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Araştırma Makalesi / Research Article

Does Human Capital Support Green Economic Growth? A Panel Data Analysis For The Nordic Countries

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Abstract

This study examines the impact of human capital on green economic growth in Nordic countries (Denmark, Iceland, Finland, Sweden, and Norway) from 2010 to 2022 using the panel data method, considering different education levels. The effect of human capital is low but complex. Country-specific findings indicate that primary and secondary education positively influence green growth in Sweden, while only primary education has a positive impact in Finland and Norway. Conversely, primary and secondary education in Denmark and secondary education in Iceland and Norway negatively affect green growth. Panel results reveal that only higher education has a significant negative impact. Internet usage, included as a control variable, generally has a positive effect. The impact of renewable energy varies; it is positive in Denmark and Finland but negative in other countries and at the panel level. Financial development is found to have a negative impact across all groups.This study contributes to the literature by analyzing the relatively underexplored role of human capital in green economic growth within Nordic countries, which are globally recognized for their strong education systems.

Keywords: *Human Capital, Green Economic Growth, Technological Development, Nordic Countries*

Beşeri Sermaye Yeşil Ekonomik Büyümeyi Destekliyor Mu? Nordic Ülkeleri İçin Bir Panel Veri Analizi

Öz

Çalışmanın amacı, farklı eğitim düzeylerini dikkate alarak beşeri sermayenin yeşil ekonomik büyüme üzerindeki etkisini Nordic ülkelerinde (Danimarka, İzlanda, Finlandiya, İsveç ve Norveç) 2010-2022 dönemi için panel veri yöntemiyle analiz etmektir. Beşeri sermayenin yeşil ekonomik büyüme üzerindeki etkisi düşük olmakla birlikte karmaşıktır. Ülke bazlı sonuçlara göre: İsveç'te ilköğretim ve ortaöğretim düzeyleri, Finlandiya ve Norveç'te ise yalnızca ilköğretim düzeyi yeşil ekonomik büyümeyi pozitif etkilerken; Danimarka'da ilköğretim ve ortaöğretim düzeyleri, İzlanda ve Norveç'te ise ortaöğretim düzeyi yeşil ekonomik büyümeyi negatif etkilemektedir. Panel sonuçlarına göre ise yalnızca yükseköğretim düzeyi anlamlı ve negatif bir etkiye sahiptir. Kontrol değişkenler olarak kullanılan, internet kullanımının genel olarak pozitif bir etkisi olduğu görülmektedir. Yenilenebilir enerjinin etkisi ise karmaşıktır; Danimarka ve Finlandiya'da pozitifken, diğer ülkelerde ve panel genelinde negatif etkiye sahiptir. Son olarak, tüm gruplarda finansal gelişmenin yeşil ekonomik büyüme üzerinde negatif bir etkisi olduğu tespit edilmiştir. Bu çalışmanın, yüksek eğitim düzeyleriyle dünya çapında tanınan ancak bu özel bağlamda nispeten az araştırılmış olan İskandinav ülkelerinde, beşeri sermayenin yeşil ekonomik büyüme üzerindeki etkisini inceleyerek literatüre katkı sağlaması beklenmektedir.

Anahtar Kelimeler*: Beşeri Sermaye, Yeşil Ekonomik Büyüme, Teknolojik Gelişme, Nordic Ülkeleri.*

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INTRODUCTION

Energy specialists, environmental activists, and legislators have consistently urged for joint endeavors to decrease the rapidly rising levels of emissions observed in recent decades. The United Nations (UN) and its affiliated organizations are collaborating to provide guidance to world leaders on strategies to restrict global temperature increase to 1.5°C. Notwithstanding these endeavors, less action has been taken to safeguard our environment. The Organization for Economic Cooperation and Development (OECD) has reported that the issue of economic progress and environmental deterioration continues to exist (Khan et al., 2023). Furthermore, climate change-induced environmental degradation incurs significant societal costs, including diminished agricultural output, heightened food insecurity, and adverse impacts on human health, all of which severely undermine social welfare. As a result of these environmental and socio-economic concerns, governments around the world are endeavoring to develop sustainable regulations to regulate global CO2 emissions (Jahanger et al., 2023).

The attainment of the Sustainable Development Goals (SDGs) is a worldwide imperative (Zhu, 2023) and is the focal point of policy discussions aimed at mitigating environmental deterioration, which is regarded as a significant obstacle in the modern era (Saud et al., 2024). Climate control is a significant objective of the SDGs and is crucial for implementing environmental sustainability measures, in conjunction with other SDGs (Dai et al., 2023). Thus, it is imperative to seek sustainable alternatives that can guarantee long-lasting economic development while upholding environmental conservation regulations. Within this particular framework, a novel notion known as green growth (GG) has surfaced (Khan et al., 2023). The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) introduced the idea of GG in 2005. GG promotes poverty reduction and enhances human well-being by prioritizing transformative measures such as economic growth, optimizing consumption patterns, enhancing the ecological efficiency of economic growth, and aligning environmental and economic development to achieve sustainable development goals (Liu et al., 2022). GG is widely recognized as a crucial factor in promoting environmental sustainability in policy and economic discussions (Liu et al., 2023).

