SECTORAL DIFFERENCES IN CAPITAL PRODUCTIVITY IN MANUFACTURING FROM THE PERSPECTIVE OF RESOURCE PRODUCTIVITY

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Abstract

The efficient use of capital (capital productivity) remains a key factor in competitive industries. Increasing attention is being paid to resource productivity, which reflects how efficiently industrial sectors use energy in a sustainable manner. The aim of this article is to assess the development of capital productivity in individual industrial sectors in the context of energy consumption—that is, resource productivity. The analysis focuses on manufacturing sectors classified by technological intensity in EU countries over the past 9 years. The analysis confirmed that technologically advanced sectors are able to use energy inputs more efficiently. This suggests that technologically advanced sectors are able to use energy inputs more efficiently, whether through innovation, modern production processes, or investments in energy-saving technologies. A positive finding is that the largest group in the EU consists of economies with improving capital productivity and energy efficiency. The study highlights the importance of investments in innovation and structural changes as key tools for improving energy productivity.

Key words: capital productivity, manufacturing, energy, EU countries

JEL Code: O44, Q57

Introduction

The high productivity of resources is one of the key prerequisites for long-term competitiveness and sustainable economic growth across all manufacturing sectors in today's economy. At the same time, investments in capital and technology play a significant role in developing the competitiveness of enterprises. The question is whether corporate investments in gross fixed capital contribute to increasing energy productivity through more efficient energy use in production processes. At the same time, capital investments focused on innovation and energy-efficient solutions support the growth of firms' economic performance while reducing the energy intensity of production. The aim of this paper is to assess changes

in capital productivity in relation to energy productivity across manufacturing sectors classified by technological intensity in EU member states.

Over recent years, the manufacturing industry of the European Union has been profoundly transformed by a combination of technological innovations, regulatory pressures and an increasing need for resource efficiency. The focus for companies is no longer just on traditional performance indicators, but increasingly on how they manage materials and energy. The change is also apparent in European policy documents where the importance of sustainable growth and the circular economy is emphasized (Figge et al., 2022).

Productivity as an economic concept has a long tradition. The basic theoretical frameworks are based on production functions that describe the relationship between inputs and outputs (Barro, 1999). However, so far empirical evidence suggests that productivity cannot be understood simply as a technical indicator, but a more general feature of the ability of firms to adapt to changes in the technological and market environment (Syverson, 2011). In this context, it is becoming clearer that the different types of productivity (labour, capital and resource) should be evaluated together.

Capital productivity is strongly associated with the investment activity of firms and their ability to modernize production technology. The introduction of automation, digitalization, and other elements of Industry 4.0 can significantly increase production efficiency, but at the same time increases capital intensity, which may weigh on financial results in the short term (Frank et al., 2019). Some studies show that modernization can also yield indirect effects, such as savings in materials or energy, which translate into growth in factor productivity (Keßler et al., 2021).

Resource productivity has come to the forefront in recent years because it links economic efficiency with environmental considerations. This indicator measures how efficiently businesses use materials and energy and is considered a key element in the transition to more sustainable production models (Malatyinszki et al., 2025). Empirical studies suggest that more efficient resource management can contribute to cost reductions or improved corporate reputation, although the impacts may vary depending on the nature of the industry and investment opportunities (Özbuğday et al., 2020). At the same time, it is noted that savings may lead to subsequent growth in production, which can offset some of the environmental benefits (Afolabi, 2025).

The EU manufacturing sector is, however, extremely diverse. Industries differ in terms of technological level, investment intensity, and input structure, creating varying conditions

for the growth of labour, capital, and resource productivity. Recent studies show that the transition toward a circular economy can contribute to long-term efficiency gains, not only in the area of materials but also in the broader context of organizational and technological changes (Qamruzzaman, 2026; Kosta & Ramadani, 2025). Although there is an extensive body of literature devoted to individual types of productivity, less attention has been paid to their interconnections at the sectoral level. This study therefore focuses on the development of capital productivity in individual segments of the EU manufacturing industry and its relationship to energy intensity.

1 Data and methodology

The paper focused on analyzing changes in capital productivity in relation to energy productivity within the manufacturing sector in individual EU member states. The paper examines whether capital investments are linked to increases in energy productivity. Based on Eurostat data, capital productivity (the ratio of GVA – Chain-linked volumes (2020), in millions of euros, to Gross fixed capital formation - Chain-linked volumes (2020), million euros) and energy productivity (ratio of GVA - Chain-linked volumes (2020), million euros to Net domestic energy use – in terajoules) for the years 2016–2024). The paper focused on the manufacturing industry in EU countries, which were categorized according to economic activity or technological intensity. The enterprises were classified into four categories. Eurostat aggregates the manufacturing industry by technological intensity based on NACE Rev. 2 at the 2-digit level: HT (high-technology), MHT (medium-high-technology), MLT (medium-low-technology), and LT (low-technology)

Based on the evolution of the economic cycle in the EU, the following periods were identified:

2016–2019 – Expansion phase (The EU gradually grew following the debt crisis. GDP, employment, and consumption indicators rose, while unemployment fell. This period of growth was relatively stable)

2020 – Recession phase (The COVID-19 pandemic caused a sharp economic downturn. Production, services, and international trade were curtailed, and GDP in most EU countries fell significantly.

