# CONNECTING INNOVATION AND ECONOMIC PROSPERITY: THE IMPACT OF R&D EXPENDITURES ON ECONOMIC GROWTH

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**Abstract**

The role of research and development (R&D) as a main foundation of innovation, productivity improvement, and a key element for national competitive advantage in the global economy is well established. This study aims to examine the relationship between R&D investment and economic growth through empirical analysis using panel regression techniques. Our results reveal that human capital specialised in science and technology significantly contributes to economic growth. Overall, innovation and a well-educated workforce are helpful in achieving sustainable development. Our model provides a statistically valid framework for analysing economic growth, enabling the formulation of sound policy recommendations while accounting for potential biases commonly found in panel data analysis.

**Keywords:** government R&D spending, human capital, empirical analysis

**JEL Classification:** O30, O47, E24

## 1. Introduction

One of the main forces behind technological improvement is research and development (R&D), which promotes innovation, boosts productivity, and fortifies a country's ability to act on the global market. R&D is important to long-term economic development since it promotes the growth of new industries and streamlines industrial procedures. Rapid industrial modernisation, more job possibilities, and

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improved economic resilience are common outcomes for countries that invest heavily in research and development.

Furthermore, a highly qualified workforce is compulsory for converting scientific discoveries into useful commercial applications, making human capital a key element in this dynamic. By encouraging cooperation between companies, academic institutions, and policymakers, government action further enhances these advantages and guarantees that research initiatives produce observable economic results.

Scholars have long investigated the connection between R&D investment and economic performance. R&D is a basic component of both national and international economic plans since the capacity to produce and utilize new knowledge turns to be more and more valuable as economies change.

Even though R&D and economic advancement are frequently associated, it is still unclear what the nature of this relationship is exactly. Depending on institutional frameworks, market conditions, and the economy's ability to absorb innovation, the degree to which R&D investment affects economic growth differs among nations, sectors, and period of time.

Through empirical research employing panel regression techniques, this study seeks to examine the relationship between R&D investment and economic growth in a European framework. Using this econometric methodology, we aim to give policymakers more insight into how R&D spending affects the main macroeconomic results and to provide a better understanding of how R&D expenditures influence growth driven by innovation.

## 2. Current state of knowledge

Both theoretical and empirical study have thoroughly investigated the contribution of R&D to economic growth. Technology advancement and innovation are becoming key forces behind sustainable development as economies shift toward knowledge-based structures.

Numerous facets of the R&D-growth association have been studied by academics, who have emphasized the need of comprehending how diverse forms of research impact economic performance. Some academics contend that R&D in the private sector directly affects productivity the most, while others emphasize how important government financing is for sustaining basic research and encouraging innovation spillovers. Additionally, because economies with a highly skilled workforce typically yield higher returns from research activities, the relationship between human capital and R&D expenditure has drawn more attention.

With early theoretical foundations established by Solow (1956), the phenomena of economic growth have been thoroughly investigated in economic literature (Aghion and Howitt, 1992; Romer, 1990). These models highlight how innovation and knowledge acquisition propel technological advancement, which is essential to sustained economic growth. Since then, empirical research has examined the effects of R&D expenditure on a range of economic variables, including GDP growth, labour productivity, and industry competitiveness, in order to test these theoretical assumptions.

While generating interest in research, the relationship between R&D and economic growth varies based on an economy's absorptive capacity, institutional characteristics, and the effectiveness of research allocation (Coe and Helpman, 1995; Griliches, 1998).

In addition to macroeconomic analyses, research has examined the effects of sectoral and regional differences in R&D expenditure. The results of Suarez et al. (2020) confirm that R&D investments drive growth in high- and medium-income countries, while only medium-income countries benefit from investments in skilled human resources. In low-income countries, neither investment type significantly influences growth.

Some academics contend that not everyone profits equally from R&D in the business environment. For example, the funding gap for innovation, finding that small firms face high capital costs despite venture capital support, while large firms prefer internal financing, with venture capital proving limited in markets lacking strong public equity options (Hall and Lerner, 2010). On the other side, smaller, younger, and less leveraged firms are more vulnerable to contractionary monetary policies, impacting their R&D investments and productivity, especially in manufacturing (Alam and Alvi, 2024).

