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Green Innovation for Competitiveness: Impact on GDP Growth in the European Union

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ABSTRACT

Since the start of the Industrial Revolution, the global climate has changed dramatically. Concentrations of greenhouse gases (GHGs) in the atmosphere have increased sharply, followed by an increase in global average temperatures. However, business activities related to environmental protection are mostly focused on the implementation of legal rules instead of voluntary initiatives such as green innovation due to doubts about costs and profit. The goal of this research is to identify the impact of green innovation on economic growth in an innovative environment and digitalization conditions by using sophisticated indexes and regression analysis. The results show that green innovations have a positive impact on economic growth in the European Union (EU). However, the impact of digitalization on economic growth is still under discussion and depends on qualitative aspects of coverage and how they are reflected in digitalization indicators. It is important to emphasize that the data of this empirical study only cover EU countries that are subject to EU regulation and have similar trends in the development and diffusion of green innovations. Non-EU countries may have different approaches and policies influencing the maturity and diffusion of green innovations. The results of this research provide a scientific basis for strategic planning at the national and business levels, encouraging a focus on the development of green innovation not only as a means of reducing the impact of climate change but also as a strategic direction for increasing competitiveness and economic growth.

KEY WORDS: green innovation, digitalization, GDP growth, European Union.

JEL Classification: A10, C30, E17, F63, O30, O40.

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1. Introduction

The excessive usage of scarce resources and the lack of attention from humans throughout the centuries have peaked, resulting in changes to the global climate. In recent years, the discussion and actions regarding climate change have been bolstered by scientists and experts, who have begun to widely speak about the need for emergency actions supported by the societies of many developed countries.

Hence, the right time to shift to a green economy is imminent. At the 26th Annual Conference of the Parties (COP26) to the United Nations (UN) Framework Convention on Climate Change (UNFCCC), governments had difficulty negotiating a final agreement. Although a compromise was found, these results do not meet the expectations of the COP for a clear and unambiguous response to limit global warming to 1.5 °C (United Nations, 2021). Looking to European Union (EU) strategies, which have declared a focus on environmental protection throughout the decades, it should be observed that the EU goal for greenhouse gas (GHG) emissions set in the Europe 2020 strategy was achieved in 2014 and has since remained below the target level (European Commission, 2021d). This fact indicates that the EU has an appropriate attitude to-

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ward environmental protection and has demonstrated this attitude in action. However, only 14 member states of the Organisation for Economic Co-operation and Development (OECD), including 9 out of 27 EU countries, namely, Sweden, Portugal, the Netherlands, Luxemburg, Italy, Ireland, France, Denmark and Austria, are participating in the green budgeting initiative of the OECD (OECD, 2021).

Staying focused on environmental issues such as climate change, energy, water, biodiversity, land use, chemicals, toxic and heavy metals, air pollution, waste management, ozone layer depletion, oceans and fisheries, and deforestation is not easy for countries and companies that play by the rules but compete globally. For example, the EU set a green line in procurement rules with a special emphasis on environmental protection. However, the procurement rules vary significantly among regions and countries, especially regarding their economic development level, and such rules still create a space for pollution and irresponsible attitudes toward scarce resources.

Unfortunately, business activities related to environmental protection are mostly focused on the implementation of legal rules instead of voluntary initiatives such as green innovation due to doubts about costs and profit. Nevertheless, smart companies are seizing competitive advantage through the strategic management of environmental challenges (Esty & Winston, 2006), and the green economy has become a competitive advantage for global players.

Therefore, recent studies in the field of the green economy emphasize the important role of government policy and actions (Khan et al., 2021), including qualitative research (Trittin-Ulbrich & Böckel, 2022) and the relationship between green innovation and firm profitability from the taxation perspective (Delbono & Lambertini, 2022). Additionally, it has been proven that a green market orientation plays an important role in the green innovation development and green performance of companies (Wang, 2020).

Many studies have evaluated the impact of green innovation through intellectual capital. Green innovation based on green intellectual capital – green human capital, green relational capital and green structural capital – has a positive impact on green performance and economic performance (Wang & Juo, 2021). Similar studies support the role of green intellectual capital and its positive impact on environmental performance via the mediating role of green innovation (Asiaei et al., 2022; Úbeda-García et al., 2022). It has been found that green innovation based on the proportion of green patent applications can significantly increase company value (Hao et al., 2022). Additionally, green innovation measured by patent applications related to environment-related technologies has emerged as an important tool in combatting environmental degradation (Koseoglu et al., 2022). Martínez-Ros and Kunapatarawong (2022) analyzed green innovation development under knowledge sources (internal and external) and found that when companies are growing in size, they shift their focus from internal to external knowledge, developing green innovation (Martínez-Ros & Kunapatarawong, 2022). Wang et al. (2022), based on a survey of 149 large, 121 medium and 81 small companies, concluded that green knowledge management is a significant positive predictor of corporate sustainable development (Wang et al., 2022).