2021–2023 – Recovery, stabilization, and weak expansion (Rapid growth followed the lifting of pandemic restrictions. At the same time, however, inflation began to rise and energy prices increased. Subsequently, inflation began to gradually decline and the economy

stabilized. Growth, however, remained relatively modest and uneven across EU member states).

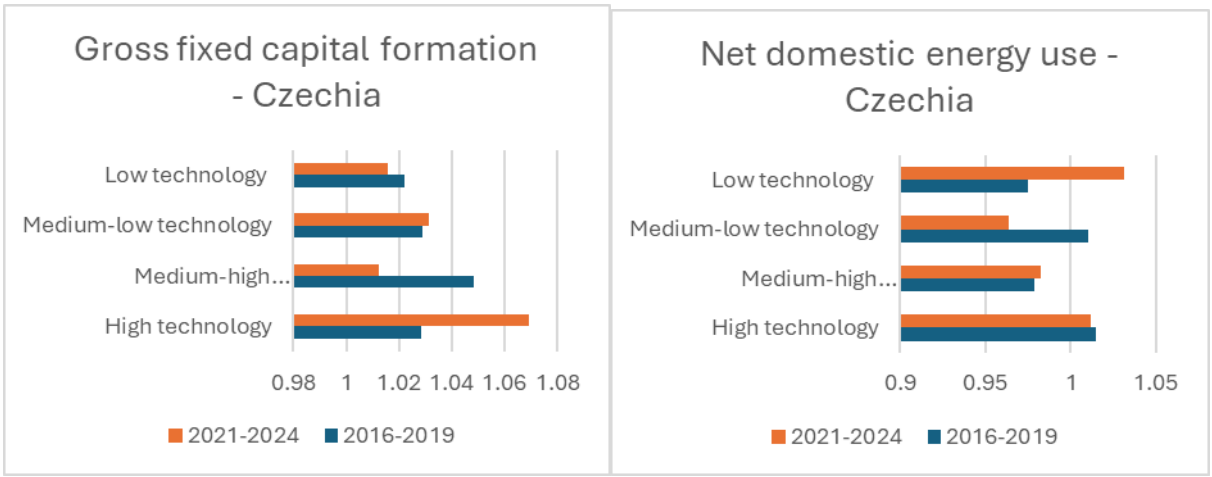
Two observation periods were subsequently selected for the analysis: 2016–2019 and 2021–2023. The year 2020 was so extreme that it was excluded from the analysis. For these periods, the geometric index was used to determine the average values of capital productivity and energy productivity, as well as their growth rates.

Cluster analysis based on Ward's hierarchical matrix (criterion = maxclust, k = 4) was used to construct clusters and subsequently calculate cluster centroids, i.e., to calculate average indices for each of the eight indicators (capital productivity and energy productivity across four sector groupings based on technological intensity). Countries are grouped according to the indices of the monitored indicators, i.e., whether productivity increased, stagnated, or declined in individual groupings based on technological intensity (high-tech, medium-high, medium-low, low-tech).

2 Results

The first section focused on the Czech Republic, specifically illustrating trends in fixed assets and electricity consumption, which serve as the basis for calculating productivity indicators. Figure 1 shows the differing trends in capital expenditures and electricity consumption across individual industrial sectors, categorized by technological intensity. In particular, the differences between the trends in high-technology and low-technology sectors are evident here.

Fig. 1: Gross fixed capital formation (index) **Figure 2 Net domestic energy use (index)**



Source: Own calculations based on the data Eurostat

The next section will focus on the growth of capital productivity and energy productivity.

Capital productivity growth above 1.2 was recorded in a relatively limited number of countries and shows significant variation across different groups based on technological intensity. In sectors with high technological intensity, countries in Western and Northern Europe (Denmark, Austria, the Netherlands, Belgium) dominate. In these countries, GDP is growing faster than gross fixed capital formation, i.e., investments in modern technologies that generate higher outputs (Table 1).

