Sustainable Economic Growth Factors in the EU: Applying a Modified Cobb-Douglas Production Function with Renewable Energy and Digitalization

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Abstract. The paper utilizes the Cobb-Douglas production function with renewable energy and digitalization to estimate the sustainable economic growth factors in the EU. Neoclassical economic theory emphasizes the role of capital and labor as input variables in the output growth models, while novel growth theories are endogenous and emphasize the role of technological advances in economic development. The time frame of the research covers 2011-2021 in order to include the latest available data for all 27 EU member states economies. The research method was fixed-effects GLS regression for the panel data. This study has investigated the impact of different factors on sustainable economic growth. The paper proves that capital and labor as classical production function have a positive impact on GDP. Renewable energy development and digital economy were revealed to be drivers of sustainable economic growth. One of the policy implications is that the governments should promote renewables and digital economy with diverse range of policy instruments for sustainable economic growth promotion by decision-makers.

1 Introduction

Due to the complexity of socioeconomic systems, understanding the key factors affecting sustainable economic growth has been and still remains one of the core challenges for the scientific community. With the evolution of scientific thought, the approaches to determining the drivers of traditional economic growth also changed. Neoclassical economic theory is one of the most recognized among scientists. It emphasizes the role of capital and labor as input variables in the output growth models [1–28]. For example, the Cobb-Douglas production function depends only on these types of inputs and their productivity. Novel growth theories are endogenous and emphasize the role of technological advances in economic development. From our point of view, both have their advantages and disadvantages that are important to take into account. This research will extend the neoclassical input-output model by adding new factors, including digital and energy factors since they are considered to play a significant role in the national economy efficiency and sustainable transition.

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From our perspective, renewable energy and digitalization are critical drivers of sustainable economic growth due to their powerful transformative impact. Renewable energy sources, such as solar and wind power, not only reduce greenhouse gas emissions and air pollution but also ensure long-term energy security. Therefore, this shift towards clean energy not only mitigates environmental degradation but also generates jobs, promotes energy resilience and technological innovation [29–46]. Similarly, digitalization optimizes resource utilization, enhances productivity, and enables evidence-based decision-making, resulting in greater economic efficiency. It supports the transition to a circular economy – an economic system that reduces waste and increases resource efficiency [47–72]. The synergy between renewable energy and digitalization offers a way towards sustainable development, where economic prosperity combines with environmental and social well-being.

This research concentrates its attention on developed economies, with a specific focus on the European Union (EU). In recent times, the EU has demonstrated a significant commitment to achieving sustainable economic development, as its ambitious goal is to become the world's first climate-neutral continent by 2050 [73–102]. Understanding the imperative of adopting a holistic approach to sustainable transition, the EU is suitable for our research. Our core objective is to investigate the factors affecting sustainable economic growth applying an augmented Cobb-Douglas production function.

2 Literature review

The bibliometric analysis for this study employed the Scopus database together with the VOSViewer software. Using specific keywords such as "sustainable economic growth," "drivers," and "factors," and constraining the search to publications between 2013 and 2023 within the Scopus Toolkit, we identified a substantial pool of 12,750 relevant scientific publications. It is worth noting that the volume of publications on this topic has demonstrated significant growth over the years. To illustrate, in 2013, there were 540 papers addressing this subject, whereas by 2022, this number is over 2,200. Within this timeframe, distinct research trends have emerged. In 2013-2016, a substantial portion of scholarly attention was directed towards exploring the roles of macroeconomic issues (inflation and unemployment) in promoting economic stability. In the next years a predominant focus was on investigating the influence of green issues (e.g., renewable energy, energy efficiency) on sustainable economic growth. Recent developments have sustained the relevance of GDP growth as a research topic, driven by the global impact of the COVID-19 pandemic. Furthermore, contemporary research trends include the relationship between digitalization and economic growth, particularly in the context of transitioning to Industry 4.0 and 5.0. The literature on sustainable economic growth continues to evolve, with novel topics such as circular economy principles, green finance, and the role of political and legal issues in sustainability.

The next step is to create a bibliometric map with the use of VOSViewer. Using the capabilities of this software, we identified four main clusters (Figure 1). The first (red) one is about economic aspects of sustainable growth (e.g., foreign direct investments, total factor productivity, entrepreneurship). The second (blue) cluster depicts the environmental challenges of the world economy (e.g., environmental pollution, carbon emission). The third (green) cluster concerns the social component of sustainability (e.g., social effects, employment). The smallest (violet) cluster concerns the interplay between urbanization processes and sustainable transition (e.g., urban area, urban development).