Green and sustainable development plays a vital role in addressing environmental concerns and advancing a more sustainable future. The core focus of this endeavor is the allocation of resources towards human capital (HC), which entails fostering the growth and empowerment of individuals via the acquisition of information, skills, and a mindset that enables them to actively participate in and guide sustainable development initiatives (Beisembina et al., 2023). The growth of HC, which encompasses education, health, and research and development (Mankiw et. al., 1992) is a crucial determinant of both economic and environmental well-being indices (Jahanger et al., 2023). Enhancing HC can lead to improved energy efficiency and reduced energy consumption in the industrial process, hence mitigating environmental impacts. Thus, it is possible to regulate carbon dioxide emissions associated with energy use. Furthermore, it is widely considered that investing in HC development can effectively decrease CO2 emissions by enhancing energy efficiency. Multiple studies have verified that improved education and training contribute to the accumulation of HC, which can effectively mitigate greenhouse gas emissions and address global warming (Jahanger et al., 2023). Therefore, education exerts a substantial influence on the green economy (Zhang & Li, 2023). A recent study by Ganda (2022) has provided further evidence supporting the notion that HC has a beneficial effect on the reduction of carbon emissions in the BRICS economies between 1990 and 2017. This emphasized the significance of ongoing environmental education in order to foster comprehension of zero emissions policies and advance sustainable environmental welfare. Additional investigation has uncovered that South Asia, when provided with sophisticated information and education, demonstrates a greater inclination to embrace green technology and encourage the sustainable utilization of natural resources (Sarkodie et al., 2020). A study conducted by Krueger et al. (2023) has confirmed that green motivation, which refers to individuals valuing the environmentally friendly aspects of their job, is widespread. The study, which involved surveying 300 participants from various OECD countries, found that this motivation is particularly common among highly skilled individuals. Furthermore, the study revealed that individuals are willing to accept lower wages in order to work for companies that prioritize environmental sustainability.

Although green economic transformation offers numerous advantages and is essential, it also presents certain problems. The primary obstacle is the insufficient amount of funds necessary to support environmentally friendly initiatives. Financiers in the economic sector are hesitant to invest in green initiatives due to the fact that these projects typically yield delayed returns and generate low future earnings. The insufficient funding for the development of green projects is a pressing issue, particularly for governments in developing nations, who require additional financial resources to support their eco-friendly initiatives and other financial endeavors (Tufail et al., 2024).

With the growing public concern for environmental issues, researchers are conducting numerous studies to elucidate the causes of environmental deterioration and tackle socio-economic problems associated with the environment (Rehman et al., 2023). Nevertheless, the findings in the current body of research regarding the correlation between HC and GG are inconclusive. Many scholars argue that there is a direct correlation between HC and GG, and propose two distinct sorts of conclusions: There are two perspectives regarding the relationship between HC and GG (or CO2 emissions). The first perspective, known as the "incentive perspective", suggests that HC promotes GG (or reduces CO2 emissions) according to studies by Ahmed et al. (2020) and Huang et al. (2021). The second perspective, known as the "hindrance perspective", argues that HC hinders GG (or increases CO2 emissions) based on research by Bayar et al. (2021) and Sarkodie et al. (2020). The existing literature suggests that the connection between HC and GG is uncertain and can alter depending on factors such as time periods, industries, macroeconomic variables, and the degree of HC regime in different locations (Çakar et al., 2021; Haini, 2021). Multiple studies provide evidence of a potential nonlinear correlation between HC and GG (Yao et al., 2020). Hence, it is evident that there is a need to elucidate the connection between HC and GG, and further research is needed. It is crucial to take into account the Nordic economies, which hold the top position in terms of HC. The premise is that enhancing the HC of nations will enable them to effectively foster GG. Previous studies have overlooked the connection between HC and GG, particularly in the Nordic nations, which are known for their high level of HC. Furthermore, it is crucial to take into account all levels of education and assess their influence on sustainable economic growth. This study examines all stages of education, including basic school, secondary education, and higher education, for the following reasons: Hence, the objective of this study is to investigate the impact of HC on the advancement of GG in Nordic countries, while considering the influence of education at all levels. This work is anticipated to enhance the existing body of knowledge on GG in the following manners. Currently, there is a lack of research exploring the impact of HC on GG in these nations, based on our current understanding. This study gathered the most recent data and examined the influence of HC on GG in Nordic economies. Furthermore, I utilized three proxy variables—basic education, secondary education, and higher education—to assess HC. Additionally, previous studies have employed alternative metrics, such as CO_2 emissions and the ecological footprint, to measure GG. While these metrics do offer insights into environmental quality, they do not comprehensively capture the concept of GG. Hence, this study used the GG indicators formulated by the Global Green Growth Institute (GGGI). In addition, this study incorporated crucial control variables such as FD, internet usage rate, REC, as well as HC, to carry out a more thorough examination of their influence on GG. The selection of these variables is predicated on the elevated levels of literacy in the Nordic nations, the advanced state of the financial system, and the pursuit of increased internet usage.

The study is structured as follows: the next section provides an overview of the theoretical framework and a review of relevant literature. The subsequent section describes the research methodology. Lastly, the final section presents the findings and conclusions.

