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The Effects of Urbanisation on Green Growth within Sustainable Development Goals

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Abstract: The Green Deal policy and Sustainable Development Goals require that the economic development of a country should be reoriented towards 'green' economic development. Currently, the globalisation and intensification of production boosts urbanisation in many countries, which may stimulate economic growth and improve citizen well-being, but may also lead to excessive consumption of resources and negative environmental impacts. Against the backdrop of these challenges, it is expedient to estimate the effects of urbanisation on the green growth of a country and define the relevant changes and instruments for achieving green growth in a country in view of urbanisation. The research covers the EU countries and Ukraine (as an official candidate for European Union membership) in the period of 2005–2020. Applying the Global Malmquist–Luenberger productivity index (to estimate green economic growth); a fixed and random effects model, GMM modelling (to evaluate the impact of urbanisation on green economic growth), this study aimed to contribute to the theoretical framework of green economic growth by extending input and undesirable output parameters of a country's productivity. The findings revealed that, in 2020, as compared to 2005, green economic growth went into a decline in all countries analysed, this decline stemmed from accelerated urbanisation. However, industrial structure and research and development appeared to be conducive to green economic growth, which justifies the idea that countries should focus on implementing structural reforms for the technological modernisation of infrastructure and industrial complexes to dispose of the shortcomings caused by urbanisation. To compensate for this negative impact, the findings of this research prompt a set of policy implications concerning dissemination of the green knowledge and technologies, green project implementation, reinforcement of incentive instruments and achievement of a synergistic balance of economic and ecological targets underlying the SDGs.

Keywords: sustainable development; green economy; renewable energy; land; innovation; industrial structure; trade openness

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1. Introduction

Environmental challenges worldwide require appropriate measures and tools to tackle them without hindering economic growth. Against the backdrop of these challenges, the European Commission adopted the Green Deal policy [1], which set the blueprint for achieving carbon-free economic growth. Setting the background for this research, it is expedient to differentiate between economic growth and economic development. According to the studies [2–7], economic growth is an integrated output of using labour, capital, energy and land. Consequently, green economic growth aims at maximising the efficiency of input resources (labour, capital and land) while simultaneously decreasing the negative impact on the nature. In view of the EU Green Deal policy [1], the reduction in CO2 emissions is crucial for a transition to a carbon-free economy, as it encourages transformations in the governmental policies that require new knowledge, innovative technologies and resources [8–21]. In turn, green knowledge and innovation technologies promote modernisation of the industrial sector, reducing its destructive impact on the environment [22–26].

Urbanisation enhances dissemination of the green knowledge and innovative technologies, bridging gaps in living conditions and making services (health, digital, etc.) available and affordable. As stated in "Transforming our world: the 2030 Agenda for Sustainable Development" [8], goal 11 aims at providing the inclusive, safe, resilient and sustainable development of cities, with goal 11.3, in particular, focusing on strengthening sustainable urbanisation among all cities around the world [8]. While accelerated urbanisation causes an increase of environmental pollution, excessive consumption and depletion of resources, economic openness promotes the enlargement of green innovations and boosts dissemination of the state-of-the-art practices to overcome the issues caused by expanding urbanisation [9–21].

Determining the effects of urbanisation on green growth of a country will allow defining the relevant changes and instruments for achieving green growth in a country in view of urbanisation. A review of publications showed that the scientific community [27–48] has not arrived at a consensus in estimating green growth of a country, which hinders a comparison of countries. As a consequence, this confines the opportunities to implement relevant instruments to achieve the SDGs and targets of the Green Deal policy. This study aims to contribute to the theoretical framework of green economic growth by extending input and undesirable output parameters of a country's productivity. The input parameter adds renewable energy as a core determinant of productivity, while the undesirable output parameter involves the integrated index of natural capital pollution which merges CO2 and non-CO2 emissions.

Considering the above, this paper aims to bridge the following gaps in the research: (a) it develops an approach to measuring the green economic growth of the EU countries and Ukraine (as an official candidate for the EU membership): extending input parameters and analysing the integrated index of natural capital pollution as the undesirable output allows considering the weight of indicators and their benchmark values (maximum and minimum values depending on an indicator), eliminating bias and subjectivity while evaluating and comparing countries; (b) it estimates the urbanisation impact on the green economic growth.

The paper has the following structure: (a) Section 2 analyses the theoretical background of studies on green economic growth and urbanisation, and the links between them; (b) Section 3 explains the applied methodology to test a hypothesis on the urbanisation impact on green economic growth; (c) Section 4 describes the core empirical outcomes with justifications; (d) Section 5 summarises the results of the research and compares the findings obtained with the previous research, outlining policy implications and the limitations of the study.

2. Literature Review

2.1. An Approach to Defining Green Economic Growth

An overview of the theoretical framework on estimating green economic growth allows differentiating between three core approaches: (1) an index-based procedure that measures green development based on the rank and values of the world indexes: the Sustainable Development Goal index, the Environmental Performance index, the Global Sustainable Competitiveness index, the Global Green Economy index, the Global Sustainability index, etc. [27–32]; (2) the green GDP procedure that estimates green economic growth based on the green GDP calculated as differences between GDP and economic losses from environmental issues [21,22,47–53]; (3) an input–output procedure that measures the maximum economic and ecological output while minimising the input of resources (labour, capital and natural resources) [48]. In addition, the analysis results outlined the following methods applied to gauge green economic growth: the global Malmquist–Luenberger productivity index, data envelopment analysis and the slack-based measure [22–26].

