovation performance required for achieving EU-level GDP by 2034. This predictive approach offers actionable insights for policymakers in the V4 region. Key findings are:

- Innovation performance and economic wealth are strongly interlinked, forming a reinforcing cycle with R&D investment.
- Among the V4 countries, the Czech Republic leads in innovation performance and convergence, while Slovakia lags behind despite moderate progress.
- Achieving EU average GDP levels by 2034 will require substantial annual increases in SII, particularly for Hungary and Poland.

The study abstracts from several other factors influencing economic growth, such as institutional quality, labor market dynamics, and environmental sustainability. Additionally, the analysis relies on secondary data, which may be subject to reporting inconsistencies. Future research can be expanded to include multifactor models

incorporating broader indicators of modern economic theory, including human capital and digitalization metrics.

The findings highlight the necessity of sustained and targeted investments in R&D, supported by both public and private sectors. Pisár and Honzová (2025) pointed out on the need of investments into e-government applications that could also speed-up the convergence process. Legislative frameworks should set measurable innovation objectives and ensure continuous monitoring and adaptation to global economic dynamics. Without such measures, the convergence process will remain slow and uneven. The legislative frameworks should also respect the cultural background and specificities of each country (Kondrla et al., 2023).

However, a significant challenge arises from the increasing pressure in the European Union to allocate up to 5% of GDP to defense spending, particularly in response to geopolitical tensions and also with the pressure to transition countries' economies to zero emissions. For countries in the convergence process, such a reallocation of resources could severely limit the fiscal space available for innovation and R&D investments. This trade-off between defence and development or CO² emissions-reduction and development must be carefully managed to avoid undermining long-term economic growth. Clark and Abbasi (2025) also point out another significant effect of armaments - subsequent negative impact on the health of the population due to decreasing expenditures on health. Policymakers should explore innovative financing mechanisms, EU-level support programs, and public-private partnerships to safeguard innovation funding. It is also important, in the case of defence investments, to find areas that will generate higher added value.

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