Other studies explore the role of government policies in fostering R&D-driven growth, by examining the specific mechanisms through which government subsidies influence the behaviour of business firms (David et al., 2000). For emerging economies, findings suggest that national investment in R&D contributes to economic growth by generating positive effects (Tung and Hoang, 2024).

Additionally, while the contribution of human capital and education to maximising R&D returns is well-documented, the influence of its composition on economic growth remains underexplored, despite evidence emphasising the importance of high-tech skills (Sequeira, 2007).

The panel data methodology has often been used for analysing the interplay between R&D and economic growth. Gokkaya et al. (2021) employ this method to investigate the impact of R&D, education, and health expenditures on economic development from 45 upper-middle and high-income countries (2000-2019). The findings suggest that while R&D expenditures have a limited short-term effect on economic growth, their influence becomes more significant in the long run. Similarly, the long-term analysis confirms that R&D activities have a positive impact on economic growth, whereas in the short term, this relationship is not significant for Arab countries (Shahateet, 2020).

Given these findings, ongoing research continues to refine the understanding of how R&D contributes to economic progress, particularly in diverse institutional and technological contexts.

## 3. Methodology

### 3.1. Description of the database and variables

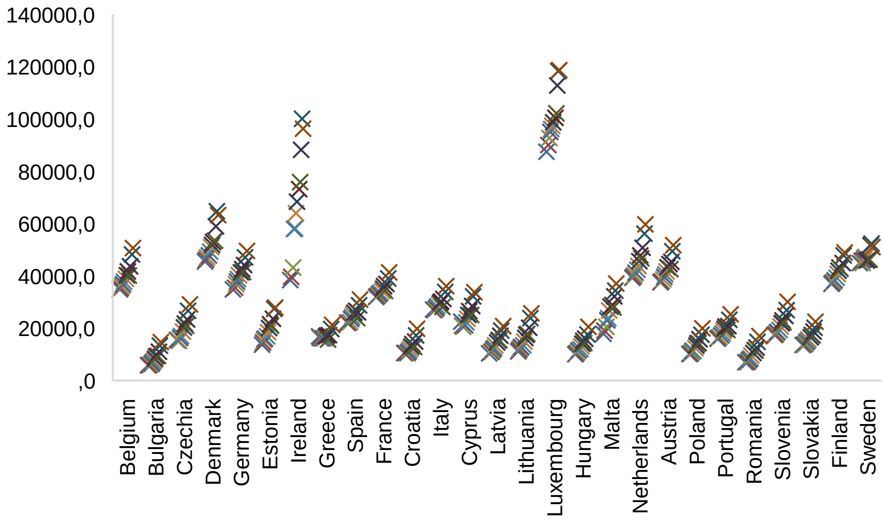
Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Sweden are the 27 EU members on which we base our analysis. The Eurostat database served as the source of the yearly economic data, which covered the years 2012–2023.

GDP per capita is used as the main dependent variable to analyse economic growth. R&D spending, labour productivity, the percentage of science and technology-related human resources in the working population (ages 25–64), and employment rates of recent graduates are the explanatory factors. Inflation and the export ratio are included as control variables.

A boxplot of GDP per capita from 2012 to 2023 is shown in Figure 1, providing a graphical representation of economic differences between countries. Certain countries consistently display higher GDP per capita than others, indicating structural economic disparities, especially those with robust financial sectors or high-value industries.

Each economy's value distribution has unique growth trends, with some economies showing consistent and predictable growth while others are characterized by turbulence and oscillations. These discrepancies could be the result of different industrial compositions, economic strategies, or outside shocks that have an impact on country economies. The information also highlights the ongoing economic gap between Eastern European countries and wealthier Western European countries, which contributes to the region's overall pattern of unequal development.