1. EXPLORING THE RELATIONSHIP BETWEEN HUMAN CAPITAL AND GREEN GROWTH: A LITERATURE REVIEW

HC development is fundamental for achieving both economic and environmental sustainability. Historically, the growth function has been associated with HC, which includes education, skills, knowledge, work, and experience. The initial discovery of this historical correlation was made by Adam Smith and David Ricardo in their traditional theories of economic growth. Later, in 1956, Solow and Swan further developed the concept by incorporating technology into the growth model. A decade after the creation of the Solow and Swan model, Nelson and Phelps highlighted the significance of education and the process of learning in the advancement of human resources. In his 1988 study, Lucas underlined that HC is a vital component of economic progress. In addition, Mankiw et al. (1992) enhanced the Solow model by include HC in addition to physical capital (Khan et al., 2023).

HC encompasses the intellectual, technical, and physical proficiencies possessed by the workforce (Liu et al., 2022). Education and health are the primary aspects that make up HC (Zhang & Li, 2023). Schultz, the renowned proponent of HC theory, contends that HC serves as the primary catalyst for economic progress. Simultaneously, HC plays a crucial role in enhancing the value of the economy's green transition. From the standpoint of the production sector, there is a strong correlation between HC and productivity. When the degree of HC development is insufficient and workers possess limited education and professional abilities, the sector will employ a significant proportion of low-skilled workers while having a scarcity of high-skilled individuals. Given these circumstances, the incremental rate at which skills contribute to production is minimal, and enhancing output mostly relies on substantial investments in physical capital, resulting in "excessive energy consumption and elevated pollution emissions," which obstructs the development of a sustainable economy. As the accumulation of HC progresses and reaches a more advanced stage, the composition of skills in the workforce changes. There is a large increase in the share of highly skilled workers, and the interdependence between capital and skills starts to intensify. Therefore, it facilitates the advancement of a sustainable economy. Furthermore, when considering consumption, the amount of HC is intricately linked to the consumption pattern. The stage of HC development at a low level correlates to a relatively low level of consumer income. Given these circumstances, as individuals acquire more knowledge and skills, they frequently focus on purchasing consumer goods that fulfill essential "material needs", such as household appliances, automobiles, and other significant items. If consumer demand continues to rise, it will lead to an increase in CO2, which would impede GG (Liu et al., 2022). While building HC is generally beneficial in lowering CO2 emissions, it can potentially lead to increased emission levels due to the stimulation of economic growth (Jahanger et al., 2023).

Once HC development beyond a specific threshold, the consumption pattern will undergo a significant transformation, known as a "qualitative leap," once fundamental "material needs" are adequately satisfied. This means that "intangible consumer goods" associated with entertainment and health will assume a prominent role (Liu et al., 2022). However, the development of HC is likely to promote technological advancements that can enhance the efficient utilization of energy, hence reducing CO2 emissions linked to energy consumption. Similarly, households with higher levels of education are said to have a greater inclination to invest in contemporary cooking fuels, which are comparatively less polluting than conventional cooking fuels. Furthermore, it is well acknowledged that the development of HC fosters an increased awareness of environmental welfare among individuals, hence motivating them to transition to clean energy sources in order to mitigate CO2 emissions (Jahanger et al., 2023). Therefore, a significant amount of human resources with strong environmental consciousness will lead to an elevated demand for eco-friendly, sustainable, and low-emission consumer products, thereby promoting green economic development. Furthermore, enhancing the consumption structure will compel the manufacturing sector to enhance and refine items. This will facilitate the production of items that are more ecologically sustainable. Thus, at this juncture, HC will effectively bolster the advancement of the green economy (Liu et al., 2022). Ultimately, there is a prevailing belief that a nation with a higher proportion of well-educated individuals possesses the ability to assert its influence and advocate for improved environmental standards from the governing authorities (Jahanger et al., 2023).

In recent times, certain academics have examined the correlation between HC and the green economy, although their findings have been incongruous. The results encompass the concepts of "incentive perspective", "inhibition perspective", and "non-linear relationship". The incentive viewpoint posits that the accumulation of HC contributes to the advancement of GG, hence mitigating CO2 emissions (Ahmed et al., 2020; Huang et al., 2021). The inhibition approach posits that HC acts as a hindrance to GG, resulting in increased CO2 emissions (Bayar et al., 2021; Sarkodie et al., 2020). The existing literature posits that the connection between HC and GG is uncertain, and it varies depending on factors such as time periods, industries, macroeconomic variables, and the level of HC regime in different locations (Çakar et al., 2021; Haini, 2021). Multiple studies provide evidence of a potential non-linear correlation between HC and GG (Yao et al., 2020). Nevertheless, these research employed other metrics, such as CO2 emissions and ecological footprint, to measure GG. Only a limited number of research have employed GG indicators, and these studies are predominantly theoretical, relying on survey data or on GG indicators themselves. Bowen (2012) conducted a theoretical analysis to investigate the impact of the shift towards GG on labor markets. It emphasizes the importance of addressing possible shortages of skills and obstacles to labor mobility in order to facilitate this shift. He asserts that these barriers also impede other forms of economic adaptation, such as the opening up of commerce. Angheluță (2015) argues that green economic transformation is crucial for developing new industries. The study provides a comparative analysis of data and assesses the employment rate of older workers in relation to their HC. Empirical studies were conducted across various entities, including firms, cities, countries, and country groups. Crifo (2024) investigates the reasons behind the increased inequality in abilities, both inside and between individuals, resulting from a growth process that combines green innovation and green HC in firm-based research. The study presents a theoretical framework and draws empirical insights based on data collected from over 2000 enterprises in 21 OECD nations in 2022. Liu et al. (2022) analyze the correlation between HC and green economic growth in 281 Chinese cities from 2011 to 2019. They employ a data envelopment analysis model based on a non-radial directional distance function to measure green economic growth performance. Empirical evidence reveals a curvilinear relationship between China's HC and green economic growth, with green innovation and industrial upgrading acting as mediators in this causal link. The study conducted by Ren et al. (2022) examine the impact of digital economy concentration on inclusive GG in 282 Chinese cities from 2004 to 2019. Their findings indicate that digital economy concentration positively affects inclusive GG. The transmission mechanism analysis shows that it influences factors such as energy use, environmental pollution, economic growth, HC, industrial structure, and technological advancement.