The positive moderating effect of environmental innovation on the relationship between environmental performance and firm financial performance was proven by Wedari, Moradi-Motlagh and Jubb (2022). Zheng & Iatridis analyzed the findings of research, dividing them between manufacturing and services benefiting from eco-innovation. They found that manufacturing companies benefit the most from their economic, environmental and operational performance, while service companies benefit from eco-innovation in terms of social performance (Zheng & Iatridis, 2022). Moreover, it was verified that green growth based on sustainable technology transfer and sustainable innovation has a positive impact on GDP growth (Fernandes et al., 2021).

There are many other studies on the impact of green (product or process) innovation on company performance. Achi et al. (2022) found that green process innovation mediates the positive relationship between corporate social responsibility (CSR) and micro, small, and medium-sized enterprise (MSME) performance. Albort-Morant et al. (2018) tested a hypothesis on the basis of 112 Spanish automotive component manufacturing companies and concluded that there is a positive and significant mediating effect of relationship learning on the knowledge base–green innovation performance relationship. Arranz et al. (2020) found that eco-innovation and innovation are interrelated and complementary in nature, which facilitates the development of future eco-innovation. Based on a dataset of 195 small and medium-sized enterprises (SMEs) in China, Chen and Liu (2020) focused on customer participation seeking to enhance green product innovation by facilitating the recognition and exploitation of opportunities. Iranmanesh et al. (2017) studied the effect of green product and process innovation on job satisfaction and concluded that they have a positive direct effect on job intensity and a negative indirect effect on job satisfaction through job intensity. Using data from 209 listed companies that belong to heavily polluting manufacturing industries, Xie et al. (2019) found that green process innovation has a positive impact on green product innovation and that both green process innovation and green product innovation can improve a company' financial performance.

Investments in research and development (R&D) and the impact of eco-innovation on GDP growth have received less attention from academia compared to studies at the company level. Banelienė (2021) researched OECD countries and found that the multiplier effect of business-financed R&D investment and its impact on economic growth depend on the economic development level. Additionally, Banelienė (2022) analyzed how sustainable economic growth could be maintained in the long run while considering three criteria, including R&D investment, gross value added per employee and country size by population, and which factors could have the highest impacts on economic growth in the COVID-19 recovery process according to supply and demand. Estimation outputs show the stronger effect of the supply side on economic growth, the higher role of human capital in small EU countries where R&D investment exceeds 3% of GDP, and the critical effect of exports on GDP growth in the large EU countries with the lowest R&D investment (Banelienė, 2022).

The research by Khan et al. (2021) was based on Northern European countries – Denmark, Norway, and Sweden – and focused on the government's role in the transition to a green economy, analyzing strategic policy documents. Mačiulytė-Šniukienė and Sekhniashvili (2021) focused their research on EU countries and found that eco-innovation development has a positive impact on economic growth and environmental performance.

Martínez-Ros and Kunapatarawong (2019) analyzed 384 articles in the Scopus database and observed that in academia, there has been a clear increase in interest in eco-innovation. However, studies on green innovation in the context of the green economy, digitalization and their impact on economic growth are lacking, and this topic is still under discussion and requires much more in-depth research.

Therefore, the research question of this study is as follows: what is the relationship between green innovation, digitalization and the green economy, and what influence do these factors have on national economic growth?

From our perspective, green innovation can have a positive impact not only on climate change but also on national economic growth. This impact may be due to the maturity of green technology, for example, investment in green energy (solar and wind). In the early stage of technological development, the cost-benefit value is negative or close to negative. As technology advances, investing in green energy can have a positive economic impact on a country's economy. A similar trend can be observed with electric cars and other green innovations. This means that investment in green innovation may be profitable. Existing research and literature analysis show that this topic has not been fully explored, and it is still unclear how investment in green innovation development can affect economic growth, especially considering the technological maturity of green innovation. Given the importance of this topic to society, the impact of green innovation on economic growth can be continuously studied. It is very important to understand when the technological maturity of green innovation reaches a level where a positive economic effect can be clearly identified. The research presented in this article contributes to a deeper understanding of this topic.

Digitalization may have a similar effect on the economy of a country, but it is not the key variable of this study. Digitalization is chosen to reduce the risk of reverse causality with respect to green innovation. This means that if growth in green innovation is driven by a high GDP per capita, a similar pattern may also occur with regard to digitalization.

This paper covers a theoretical approach and an empirical background that observe the current situation and current needs to ground the added value created by green innovation to enhance the will of world leaders to support the necessary actions in the field of climate change without damaging the economies of their countries. Additionally, this section addresses the general view regarding the measurement of the innovativeness of countries from the green innovation perspective with a focus on quantitative and qualitative aspects. The methodology section is focused on presenting the model constraints, describing the model idea, the variables, and the hypotheses proposed. For modeling, sophisticated data on innovations, green incentives, and digitalization in EU countries are used, and the least squares method is applied for estimation. The results show the estimation outputs and prove that green innovation has a positive impact on economic growth in EU countries. The summary of this research and its insights are provided in the discussion and conclusion sections, with a clear focus on the added value of green innovation in the economies of the countries chosen for this research.

