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# THE IMPACT OF CREATIVITY AS A FACTOR OF ECONOMIC DEVELOPMENT ON GDP GROWTH IN EU COUNTRIES

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**Abstract.** This study examines the critical role of creativity in economic development and its significant impact on GDP growth within the European Union. Using Principal Component Analysis (PCA), the study evaluates and quantifies the impact of specific indicators of creative development on economic performance. Based on data collected from 28 EU countries and Switzerland, the analysis shows that regions characterised by a higher concentration of creative activity and innovation infrastructure tend to have higher GDP growth. The methodology involves a careful selection, standardisation and evaluation of key variables representing creative development, ensuring consistency in comparisons across countries. PCA allows complex datasets to be distilled into three principal components that together account for 78.33% of the total variance, providing a comprehensive view of the multidimensional nature of creative economic activity. The primary aim of this research is to explore how creativity can act as a driver of sustainable economic growth and to provide practical recommendations for policy makers seeking to maximise this potential. The findings highlight the important role of human capital, cultural vibrancy and the creative industries in fostering regional economic resilience and innovation. Among the factors examined, the number of R&D personnel per million inhabitants emerges as a critical determinant, with a strong positive correlation with GDP per capita. In addition, the share of employees in innovative firms and the presence of design-oriented firms were found to be key drivers of growth, highlighting the importance of fostering creativity and innovation across different sectors of the economy. The study concludes that supporting creative industries, increasing R&D investment and fostering an environment conducive to innovation are essential strategies for increasing GDP growth, even in resource-constrained regions. These findings highlight the need for strong institutional support and targeted policies to develop creative potential and stimulate economic progress. This research advances the understanding of the role of creativity in economic development by providing a structured framework for future analysis. The authors exhort policymakers to employ these insights to devise initiatives that harness creativity as a means to attain long-term economic resilience, innovation, and regional competitiveness in an evolving global economy. The present research prompts future investigation, with a particular focus on the direct impact of creative industries in specific sectors, such as technology or cultural industries, on economic growth and innovation.

**Keywords:** creativity, economic growth, GDP growth, principal components analysis.

**JEL Classification:** F43, C38

## 1. Introduction

In recent years, creativity has been identified as a significant catalyst for economic development, with studies highlighting its potential to stimulate regional growth and innovation (Florida & Mellander, 2023; Kačerauskas, 2023). The notion of the creative economy encapsulates the dynamic interaction between cultural dynamism, entrepreneurship, and human capital, thereby establishing a foundation for sustainable economic advancement. Recent studies

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have emphasised the substantial role of creative and cultural industries in promoting economic resilience and regional efficiency.

Cerisola & Panzera (2022) demonstrated how cultural and creative cities act as catalysts for regional economic efficiency, emphasising the importance of contextual factors in amplifying cultural vibrancy and fostering the creative economy. Their findings highlight the necessity of tailored strategies to harness creativity for economic growth, especially in regions with diverse socio-economic dynamics.

In a similar vein, Audretsch and Belitski's (2021) study examined the relationship between entrepreneurial ecosystems and the creative class, proposing a typology for regional economic development. Their research revealed that regions with vibrant creative ecosystems exhibited stronger economic performance, driven by the synergy between entrepreneurship and cultural industries.

Mellander & Florida (2021) further emphasise the central role of human capital and the creative class in regional development. Their research shows how concentrations of skills and talent can stimulate innovation and competitiveness, and provides a roadmap for harnessing creativity to achieve sustainable economic growth.

Despite this progress, a comprehensive understanding of how specific indicators of creative development influence economic growth remains limited, particularly within the European Union. This **study aims** to fill this gap by using Principal Component Analysis (PCA) to assess the impact of creative development on GDP growth in EU countries. By identifying key creative indicators and quantifying their impact, this research aims to provide policy makers with actionable insights to promote sustainable economic development through creativity.

## 2. Literature Review

In recent decades, the concept of creativity has been interpreted and assessed through a variety of theoretical lenses. These include psychological interpretations (Hennessey, Altringer & Moran, 2020) and economic analyses of both the meso- and macro-levels (Kačerauskas, 2023).

Psychological theories posit that creativity is associated with distinctive characteristics of intellectual development and the capacity to attain unconventional outcomes in conventional processes. Creative endeavours, frequently propelled by intrinsic motivation, have been regarded by scholars as the domain of the individual, not invariably accompanied by external acknowledgement or financial compensation (Kaufman & Sternberg, 2010; Lin, 2023).

In the context of economic development, creativity is examined through production (Firmansyah & Yayan, 2024; Astor et al., 2021) and systems approaches (Dzhakisheva et al., 2024). The production approach emphasises creativity as the result of efforts by individuals or entities to develop new products or production processes (primarily inventions) (Martial et al., 2024), which subsequently improve the economic conditions of a limited number of economic factors (Sari & Ismiwati, 2024).