Liu et al. (2023) examine the impact of HC on environmentally sustainable economic growth in China from 1991 to 2019 using the ARDL technique. Their findings show that education positively influences China's sustainable economic growth over time. Additionally, renewable energy use, internet access, and financial system development support the long-term growth of environmentally sustainable economic growth. Tufail et al. (2024) conducted a study on a set of countries and examined the use of green financing as a policy tool to promote GG. They specifically focused on 19 selected OECD economies from 1990 to 2021, using the Moment quantile regression approach. Their research demonstrates that the utilization of green finance and the development of HC contribute to the acceleration of GG. Ngo et al. (2022) examine the impact of HC, education expenditures, and financial development (FD) on GG across 36 nations. The study uncovers a reciprocal relationship between the advancement of financial systems and the promotion of environmentally sustainable economic growth. Furthermore, it uncovers the significant importance of HC and education expenditures in the connection between FD and sustainable economic growth. The study conducted by Wang et al. (2023) examine the role of renewable energy consumption (REC), environmental policies, human development, and R&D expenditure in influencing the environmentally sustainable growth of BRICS economies from 1990 to 2019. Their findings show that these factors significantly impact GG, particularly in the upper tertiles. Ecological governance mitigates the positive effects of renewable energy, suggesting that strict environmental policies encourage a shift toward sustainable energy and eco-friendly economic growth. The study conducted by Şentürk (2024) examines the relationship between the development of HC and the promotion of environmentally sustainable economic growth in the BRICS countries from 1990 to 2020. This analysis is carried out using panel causality analysis. The results indicate a reciprocal causal link between the variables. The significance of human development in achieving GG and sustainable development has been established.

The literature analysis appears to lack research specifically investigating the impact of human capital on green economic growth in the Nordic economies, even though these economies are characterized by a high level of human capital. Due to their abundant HC, strong economic capacity, and unwavering dedication to sustainability, the Nordic countries possess the ability to greatly contribute to the promotion of GG. Consequently, they may serve as a noteworthy model for the international community. Furthermore, by examining the findings about the incentive and obstacle perspectives on the correlation between HC and GG, it becomes evident that there is a need for greater elucidation of the relationship between the two. Therefore, it is anticipated that this will promote the advancement of economies that have not yet recognized the significance of HC and GG, thereby facilitating the development of these indicators.

2. DATA AND METHOD

2.1. Data

The urgent need to address environmental challenges and promote sustainable development has gained international awareness in recent years. Concurrently, the concept of "GG" has gained prominence in reaction to the escalating problems brought forth by climate change and the unsustainable use of natural resources. GG is an economic development model that aims to produce wealth while minimizing harm to ecosystems. This article seeks to examine the influence of HC on GG in 5 Nordic economies from 2010 to 2022. The study will also consider the internet usage rate, FD, and REC as control variables, based on the theoretical framework and existing literature. Table 1 provides a thorough examination of the variables, including their representations, measurements, and pertinent data sources.

Table 1: Summary of Variables

Abbreviations	Variables	Description	Source
GG	Green growth	Index	Global Green Growth Instituve
Net	Internet use	Individuals using the Internet (% of population)	World Bank (WB)
FD	Financial development	Index	International Monetary Fund (IMF)
REC	Renewable energy consumption	Renewable energy consumption (% of total final energy consumption)	Our World in Data
Pri	Human capital	Primary school enrollment, (% gross)	WB
Sec		Secondary school enrollment, (% gross)	WB
Ter		Tertiary school enrollment, (% gross)	WB

Panel data is widely acknowledged as a more flexible and comprehensive approach for studying issues and their constituents. The study resulted in the creation of four models. Model I focuses on primary education, Model II focuses on secondary education, Model III focuses on higher education, and Model IV considers all education levels collectively.