2. Theoretical Approach and Empirical Background

Since the beginning of the Industrial Revolution, the global climate has changed dramatically. Concentrations of greenhouse gases (GHGs) in the atmosphere have risen sharply, followed by a rise in global average temperatures. These high concentrations of CO2 and other GHGs are mainly due to emissions from developed countries. Modern developed economies have historically contributed significantly more to the problem of global warming due to two centuries of industrial development (Cirman et al., 2009; Mulder et al., 2021; United Nations, 2013).

To avoid the negative potential outcomes of global warming, in 2015, countries adopted the Paris Agreement on Climate Change. The Paris Agreement, adopted by 196 parties at COP26, is an agreement for establishing a new climate change regime after the Kyoto Protocol, a legally binding international treaty on climate change. The goal of the Paris Agreement was to limit global warming to well below 2 °C, preferably 1.5 °C, compared to preindustrial levels (Allan et al., 2021; United Nations Environment Programme, 2021). To achieve this long-term temperature goal, countries aimed to reach a global peak of GHG emissions as soon as possible to achieve a climate-neutral world by the middle of this century.

The sixth edition of the United Nations Environmental Programme (UNEP) Adaptation Gap Report (2021) presented at the Glasgow Climate Conference in 2021 finds that climate impacts continue to outpace attempts to change the situation. According to the report, 2021 was the year when the effects of climate on developed and developing countries hit countries particularly hard. The Intergovernmental Panel on Climate Change (IPCC) has warned that in the best cases, there is a 50% chance of limiting global warming to a 1.5 °C rise this century. Funding to combat global warming is a key issue in this discussion. The gap between the actual and necessary adaptation costs is widening. The estimated adaptation costs could reach US$280-500 billion per year by 2050 for developing countries alone (United Nations Environment Programme, 2021).

The potential negative consequences of these efforts for the economic development of countries are alarming. There are concerns that countries' commitments to reduce CO2 emissions could reduce a country's competitiveness, increase unemployment, and increase the prices of products, especially food. It is thought that the funds to combat global warming would be more effectively used to tackle social problems and boost economic growth (Hovi et al., 2012). For example, the United States withdrew from the Paris Agreement in 2017 (Rajamani & Brunnée, 2017). The exit of the United States, which is the second largest GHG emitter, from the Paris Agreement would seriously challenge the achievement of the goals of the agreement. For the same reasons, many countries are reluctant to make higher commitments to reduce GHG emissions. As the Paris Agreement obligates developed countries to identify a quantified target for reducing GHG emissions, called nationally determined contributions (NDCs), for themselves, they choose the target and its baseline (Allan et al., 2021). According to Rowan (2019), roughly half of the NDCs of the target to reduce emissions are below “business as usual”, and a quarter include a reduction target below a reference year (Rowan, 2019).

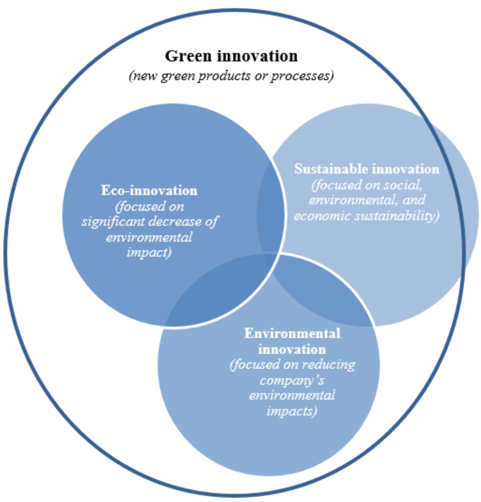
All of these facts lead to the conclusion that there is a prevailing opinion, especially among politicians, that measures to reduce GHG emissions are detrimental to national economies. Such an approach discourages investment in measures and technologies to reduce GHG emissions and hampers the fight against global warming.

Despite this approach, financial institutions are more optimistic about green investment. The United Nations Conference on Trade and Development (UNCTAD) (2021) estimates that the value of sustainability-themed investment products in global capital markets amounted to US$3.2 trillion in 2020, up more than 80% from 2019 (UNCTAD, 2021). These products include sustainable funds (more than US$1.7 trillion), green bonds (more than US$1 trillion), social bonds (US$212 billion), and mixed-sustainability bonds (US$218 billion). Sustainability-themed funds have continued their growth despite volatile markets in 2020 (UNCTAD, 2021). It is important to emphasize that sustainability-themed funds are those that, in addition to value criteria, assess the impact of investments on society and apply environmental, social, and corporate governance criteria. They can pursue sustainability-related topics or explicitly aim to create measurable social impacts. An UNCTAD (2021) study shows that investment in eco-innovation, green technologies, and sustainable innovation can not only have a positive effect on combating global warming but also be profitable.