The concept of a creative economy is predicated on an economic perspective that prioritises innovation and new ways of thinking (Ausat, 2022). According to Wiesand & Sondermann (2005) and Dinardi (2020), from an industrial perspective, the creative economy can be categorised into the commercial, community, and informal sectors. A wide range of activities can be classified as highly Industrialised, including advertising and marketing, broadcasting, the film industry, internet and mobile content, the music industry, electronic publishing and printing, and video and computer games. In contrast, less industrialised activities encompass museums, library services, fine arts such as painting and sculpture, and performing arts. Additional creative activities include sectors like crafts, fashion, and design.

Peter Higgs and Stuart Cunningham of the Centre of Excellence for Creative Industries (CCI) at Queensland University of Technology developed an approach known as the "Trident" method (Higgs et al., 2005). This method enhances the production approach by incorporating additional employment opportunities within creative industries. The concept is further supported by Bakhshi, McVittie & Simmie (2008) and is further investigated in the context of representation by England and Faggian (2022).

The systems approach is predicated on the establishment of external environmental characteristics that shape specific psychological traits of economic entities (Dzhakisheva, 2024; Porfirio, 2023). In synthesising these traits, authors observed that creative actors within economic systems, when proposing innovative and non-trivial solutions to problems, often demonstrated a strong understanding of traditional problem-solving methods. This approach can be further subdivided into two distinct methods: the *cluster approach* (Elmia, A., 2023) and the *territorial approach* (Martínez & Méndez-Ortega, 2020; Cerisola & Hellmanzik, 2024; Lishchynskyy & Lyzun, 2024).

The cluster approach is centred on groups of enterprises with similar activities that interact with one another, without being confined to specific administrative or territorial boundaries (Namyślak & Spallek, 2021). Research on creativity in such organisations, where there is a high concentration of creative enterprises, highlights them as a kind of epitome of the creative class (Qian, 2023). The aforementioned organisations are predominantly associated with artistic principles in their operations, thus distinguishing them from other intellectual fields, such as science and technology. Researchers have posited that these artistic principles, and by extension creativity, are most prominent in sectors dedicated to cultural production, which are commonly referred to as cultural industries. The size of these industries is indicative of the extent to which creativity exerts influence on the economy and society (Wagner & Portillo, 2024).

A high concentration of creativity in the cultural industries offers significant potential to influence other sectors of the economy. The conditions for realising this potential are closely linked to the spread of post-industrial trends. These trends include the customisation of production and an increased emphasis on intangible elements such as marketing and design. This shift transforms the emotional, psychological and playful aspects of human activity into key drivers of supply and demand (Judijanto et al., 2023).

The territorial approach to the creative economy can be divided into two perspectives:

1. **Creative economy rooted in creative industries.** Some authors define the creative economy as essentially based on the creative industries. Highly industrialised creative activities include advertising, marketing, broadcasting, the film industry, internet and mobile content, the music industry, electronic publishing, printing and video games. Less industrialised creative activities include museums, library services, visual arts (e.g., painting and sculpture) and performing arts. Furthermore, other creative activities such as the craft industry, fashion, and design are included (Kniazevych, Strilchuk, & Kraychuk, 2024; Martin et al., 2015; Wiesand & Sondermann, 2005).
2. **Creativity as the foundation of innovation across all sectors.** Conversely, other authors posit that creative activity serves as the foundation for innovation in any field and advocate for the creative development of all sectors of a country's economy (Lee, Florida, & Gates, 2010).
3. As Landry (2012) and Florida (Florida, 2002; Florida, 2014; Florida & Mellander, 2023) have demonstrated, this concept has been expanded upon by means of the development of a theory of creativity. This theory highlights the significant influence of environmental creativity on numerous regional processes. Researchers studying the specifics of this phenomenon have acknowledged that creative behaviour is primarily shaped by external opportunities and the level of development of economic entities involved in creative activities (Kaufman & Sternberg, 2010; Richter et al., 2012; Vasić & Gajić, 2023).

At present, there is a plethora of research on the creative development of national economies, leading to extensive exploration and a wide range of methods to promote creativity. Within this framework, creativity is frequently regarded as a distinct resource, suitable for productive application under specific external conditions (Shima et al., 2024).

In evaluating the creativity of an economy, a critical role is played by the structural characteristics of the environment, particularly the significance and role of creative activity within its value system (Centárová, 2020). It is posited that these activities are embodied and realised through innovative ideas, development, and practical application. By analysing creativity through the lens of socio-economic activities and individual motivation within the framework of post-industrialist theoretical concepts, the author identifies creativity as a fundamental economic resource and introduces the concept of the creative class, defined as a group of highly innovative and advanced individuals.

In order to establish a systemic understanding of creativity as a focus for strategic influence at macro- and meso-levels, a specialised index was developed to measure creativity. This index served as a foundation for outlining macro- and meso-economic policy directions aimed at fostering creative development. Among these initiatives, R. Florida's widely recognised 3T framework (Florida & Mellander, 2023) has gained considerable prominence for its impactful approach to fostering creativity and innovation.