Model I: $\ln GG = \alpha_{0it} + \alpha_{1it}\,Pri + \alpha_{2it}\ln FD + \alpha_{3it}\mathrm{Net} + \alpha_{4it}\mathrm{REC} + \varepsilon_{it}$

Model II: $\ln GG = \beta_{0it} + \beta_{1it}\,Sec + \beta_{2it}\ln FD + \beta_{3it}\mathrm{Net} + \beta_{4it}\mathrm{REC} + \varepsilon_{it}$

Model III: $\ln GG = \varphi_{0it} + \varphi_{1it}\,Ter + \varphi_{2it}\ln FD + \varphi_{3it}\mathrm{Net} + \varphi_{4it}\mathrm{REC} + \varepsilon_{it}$

Model IV: $\ln GG = \theta_{0it} + \theta_{1it}\,Pri + \theta_{2it}\mathrm{Sec} + \theta_{3it}\mathrm{Ter} + \theta_{4it}\ln FD + \theta_{5it}\mathrm{Net} + \theta_{6it}\mathrm{REC} + \varepsilon_{it}$

i=1,2,3,……N represent cross section units whereas t=1,2,3,……T represent the time variable and Ɛ is used for the panel error. α, β, φ and θ are the coefficients.

In order to thoroughly examine the panel data, this study does a comprehensive statistical analysis of the chosen components. The mean, median, range, lowest, and highest values—basic statistical indicators that provide important context for the dataset—are included in this study. In addition, the standard deviation is calculated to evaluate the degree of variation from the mean, indicating the temporal variability of the data.

Table 2: Summary Statistics

Countries	Variables	Obs	Mean	S. D	Min	Max
Panel	GG	65	66.15	9.538	42.13	74.3
	Net	64	94.19	3.733	86.42	99.68
	REC	65	.5080	.2254	.1611	.8761
	FD	60	.6541	.0897	.4821	.7959
	Pri	60	102.6	7.483	97.78	123.7
	Sec	60	125.4	14.03	102.1	153.6
	Ter	60	80.43	8.57	64.95	100.8
DNK	GG	13	73.24	.6000	72.4	73.9
	Net	13	95.41	3.200	88.72	98.86
	REC	13	.2966	.0825	.1611	.4304
	FD	13	.6803	.0222	.6515	.7252
	Pri	12	100.8	.4156	100.1	101.5
	Sec	12	128.8	4.585	118.9	133.7
	Ter	12	80.34	3.342	72.49	83.98
FIN	GG	13	69.74	.6086	68.61	70.65
	Net	13	89.35	2.373	86.42	92.98
	REC	13	.2790	.0550	.1970	.3849
	FD	12	.6322	.0131	.6042	.6524
	Pri	12	99.62	.1366	99.33	99.81
	Sec	12	138.5	18.04	108.6	153.6
	Ter	12	92.77	3.310	89.32	100.8

ISL	GG	13	48.61	5.131	42.13	53.08
	Net	12	97.62	1.993	93.39	99.68
	REC	13	.8267	.0277	.7827	.8761
	FD	12	.5129	.0263	.4821	.5698
	Pri	12	98.77	.1203	98.55	98.95
	Sec	12	114.9	4.338	108.8	122.0
	Ter	12	76.62	4.902	69.34	86.52
NOR	GG	13	65.82	.2683	65.29	66.22
	Net	13	96.18	1.873	93.39	99
	REC	13	.6946	.0200	.6573	.7229
	FD	12	.6647	.0342	.6235	.7304
	Pri	12	99.33	.2795	98.88	99.69
	Sec	12	116.0	2.825	112.1	119.9
	Ter	12	80.51	7.097	71.06	93.92
SWE	GG	13	73.32	.7403	72.29	74.3
	Net	13	92.65	2.108	89.24	95.00
	REC	13	.4432	.0501	.3856	.5331
	FD	12	.7802	.0128	.7601	.7959
	Pri	12	114.8	9.832	97.78	123.7
	Sec	12	128.6	16.01	102.1	142.6
	Ter	12	71.93	6.059	64.95	85.94

When the indicators of the countries are evaluated in general, the countries with the highest GG indicators are Sweden (74.3) and Denmark (73.9), and the countries with the lowest values are Iceland (53) and Norway (66.2). In HC indicators, the highest in primary education are Sweden (123.7) and Denmark (101.5), in secondary education the highest are Finland (153.7) and Sweden (142.6), in higher education Finland (100.8) and Norway (93.9). The country with the lowest value is Iceland (98.9) in primary education, Norway (119.9) in secondary education and Denmark (83.9) in higher education.

2.2. Method

2.2.1. Panel Data

The main emphasis of this work is on the analysis of panel data, which necessitates the utilization of econometric procedures that are appropriate for panel data. An initial concern arises from the presence of strong correlations among independent variables, which leads to the problem of multicollinearity. When multicollinearity occurs, it leads to issues such as biased estimate of regression coefficients, an increase in the variance and standard error of the coefficients, and a decrease in statistical power. Prior to estimating the model, it is necessary to test for the presence of multicollinearity among the independent variables (Gujarati, 2011). The

Variance Inflation Factor (VIF) test was employed to address this issue. This test assesses the extent to which inflated coefficients of standard errors in the regression model contribute to bias in p values. The maximum acceptable VIF is four times the square of the standard errors (Arvas et al., 2023).