The term "green innovation" should be clarified for further analysis. According to Díaz-García et al. (2015), there are four different terms used in the literature to describe innovations that have a reduced negative impact on the environment: "green", "eco", "environmental" and "sustainable". These terms can be used interchangeably in macroeconomic research, but there are some differences that may be important to identify in disciplines such as microeconomics or product design. Fussler and James (1996) stated that eco-innovation is new product and process development that simultaneously focuses on creating value for customers and businesses and significantly decreasing environmental impacts. According to Chen et al. (2006), green innovation is defined as a hardware or software innovation related to green products or processes and

Figure 1

Relationships Among Green Innovation, Eco-innovation, Environmental innovation, and Sustainable Innovation



includes technological innovation in the fields of energy saving, pollution prevention, waste recycling, green product design, or corporate environmental management. Comparing the above definitions of eco-innovation and green innovation, it is clear that the objective of green innovation is not always to “significantly decrease environmental impacts”.

According to Szekely and Strebel (2013), sustainable innovation can be described as creating something new that raises social, environmental, and economic performance. Such innovation covers changes in technologies, processes, operational practices, business models, thinking, and business systems (Szekely & Strebel, 2013). According to the above definition, sustainability is a key element of sustainable innovation, but not all green innovations can be sustainable, nor can all innovations have economic sustainability.

Environmental innovation is more focused on reducing a company's environmental impacts and can be described as organizational implementations and changes with a clear focus on environmental protection, with implications for companies’ products, manufacturing processes and marketing and with different degrees of novelty. These innovations can be incremental or radical, where the main objective is to reduce the company's environmental impacts (Días Angelo et al., 2012). Environmental impacts can be described as actions taken by companies that focus on protecting and minimizing damage to the environment and that cover components such as climate change, natural resources, pollution and waste, and environmental opportunities (Lee & Suh, 2022).

Based on the analysis of the above definitions, green innovation is a broader concept that includes eco-innovation, environmental innovation, and sustainable innovation (see Fig. 1).

This is in line with the statement on the term “green innovation” in the Oslo Manual. The impact of business activities and products on the natural environment can also drive business innovation, for instance, when companies aim to reduce these impacts through green innovations (OECD/Eurostat, 2018). According to this statement, any business innovation aimed at reducing negative impact (significant or insignificant) on the natural environment can be described as a green innovation. The term “green innovation” is used deliberately in this study, as this term is more appropriate for macroeconomic research because green innovation is a broader concept that includes eco-innovation, environmental innovation and, in part, sustainable innovation.

Many authors have analyzed the impact of different factors on economic growth. Odoardi and Pagliari (2019) analyzed household wealth as a factor of economic growth. Kłopocka and Wilczyński (2021) analyzed the impact of credit supply on unemployment risk and household savings. Recent studies have analyzed how different crises, including the COVID-19 crisis, have impacted different economic indicators, including GDP growth (Sinković et al., 2022). However, the impact of investment in the development of green innovation on economic growth has not been fully explored. Some studies show that, in general, technological innovation can have a positive effect on economic growth. However, it may have a negative impact on a sustainable economy, as increased economic activity leads to increased carbon dioxide emissions due to increased productivity (Su et al., 2021). On the other hand, some green innovations, such as renewable energy consumption and energy use, may have positive and significant associations with sustainable economic development (Nguyen et al., 2022). Innovations related to financial development, industrialization, trade, and energy consumption have also been found to be factors that harm environmental quality (Khan et al., 2022). Green innovation, by definition, should have a positive impact on the quality of the environment, but at the same time, it can have a positive or negative impact on economic growth. This fact can be attributed to the different maturities and levels of diffusion of green innovations (Rogers, 1995). Green innovation in countries with high green innovation maturity and a high level of diffusion may show a positive effect on economic growth, while low green innovation maturity and a low level of diffusion may show a negative effect.

All the macroeconomic studies noted above have the risk of reverse causality. Similar challenges arise when analyzing the impact of green innovation on economic growth. In theory, it is possible that wealthier countries (countries with a high GDP per capita) have more resources to develop green innovation. To reduce the risk of reverse causality with respect to green innovation, digitalization is analyzed as a similar causal factor. This means that if growth in green innovation is driven by a high GDP per capita, a similar pattern may also occur with regard to digitalization.

Examining the empirical background, the basic principle in the elaboration of eco-efficiency indicators is a determination of the ratio between the value of a product or service and its environmental impact by increasing the value of the product or service or decreasing its environmental impact (Albu, 2017). However, this state is based on the microlevel, not the macrolevel, where a much broader spectrum of factors is involved in building a green economy and where qualitative factors play an increasingly important role in the long run.

OECD lessons from a peer-learning exercise in the field of the green economy stress the importance of the following factors: strong policy commitment and leadership, robust systems, processes and tools, capacity and continuous skill development, shared knowledge, learning and engagement, and well-supported country systems (OECD, 2019). The evaluation of these factors should be based more on qualitative factors but with a strong attitude toward evaluating progress and keeping it on track by monitoring quantitative indicators.

Many innovativeness indicators have been used in recent decades. All of them have mostly been based on quantitative data with a focus on evaluating and comparing countries and regional and local economies worldwide. One such index at the global level is the global innovation index (GII), which consists of subindicators for seven fields—institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs—and covers the ease of doing business subindicators. The GII is provided by the World Intellectual Property Organization (2021) for 132 economies.