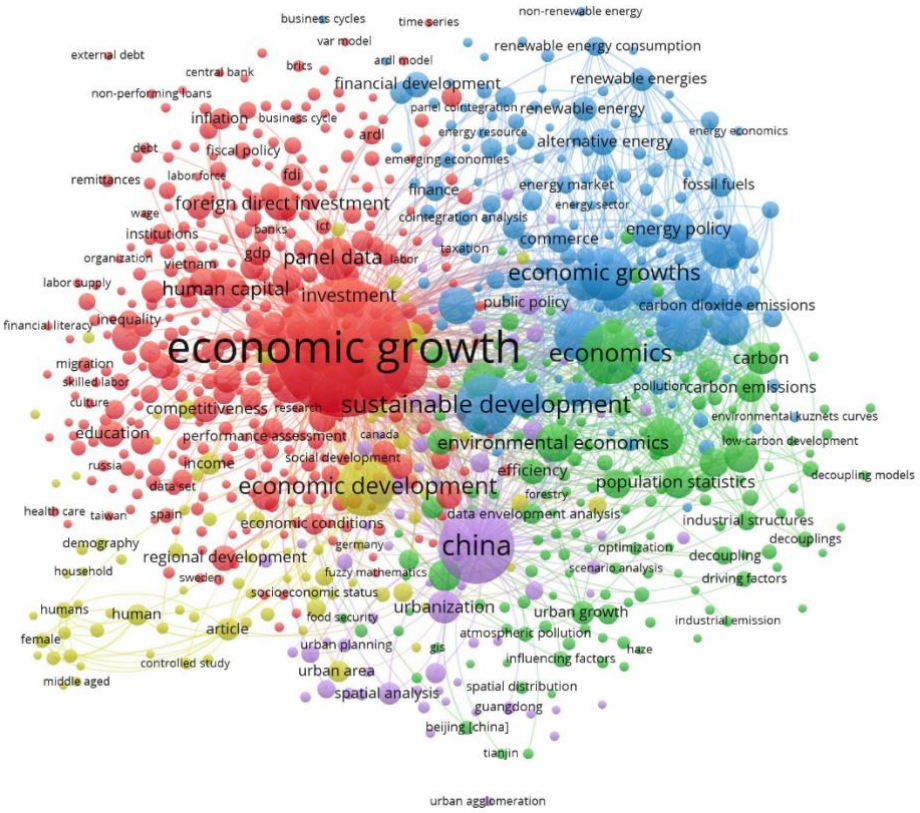

Fig. 1. The bibliometric map of the keywords to the topic

Sustainable economic growth is a broad concept with different definitions and frameworks. Many researchers have highlighted the importance of balancing economic growth with environmental and social components (Table 1).

Table 1. Different approaches to define the concept of «sustainable economic growth»

№	Definition
1	Sustainable economic growth is a form of economic progress that minimizes negative environmental impacts and maximizes resource efficiency [103]
2	Sustainable economic growth is a long-term development strategy that seeks to achieve a harmonious balance between economic expansion, environmental protection, and social well-being [104]
3	Sustainable economic growth is strategies and practices that contribute to the restoration and improvement of ecosystems, communities, and overall well-being while maintaining economic vitality [105]

Pierra et al. [106] described the role of education and science in sustainable economic growth, emphasizing their crucial role for green transition. The impact of life expectancy on economic productivity was revealed by [107]. Human capital was unfolded to positively affect sustainable economic growth, according to Prasetyo & Kistanti [108]. Yousefi [109] discussed the positive role of information technologies on sustainable economic growth, indicating the transformative impact of digitalization in developing countries. Similarly,

Adenle et al. [110] investigated the positive relationship between digitalization and smart agriculture. The industrial policy has a controversial effect on sustainable economic growth and sustainable transition in general, following [111]. Tu et al. [112] considered digital transformations as a powerful instrument to achieve long-term sustainable economic growth. There is some research concerning the impact of socio-political factors on sustainable economic growth. Kim et al. proved that corruption is a significant barrier to growth due to general inefficiency and lower productivity [113]. These authors also underline the necessity to balance public debt to support macroeconomic stability and economic growth. Khan et al. analyzed the role of political regimes in Asia and their compliance with the sustainable agenda, emphasizing the role of local governance in enhancing sustainable economic growth and environmental conservation [114].

Most scholars emphasized that renewable energy affects sustainable economic growth. Analyzing selected Asian economies, the study proves that renewable energy development has a strong impact on the economic growth of these countries [115–137]. Another study, applying a VECM method, demonstrated that renewable energy consumption stimulates sustainable growth in both short- and long-run [158–]. The role of renewable energy on the microeconomic level was discussed by He et al. [159], who investigated more than a hundred Chinese enterprises. The findings show that investments in renewables have a payback period (on average 4-6 years) and provide the businesses with a variety of development opportunities. Some scholars underlined the possibility of negative short-term socio-economic impacts of renewable energy deployment at a local level, including unemployment in regions with high dependence from fossil fuels [160]. Similar results were obtained by [161].

The augmentation of the traditional Cobb-Douglas function with new factors (renewable energy and digitalization) allows for a more comprehensive analysis of their impact on economic growth and productivity. This approach recognizes the changing dynamics of modern economies, where sustainable practices and digital technologies play a crucial role in shaping economic outcomes. Our research can potentially reveal how renewable energy and digitalization interact with traditional factors of production (capital and labor) to influence economic growth. Therefore, it will serve as a valuable resource for decision-makers, stakeholders, and practitioners across a wide range of sectors and disciplines and help them make more informed choices that align with sustainability and economic development objectives.