Table 3: Multicollinearity Test (Dependent Variable: lnGG)

Variables	VIF	1/VIF
REC	3.19	0.313034
Pri	2.69	0.37171
lnFD	2.66	0.3762
Sec	2.31	0.4330
Ter	2.01	0.4973
Net	1.85	0.5406
Mean VIF	2.45	

The VIF test results indicate that there is no multicollinearity, as evidenced by the average VIF of 2.45 and the individual VIFs of the independent variables, which are presented in Table 3. All variables have VIF values that are less than 5. This indicates that the issue of multicollinearity has been resolved in the model. In order to assess the impact of HC on green economic growth, it is necessary to choose the most suitable estimation model among the Fixed Effects Model (FE), Random Effects Model (RE), and the classical model (Pooled). For this choice, the F-test, Breusch-Pagan LM test, and Hausman test (H-Test) were conducted. The analysis findings may be found in Table 4.

Table 4: Results of F test, LM, and Hausman Tests

Tests	Type	Statistics		Effective Estimator
F-Test	Pooled	F-sta.	25.29	FE
	FE	Prob	0.00	
LM Test	Pooled	χ^2 sta.	0.00	Pooled
	RE	Prob> χ^2	1.00	
H-Test	FE	χ^2 sta.	471.96	FE
	RE	Prob	0.00	

To determine the effective estimator, a series of tests are conducted. Firstly, an F-Test is performed to assess the effectiveness of the FE and Pooled estimators. Next, an LM Test is conducted to evaluate the reliability of the RE and Pooled estimators. Finally, a Hausman test is carried out to compare the FE and RE estimators. The findings indicated that the most efficient estimator was the FE model.

The purpose is to acknowledge the presence of cross-sectional dependence (CD) in panel data. While the economies being examined may have certain commonalities, these similarities can result in inaccurate conclusions in econometric research, particularly when using panel estimates. Various elements contribute to a country's high level of interconnectedness with the global economic market in the present period of globalization. Therefore, altering a single characteristic in a specific area can have an impact on another region or country. Failure to account for CD can result in imprecise or distorted findings (Tufail et al., 2024). Prior to conducting a comprehensive assessment, it is necessary to test the model for autocorrelation, heteroscedasticity, and CD. The Modified Wald test is conducted to detect heteroscedasticity, the Durbin-Watson and Baltagi-WU LB tests are conducted to investigate autocorrelation, and the Pesaran tests are conducted to discover potential CD. Table 5 contains the information on these exams.

Table 5: Heteroscedasticity, Autocorrelation, and CD Test Results

		Model I		Model II		Model III		Model IV	
	Tests	Test Statistics	Result	Test Statistics	Result	Test Statistics	Result	Test Statistics	Result
HC	MWald	367.23	✓	538.32	✓	437.32	✓	498.14	✓
		0.000		0.000		0.000		0.000	
AC	D-W and Baltagi-Wu LBI	.6887	✓	.71683	✓	.8932	✓	.9144	✓
		.9021		.92629		1.187		1.2098	
CD	Pesaran	0.267	X	0.708	X	1.269	X	1.716	X
		0.7894		0.479		0.2044		0.0862	

Note: AC, Autocorrelation; HC, Heteroscedasticity; ✓, Available; X, None

It was determined that the effective estimator was FE. Subsequently, it is imperative to assess heteroscedasticity, autocorrelation, and CD issues for all models. All tests conducted on this show the frequency of these diseases, with the exception of CD. According to Hoechle (2007), when considering these findings, it is recommended to adjust standard errors using robust standard errors, while keeping the estimators same. Several robust estimators have been constructed to accurately predict the prevalence of the above conditions, and one of these estimators is the Driscoll-Kraay estimator. This estimator is applicable for the aforementioned problems. Furthermore, it has been demonstrated that it yields robust outcomes in situations when N<T and N>T, as evidenced by the research conducted by Driscoll and Kraay in 1998. Aside from the presence of CD in panel data, it is imperative to take into account the existence of slope heterogeneity. Furthermore, country-specific outcomes are crucial for conducting individual assessments of nations. To assess if the slope coefficients are homogenous or heterogeneous, a homogeneity test must be conducted. This test will help determine whether panel or group-based results should be considered. The homogeneity test devised by Pesaran and Yamagata (2008) was utilized for this purpose.

Table 6: Homojenity Test Results

Pesaran and Yamagata (2008)	t-statistics	p-value
Δ	1.442	0.149
Δ adj	2.497	0.013

Homogeneity test results are complex. Put simply, the delta test data suggests that it is uniform, whereas the delta adj data suggests that it is diverse. In the current investigation, the Driscoll-Kraay estimator was used to produce both country-based and panel-based results due to the intricate nature of the outcomes. The estimation results are shown in Table 7.