At the regional level, the EU observes countries' innovativeness by using the European innovation index (EII), which is based on subindicators, such as framework conditions (human resources, attractive research systems, digitalization), investments (finance and support, firm investment, use of information technologies), innovation activities (innovators, linkages, intellectual assets), impacts (employment impacts, sales impacts, environmental sustainability), and other contextual structural indicators. The EII was calculated by the European Commission (2021b) and provided for all EU countries and ten more European economies.

In the field of digitalization, Nesta (2019) proposed a new indicator, the European digital social innovation index (EDSII), which was carefully developed for 60 European cities, including 25 capital cities of EU countries. Additionally, it was based equally on quantitative and qualitative data. The EDSII has subindicators for the field of civil society, collaboration, skills, infrastructure, funding, and diversity and inclusion. A few indicators, such as digital inclusion (DI), are included in the EDSII on the basis of another regional index, the digital economy and society index (DESI), estimated by the European Commission (2021a) for EU countries. At the same time, the DESI was based on five subindicators: connectivity, human capital, the use of internet services, the integration of digital technology, and digital public services.

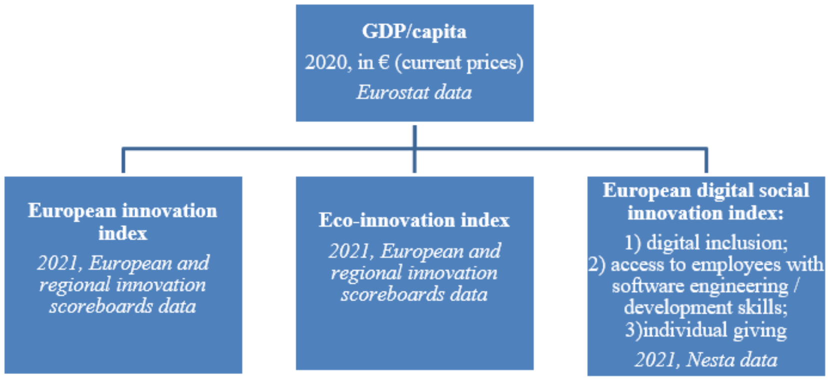
The green economy or eco-economy at the EU level is represented by the eco-innovation index (EcoII) with subindicators such as eco-innovation inputs, activities and outputs, resource efficiency outcomes, and socioeconomic outcomes (European Commission, 2021c). It is a part of the EII.

To summarize the indicators noted above, all of them take into account human capital, skills and creative activity, available infrastructure, and the attitude toward environmental sustainability. Additionally, they can help to answer the research question regarding the relationship between green innovation, the green economy and digitalization and what influence these factors have on national economic growth.

3. Methodology: Model and Data

Taking into account innovativeness indicators and the main idea of this paper to evaluate and find a relationship among innovativeness, the green economy, and digitalization, three indicators were chosen for the model: the EII, the EcoII, and the newly developed EDSII, as well as its subindicators – DI, access to employees with software engineering/development skills, and individual giving (see Fig. 2).

Figure 2
Structure of the Model



All three indexes are described in detail in the empirical background. However, the chosen subindicators of the EDSII need an additional explanation:

Digital inclusion (DI) represents the score for the basic skills and usage subdimension of the human capital dimension of the DESI. The basic skills and usage subdimension capture information about whether the population is able to use the internet and uses it on a regular basis and whether the population possesses at least a basic level of digital skills in at least one of four digital competence domains: information, communication, content creation or problem solving. The components of the DI are as follows: the skills of internet users (at least basic digital skills, above basic digital skills, at least basic software skills) and advanced skills and development (information and communication technology (ICT) specialists, female ICT specialists, ICT graduates) (Nesta, 2019; European Commission, 2021a);

Access to employees with software engineering/development skills: This subindicator is the number of users on the Stackoverflow (for programmers) forum in a city per active population [age 16-64]. It is included to represent the qualitative aspect of digitalization (Nesta, 2019);

Individual giving: This subindicator is the score for donating money to charity. It is based on responses to the following survey question: "Did you donate money to charity in the last 12 months (yes/no)?". At the initial stage, this indicator was included in the model as a dummy variable (Nesta, 2019).

The geographical coverage of this research is based on the EU area. Due to the limitations of the EDSII, only 25 out of 27 EU countries were included because the EDSII subindicators were calculated for the capital cities of 25 countries.

The mathematical expression of the model is as follows:

$$GDP/capita = EII + EcoII + DI + SWE + IG + \varepsilon \qquad (1)$$

where GDP/capita – GDP per capita in current prices (€, 2020), Eurostat data; *EII* – European innovation index for 2021, with data from the European Commission; *EcoII* – eco-innovation index for 2021 (as part of EII), with data from the European Commission; *DI* – digital inclusion; *SWE* – access to employees with software engineering/development skills; and *IG* – individual giving, with 2019 data from Nesta for the EDSII subindicators (see Equation 1, Appendix A).

In this context, two hypotheses are proposed:

H1. Green innovations have a positive impact on economic growth in an innovative environment.