**Figure 1**
**The boxplot of GDP per capita over the period from 2012 to 2023**

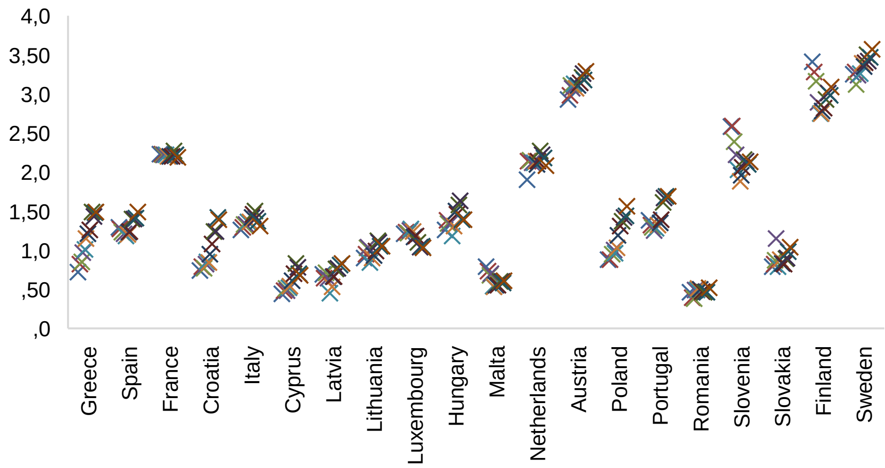



*Source: own processing using Eurostat data*

The distribution of R&D spending by country during the same time period shows a similar pattern of discrepancy (Figure 2). Certain economies, particularly those with highly developed technology sectors or robust innovation programs, continuously devote larger percentages of their resources to research and development (R&D), solidifying their status as leaders in both economic growth and technological advancement. Other nations, on the other hand, have lower investment levels, which would limit their capacity to promote long-term innovation and productivity increases. The variance within each nation is a reflection of various industrial systems, national priorities, and the availability of money for research projects. While some economies exhibit consistent and long-term investments in research and development, others exhibit more variable expenditure patterns that are impacted by changes in governmental policies, economic cycles, or outside financial constraints.

**Figure 2**

**The boxplot of R&D expenditure over the period from 2012 to 2023**




*Source: own processing using Eurostat data*

### 3.2. Theoretical presentation of methodology

Panel regression techniques are used in our investigation to look into the factors that affect GDP per capita. To choose the best estimating technique, we first perform a number of diagnostic tests using the methodology described in (Wooldridge, 2009). To select between the Pooled Ordinary Least Squares (OLS), Fixed Effects (FE), or Random Effects (RE) models, we have to check for exogeneity, homoscedasticity, and the presence of autocorrelation.

We use both the Breusch-Pagan test and the White heteroskedasticity test to evaluate homoscedasticity. While the Breusch-Pagan test looks for heteroskedasticity explicitly related to the independent variables, the White test looks for heteroskedasticity in a broader sense. Alternative ways of modelling or resilient standard errors are taken into consideration if heteroskedasticity is detected.

The Durbin-Watson test, which assesses whether serial correlation exists in the residuals, is then used to examine autocorrelation. While values significantly below or above 2 imply positive or negative autocorrelation, respectively, a value near 2 indicates no autocorrelation. Generalized least squares (GLS) techniques or the addition of lagged dependent variables are two appropriate solutions that are taken into consideration if serial correlation is found.

We apply the Hausman test, which contrasts the consistency of the RE and FE estimators, to ascertain whether the FE or RE model is more appropriate. Rejecting the null hypothesis implies that the FE model is more appropriate because of possible endogeneity in the regressors, while the null hypothesis of the test presupposes that the RE model is the preferred specification because of its efficiency. The FE model is represented as:

$$y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it} \qquad (1)$$

where $\alpha_i$ represents entity-specific effects, $X_{it}$ is the vector of explanatory variables, and $\varepsilon_{it}$ is the error term. The RE model, in contrast, assumes that $\alpha_i$ is a random variable:

$$y_{it} = \alpha + \beta X_{it} + u_i + \varepsilon_{it} \qquad (2)$$

where $u_i \sim N(0, \sigma_u^2)$ captures unobserved heterogeneity. If the RE model is deemed appropriate, we proceed with estimation using Generalized Least Squares (GLS) to account for within-group correlation and heteroskedasticity.

Based on these diagnostic tests, a proper estimator is selected for the final model definition. The selected model ensures computational efficiency while allowing us to capture both within-entity and between-entity differences. Additionally, we use an F-test to determine the joint significance of the explanatory variables and evaluate the model's overall fit.

The main factors influencing GDP per capita are informed by the estimation results. Through careful examination of potential biases and inconsistencies inherent in panel data analysis, the methodology guarantees that policy recommendations are produced from a statistically valid foundation.