Adamowicz [27] outlined three definitions—green economy, green growth and low-carbon development—and proposed calculating green economic growth based on the methodology developed by the experts from the United Nations, UNEP, UNCTAD, OECD and the World Bank. The UNEP green economy was defined as the one that enhanced human well-being, minimised inequalities and ecological risks. In addition, Barbier [31] proposed gauging green development by the efficiency of natural resource use and environmental quality. According to the UNEP methodology, the green economy is estimated by three groups of indicators: environmental (climate change, ecosystem management, the efficiency of resource use and waste management), policy (green investment, green taxes, green fiscal policy, carbon price, green education and green procurement) and well-being and inequality (employment, access to resources, health, human capital and natural capital) [27,30]. The OECD experts proposed using 26 indicators grouped according to four subindexes to estimate a country's green growth: environmental and resource productivity of the economy (carbon, energy, resource and multifactor productivity), a natural asset base (natural resources, renewable and non-renewable stocks, biodiversity and ecosystems), the environmental dimension of the quality of life (environmental health and risk, environmental services and amenities) and economic opportunities and policy responses (technology and innovation, environmental goods and services, international financial flows, prices and transfers, regulations and education) [32].

Furthermore, there is an emphasis on the significance of education on green issues [9–13] and technological innovations [33–46] so as to achieve green economic growth. Applying green GDP was researched as a measure of green economic growth [49–58]. In addition, it was proposed to add human capital and economic losses from environmental degradation to GDP [49–51]. Ecosystem services were proposed to be gauged while estimating green GDP [52]. At the same time, there was an emphasis on the necessity to consider the economy openness while measuring green GDP [58]. In addition, green growth depends on available financial resources [54–59].

A vast range of researchers [24–26,60,61] maintain that economic development should be coherent with ecological development. The concept of sustainable development implies that green economic growth can be achieved without compromising economic efficiency [17–21,42–46,60]. Zhong [60] argued that green economic growth promotes harmonising a country's economic, social and ecological development. Wang and Yi [61] estimated green economic growth to be based on the production theory for Chinese cities. In this case, the desired outputs were economic (GDP per capita) and ecological (urban green coverage rate). The undesirable outputs were measured by industrial wastewater, SO2 and soot emissions, and the compound environmental pollution index. In addition, the input variables comprised the number of employees, gross fixed capital stock, fixed inventory and energy consumption. The study [62] applied production theory to estimating the green economic growth of Belt and Road Initiative countries. Labour, capital and energy were the input data, while air pollution (measured by CO2 emissions) was the undesired output and GDP was the desired output. According to the findings, Qatar, Saudi Arabia, Singapore and the UAE are the leaders in green economic growth among the 28 Belt and Road Initiative countries.

2.2. An Approach to Defining the Impact of Urbanisation on the Green Economic Growth

An overview of the relevant research showed that urbanisation could promote economic growth due to an increase in the quality of life, dissemination of knowledge and innovations, and levelling inequalities in the access to resources and capital [63,64]. At the same time, economic growth requires more resources (capital, human and natural), which exerts an increasingly destructive impact on the environment. It was confirmed that urbanisation stimulates economic growth in developing and developed countries [65–70].

While analysing the impact of urbanisation on the regional growth in China [65,66], a phenomenon of "urbanisation without growth" caused by excessive migration from rural to urban regions in developing countries was defined. It was proven that urbanisation is conducive to economic growth in developed countries, but it restricts the economic growth of developing countries [71,72].

Furthermore, there was studied a nonlinear relationship between economic growth and urbanisation caused by over-urbanisation [65]. Developed countries have a higher proportion of the labour force employed in non-agricultural sectors than developing countries, compared to urban populations [65]. In addition, the impact of urbanisation is determined by the regions and countries' economic conditions, with urbanisation causing gaps and inequalities between cities and mega-cities [66–73]. The study [74] confirmed that urbanisation leads to changes in food demand and land use. Researchers also concluded that urbanisation could have a positive effect on the economic growth if the government pursued effective policies and that an effective policy of spreading technological innovation allows overcoming the issues of over-urbanisation and helps reduce environmental pollution [75–79]. Chen [80] emphasised that urbanisation positively affects GDP per capita and carbon tax; yet it causes CO2 emissions. Based on the empirical results of the Granger causality test, Khoshnevis and Golestani [81] justified the bidirectional causality among economic growth, CO2 emissions and urbanisation. In view of the fact that urbanisation was proven to play a core role in managing climate change [82], it was emphasised that SDGs could be achieved only in the case of eliminating environmental threats [82,83].

Researchers [62] confirmed that urbanisation spurs environmental pollution and intensification of using resources. Even more, a U-shaped relationship between pollution and green economic growth was determined [83–87]. Urbanisation was applied as a control variable in estimating green economic growth [62], with urbanisation being measured by the share of population living in urban areas [62,87,88]. These findings prompted the conclusion that urbanisation negatively impacts the green growth of Belt and Road Initiative countries. It was proven that rapid urbanisation increases water pollution in the cities along the Yangtze River Economic Belt [88]. Yet, another study [89] confirmed the positive effect of urbanisation on the green economic growth of the Chinese cities. Li, Dong and Dong [90] applied urbanisation rate as the control variable to estimate the interconnections between green growth, green trade and green energy. Their findings [90] demonstrated that urbanisation negatively influenced green growth in China, to say nothing about promoting it. Similar conclusions were made in the research conducted by Izakovicova, Petrovic and Pauditsova [91], who argued that without relevant effective governance and planning, urbanisation results in the environmental degradation.