H2. Digitalization has a positive impact on economic growth in an innovative environment.

An innovative environment is represented in the model by the EII.

The least squares method was applied for modeling, and 25 observations for 25 EU countries were used. Luxembourg and Malta were excluded due to a lack of data on the EDSII and its subindicators. Estimation was performed using EViews software.

4. Results

The estimation results show a positive impact of green innovations on economic growth. However, digitalization, represented by DI, has a negative impact on economic growth in an innovative environment, as the model is constrained.

$$GDP/capita = 197.88*EII + 145.85*EcoII - 1039.20*DI + 24467.31*SWE + 565.53*IG + \varepsilon \quad (2)$$

The most important indicator in this estimation is access to employees with software engineering/development skills (*SWE*), which is measured by the number of users on the Stackoverflow (for programmers) forum (per active population [age 16-64]): 1 percentage point (pp) in the EU average can create 245 € GDP per capita per year. Raising the *EII* by one point can create 198 € GDP per capita per year, and an increase in the EcoII point can create 146 € GDP per capita per year. The most surprising impact on GDP comes from individual giving (*IG*), which reflects society's intention to donate money to charity and was included in this model as a dummy variable at the initial stage. A one-unit increase in this activity can create 566 € GDP per capita per year. DI, which represents the score for the basic skills and usage subdimension of the human capital dimension of the DESI, such as the skills of internet users (at least basic digital skills, above basic digital skills, at least basic software skills) and advanced skills and development (ICT specialists, female ICT specialists, ICT graduates), shows a negative impact on economic growth. This result can be explained by the idea that the skills of internet users are used only partially for work activities and the quantitative numbers of specialists and graduates can stealthily support the assumption of successful careers and a strong focus on GDP creation (see Equation 2, Table 1).

To summarize the estimation results, green innova-

Table 1
Estimation Results: The Basic Equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EII	197.8816	83.67166	2.364977	0.0283
EcoII	145.8526	69.48199	2.099143	0.0487
DI	-1039.204	267.9675	-3.878097	0.0009
SWE	24467.31	8270.574	2.958357	0.0078
IG	565.5294	116.8126	4.841341	0.0001
R-squared	0.885660	Mean dependent var		28131.15
Adjusted R-squared	0.862793	S.D. dependent var		16303.79
S.E. of regression	6039.171	Akaike info criterion		20.42678
Sum squared resid	7.29E+08	Schwarz criterion		20.67055
Log likelihood	-250.3347	Hannan-Quinn criter.		20.49439
Durbin-Watson stat	2.233874			

tions have a positive impact on economic growth in an innovative environment, proving H1. However, digitalization, as measured by the DESI human capital subindicator, shows a negative impact on economic growth, rejecting the hypothesis that digitalization has a positive impact on economic growth. Considering that the meaning of digitalization is broader than that captured by the DESI subindicator included in the model, the impact of digitalization on economic growth is still under discussion and depends on qualitative, not only quantitative, aspects of coverage and how they are reflected in digitalization indicators.

In addition, the proposed hypotheses were supported by supplementary estimation including GDP growth indicators for 2020 and 2021 as independent variables (see Equation 3, Table 2).

$$GDP/capita = 176.13*EII + 194.21*EcoII - 726.43*DI + 435.91*IG + 1321.39*{}_{\Delta}GDP_{2020} + 806.16*{}_{\Delta}GDP_{2021} + \varepsilon \quad (3)$$

where ${}_{\Delta}GDP_{2020}$ – GDP 2020% change in the previous period (current prices, chain linked volumes); and ${}_{\Delta}GDP_{2021}$ – GDP 2021% change in the previous period, Eurostat data.

In this estimation, the independent variable SWE – access to employees with software engineering/development skills in this estimation was irrelevant. This result also shows that further discussion of the impact of digitalization on economic growth is needed.

Normality tests of both estimations support the validity of the modeling results, showing that the hypothesis of a normal data distribution is not rejected (see Appendix B).

5. Discussion

Existing research and literature analysis show that the impact of green innovation on a country's economic growth has not been fully explored, and it is still unclear how investments in green innovation development can affect economic growth. Some studies show that, in general, technological innovation can have a positive effect on economic growth but simultaneously have a negative effect on the green economy, as increased economic activity leads to increased carbon emissions due to increased productivity (Su et al., 2021). Many green innovations are technological innovations; thus, in this respect, our finding of a positive impact of green innovation on economic growth is consistent

Table 1

Estimation Results: The Equation with Independent Variables of GDP Growth

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EII	176.1264	71.48598	2.463790	0.0235
EcoII	194.2057	61.03956	3.181637	0.0049
DI	-726.4346	229.7487	-3.161866	0.0051
IG	435.9075	107.5442	4.053287	0.0007
ΔGDP2020	1321.393	315.0620	4.194072	0.0005
ΔGDP2021	806.1597	357.5607	2.254609	0.0362
R-squared	0.921206	Mean dependent var		28131.15
Adjusted R-squared	0.900471	S.D. dependent var		16303.79
S.E. of regression	5143.557	Akaike info criterion		20.13444
Sum squared resid	5.03E+08	Schwarz criterion		20.42697
Log likelihood	-245.6805	Hannan-Quinn criter.		20.21558
Durbin-Watson stat	2.470034			

with existing research. On the other hand, in principle, innovation should have a positive effect on the green economy due to the level of dominance of green technological innovation. Technological innovation, with the predominance of green technological innovation, can have a positive effect on the green economy, while countries where green technological innovation has not been developed may have the opposite effect. This phenomenon can be observed in this study by comparing the EII with the EcoII, which is a subindex of the EII. For example, the EII of Belgium is very similar to that of Denmark, but they have a significantly different EcoII (see Appendix A, Table A.1).