The high-tech group also includes some countries in Southeast Europe (Bulgaria, Croatia, Greece), where the increase was driven by a low initial level of capital productivity. This suggests that more efficient use of capital is not exclusively linked to economic development but may be related to ongoing modernization and investments in technology-intensive sectors. In the medium-high technology sector group, the countries with the highest capital productivity growth are primarily those in Central and Eastern Europe (Romania, Slovenia, the Czech Republic, Poland, Slovakia), along with Ireland. The results suggest that these sectors represent a significant source of capital efficiency growth in economies undergoing structural transformation and an intense inflow of investment.

Tab. 1: Growth in capital productivity in EU countries by sector group based on technological intensity (countries with growth > 1.2)

High technology	Denmark Bulgaria, Croatia, Greece, Austria, Netherlands, Belgium
Medium-high technology	Romania, Slovenia, Ireland, Czechia, Poland, Slovakia
Medium-low technology	Netherlands, Romania
Low technology	Bulgaria, Croatia, Ireland, Netherlands

Source: Own calculations based on the data Eurostat

In the medium-low technology sector group, the number of countries with significant growth in capital productivity is very limited. The Netherlands and Romania appear repeatedly in this group, while Bulgaria, Croatia, and Ireland achieve higher growth only in low-technology sectors. This may suggest that the potential for increasing capital productivity is generally lower in these sectors than in more technology-intensive sectors.

Table 2 Growth in energy productivity in EU countries by sector group based on technological intensity (countries with growth > 1.2)

High technology	Greece, Lithuania, Belgium, Denmark, Sweden, Slovenia, Latvia, Netherlands, France, Bulgaria, Germany, Spain, Austria, Estonia
Medium-high technology	Latvia, Slovenia, Greece, Lithuania, Croatia, Austria, Netherlands, Romania, Poland, Sweden
Medium-low technology	Lithuania, Croatia, Romania, Estonia, Greece, Poland, Cyprus, Netherlands, Portugal
Low technology	Denmark, Croatia, Ireland, Lithuania, Slovenia, Sweden France

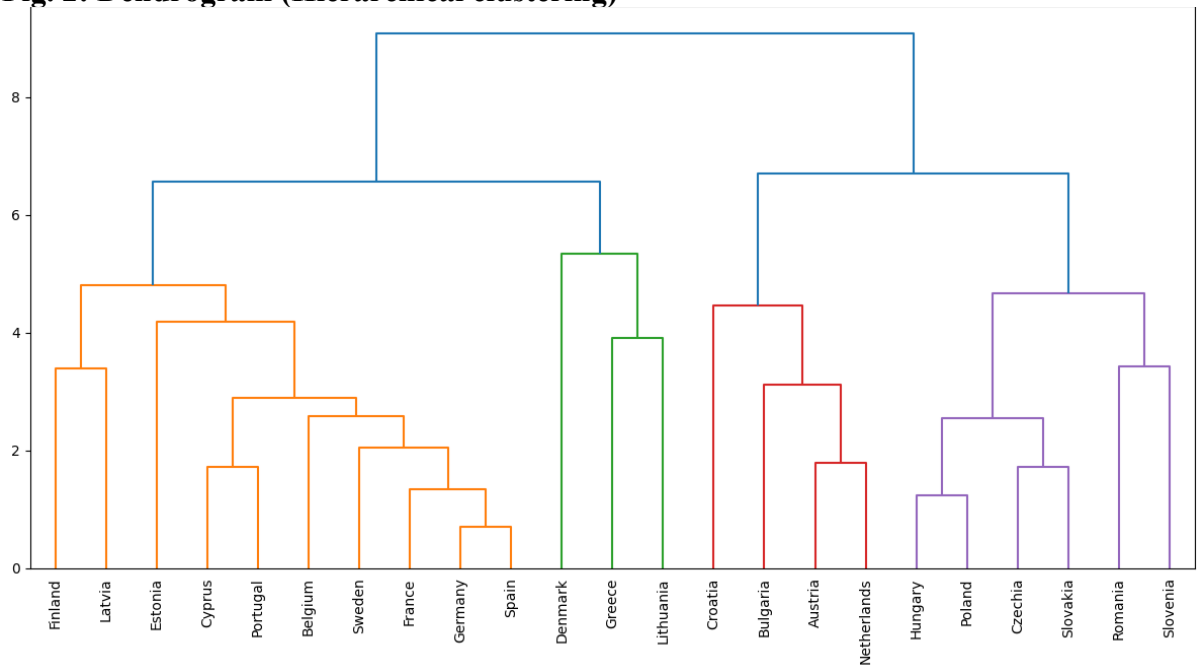
Source: Own calculations based on the data Eurostat

Growth in energy productivity above 1.2 is significantly more widespread than in the case of capital productivity (Table 2). The largest number of countries showing high growth are found in sectors with high technological intensity. Among them, Greece, Lithuania, Belgium, Denmark, Sweden, Slovenia, the Netherlands, and Austria appear repeatedly. This suggests that technologically advanced sectors are able to use energy inputs more efficiently, whether through innovation, modern production processes, or investments in energy-saving technologies.