The proposed creativity index is predicated on three fundamental elements: technological development, tolerance, and talent within the assessed socio-economic space. Collectively, these elements are referred to as the "3T" index. The first element, technological development, is evaluated using the following metrics: the number of high-tech companies in the region, their contribution to total regional production, and the number of patents they have obtained. This is measured by the Global Technology Index, which includes three primary measures: the Global Research & Development Investment Index (R&D expenditure as a percentage of GDP), the Global Researchers Index (number of R&D personnel adjusted for population) and the Global Innovation Index (patents per capita).

The second element, talent, is quantified using the Composite Talent Index, which is the arithmetic mean of the indices for the creative class, human capital and scientific talent. The third element measures the share of people employed in creative occupations in the total labour force.

According to the methodology of R. Florida, the human capital index is calculated as the share of employed persons with tertiary education. The scientific talent index is determined by the number of researchers (scientists) per million inhabitants, excluding technicians, support staff and other non-research personnel from the total number of persons engaged in research and development (Florida, 2002).

The final component of the Creativity Index is the Tolerance Index, which consists of the Bohemia Index and the Immigration Index. The bohemian index measures the share of the arts-oriented population in the total population of a region, while the immigration index reflects the share of immigrants in the population of a region (Vitálišová, Vaňová & Borsekova, 2013). Based on the ideas of Florida (2002), these elements together enabled the identification of unique spatial centres that attract creative individuals, thereby driving innovation and economic growth. The conceptual appeal and practical applicability of this model provided the basis for its further refinement and development, as well as for the adoption of corresponding economic policies (Daubaraite & Startiene, 2022).

Within the scope of the first approach, the 3T index was refined, and new related indicators were introduced, including the European Creativity Index, the Euro-Creativity Scoreboard, and others.

The indices of creativity that have been identified as the most significant include the Creative Space Index, Cultural Life Index, Creativity Index, Global Creativity Index, Hong Kong's Creativity Index, Intercultural Cities Index, Creative City Index, and European Creativity Index, in addition to others. The Creative Space Index (CSI) incorporates 37 indicators that span five critical areas: openness, cultural environment, talent, technology, tourism, industry, and innovation. The Cultural Life Index is a metric that gauges the performance of countries or regions by examining the availability of cultural resources, the extent of cultural participation, and the accessibility of cultural products (Picard, Grönlund, & Toivonen, 2003; Herrera-Usagre, 2019).

The Florida Creativity Index is a tool used to assess the economic potential of specific regions. This is achieved by means of analysis of talent, technology, and tolerance. Tolerance is measured by factors such as the proportion of foreign-born and LGBTQ+ populations. Technology is measured by the number of patents per capita. Talent is measured by the proportion of the creative class in the workforce (Florida & Tinagli, 2004). The Global Creativity Index (GCI) is a metric used to evaluate economic growth and prosperity across countries and regions. It employs the "3Ts" framework developed by Florida, which includes Talent (two variables), Technology (three variables), and Tolerance (two variables). This index builds upon Florida's original creativity metric, which was first introduced in 2002 (Martin Prosperity Institute, 2015).

Hong Kong's Creativity Index is a tool used to monitor the city's creative competitiveness over time in relation to its neighbouring regions. It evaluates various dimensions, including structural and institutional capital, human capital, social capital, and cultural capital (Hui et al., 2006). Table 1 provides a comparative overview of creativity indices and their dimensions.

The study by Boschma & Fritsch (2007) confirmed a correlation between the growth of the creative class and several factors, including increased employment, improved regional attractiveness for living and working, and the promotion of an atmosphere of tolerance and openness. This relationship was observed in 450 regions in eight European countries and remains an important aspect of European development (Creative Europe, 2024).

Table 1
**Overview of creativity indices and their dimensions**

| | Florida's Creative Index | Silicon Valley's Creative Community Index | Euro-Creativity Index | Hong Kong Creative Index | Czech Creative Index | Composite Index of the Creative Economy | European Creativity Index | Creative City Index | Baltimore Creativity Index | Landry's Creative City Index | Creative City Index | Global Creative Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of indicators | 9 | 11 | 9 | 88 | 6 | 8 | 32 | 32 | 9 | 15 | 72 | 23 |
| Human capital, talent & education | + | + | + | + | + | + | + | + | + | + | + | + |
| Openness, tolerance & diversity | + | + | + | + | + | + | | + | + | + | + | + |
| Culture, recreation & tourism | | + | | + | | | + | + | | + | + | |
| Technology & innovation | + | + | + | + | + | + | + | + | + | + | + | + |
| Government & regulations | | + | | + | | | | + | | + | + | |
| Business activity & economy | | | | | | | | | | | | |
| Entrepreneurship | | + | | + | | + | + | | | + | | |
| Infrastructure | | | | + | | | | | | + | + | |
| Environment | | | | | | | | | | + | + | |
| Liveability & amenities<br>Transportation & accessibility | | | | | | + | | | + | + | + | |
| Branding and recognisability | | + | | | | | | | | + | + | |

The promotion of creativity can therefore form the basis for the implementation of specific policies and programmes, including those at regional and sub-regional levels. An important extension of this concept has been research into the relationship between creativity and innovation within economic units. However, much of this research has primarily emphasised the positive effects of creativity, often overlooking instances of negative experiences (Walia, 2021).