Thus, the current publications on the relationship between urbanisation and green economic growth show no unanimous opinion among scientists. The findings, however, maintain that the impact of urbanisation on green economic growth depends on the level of a country's development, education, proportion of industries, economic openness and the rural areas' development. Considering the above, this paper aimed to estimate the effects of urbanisation on the green growth of a country.

3. Materials and Methods

3.1. Assessing the Green Economic Growth

In accordance with the neoclassic economic theory, a country's development has a natural constant tendency to achieve long-term stability. The growth rate of production is exogenous in relation to technical progress and the growth rate of employment [41,55,92]. Consequently, the macroeconomic production function is the functional equation between input factors (capital and labour) and the output parameter (the volume of production):

$$Y_i(t) = F_i(K_i(t)L_i(t)) \quad (1)$$

where $Y_i(t)$ is the GDP in a country I in t-time; $F_i(K_i(t)L_i(t))$ is a production function in a country i in t-time; $L_i(t)$ is labour force in a country i in t-time and $K_i(t)$ is the gross capital formation in a country i in t-time.

Along with this, Function (1) did not consider the undesired outputs of production, which resulted in the non-objective assessment. Natural parameters were not considered in production, while natural parameters directly influenced its efficiency. Considering the Sustainable Development Goals [8–21], economic growth should be accompanied by a transition to carbon neutrality, which reduces greenhouse gas emissions by production [22–26]. In this case, while evaluating green economic growth (*Ged*), it was necessary to allow for ecological issues. Taking this into consideration and based on the papers [22–26], *Ged* was measured by the global Malmquist–Luenberger productivity index, which uses stochastic frontier analysis and data envelopment analysis:

$$Ged_t^{t+1} = \left[\frac{1+D_i^G\left(x^t,y^t,\, b^t\right)}{1+D_i^t\left(x^t,y^t,\, b^t\right)} \times \frac{1+D_i^{t+1}\left(x^{t+1},y^{t+1},\, b^{t+1}\right)}{1+D_i^G\left(x^{t+1},y^{t+1},\, b^{t+1}\right)}\right] \times \frac{1+D_i^t\left(x^t,y^t,\, b^t\right)}{1+D_i^{t+1}\left(x^{t+1},y^{t+1},\, b^{t+1}\right)} \quad (2)$$

where $x^t, y^t, x^{t+1}, y^{t+1}$ are the input and output parameters of the production function in a country i in times t and t + 1, respectively; b^t, b^{t+1} are the undesirable outputs of the production function in a country i in times t and t + 1; and $D_i^t\left(x^t, y^t,\, b^t\right)$ and $D_i^{t+1}\left(x^{t+1}, y^{t+1},\, b^{t+1}\right)$ are the distance functions of the decision-making units in times t and t +1, respectively.

Model (1) applied gross domestic product (GDP) as an output parameter. In contrast to previous publications [22–26], this study considered the following input parameters: labour force (L), gross capital formation (K) and renewable energy. The consideration of energy is explained by its core role in providing physical capital [2–7], energy being the largest consumer of fossil natural resources. This fact justifies replacing non-renewable resources with renewable energy to provide for the production process in the country. Furthermore, renewable energy allows a reduction in air emissions and in the use of fossil natural resources (coal, oil, gas, etc.), thus contributing to achieving carbon neutrality.

Previous studies [22–24,27,60,61,81,87,88] used one of the following indicators as an undesired outcome: the ratio of carbon dioxide (CO2) emissions to population, excluding AFOLU (E_{1m}); the ratio of non-CO2 emissions (CH4, N2O) to population, excluding AFOLU (E_{2m}) and the ratio of agriculture non-CO2 emissions (CH4, N2O) to population (E_{3m}). This research added an integrated index of natural capital pollution (E_m) to Model (2), which merged CO2 and non-CO2 emissions. This allowed a comparison of countries by environmental pollution, not to mention the fact that reduction in CO2 emissions is one of the objectives in the framework of SDGs. In a similar vein, the entropy method provided an opportunity to calculate E_m, allowing for the value of undesirable outputs of the production process (E_{1m}, E_{2m}, E_{3m}), their benchmark maximum/minimum values and eliminating bias and subjectivity in assessing and comparing countries:

$$E_m = \varphi_1 E_{1m} + \varphi_2 E_{2m} + \varphi_3 E_{3m} \quad (3)$$

where φ_j is weight coefficients of indicators of E_m:

$$\varphi_j = \frac{\left(1 - \left(-\frac{1}{\ln(n)} \sum_{t=1}^{m} \left(\frac{(1+H_{ij})}{\sum_{t=1}^{m}(1+H_{ij})} \times \ln\left(\frac{(1+H_{ij})}{\sum_{t=1}^{m}(1+H_{ij})}\right)\right)\right)\right)}{\sum_{i=1}^{n}\left(1 - \left(-\frac{1}{\ln(n)} \sum_{t=1}^{m} \frac{(1+H_{ij})}{\sum_{t=1}^{m}(1+H_{ij})} \times \ln\left(\frac{(1+H_{ij})}{\sum_{t=1}^{m}(1+H_{ij})}\right)\right)\right)} \quad (4)$$

where H_{ij} is normalised *j*-indicators of *i* countries in *t* time; *m* is an analysis period; *n* is the number of studies.