3 Methods and data

The classical Cobb-Douglas production function is as follows:

$$Q = AK^{\alpha}L^{\beta} \quad (1)$$

where Q - represents the quantity of output produced; A is the total factor productivity or the level of technology and efficiency; L is the quantity of labor input; K is the quantity of capital input; α and β are the output elasticities of capital and labor.

According to the key objective of this study, we will modify this function by adding new factors that reflect renewable energy development and digital economy. The first model will use capital, labor and renewable energy as independent variables, whereas the second – capital, labor and digital economy. In addition, we will convert variables into a natural logarithm form, as demonstrated below.

$$\ln GDP_t = \alpha_1 \ln K_t + \alpha_2 \ln L_t + \alpha_3 \ln RE_t \quad (2)$$

$$\ln GDP_t = \alpha_1 \ln K_t + \alpha_2 \ln L_t + \alpha_3 \ln DIGIT_t \quad (3)$$

It is important to underline that gross fixed capital formation is a proxy for K_t, labor force – for L_t, final renewable energy consumption – for RE_t, human resources in digital sphere – for $DIGIT_t$. As a dependent variable we chose real GDP as a standard measure of the national economic output.

The data for analysis was taken from trustworthy sources, including the World Bank and the Eurostat. The time frame of the research was 2011–2021 in order to include the latest available data. The research method was chosen to be a panel data analysis (fixed-effects GLS regression). We performed data pre-processing with the use of Microsoft Excel and estimation – STATA 16.0.

4 Results and discussion

Applying STATA 16.0 to the abovementioned models, we got the following results.

Table 2. Regression estimations results

$lnGDP_t$	**(1)**	**(2)**
	Model 1	**Model 2**
lnK_t	0.441***	0.348***
	(0.000)	(0.000)
lnL_t	0.479***	0.453***
	(0.000)	(0.000)
$lnRE_t$	0.043***	
	(0.000)	
$lnDIGIT_t$		0.255***
		(0.000)
Const.	7.901***	10.794***
	(0.000)	(0.000)
Observ.	297	297
R-squared	0.9511	0.9718
Number of countries	27	27
p-value in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

In both models, capital and labor have a statistically significant impact on real GDP. When gross fixed capital formation increases by 1%, real GDP rises on average by 0.441% (model 1), 0.348% (model 2). Similarly, when labor force increases by 1%, real GDP rises by 0.479% (model 1) and 0.453% (model 2). Capital and labor are essential drivers of GDP growth because they are the primary inputs in the production process. GDP growth over the long term is closely linked to the accumulation of both physical capital and human capital (education and skills of the workforce). This continuous investment in capital and labor is critical for maintaining economic growth over time.

Renewable energy was unfolded to be a driver of the GDP growth. When renewable energy consumption grows by 1%, real GDP increases by 0.043%. Similar results were obtained by [162]. Chen et al. [163], however, found another nexus (renewable energy stimulates growth in developing countries, but not in developed ones). This impact is not so strong compared to capital and labor, however, its role in promoting growth will be expanding since the share of renewables in total energy mix is constantly growing. From our perspective, renewable energy is a critical driver of green growth, offering economic, environmental, and social benefits. It contributes to reducing greenhouse gas emissions,

creating jobs, fostering innovation, and enhancing energy security, all of which are consistent with the principles of sustainable and environmentally responsible economic development.

Digitalization was proved to be a crucial factor affecting GDP positively. When number of people employed in the digital sphere increases by 1%, real GDP rises by 0.255%. Digitalization enables more efficient resource use, promotes innovation in sustainable practices, and helps policy-makers adopt evidence-based decisions. It offers solutions to environmental challenges while fostering economic development and inclusivity.

5 Conclusions and policy implications

This study has investigated the impact of different factors on sustainable economic growth. It was confirmed that capital and labor as classical production function have a positive impact on GDP. It is crucial that business should invest more in energy-efficient capital (equipment, buildings) and use green technologies. In addition, employees should also be engaged in sustainable activities and understand the importance of green technologies implementation.

Renewable energy development was revealed to be a driver of sustainable economic growth. Therefore, government should promote renewables with financial and non-financial incentives. For example, in some cases it may be useful to consider setting carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems. Green finance is another promising issue. By promoting green finance instruments (e.g., green bonds) into renewable energy projects and other environmentally sustainable initiatives, it is possible to create more opportunities for their successful implementation.

The development of digital economy also simulates sustainable economic growth. Digitalization is a complex process, which requires profound efforts and strong vision from all stakeholders. For example, governments should transform most public services (getting permits, licenses or documents) to make them online-accessible. Private companies should implement new digital technologies into their operational processes. For example, businesses can use data analytics to get valuable recommendations from large volumes of information. This will help to adopt evidence-based decisions, optimize operations, and understand customer behavior for better targeting and product development. NGOs and educational institutions should raise general awareness about advantages of digitalization and the ways to cope with possible challenges of these transformative processes.

The core finding of this study is that sustainable economic growth is influenced by many factors, and a diverse range of policy instruments should be applied for its promotion by decision-makers. Further research may extend the models with new variables and/or estimate them with other econometric methods.

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