Another approach was to examine the relationship between creativity and innovation through the lens of entrepreneurship. Entrepreneurship was understood as the activity of business owners who create economic value in the form of new products, processes and markets on an expanding scale (Ahmad & Seymour, 2008; Dej et al., 2013). According to the authors, high growth rates, reflected in in creased revenue and employment, inevitably indicate innovative activity, since a significant increase in production requires the introduction of fundamentally new elements. Innovation is contingent upon the capacity of individuals or entities to deliberately identify and exploit new opportunities, a process that inherently involves creativity. Consequently, production growth and entrepreneurial success are recognised as automatic indicators of creativity.

## 3. Methodology

In order to develop a model of creative development for EU countries and to test the hypothesis proposed in the article, it is essential to establish the relationships between the factors influencing a country's creativity and to determine the extent of each factor's impact on GDP per capita.

The creation of the model is initiated by the cleaning and preparation of the database for Principal Component Analysis (PCA). At this stage, indicators representing the creative development of countries are selected and standardised to ensure comparability across all analysed countries.

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Assume that certain indicators of the country's development and its creative potential are represented by a set of factors $y_{li}^{0}$ ,

where $i$ – the factor number (i =1, 2, 3, ..., n),

l – the ordinal number of the country in question on the list (l = 1, 2, 3, ..., t),

n – number of indicators characterising the level of creative development of the country,

t – number of investigated EU countries.

The values of each factor at different points in time (l) for different economic objects form a vector $y_i^0 = \left\{ y_{1i}^0, y_{2i}^0, \ldots, y_{ti}^0 \right\}^T$ .

The factor space of economic systems (countries) can be represented as a matrix of initial factors $Y^0$, where each column of the matrix contains the values of a single factor ($i$) for various economic states (countries), and each row includes the values of all factors for a specific state of each country under consideration. Accordingly, the state space of economic objects is described as:

$$Y^0 = \left[ y_1^0 \;\; y_2^0 \; \ldots \; y_t^0 \right]. \tag{1}$$

The arithmetic mean values of the factors are used as the center of the distribution within the factor space.

The centered factor space will be represented by the matrix Y, where each element is defined as:

$$y_{li} = y_{li}^0 - \overline{y_i} \, , \tag{2}$$

where $\overline{y_i} = \frac{1}{t} \sum_{l=1}^{t} y_{li}^0 ,$ (3)

Principal components represent a grouping of initial factors where the factors within each group are interrelated, while each group (principal component) is independent of the others. The weighting coefficients of the principal components are determined by solving the eigenvalue problem.

The covariances of the factors of economic objects are represented by the covariance matrix P, which is calculated using the formula

$$P = \frac{1}{t} * Y^T * Y, \tag{4}$$

The eigenvectors of the covariance matrix P are determined by solving the following equation

$$\left( P - \theta \rho \right) m_0 = 0, \tag{5}$$

where $\rho$ is the identity matrix, m is the eigenvector associated with the solution of the eigenvalue equation, (3), $\theta$ is the eigenvalue. A detailed description of the methods for calculating the principal components can be found in Mazziotta & Pareto (2024).

The eigenvectors of the equation are scaled, ensuring consistency in their representation. Each eigenvector possesses the same dimensionality as the state vector of the economic object, thereby enabling it to be designated as an eigenstate. Given that an eigenvector is determined solely up to a scalar multiple, the components of the eigenstate predominantly reflect the relationships among the initial factors as opposed to their absolute magnitudes. Henceforth, the components of the eigenstate will be referred to as the characteristics of the eigenstate.

The principal components matrix $M_o$ is constructed using the eigenvectors corresponding to the largest eigenvalues.

$$M_o = [m_{01}\ m_{02}\ ...,\ m_{0t}]. \quad (6)$$

Any row of matrix factors Y can be represented as the sum of the principal components (formula 7)

$$y_{li} - \overline{y_i} = \sum_{q=1}^{d} m_{0qi}\, z_{ql}, \quad (7)$$

here $z_{ql}$ is the value of the *k*-th principal component at the *l*-th moment in time,

$V_{oji}$ is the value of the *i*-th element (factor) of the q-th principal component.

The values of the *l*-th principal factor at different time points form the vector $z_l$, Using this, the formula for the main principal component (PCA0) can be expressed as:

$$Y = ZM_0^T, \quad (8)$$

where Z is the matrix of principal factors, consisting of the vectors $z_l$, $M_0^T$ is the transposed matrix of principal components.