Table 7: Estimation Results

Dependent Variable (GG)		Net	REC[2]	lnFD[3]	Pri	Sec	Ter	C	R^2 Wit.	Prob
DNK	Model I	.0003** (.0001)	.014** (.006)	-.083** (.021)	-.003*** (.0004)			2.10*** (.043)	.934	0.000
	Model II	.0006* (.0003)	.025*** (.004)	-.052 (.034)		-.0003 (.0002)		1.83*** (.007)	.891	0.000
	Model III	.0004 (.0004)	.033** (.008)	-.070* (.033)			-.0004 (.0005)	1.83*** (.066)	.884	0.000
	Model IV	.0004** (.0002)	-.012 (.013)	-.037* (.018)	-.003** (.0007)	-.0008** (.0002)	.0014** (.005)	2.14*** (.066)	956	0.000
FIN	Model I	.0007*** (.0001)	.051*** (.007)	-.002 (.025)	.004** (.0019)			1.31*** (.205)	.922	0.000
	Model II	.0008*** (.0001)	.047*** (.006)	-.008 (.026)		-.0001 (.0002)		1.75*** (.019)	.906	0.000
	Model III	.0010** (.0003)	.048*** (.007)	-.048 (.058)			-.0002 (.0002)	1.74*** (.019)	.914	0.000
	Model IV	.0010** (.0004)	.066*** (.013)	-.035 (.076)	.003 (.004)	-.0003 (.0002)	.0003 (.0004)	1.51*** (.066)	937	0.000
ISL	Model I	.0149** (.0064)	-.682 (.531)	-.338 (.345)	-.115 (.154)			12.00 (16.03)	.716	0.000
	Model II	.0215** (.0051)	-.345 (.223)	-.045 (.506)		-.0036** (.0016)		.247 (.349)	.788	0.000
	Model III	.0155** (.0048)	.151 (.380)	-.239 (.370)			-.0032 (.0039)	0.216 (.480)	.738	0.000
	Model IV	.0194** (.0007)	-.627 (.515)	-.0291 (.664)	-.094 (.148)	-.0034* (.0017)	-.0003 (.0032)	9.97 (15.32)	.799	0.003

NOR	Model I	-.0003 (.0001)	.002 (.025)	-.001 (.026)	.004** (.001)			1.49*** (.104)	.535	0.004
	Model II	-.0003 (.0002)	.011 (.028)	-.012 (.028)		-.0003** (.0001)		1.89*** (.031)	.559	0.0183
	Model III	-.0002 (.0002)	.006 (.029)	-.009 (.031)			-.0001 (.0008)	1.85*** (0.028)	.506	0.1862
	Model IV	-.0005 (.0003)	-.029 (.037)	-.016 (.029)	-.002 (.011)	-.0007 (.0007)	.0001 (.0003)	2.13 (1.19)	.581	0.003
SWE	Model I	-.0007 (.0005)	-.015 (.035)	-.183 (.166)	.0003** (.001)			1.87 (.050)	.787	0.000
	Model II	-.0007 (.0005)	.022 (.036)	-.186 (.163)		.0002** (.0006)		1.89*** (.048)	.788	0.000
	Model III	-.0004 (.0004)	.002 (.049)	-.747** (.213)			-.0005*** (.0001)	1.87*** (.044)	.712	0.000
	Model IV	-.0006 (.0006)	-.017 (.034)	-.381 (.238)	-.0002 (.001)	.0002 (.0004)	-.0002 (.002)	1.89*** (.089)	.808	0.000
Panel	Model I	.0037** (.0014)	-.141** (.063)	-.389** (.243)	.0004 (.0002)			1.41*** (.084)	.246	0.000
	Model II	.0036** (.0014)	-.155 (.087)	-.406 (.231)		.0002 (.0002)		1.44*** (.089)	.248	0.003
	Model III	.0041** (.0011)	-.031 (.044)	-.528** (.172)			-.0020** (.0005)	1.51*** (.061)	.395	0.000
	Model IV	.0041** (.001)	-.435 (.681)	-.524** (.169)	.0009 (.0003)	.0008 (.0001)	-.002** (.005)	1.49*** (.061)	.398	0.000

According to the findings from the Driscoll-Kraay estimator, applied both at the country and panel levels in Model I for Denmark, the primary education variable is significant but has a negative coefficient. Accordingly, a 1% increase in primary education reduces GG by approximately 003%. Secondary education in Model II and higher education in Model III are statistically insignificant and have a negative sign. However, in Model IV, where all education levels are included together, all education levels are significant. However, while primary and secondary education have a negative impact; Higher education has a positive impact. Accordingly, while a 1% increase in primary education reduces GG by 003% and in secondary education by 001%, respectively; A 1% increase in higher education increases GG by 001%. Internet usage rate (net), used as control variables, has a significant and positive effect in all models (except Model III). It also has a significant and positive effect on REC in all models (except Model IV). Finally, FD has a significant but negative impact in all models (except Model II).

In Model I for Finland , the coefficient for the primary education variable is both significant and positive, whereas the coefficients for other education levels are not statistically significant. Therefore, a 1% rise in basic education results in a 0.04% increase in GG. The control variables, internet usage rate (net) and REC, have a consistently favorable and significant impact in all models. FD has a statistically insignificant and negative coefficient in all models.

For Iceland, the secondary education variable has a significant and negative coefficient only in Model II and Model IV, whereas other education levels are not significant. Hence, a mere 1% rise in secondary schooling results in a decrease of 0.04% in GG. Out of the control variables, only the internet usage rate has a substantial and positive impact in all models, whilst the remaining variables have insignificant and negative coefficients.