Proceeding from the publications [14–21], this study applied Formula (5) to estimate the efficiency of the government reforms and programmes in achieving sustainable development goals:

$$EfGed_t = \frac{\left[\frac{1+D_i^G\left(x^t,y^t,\, b^t\right)}{1+D_i^t\left(x^t,y^t,\, b^t\right)} \times \frac{1+D_i^{t+1}\left(x^{t+1},y^{t+1},\, b^{t+1}\right)}{1+D_i^G\left(x^{t+1},y^{t+1},\, b^{t+1}\right)}\right] \times \frac{1+D_i^t\left(x^t,y^t,\, b^t\right)}{1+D_i^{t+1}\left(x^{t+1},y^{t+1},\, b^{t+1}\right)}}{\frac{D_i^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_i^t\left(x^t,y^t\right)}} \quad (5)$$

where $EfGed_t$ is an efficiency of the government reforms and programmes in achieving sustainable development goals.

If $EfGed_t \geq 1$ ("the green group"), the green growth of a country was concurrent with the reduction in environmental pollution. Otherwise, if $EfGed_t < 1$, countries belonged to the "yellow group".

The Gaussian kernel density function [93,94] allowed the analysis of the dynamic distribution evolution for the "Green" and "Yellow group" of the EU countries:

$$K(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \quad (6)$$

where x is equally distributed observations, representing the average of the observed values, and $K(x)$ is a kernel density function.

The input data and descriptive statistics for variables to analyse green economic growth are shown in Table 1.

Table 1. Variables of the green economic growth analysis.

Symbol	Meaning	Sources	Mean	Std. Dev.
L	Labour force, total	World Data Bank [95]	8,772,342	1.12×10^7
K	Gross capital formation (current USD)		1.29×10^{11}	1.89×10^{11}
RE	Use of renewables for electricity (Gigawatt-hour)	Eurostat [96]	28,503.65	40,536.91
GDP	Gross Domestic Product	World Data Bank [95]	33,099.04	22,036.23
E_m	Integrated index of natural capital pollution:		–	–
E_{1m}	Ratio of carbon dioxide (CO2) emissions to population, excluding AFOLU	Eurostat [96]	7.617	3.418
E_{2m}	The ratio of non-CO2 emissions (CH4, N2O) to population, excluding AFOLU	Eurostat [96]	1.005	0.512
E_{3m}	The ratio of agriculture non-CO2 emissions (CH4, N2O) to population	Eurostat [96]	$2.22/10^5$	$2.31/10^5$

The findings of univariate statistics (means and standard deviation) showed a significant dispersion of variables.

3.2. Assessing the Impact of Urbanisation on the Green Economic Growth

Proceeding from the research [66–73,82–87], the influence of urbanisation on the green economic growth was assessed by means of static and dynamic regression models.

A static model is expressed as follows:

$$Ged_{i,t} = \beta_0 + \beta_1 Urban_{i,t} + \rho \mathrm{Contr}_{i,t} + e_{i,t} \quad (7)$$

where $Urban_{i,t}$ is urbanisation in a country i in time t; $\mathrm{Contr}_{i,t}$ is control variables in a country i in time t; β_0, β_1, ρ are searching parameters of the model; and $e_{i,t}$ is the error term.

A dynamic model is expressed as follows:

$$Ged_{i,t} = \alpha_0 + \alpha_1 Ged_{i,t-1} + \alpha_2 Urban_{i,t} + \gamma \mathrm{Contr}_{i,t} + \mu_{i,t} + e_{i,t} \quad (8)$$

where $Ged_{i,t-1}$ is green economic growth in an *i*-country–in $t - 1$-time; $\alpha_0, \alpha_1, \alpha_2, \gamma$ are searching parameters of the model; $\mu_{i,t}$ is country-specific effects.

The study applied the Hausman test [97–99] between two models with fixed (FE) and random (RE) effects to estimate the β_0, β_1, ρ parameters of the static Model (7). The GMM [100,101] was applied to estimate $\alpha_0, \alpha_1, \alpha_2, \gamma$ of the dynamic Model (8). This provided an opportunity to allow for the speed of output data changes because of the input data changes. Thus, $Ged_{i,t-1}$ gave an opportunity to take into account the dynamic character of green economic growth.

Based on the theoretical framework [63,64,69,71,72,81], this study used a share of urban population in the total population as the indicator to estimate urbanisation and applied the following explanatory variables:

- *industrial structures*: as the countries' industrial development results in an increase of environmental pollution [88], industrial structures directly influence green economic growth;
- *research and development* (R&D): energy- and resource-saving technologies allow for intensification of industry and concurrently minimise its negative impact on the environment [8–21], which justifies such a variable such as R&D being measured by the number of patent applications in the country [22–26];
- *economic openness*: a variable that allows pursuing an efficacy policy on attracting highly qualified labour resources, innovations and knowledge to achieve sustainable development goals [8–26], which could concurrently raise new macroeconomic issues, primarily related to boosting economic growth.

The descriptive statistics of the explanatory and control variables for Models (7) and (8) are shown in Table 2.