Another issue to discuss is the risk of reverse causality. It is possible that wealthier countries (countries with a high GDP per capita) have more resources for green innovation; thus, a high green innovation index could be influenced by resource availability. For this study, digitalization was chosen to reduce the risk of reverse causality with respect to green innovation. This means that if growth in green innovation is driven by a high GDP per capita, a similar pattern may also occur with regard to digitalization. The results of our analysis demonstrate that there is no correlation between digitalization and growth; at the same time, there is a high correlation between green innovation and economic growth (GDP per capita).

It is possible that the availability of resources drives the development of green innovation, while the impact of green innovation on economic growth is less obvious. There are examples of countries with a high GDP per capita and a low EcoII. The different effects of green innovation on economic growth may also be due to different maturities and levels of diffusion of green innovations (Rogers, 1995). Countries with high green innovation maturity and a high level of diffusion can show a positive effect on economic growth, while countries with low maturity and a low level of green innovation diffusion can show a negative effect. Given the importance of the topic to society, the impact of green innovation on economic growth could be continuously studied to trace the impact of green innovation on economic growth.

The results of this research provide a scientific basis for strategic planning at the national and business levels, encouraging a focus on the development of green innovation not only as a means of reducing the impact of climate change but also as a strategic direction for increasing competitiveness and economic growth.

6. Conclusion

In conclusion, green innovations have a positive impact on economic growth in an innovative environment. However, digitalization, as measured by the DESI human capital subindicator, shows a negative impact on economic growth and does not promote economic growth. Considering that the meaning of digitalization is broader than that captured by the DESI subindicator included in the model, the impact of digitalization on economic growth is still under discussion and depends on qualitative, not only quantitative, aspects of coverage and how they are reflected in digitalization indicators.

While evaluating the impact of separate variables on GDP growth, the most important indicator in the estimation is access to employees with software engineering/development skills (SWE), which is measured by the number of users on the Stackoverflow (for programmers) forum (per active population [age 16-64]): a 1 pp increase in the EU average can create 245 € GDP per capita per year. Raising the EII by one point can create 198 € GDP per capita per year. Increasing the EcoII by one point can create 146 € GDP per capita per year. The most surprising impact on GDP comes from individual giving (IG), which reflects society's intention to donate money to charity. A one-unit increase in this activity can create 566 € GDP per capita per year. DI, which represents the score for the basic skills and usage subdimension of the human capital dimension of the DESI, such as internet user skills (at least basic digital skills, above basic digital skills, at least basic software skills) and advanced skills and development (ICT specialists, female ICT specialists, ICT graduates), has a negative impact on economic growth. This result can be explained by the idea that the skills of internet users are used only partially for work activities and the quantitative numbers of specialists and graduates can stealthily support the assumption of successful careers and a strong focus on GDP creation.

This study nonetheless has certain limitations. The major limitation of this study is the lack of indicators at the EU level, which would be further based on the qualitative aspects of green innovation and digitalization activities. Additionally, the data in this empirical study are based on a short period of time and only cover EU countries that are subject to EU regulation and have similar trends in the development and diffusion of green innovations. Non-EU countries may have different approaches and policies influencing the maturity and diffusion of green innovations. Countries with high green innovation maturity and a high level of diffusion may show a positive effect on economic growth, while countries with low green innovation maturity and a low level of diffusion may show a negative effect.

Another limitation is related to the risk of reverse causality when analyzing the impact of green innovation on economic growth. It is possible that wealthier countries (countries with a high GDP per capita) have more resources to develop green innovation. To reduce the risk of reverse causality with respect to green innovation, digitalization was analyzed as a similar causal factor. This reduced the risk of reverse causation but did not completely eliminate it. Green innovation can be interrelated with economic growth. This means that the development of green innovations could be influenced by the economic wealth of the country, such that only after reaching a certain maturity can green innovations influence the growth of the country's economy.

Based on the implications and limitations of this study, the following future research could be recommended. First, to test how the maturity and level of diffusion of green innovations influence countries' economic growth, the study should also be extended by including non-EU countries. In particular, it would be important to analyze the impact of green innovation on economic growth for categories of countries separately having low, medium and high GDP per capita. The value of the recommended study increases if a longitudinal approach for statistical data collection is adopted. The second recommendation concerns the test of reverse causality with respect to green innovation and economic growth. Regarding this recommendation, the development of the most advanced green innovations, such as solar, wind energy, electric cars, etc., and its impact on the economic growth of the countries could be analyzed. For such studies, it would be recommended to adopt a longitudinal approach supplemented with qualitative data.