A comparison of the growth rates of the monitored indicators shows that energy productivity growth is more pronounced within the EU and affects a greater number of countries and sectors than capital productivity growth. The results also confirm that more technology-intensive sectors represent significant potential for increasing the productivity and competitiveness of European economies.

The next step in the analysis was to assess the growth rates of both productivity indicators in context. Cluster analysis (see above) was used, on the basis of which four clusters were classified according to changes in capital productivity and energy productivity (Table 3) and according to the grouping of sectors by technological intensity (Figure 2).

Fig. 2: Dendrogram (Hierarchical clustering)



Source: Own calculations based on the data Eurostat

Cluster A – Economies with Improving Energy Efficiency

These countries show growth in both capital and energy productivity across most technology categories. Capital productivity is stagnating, particularly in ML and LT. Energy productivity is growing in all categories, most notably in high-tech (+42%). Ten countries fall into this cluster: Belgium, Cyprus, Estonia, Finland, France, Germany, Latvia, Portugal, Spain, and Sweden.

Cluster B – Growth Driven by High-Tech Sectors (Energy Leaders)

The greatest improvement is occurring in the high-tech and medium-high-tech sectors. Countries in this cluster are achieving the most significant growth in energy productivity of all clusters, while at the same time there is a decline in capital productivity outside of high-tech. This cluster includes 3 countries: Denmark, Greece, and Lithuania. This cluster represents the most significant structural change.

Cluster C – Growth in Traditional Sectors (growth in both capital and energy productivity)

Productivity is growing mainly in medium-low and low-tech sectors. Countries in this cluster achieve the strongest growth in capital productivity, particularly in high-tech (+70%) and low-tech (+50%) sectors, along with above-average growth in energy productivity. This is the cluster with the most comprehensive growth in both types of productivity. Four countries fall into this cluster: Austria, Bulgaria, Croatia, and the Netherlands.

Cluster D – Industry-oriented economies with growth in medium-high-tech

In the countries in this cluster, capital productivity is growing primarily in medium-high-tech sectors (+43%), while energy productivity is rising slightly. In high-tech sectors, capital productivity is declining. This cluster includes 6 countries: the Czech Republic, Hungary, Poland, Romania, Slovakia, and Slovenia.

Tab. 3: Centroids (the average of the change indices assigned to individual clusters using Ward's method)

Cluster	Capital productivity				Energy productivity			
	High-tech	M-H tech	M-L tech	Low tech	High-tech	M-H tech	M-L tech	Low tech
A	1.003	0.942	0.747	0.811	1.424	1.080	1.097	1.045
B	1.502	0.751	0.745	0.683	2.393	1.279	1.332	1.317
C	1.705	1.093	1.159	1.504	1.348	1.324	1.236	1.144
D	0.833	1.430	1.056	0.948	1.066	1.267	1.141	1.029

Note: CP = Capital Productivity, EP = Energy Productivity, HT = High-tech, MH = Medium-high-tech, ML = Medium-low-tech, LT = Low-tech.
Source: Own calculations based on the data Eurostat

Conclusion

Investing in new technologies, innovation, and the modernization of manufacturing is essential to ensuring a successful future for the manufacturing sector. On the other hand, it is important to increase energy productivity, which enables higher output with lower energy consumption and more efficient use of available resources. The aim of this paper was to assess changes in capital productivity and their relationship to energy productivity in individual sectors of the manufacturing industry in EU member states, classified by technological intensity. The analysis showed that increases in capital productivity were observed in a relatively limited number of countries and exhibit significant differentiation among individual groups based on technological intensity. In sectors with high technological intensity, countries in Western and Northern Europe (Denmark, Austria, the Netherlands, Belgium) dominate. From the perspective of energy productivity, the trend is more positive.

The greatest growth in energy productivity was recorded in countries showing high growth in sectors with high technological intensity. This suggests that technologically advanced sectors can use energy inputs more efficiently, whether through innovation, modern production processes, or investments in energy-saving technologies. A subsequent cluster analysis found that most EU economies (10 countries) belong to the group of energy-

improving economies, showing growth in both capital and energy productivity across most technology categories. According to a study by Alofaysan et al. (2024), innovations in green technologies are among the key factors influencing improvements in energy efficiency in industry. The result of paper suggests that a significant portion of EU economies is successfully moving toward more efficient use of both capital and energy, creating favourable conditions for sustainable growth and strengthening the competitiveness of European industry in the future. The main limitation of the analysis is its focus solely on the industrial sector. Further analysis will focus on material productivity.

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