Table 2. Explanatory and control variables for regression models.

Symbol	Meaning	Sources	Mean	Std. Dev.
		Explanatory Variable		
Urban	Urban population (% of the total population)	World Data Bank [95]	72.285	12.505
		Control variables		
InS	Industry (including construction), value added (% of GDP)	World Data Bank [95]	14.464	5.103
R&D	Patent applications	World Data Bank [95]	3503.1	9115.732
TO	Trade (% of GDP)	World Data Bank [95]	123.664	64.069

The population growth rate in the EU and all Europe loses its momentum from year-to-year, leading to huge diversification among the EU countries and regions, which weakens their competitive position, as well as their ability to achieve green growth based on knowledge, technical progress, innovation and the effective use of the modern science achievements. This research was staged to cover the period of 2005–2020, focusing on the EU countries and Ukraine as an official candidate for EU membership. Similar to the EU countries (Poland, Hungary, Czech Republic, Bulgaria, Romania, Latvia, Lithuania), Ukraine follows a gradual transformation of its foreign and home policy to implement the European vector of development. The research was informed by the data of the World Data Bank [95] and Eurostat [96]. It should be noted that Bulgaria was excluded from the analysis of industrial structure impacts on the green economic growth due to the lack of open data.

4. Results

The empirical results assessing an integrated index of natural capital pollution are shown in Table 3. The ratio of non-CO2 emissions (CH4, N2O) in agriculture to the population had the highest weight coefficient (0.3543), followed by the ratio of non-CO2 emissions (CH4, N2O) to population, excluding AFOLU (0.328), and the ratio of carbon dioxide (CO2) emissions to population, excluding AFOLU (0.3177) of the integrated index of natural capital pollution.

Table 3. An integrated index of natural capital pollution and weight of the relevant indicators.

Indicator					Weight	
The ratio of carbon dioxide (CO2) emissions to population, excluding AFOLU					31.77%	
The ratio of non-CO2 emissions (CH4, N2O) to population, excluding AFOLU					32.80%	
The ratio of non-CO2 emissions (CH4, N2O) in agriculture to the population					35.43%	
$E_m = 0.3177E_{1m} + 0.3280E_{2m} + 0.3543E_{3m}$						
Country	**Mean**	**CV**	**Skewness**	**Kurtosis**	**Min**	**Max**
Austria	0.834	0.043	0.239	5.229	0.750	0.926
Belgium	0.826	0.044	0.804	4.225	0.771	0.922
Bulgaria	0.871	0.019	1.221	5.152	0.847	0.919
Croatia	0.905	0.014	1.001	4.704	0.886	0.940
Cyprus	0.927	0.020	−0.255	1.800	0.899	0.954
Czech Republic	0.794	0.036	0.627	3.592	0.755	0.865
Denmark	0.734	0.079	1.155	4.862	0.657	0.896
Estonia	0.772	0.052	2.112	7.121	0.734	0.899
Finland	0.813	0.045	−0.178	1.818	0.751	0.868
France	0.844	0.024	−0.109	1.836	0.812	0.877
Germany	0.846	0.022	0.771	2.871	0.822	0.887
Greece	0.846	0.039	0.928	3.627	0.807	0.931
Hungary	0.917	0.014	0.476	3.532	0.897	0.948
Ireland	0.342	0.306	2.047	8.187	0.202	0.681
Italy	0.887	0.029	0.493	3.103	0.851	0.949
Latvia	0.889	0.016	2.218	8.193	0.876	0.934
Lithuania	0.842	0.023	2.739	10.554	0.820	0.908
Luxembourg	0.644	0.125	0.347	2.648	0.521	0.823
Malta	0.963	0.022	0.081	1.805	0.931	0.995
Netherlands	0.786	0.039	2.390	8.649	0.758	0.886
Poland	0.855	0.017	2.686	10.111	0.842	0.904
Portugal	0.867	0.023	1.539	6.775	0.836	0.927
Romania	0.905	0.018	1.296	5.811	0.885	0.953
Slovak Republic	0.894	0.019	0.451	3.421	0.867	0.936
Slovenia	0.847	0.034	1.034	4.524	0.812	0.927
Spain	0.873	0.031	0.733	4.772	0.829	0.946
Sweden	0.927	0.027	0.628	3.378	0.890	0.990
Ukraine	0.900	0.027	0.140	2.183	0.866	0.950

Note: CV is a coefficient of variation.

The findings in Table 3 show that Malta (0.963), Romania (0.905) and Cyprus (0.927) had the highest average value of the integrated index of natural capital pollution, while the minimum values were calculated for Ireland (0.202 in 2005), Luxembourg (0.521 in 2005) and Denmark (0.657 in 2006).