## 4. Results and interpretation

### 4.1. Empirical results

Following the methodology outlined, we apply the Pooled Ordinary Least Squares (Pooled OLS) model to estimate the determinants of GDP per capita. The choice of the Pooled OLS model is based on diagnostic tests, including the White heteroskedasticity test, Breusch-Pagan test, and Durbin-Watson test. The results indicate that heteroskedasticity and autocorrelation are not present in the dataset, making the Pooled OLS approach the most appropriate estimation method.

Pooled OLS Estimation Summary:

- R-squared (Overall): 0.9509
- F-statistic: 1022.6 ($p < 0.01$)
- Log-likelihood: 28.428
- Covariance Estimator: Clustered

The model explains approximately 95.09% of the variation in GDP per capita, indicating a strong fit. The F-statistic and its p-value confirm the joint significance of the explanatory variables, supporting the robustness of the model.

**Table 1**

**Parameter Estimates**

| Variable | Coefficient | Std. Error | T-stat | P-value | 95% Confidence Interval |
|---|---|---|---|---|---|
| Constant | 0.0081 | 0.0037 | 2.167 | 0.0310 | (0.0007, 0.0154) |
| R&D expenditure | 0.0396 | 0.0161 | 2.465 | 0.0142 | (0.0080, 0.0711) |
| Labour productivity | 0.0831 | 0.0122 | 6.816 | 0.0000 | (0.0591, 0.1071) |
| Human resource in science & technology | 0.2871 | 0.0398 | 7.210 | 0.0000 | (0.2088, 0.3655) |
| Employment rates of recent graduates | 0.1127 | 0.0230 | 4.897 | 0.0000 | (0.0674, 0.1580) |
| Exports ratio | -0.0077 | 0.0022 | -3.550 | 0.0004 | (-0.0120, -0.0035) |
| Inflation | 0.6496 | 0.0370 | 17.545 | 0.0000 | (0.5768, 0.7225) |

*Source: own processing*

### 4.2. Interpretation of results

GDP per capita stays marginally positive when all explanatory variables are at their baseline, according to the calculated intercept, which is modest but statistically significant. This implies that other economic variables that were left out of the model can still have a small impact on GDP calculation.

The coefficient for government spending on R&D is positive and statistically significant. According to this research, more government spending on R&D raises GDP per capita, perhaps through fostering productivity growth and technological innovation. The assumption that increases in worker efficiency result in better economic performance is further confirmed by the large and considerable positive influence that labour productivity exhibits.

A particularly strong relationship is observed between GDP per capita and human resource investment in science and technology. The large and highly significant coefficient underscores the importance of investing in human capital, especially in scientific and technical fields, to drive long-term economic growth. Similarly, employment rates of recent graduates have a positive and significant effect, suggesting that a well-integrated workforce enhances economic performance.

Interestingly, the GDP to exports and imports ratio exhibits a negative and statistically significant coefficient. This suggests that higher trade exposure may be associated with lower GDP per capita, potentially due to trade imbalances, structural dependencies, or the competitiveness of domestic industries. Further research is required to better understand this relationship.

Finally, inflation demonstrates a strong and positive impact on GDP per capita. This finding suggests that moderate levels of inflation may be beneficial for economic growth, as they can stimulate spending and investment. However, it remains essential to ensure that inflation does not reach excessive levels, which could destabilise economic performance.

## 5. Conclusions

Our results underline the importance of R&D investment in promoting industrial change and increasing productivity, which in turn drives economic growth. However, the effects of R&D differ in different economies due to factors including market conditions, institutional frameworks, and the capacity to adopt new ideas. By using panel regression approaches to evaluate the relationship between R&D spending and macroeconomic performance, this study advances the empirical understanding of these dynamics.

The findings show that economic growth is significantly influenced by investments in human capital, especially in science and technology. The necessity of encouraging innovation and a competent workforce is further supported by the favourable effects of labour productivity, government R&D investment, and employment rates. Conversely, it seems that trade exposure and GDP per capita are negatively correlated, indicating the necessity of cautious trade policy management. For policymakers looking to boost economic development by calculated investments in workforce integration, education, and research, the findings offer insightful information.

Even with the wealth of study in this field, there is still much to learn about the exact mechanisms by which R&D affects economic growth, especially when considering different institutional frameworks and economic environments.

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