By multiplying equation (8) on the left by the matrix $M_0^T$, the following formula is employed to calculate the matrix of principal factors:

$$Z = YM_0. \quad (9)$$

The matrix of principal factors, denoted by Z, represents a newly reduced space that captures the dynamics of deviations of the initial factors from their arithmetic mean values. The dimension of this reduced space is equal to *p x t*, which is n/p times smaller than the original dimension.

The total variability of the process (σ) is defined as the sum of the variances σi of each *i*-th factor. Each principal component is representative of an independent subprocess within the overarching process of change in the features of the object under study. Independence is indicated by the absence of correlation between different subprocesses identified by the principal components. The contribution of each principal component to the total variability of the process is quantified by its eigenvalue. It can be demonstrated that the sum of all eigenvalues is equivalent to the sum of the variances of all the features of the object under study. Therefore, the eigenvalue of a given principal component functions as a measure of its contribution to the total variability of the process.

The principal factors are determined using an orthogonal linear transformation of matrix *X*. Subsequently, the following equation can be written

$$AM_0 = V_0W, \quad (10)$$

where W is a diagonal matrix, its *i* is a diagonal element equal to $\theta_i$.

The analysis of a country's creative development is predicated on the evaluation of the extent to which the outcomes of an enterprise's activities over a given period align with the objectives set forth in management decisions. In general, the assessment of the effectiveness of management decisions can be expressed as follows:

$$\varepsilon = {}^{S_f}\!/_{S_W}, \quad (11)$$

where $S_f$ – represents the variance of the processes aligned with management goals,

$S_w$ – denotes the total variance of all processes. In this study, the dispersion of a process is defined as the sum of the variances of the factors that characterise the process.

Clustering was then performed using the classical k-means method with a quadratic Euclidean distance norm. The cluster center coordinates were determined as the average value of each coordinate from the data vectors within the cluster. If the center of the cluster *r* $X_r = (x_{r1}, \ldots, x_{rd})$ is represented as a vector in *d*-dimensional space, and the data vectors

$A_r = (a_{r1}, \ldots, a_{rd})$, $r = 1,n$ also have *d* dimensions, then the new cluster center is determined as:

$$X'_{rk} = \sum_{y \in C_r} \frac{y_k}{|C_r|}, k = \overline{1,d}. \quad (12)$$

The determination of the optimal number of casters is achieved through the implementation of the Silhouette Coefficient, which is derived through the calculation of the average intra-cluster distance (a) and the average distance to the nearest cluster (b) for each sample. The coefficient is calculated using the following formula: (b - a) / max(a, b), where b signifies the distance between a sample and the nearest cluster to which it does not belong. The average silhouette value, derived from this calculation, was then utilised as a metric to determine the optimal number of clusters.

The authors employed statistical data from the European Union (EU) countries, utilising the EUROSTAT portal, the official portal for European data (data.europa.eu), the OECD (Organisation for Economic Co-operation and Development), Our World in Data (https://ourworldindata.org/), and Statista.

The statistics data encompasses information pertaining to 28 EU countries and Switzerland. However, due to the absence of pertinent information regarding Luxembourg, the country was excluded from the scope of the research.

## 4. Results

In order to explore the relationship between the indicators in greater depth and identify the critical ones, a selection of 10 indicators was made that, in the opinion of the authors, best align with the Euro-creativity metric and comprehensively represent the overall level of economic creativity.

According to the R. Florida and Euro-Creativity indices, the initial indicator is Technology. The Technology Index comprises the following elements:
1. R&D expenditures (including in-house & contracted-out), as a percentage of total expenditures on innovation activities per capita.
2. The number of professionals engaged in R&D, per 1 mln population.
3. Firms that applied for patents, as a percentage of total firms.
4. Firms that registered a design, as a percentage of total firms.

The second indicator of the creativity level of economy is Talent. This indicator is determined by the following:
1. Share of persons employed in innovative firms in total employment.
2. Number of reserchers per 1 mln population.
3. Share of adults with higher education.
4. Share of ***workforce in the creative industries.*** The following sectors are represented: publishing and content art; information and communications; ICT services; financial and insurance activities; architectural, engineering, technical testing; professional, scientific and technical activities (in part); research and development; and advertising and marketing research.

Tolerance Index consists of:
1. The share of people with an artistic orientation in the population of the region.
2. The share of immigrants in the region's population.

The creation of 10 principal components (PCs) was informed by the principal components analysis method.

As demonstrated in Table 1, the first principal component accounts for 35.29% of the total variation, while the second component contributes an additional 21.52%. Collectively, these components elucidate a substantial proportion of the variability present in the data.

As illustrated in Table 2, the first principal component accounts for 47.43% of the total variation, followed by the second with 19.38%, and so on. According to the Kaiser criterion, only factors with eigenvalues equal to or greater than 1 are selected. In principal component and factor analysis methods, component variance serves as a measure of their informativeness. Consequently, the first three principal components retain 78.33% of the information from the original 10 variables. These three principal components, representing a linear combination of the initial indicators of economic creativity development, are deemed sufficient for practical application.