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Appendix A

Table A.1

Data Used for Modeling

Country	GDP/capita 2020, in € (current prices)*	European innovation index (EII) 2021**	Eco innovation index (EcoII, sub index of EII) 2021**	Individual giving (sub index of EDSII)***	Access to employees with software engineering/ development skills (sub index of EDSII)***	Digital inclusion (sub index of EDSII)***	GDP 2020% change on previous period (current prices, chain linked volumes)****	GDP 2021% change on previous period (current prices, chain linked volumes)****
Austria	42615	133.62	130	54	0.34	35.55	-6.70	4.80
Belgium	39156	143.52	85	45	0.13	34.14	-5.70	6.20
Bulgaria	8724	50.06	34	18	0.28	16.50	-4.40	4.20
Croatia	12144	78.22	72	25	0.26	27.33	-8.10	10.20
Cyprus	24266	106.48	56	42	0.10	29.05	-5.00	5.50
Czechia	20129	94.41	96	21	0.26	31.85	-5.50	3.50
Denmark	53672	147.51	146	56	0.36	40.85	-2.00	4.90
Estonia	20192	128.29	73	27	0.54	34.45	-3.00	8.30
Finland	42743	151.38	145	39	0.24	40.48	-2.20	3.00
France	34208	122.30	107	27	0.18	32.12	-7.80	6.80
Germany	40492	137.92	123	55	0.11	36.83	-3.70	2.60
Greece	15471	88.49	75	7	0.19	22.90	-9.00	8.30
Hungary	13985	76.42	54	22	0.24	27.25	-4.50	7.10
Italy	27725	108.08	112	35	0.03	23.09	-9.00	6.60
Latvia	15470	55.87	86	21	0.43	28.05	-3.80	4.50
Lithuania	17719	92.08	82	19	0.32	28.35	-0.10	5.00
Netherlands	45962	138.50	110	66	0.25	31.73	-3.90	4.90
Poland	13796	65.88	59	24	0.08	25.20	-2.20	5.90
Portugal	19434	90.26	100	20	0.04	25.63	-8.40	4.90
Ireland	75108	121.27	97	64	0.69	28.09	6.20	13.60
Romania	11287	35.09	57	20	0.14	15.92	-3.70	5.90
Slovakia	16871	70.98	62	31	0.13	31.15	-4.40	3.00
Slovenia	22386	100.49	94	35	0.24	28.76	-4.20	8.10
Spain	23703	95.99	104	35	0.08	30.36	-10.80	5.10
Sweden	46022	156.45	143	57	0.42	42.16	-2.20	5.10

*Calculated by authors based on Eurostat data, 2021a, 2021b.

**Source: European and regional innovation scoreboards 2021.

***Source: Nesta, 2021.

****Source: Eurostat data, 2022.

Appendix B

Figure B.1
Normality Test: The Basic Equation

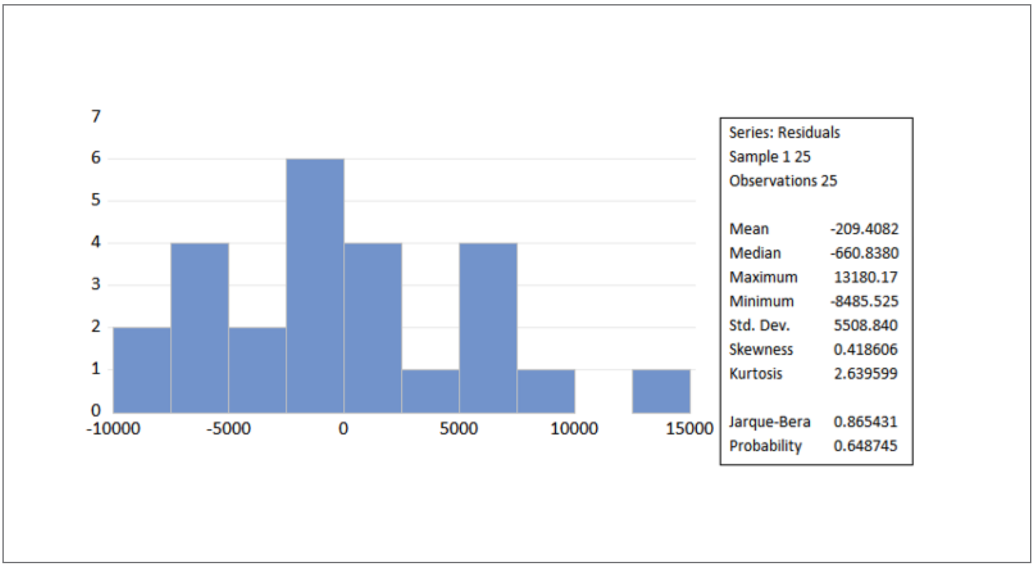

Figure B.2
Normality Test: The Equation with Independent Variables of GDP Growth