In Model I for Norway, the primary education variable has a significant and positive coefficient; Secondary education has a significant but negative coefficient. Accordingly, a 1% increase in primary education increases GG by 004%; A 1% increase in secondary education reduces GG by 0003%. The variables used as control variables are insignificant and have different effects in all models.

Model I for Sweden shows that the primary education variable has a substantial and positive coefficient, while Model II shows that the secondary education variable also has a significant and positive coefficient. However, higher education has a significant but negative coefficient. Based on the data, a 1% increase in elementary education results in a 0.003% rise in GG. Similarly, a 1% increase in intermediate education leads to a 0.002% gain in GG. However, a 1% increase in higher education causes a 0.005% decrease in GG. The control variables have negligible and distinct impacts in all models, except for the FD in Model III.

According to the panel-based results, the variable for higher education in Model III, which is one of the indicators used to measure HC in this study, has a significant coefficient that is negative in nature. Consequently, a 1% rise in higher education results in a 0.02% decrease in GG. While other education measures display positive coefficients, they lack statistical significance. Although the control variable of internet usage rate (net) has a large and positive impact in all models, the coefficient for REC is small and negative in all models, except for Model I. FD has a strong and consistently negative influence in all models, with the exception of Model II.

When considering all outcomes, the impact of HC on green economic growth is generally low but varies. Based on this information, it can be observed that primary and secondary education levels in Sweden, as well as primary education levels in Finland and Norway, contribute positively to GG. However, primary and secondary education levels in Denmark, as well as secondary education levels in Iceland and Norway, have a negative impact on GG. Only higher education in the panel results exhibits a significant and unfavorable impact. The impact of internet usage is predominantly beneficial. The influence of renewable energy is multifaceted. In Denmark and Finland, it has a beneficial impact, but in other nations and panels, it has an adverse effect. Ultimately, FD exerts a detrimental impact on all demographic cohorts.

3.CONCLUSION

In the study, the effect of HC on green economic growth was analyzed for the period 2010-2022 in Nordic countries (Denmark, Iceland, Finland, Sweden and Norway), taking into account different education levels. The findings obtained from the Driscoll-Kraay estimator were evaluated on a country and panel basis. The impact of HC on green economic growth is low but complex. According to this; While primary and secondary education levels in Sweden and only primary education levels in Finland and Norway have a positive effect on GG, primary and secondary education levels in Denmark and secondary education levels in Iceland and Norway have a negative effect. In the panel results, only higher education has a significant and negative effect. Internet use generally has a positive effect. The impact of renewable energy is complex. It has a positive effect in Denmark and Finland and a negative effect in other countries and panels. Finally, FD has a negative effect in all groups.

The results partially corroborate the research that has determined that HC has a favorable impact on the green economy (Liu et al. 2023, Şentürk 2024, and Tufail et al. 2024). In a study conducted by Liu et al. (2023), they observed a detrimental impact in the short term and a beneficial impact in the long term, while examining comparable variables to those in the present study. Hence, it provides limited support for the present research. The current study is supported by previous research conducted by Liu et al. (2022), and Wang et al. (2023) which found that the influence of HC on the green economy is varied. Research conducted by Ngo et al. (2022) and Ren et al. (2022) highlights the significant influence of HC on the green economy, emphasizing its beneficial impact. Thus, both the present study and other studies highlight the intricate nature of the impact of HC on green economic growth. The impact of this phenomenon differs based on variables such as the economic status of nations, duration, and exposure to various indicators. In this context, it is necessary to implement policies that will have a beneficial impact on the relationship between HC and green economic growth. In this context, policies that will have a beneficial effect on the relationship between HC and green economic growth need to be implemented. Because the findings show that developments at the level of education should be supported by policies aimed at ensuring conscious producer and consumer understanding. Making regulations that can benefit from applications such as internet technology and artificial intelligence in the development of these policies will contribute to achieving a wider impact with less cost. Since gaining a conscious producer and consumer understanding will bring about the interaction of human capital accumulation with other indicators, internet use will also contribute to an evolution that will positively contribute to the green economic transformation from renewable energy and financial development variables. In summary, anything that focuses on education and therefore human capital accumulation has the feature of being more sustainable and permanent.

While the study offers valuable insights to the existing body of literature, it is not without limitations. The analysis is restricted to the economies of five Nordic countries. Additionally, although the initial aim was to include data spanning the period before 2010 and up to 2023, the empirical study was limited to the years 2010 to 2022 due to data availability constraints. The study examines the influence of only three control factors in representing GG. In future research, it is recommended to incorporate additional control variables and specifically examine individual regions and nations that exhibit similar levels of socio-economic growth. Additionally, it can examine the impact of many socio-economic factors on GG, including social security, inequality of opportunity, and health. Therefore, it has the potential to result in useful and new discoveries.

AUTHOR STATEMENT

Statement of Research and Publication Ethics

This study has been prepared in accordance with scientific research and publication ethics.

Ethics Committee Approval

Ethics committee approval is not required as this research does not include analyses that require ethics committee approval

Author Contributions

Author Contribution rate (100%)

Conflict of Interest

There is no conflict of interest for the authors or third parties arising from the study.

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