The linear coefficients of the principal component values in Table 3 are utilised to derive an equation that illustrates the influence of the initial indicators on the economic growth of EU countries via the principal components. PCA1, which accounts for 47.43% of the link between economic growth and the creative development of the economy, exhibits the following correlations with the indicators under analysis:

$$PCA1=0.3973Y1+0.2894Y2+0.2478Y3+0.6876Y4+1.5343Y5+1.0076Y6-1.3167Y7+1.093Y8+0.109Y9-1.882Y10$$

$$PCA2=0.1511Y1-0.8473Y2+0.4112Y3-0.6663Y4+0.1735Y5-0.1192Y6-0.04686Y7+0.2668Y8-1.2576Y9-1.2576Y10$$

Table 2
**Variance of principal components**

| Component | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 | PC 7 | PC 8 | PC 9 | PC 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dispersion | 5,95 | 2,43 | 1,89 | 0,62 | 0,59 | 0,47 | 0,41 | 0,29 | 0,17 | 0,02 |
| Variance, % | 47.43 | 19.83 | 11.07 | 9.15 | 4.52 | 2.97 | 2.14 | 1.62 | 0.71 | 0.56 |
| Sum, % | 47.43 | 67.26 | 78.33 | 87.48 | 92.00 | 94.97 | 97.11 | 98.73 | 99.44 | 100.00 |

Table 3
**The following presentation provides a visual representation of the findings derived from the calculation of the influence of each factor on the economic growth of EU countries**

| Indicator | | PCA1 | PCA2 | PCA3 |
|---|---|---|---|---|
| GDP per capita | X | 0.1061 | 1.4247 | 0.0786 |
| Number of specialists employed in research and development per 1 million population | Y1 | 0.3973 | 0.1511 | -0.35401 |
| R&D expenditures | Y2 | 0.2894 | -0.8473 | -0.2195 |
| Firms that registered a design | Y3 | 0.2478 | 0.4112 | 0.5175 |
| Firms that applied for patents | Y4 | 0.6876 | -0.6663 | 0.1062 |
| Share of persons employed in innovative firms | Y5 | 1.5343 | 0.1735 | -0.0581 |
| Number of researchers per 1 million population | Y6 | 1.0076 | -0.1192 | -0.11946 |
| Share of adults with higher education | Y7 | -1.3167 | -0.04686 | -0.3291 |
| Share of **workforce in the creative industries** | Y8 | 1.093 | 0.2668 | 0.4545 |
| Share of art-oriented population in the regional population | Y9 | 0.109 | -1.2576 | 0.0046 |
| Share of immigrants in the regional population | Y10 | -1.882 | -0.0265 | 0.0664 |

PCA3=-0.35401Y1-0.2195Y2+0.5175Y3+0.1062Y4-0.0581Y5-0.11946Y6-0.3291Y7+0.4545Y8+0.0046Y9+0.0664Y10

The correlation coefficients of the three components exhibit bipolar characteristics. Based on the signs of the loadings of the indicators on the components, Y1, Y2, and Y3 can be classified into two categories:

– Indicators that show a direct correlation: number of specialists employed in R&D per 1 million population, firms that have registered an industrial design.

– Indicators that are inversely related: the share of adults with higher education, the share of immigrants in the region's population.

The PCA1 component is found to be primarily influenced by the Y5 and Y10 indicators, PCA2 is predominantly determined by the Y3 and Y9 indicators, and PCA3 is mainly shaped by the Y3 and Y8 indicators.

The subsequent analysis of the identified independent components indicates that the increase in GDP per capita exhibits the strongest direct correlation with the fundamental factors of the share of persons employed in innovative firms and the number of researchers (excluding R&D) per 1 million population. However, models based on PCA2 and PCA3 rely on reducing R&D activities and their funding, which contradicts the principles of modern global development and the strategic goals of European countries. Consequently, the subsequent discussion will focus on the GDP per capita growth model, with particular emphasis on the contributions of the first principal component.

The clusters generated by the selected model are then mapped onto GDP per capita (in monetary terms) in order to assess the appropriateness of the model developed on the basis of PCA0 (see Figure 1 Correlation PCA dimension 0 on GDP per capita).

The possibility of enhancing GDP per capita within EU countries can be achieved chiefly through the advancement of creative industries and the augmentation of research within innovative corporations. Despite the present negligible influence of the art industry on GDP per capita growth, it is imperative to contemplate the long-term appreciation of art objects.

A salient feature of this model is that a comparatively modest increase in the number of researchers involved in research is accompanied by a substantial increase in funding and a significant expansion in the workforce within innovative companies.

The personnel levels in innovative companies, as reflected in the base model, can be interpreted as an indicator of the need to expand staffing in specific countries or industries.

A more detailed analysis of EU countries was conducted by means of a clustering procedure. PCA results were used to create various clustering configurations ranging from $k$=2 to $k$=12 using the K-means method, and the Silhouette Coefficient was calculated for each configuration (see Table 4).