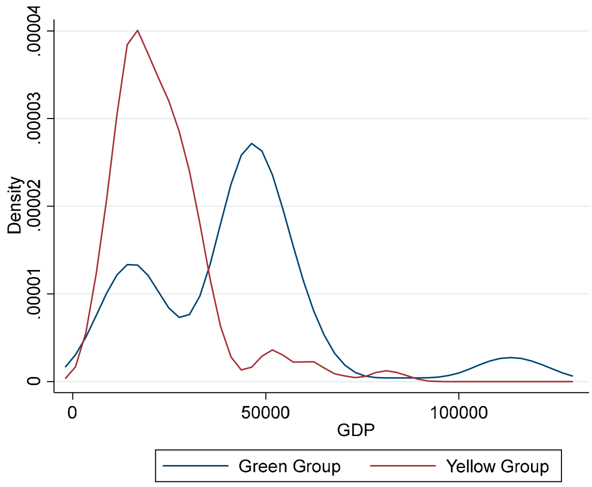
The empirical results of green economic growth and efficiency of the government reforms and programmes on achieving sustainable development goals among countries analysed in the period of 2005–2020 are summarised in Table 4. The highest average value of green economic growth was in Germany (1.0024), Latvia (1.0032), Romania (1.0022), the Slovak Republic (1.0021) and Poland (1.0020). Considering the findings, 14 countries belonged to the green group and 14 belonged to the yellow group. The yellow group was led by the following countries, which were close to the green group: Malta (0.999), Italy (0.995) and Poland (0.955). Cyprus, Bulgaria, Ireland, and Greece had the lowest average values in the yellow group.

Table 4. The empirical results of green economic growth and efficiency of the government reforms and programmes on achieving sustainable development goals among countries analysed in the period of 2005–2020.

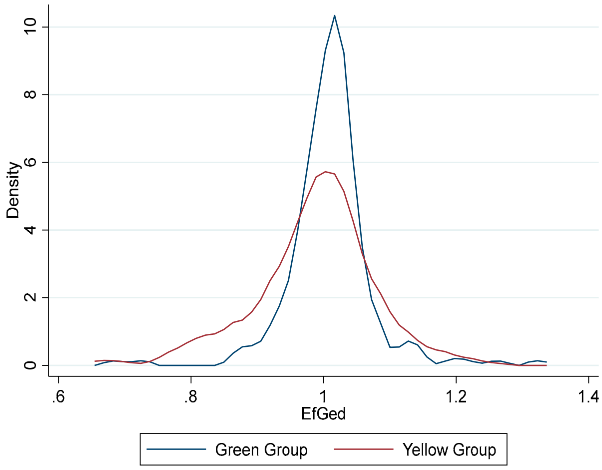
Country	Min	Max	Mean		Country Group	Country	Min	Max	Mean		Country Group
	Ged		*Ged*	*EfGed*			*Ged*		*Ged*	*EfGed*	
Austria	0.972	1.023	1.000	1.012	Green	Italy	0.980	1.017	0.999	0.995	Yellow
Belgium	0.975	1.022	1.000	1.013	Green	Latvia	0.981	1.021	1.003	0.986	Yellow
Bulgaria	0.996	1.007	1.002	0.980	Yellow	Lithuania	0.985	1.016	1.004	0.992	Yellow
Croatia	0.992	1.011	1.001	0.991	Yellow	Luxembourg	0.957	1.046	0.994	1.002	Green
Cyprus	0.781	1.078	0.968	0.981	Yellow	Malta	0.742	1.069	0.994	0.999	Yellow
Czech Republic	0.985	1.020	1.002	1.004	Green	Netherlands	0.971	1.029	1.001	1.012	Green
Denmark	0.959	1.024	0.999	1.010	Green	Poland	0.989	1.012	1.002	0.995	Yellow
Estonia	0.977	1.028	1.004	1.006	Green	Portugal	0.988	1.012	1.001	0.990	Yellow
Finland	0.968	1.028	1.002	1.011	Green	Romania	0.991	1.011	1.002	1.005	Green
France	0.975	1.021	1.000	1.010	Green	Slovak Republic	0.989	1.013	1.002	0.987	Yellow
Germany	0.973	1.021	1.002	1.013	Green	Slovenia	0.984	1.021	1.002	0.988	Yellow
Greece	0.983	1.019	0.998	0.968	Yellow	Spain	0.983	1.018	0.999	0.990	Yellow
Hungary	0.989	1.010	1.001	1.009	Green	Sweden	0.966	1.026	1.001	1.019	Green
Ireland	0.820	1.053	0.985	0.979	Yellow	Ukraine	0.964	1.023	0.999	1.005	Green

Note: *Ged* is the green economic growth, $EfGed$ is efficiency of the government reforms and programmes on achieving the Sustainable Development Goals.

The findings of the Gaussian kernel density function for GDP and EfGed showed that the peak value of GDP in the green group countries had significantly shifted to the right compared with that of the yellow group countries (Figure 1a). In addition, the yellow group frequently demonstrated a lower GDP than the green group countries (Figure 1a). Moreover, the EfGed was frequently higher than one in the countries from the green group as compared with the yellow group (Figure 1b).



(**a**)



(**b**)

Figure 1. Visualisation of empirical findings of the Gaussian kernel density function for GDP (**a**) and EfGed (**b**).

This leads to a conclusion that the green group countries were more stable against external shocks and provided effective policies for achieving green economic growth and sustainable development goals.

The assessment results of the static Model (7) are shown in Table 5. The empirical results of the Hausmann test confirmed the necessity of interpreting the findings for the green groups countries under the fixed effect model. The results allowed rejecting the null hypothesis "H0: the random effect model is suitable" at the 1% statistically significant level. In addition, the Chi2 changed from 12.46 to 21.08 with Prob > Chi2 = 0.000. At the same time, the results of the random effect model were used to explain the findings for the yellow group countries. In this case, the Hausmann test showed that the null hypothesis could be accepted, i.e., "H0: the random effect model is suitable", at the 1% statistically significant level. The value of Chi2 changed from 0.70 to 2.78 with Prob > Chi2 from 0.4033 to 0.2491.