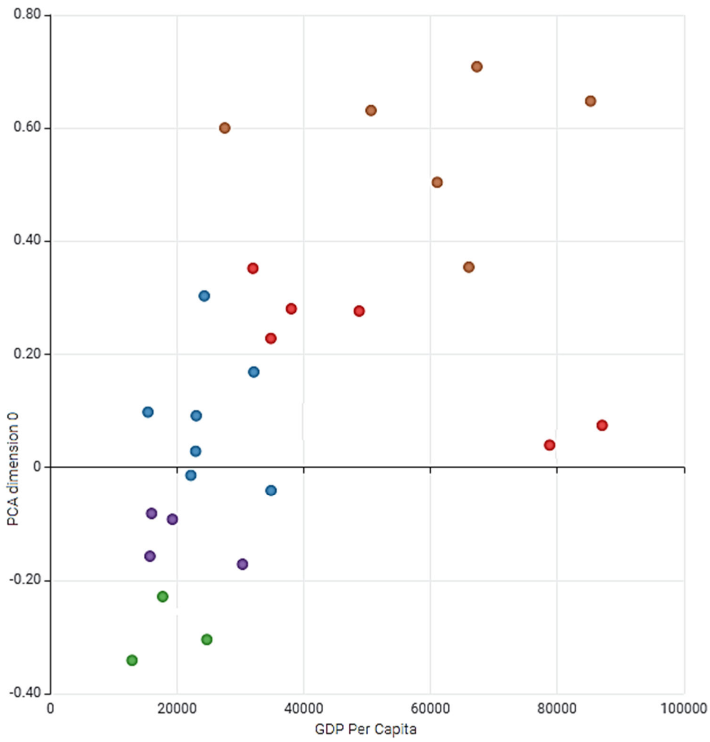


**Figure 1. Correlation PCA dimension 0 on GDP per capita**

The highest Silhouette Coefficient value (0.5047) corresponds to five clusters, representing the optimal level of alignment between the constructed cluster structure and the input data. The cluster analysis thus revealed intra-group homogeneity in country profiles based on the level of creativity.

Table 4
**Silhouette Coefficients for created clusters**

| Number of clusters | Silhouette Coefficient |
|---|---|
| 2 | 0.1597 |
| 3 | 0.2697 |
| 4 | 0.4925 |
| 5 | 0.5047 |
| 6 | 0.4445 |
| 7 | 0.3878 |
| 8 | 0.2688 |
| 9 | 0.2862 |
| 10 | 0.3203 |

Five distinct clusters were identified, and Figure 2 presents a 3D visualisation of these clusters from various perspectives.

The initial cluster (depicted in brown) encompasses the most developed countries, recognised as leaders in creative development: namely, Denmark, Finland, Sweden, France, the Netherlands, Germany, and Switzerland. These nations demonstrate a high level of proficiency in cultivating innovation across diverse industrial sectors, reflecting their advanced level of creativity, substantial research and development activities, and robust governmental support for the creative sector of the economy.

The cluster centre is defined by the following coordinates in Principal Component Analysis (PCA) space PCA0 = 0.8314, PCA1 = 0.4875 and PCA2 = 0.1874. These countries are characterised by high efficiency in using creative potential to drive economic development. A positive correlation is observed between GDP per capita and the number of firms registering designs and applying for patents.

However, further GDP per capita growth in these countries necessitates an increased share of the labour force in creative industries. Factors that have a detrimental effect on economic growth include the share of emigrants within these countries. Additionally, the correlation between GDP per capita and the share of people with higher education is negative, potentially due to the reduced demand for formal education in the rapidly growing art industries, which have significantly expanded their influence in recent years.

The second cluster (shown in red) includes Spain, Italy, Austria, Estonia and Ireland. These countries have relatively high levels of creativity and substantial R&D expenditure. The centre of the cluster is located at the following PCA coordinates PCA0 = 0.4231, PCA1 = 0.1862 and PCA2 = 0.2802. These coordinates reflect the overall efficiency of the cluster in creative development and a strong positive correlation with the analysed indicators.

A notable feature of this cluster is its weaker institutional base compared to the leading countries, which is crucial for fostering creative potential. This is evidenced by a lower number of innovative firms, fewer patents related to creative development and limited innovation arising from creative activities. In addition, these countries lack reliable systems and structures to support and promote creative development.

A further challenge is the absence of effective coordination among the various stakeholders, which hinders the execution of innovation strategies. While stakeholder interest and engagement in the creative