Table 5. The findings of the static model for analysing urbanisation impact on green economic growth in the green and yellow group countries (applied the fixed and random effects model).

Variables	Model (1)		Model (2)		Model (3)		Model (4)	
	FE	RE	FE	RE	FE	RE	FE	RE
	Coef. (*p* Value)	Coef. (*p* Value)	Coef. (*p* Value)	Coef. (*p* Value)	Coef. (*p* Value)	Coef. (*p* Value)	Coef. (*p* Value)	Coef. (*p* Value)
Green Group (the number of observations—224)								
Urban	−0.0035141 (0.000) *	−0.0000958 (0.262)	−0.002384 (0.019) **	0.0000453 (0.654)	−0.0034834 (0.000) *	−0.0000959 (0.263)	−0.0045959 (0.000) *	−0.0000797 (0.375)
InS	–	–	0.0025295 (0.001) *	0.0006744 (0.011) **	–	–	–	–
R&D	–	–	–	–	−0.0058001 (0.163)	0.001557 (0.796)	–	–
TO	–	–	–	–	–	–	0.039867 (0.006) *	−0.001515 (0.556)
const	1.27214 (0.000) *	1.007923 (0.000) *	1.147275 (0.000) *	0.9870137 (0.000) *	1.311395 (0.000) *	1.006815 (0.000) *	1.167167 (0.000) *	1.013847 (0.000) *
Hausman test	chi2(1) = 12.46 Prob > chi2 = 0.000		chi2(2) = 18.80 Prob > chi2 = 0.000		chi2(2) = 14.65 Prob > chi2 = 0.000		chi2(2) = 21.08 Prob > chi2 = 0.000	
Yellow Group (the number of observations—224)								
Urban	−0.0021181 (0.377)	−0.0001307 (0.099) ***	−0.0028261 (0.294)	−0.0000118 (0.069) ***	−0.0026965 (0.262)	−0.0001031 (0.073) ***	−0.0036062 (0.173)	−0.0001169 (0.045) **
InS	–	–	0.0015681 (0.238)	0.0006673 (0.060) ***	–	–	–	–
R&D	–	–	–	–	−0.0058859 (0.494)	0.0020176 (0.015) **	–	–
TO	–	–	–	–	–	–	0.0346183 (0.188)	−0.0033887 (0.552)
const	1.139955 (0.000) *	1.005919 (0.000) *	1.164256 (0.000) *	.9866632 (0.000) *	1.21323 (0.000) *	0.9937163 (0.000) *	1.077469 (0.000) *	1.020929 (0.000) *
Hausman test	chi2 = 0.70 Prob > chi2 = 0.4033		chi2 = 1.45 Prob > chi2 = 0.4837		chi2 = 1.91 Prob > chi2 = 0.3839		chi2 = 2.78 Prob > chi2 = 0.2491	

Note: Urban—urbanisation; InS—industry (including construction), value added (% of GDP); R&D—patent applications; TO—Trade (% of GDP); FE—fixed effect model; RE—random effect model; *, ** and ***—statistically significant at the 1%, 5% and 10% levels.

The regression results (Table 5) for all models and countries' groups prove the statistically significant impact of urbanisation on the green economic growth. However, this impact was negative for both groups of countries. Thus, the growth of urbanisation caused a decline in the green economic growth for all countries from the green and yellow groups. In the case of panel data of the green group countries, the growth of urbanisation by 1% resulted in a decline in the green economic growth by 0.0035141 points (considering Model (1) from Table 5). It should be emphasised that adding the explanatory variables of industrial structures (Model (2) in Table 5), research and development (R&D) (Model (3) in Table 5) and economic openness (Model (4) in Table 5) did not change the direction of the urbanisation impact on the green economic growth. For Model (2), the increase of urbanisation by 1% lead to a decline in the green economic growth by 0.002384 with statistical significance of 5%; for Model (3)—0.0034834 (statistical significance 1%); for Model (4)—0.0045959 (statistical significance at 1%). In addition, industrial structures and economic openness showed a positive statistically significant impact on the green economic growth for the green group countries, confirming the effective implementation of sustainable development goals into the country's economic growth strategy. Similar results were found for the countries from the yellow group. However, further urbanisation lead to a slower decline in the green economic growth. Thus, the growth of urbanisation by 1% caused a decline in green economic growth by 0.0001307 points for Model (l) (statistical significance 10%); 0.0000118 points for Model (2) (statistical significance 10%); 0.0001031 points for Model (3) (statistical significance 10%) and 0.0001169 points for Model (4) (statistical significance 5%). Industrial structures and research and development showed a statistically significant impact on the green economic growth for all panel data of the yellow group countries, with the statistical significance at the 10% and 5% levels.

The findings of the dynamic Model (8) assessment are summarised in Table 6. Its results showed that urbanisation negatively affected the green economic growth for all the countries analysed. The impact was statistically significant at the 1% level for the green group countries and at the 5% level for the yellow group countries. These results are coherent with the findings of other studies [102,103], which justify that urbanisation supports economic growth at a certain level of development, and then the economic growth is restricted.

Table 6. The findings of GMM modelling for the analysis of urbanisation impacts on green economic growth among the analysed green and yellow Group countries (dynamic model).

Variables	Green Group		Yellow Group	
	Coef.	*p* Value	Coef.	*p* Value
Ge_{t-1}	−0.102	0.137	−0.022	0.780
Urban	−0.006	0.003	−0.006	0.040
InS	0.004	0.006	0.007	0.060
R&D	0.0017	0.019	0.0026	0.025
TO	0.0076	0.000	−0.0054	0.196
Arellano–Bond test for AR(1)	z = −1.81 Pr > z = 0.071		z = −5.46 Pr > z = 0.000	
Arellano–Bond test for AR(2)	z = −1.42 Pr > z = 0.154		z = −2.21 Pr > z = 0.027	
Sargon test	chi2 = 334.39 Prob > chi2 = 0.000		chi2 = 177.04 Prob > chi2 = 0.000	
Hansen test	chi2 = 26.93 Prob > chi2 = 1.000		chi2 = 8.41 Prob > chi2 = 0.178	

Note: Ged_{t-1}—green economic growth in t − 1-time; Urban—urbanisation; InS—industry (including construction), value added (% of GDP); R&D—patent applications; TO—Trade (% of GDP); FE—fixed effect model; RE—random effect model.

The regression coefficient for control variables in the dynamic Model (8) was similar for the panel data of the countries from green and yellow groups by directions and statistical significance. The industrial structure and research and development positively and statistically significantly influenced the green economic growth in both models (for the green group countries at the 5% level, for the yellow group countries at 10%). This confirmed that countries should focus on implementing structural reforms for the technological modernisation of infrastructure and industrial complexes to eliminate the shortcomings caused by urbanisation. Primarily, it requires the development of innovation points for growth (technology parks, start-up centres, technology transfer centres, etc.).

5. Discussion & Conclusions

The empirical results showed that, compared to 2005, in 2020, the green economic growth lost momentum in all the countries analysed. First, this could have been caused by the reorientation of all resources to overcome the consequences of COVID-19 (which started at the end of 2019). Compared to 2005, in 2020, the most significant restrain in the green economic growth was in the following countries: Bulgaria, Croatia and Cyprus. In 2020, Sweden, Belgium and Germany had the highest average value of green economic growth, providing an example for Ukraine to follow and implement the experience of the leading countries (Sweden, Belgium and Germany) to stimulate its green economic growth.

The findings of this research confirmed the hypothesis that urbanisation shows negative statistically significant impact on the green economic growth, which further supports the conclusions made by the previous studies [71,102]. Considering that SDGs aim to achieve green growth, to reduce the environmental degradation and social and income inequalities among countries, prior studies [103–108] confirmed that urbanisation allowed improving well-being, redressing income inequalities and enhancing the quality of life. Nevertheless, urbanisation was found to lead to environmental degradation, non-efficacy in using land resources and changes of landscape and land system, which consequently hinder the achievement of SGDs.

Furthermore, the results showed that industrial structure and R&D promoted green economic growth for all countries, and openness of the economy only for the green group countries. In particular, the growth of industrial structure by 1% encouraged the green economic growth on average by 0.003 points for the green group and 0.0035 for the yellow group. Advancing the economy openness lead to enhancing the green economic growth on average by 0.0076 points for the green group and R&D—on average by 0.0017 points for the green group and 0.0021 for the yellow group.

The findings of this research prompted the following policy implications:

1. Neglecting the impact of urbanisation on the green economic growth could complicate the achievement of the goals of a carbon-free economy. The government should frame relevant policies to compensate for the environmental degradation caused by urbanisation.
2. Developing a green educational network that allows for dissemination of the green knowledge and technologies among all members due to sharing the best practices, as it is necessary to increase green consciousness and awareness among the urban population. Thus, the yellow group countries should analyse and implement the experience of the green group countries. Green knowledge and technologies should be shared among all sectors and levels (from local to national). This contributes to modernising the industrial and energy sectors, which are the core forces in reorientating towards carbon-free economy.
3. Urbanisation could result in deep structural disbalances and gaps (in energy intensity, inefficient investment structure, declining new buildings, etc.). In this case, it is necessary to launch a green project to eliminate the abovementioned issues. Furthermore, this requires providing information on assessable financial resources and investment options for green projects that boost renewable energy and green technologies in the country. In addition, it is necessary to pursue policies that enhance the transparency and accountability of green project implementation and its impact throughout life.
4. The government should reinforce the incentive instruments (green taxes, feed-in tariffs, green penalties, etc.) to implement the concept of smart and green cities, which allows for the green economic growth of a country concurrently eliminating the issues caused by accelerated urbanisation.
5. Additionally, achievement of green growth could produce the synergy effect of balancing economic and ecological targets underlying the SDGs. However, it requires relevant transparency and accountability of effects within SDGs achievement.

Despite the actual findings, the study had several limitations. In this research, CO2 and non-CO2 emissions were taken into account while assessing green economic growth. However, it is necessary to extend indicators that influence the green economic growth for them to include waste, water pollution, soil degradation, etc. The lack of data limits the unit assessment of the green economic growth at a city level. Further research should focus on a city level as the finer level of spatial units. In addition, it is necessary to extend the number of countries for analysis and compare developed and developing countries. As the green economic growth cannot be realised without the effective governance of the country (corruption, voice and accountability, transparency, etc.), it is necessary to consider the impact of the government quality on the green economic growth. In addition, the green economic growth requires relevant environmental regulation, which should also be included in further research.

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