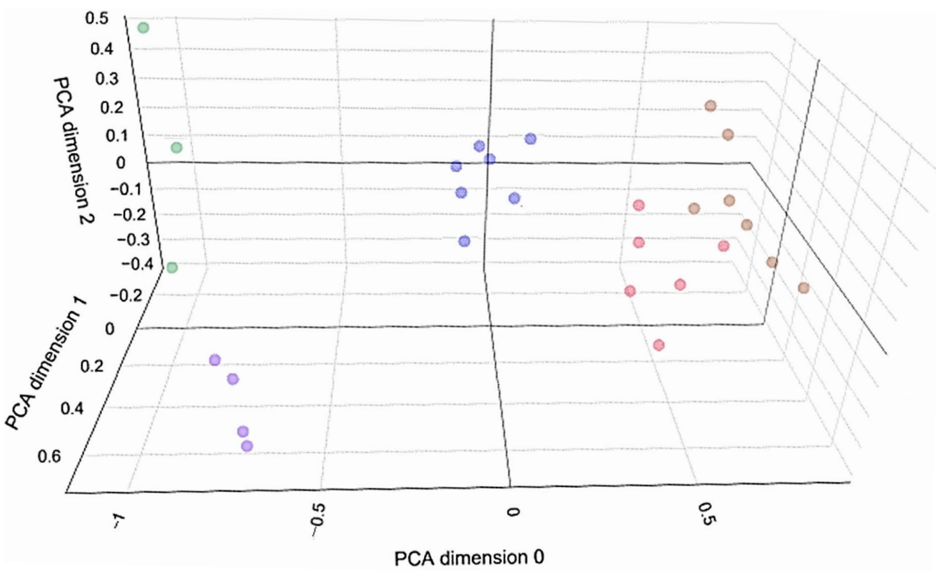


**Figure 2. Clusters by creative economic development based on PCA dimensions**

industries within this cluster are significant (as indicated by the proximity of the countries in Figure 1), they remain below the levels seen in leading countries.

The third cluster (illustrated in blue) encompasses the following countries: Iceland, Croatia, Latvia, Lithuania, Poland, Portugal, the Czech Republic, and Greece. These countries exhibit a below-average level of creativity and a GDP per capita that is also below the average. The centre of this cluster is situated at the following PCA coordinates: PCA0 = 0.1496, PCA1 = 0.0214, and PCA2 = 0.21067.

These countries currently face challenges in fostering creativity, mainly due to underdeveloped infrastructure and limited capital resources. However, significant progress has already been made in raising levels of creativity. Although their indicators are lower than those of the leading cluster, this indicates considerable potential for growth and improvement.

The implementation of sustainable development strategies, increased stakeholder engagement, full integration of scientific research into practice, and the introduction of measures to stimulate creativity have the potential to advance these countries into the cluster of nations with highly developed economies.

The fourth cluster comprises Cyprus, Hungary, Slovenia and Slovakia. This cluster is characterised by a stable, above-average level of innovation. According to PCA, its centre lies at PCA0 = -0.6829, PCA1 = 0.4905 and PCA2 = -0.3447. These countries currently face challenges in promoting creative industries, which is reflected in their below-average levels of innovation. In addition, their low economic growth rates indicate insufficient basic support and infrastructure for development. The challenges faced by this cluster are similar to those of the fifth cluster.

The fifth cluster is characterised by a suboptimal level of creativity development, with its PCA centre at PCA0 = -1.0815, PCA1 = 0.1052, and PCA2 = -0.2475. These coordinates underscore the cluster's overall inefficiency in terms of creativity and associated indicators. This group encompasses countries in the developmental catch-up phase, notably Malta, Romania, and Bulgaria. A salient feature of this group of countries is the underdeveloped institutional framework necessary for the implementation of strategies that are geared towards sustainable creativity development and overall national well-being. These countries also lack reliable systems and structures to support and promote the creative sector. Furthermore, poor coordination among stakeholders hinders the implementation of government support and funding strategies. Stakeholder interest and involvement in the development of creative industries are relatively low in this group of countries.

The analysis indicates that countries falling within both clusters encounter considerable difficulties in establishing an environment that is conducive to innovation. In order to address these challenges, it is essential to enhance institutional frameworks, optimise stakeholder coordination, and augment interest and investment in innovation and sustainable development initiatives.

## 6. Conclusions

This method enabled the demonstration of the impact of certain parameters of creative economic development on economic growth indicators, even under conditions of limited information. Notably, the three principal components explained 78.33% of the available data. Through analysis, it was concluded that the following factors significantly contribute to fostering economic growth.

1. Number of R&D professionals per million population. This factor shows the strongest correlation with GDP per capita. As it takes into account R&D expenditure and the involvement of highly educated people in research, it highlights several potential strategies to boost GDP growth:
– Increasing funding for R&D across various sectors.
– Encouraging firms to engage in R&D activities.
– Creating favorable conditions for training highly qualified professionals capable of conducting advanced research.

2. Share of employees in innovative firms. A robust correlation exists between this factor and GDP per capita, which is closely associated with the preceding parameter. This underscores the significance of cultivating creativity in the development and implementation of innovations. Future research could concentrate on identifying which industries achieve the most favourable outcomes from innovation, as well as the factors influencing the success of these firms. For instance, attention could be given to the productivity growth rates of employees in innovative firms, which should exceed the average growth rate in the industry.

3. Number of firms engaged in design. The presence of design-oriented firms has been shown to have a positive effect on GDP per capita across all three principal components analysed. This finding highlights the potential for further economic development within EU countries by supporting such firms.

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