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Role of green technology, environmental taxes, and green energy towards sustainable environment: Insights from sovereign Nordic countries by CS-ARDL approach

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ABSTRACT

This study analyzes comprehensively the role of green technology, environmental taxes, and green energy toward a sustainable environment in 5 sovereign Nordic countries by also considering income and population. For this purpose, annual data of Nordic countries from 1995 to 2020 is extracted and the cross-sectional augmented autoregressive distributed lag (CS-ARDL) technique is applied to test short-run and long-run compatibilities of the indicators on carbon dioxide (CO_2) emissions. Moreover, Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) approaches are applied for robustness checks. The empirical results reveal that (i) green technology, environmental taxes, and green energy have a negative association with CO_2 emissions in the both short-run and long-run; (ii) income and population have a positive association between CO_2 emissions in the both short-run and long-run; (iii) AMG and CCEMG approaches report similar findings with the CS-ARDL and validate the robustness in turn. Thus, the empirical results confirm the contributing role of green technology, environmental taxes, and green energy toward a sustainable environment in 5 sovereign Nordic countries. Moreover, policy implications are discussed.
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1. Introduction

Green strategies can be a cure for a contaminated environment. Green approaches rely on nature-oriented renewable resources, thus appreciating acquiring sustainable development goals (SDGs) (Bigerna et al., 2021). Due to ongoing environmental degradation issues, ecologists stress that countries have renovated their traditional business operations with green technologies and secured the world from the haze of environmental contagion (Shao et al., 2021). Comparatively, the ingredients involved in technology development procedures and the components intricate in green technology have fewer negative effects on the environment. According to Liu et al. (2022), characteristics inbound with green technology mitigate CO_2 emissions and significantly reduce greenhouse gases (GHG) that adversely affect resources and human life. Research and development departments prove that innovation in green technology provides ultra-modern systems that are less pollution-intensive and prevents wastages in the form of raw materials, water, and gases. Such enclosures increase the effectiveness and productivity level of firms (Wang and Liu, 2021). However, marvels of green technology not only bond to upper-level technical evolutions but cover the domestic and commercial level business to nourish their specialized machines. This ideology has

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been perfectly embraced by developed nations, such as Nordic countries (Miremadi et al., 2019) that cultivate socially equitable appliances, which consume the least possible energy and become the highest environmental technology exporters.

Regardless, developed nations contribute 40% of CO_2 emissions, but this figure will be overturned in 2040 (International Energy Agency-IEA, 2018). Though, the constant tussle to lessen the environmental humiliation has been analyzed from the sustainability reports of industrialized markets that how they nourish their green technical development programs through strategic campaigns of environmental taxes to acquire economic resilience and sooner result in corrosion of environmental pollution (Ghazouani et al., 2020). In addition, Shahzad (2020) investigate that European nations try to sustain the employment of green technological growth from environmental taxes to control the overconsumption of CO_2 emissions. These taxes mold perception of expanding on environmentally harmful goods due to increased prices (Ghazouani et al., 2021). For instance, governments and companies impose multiple taxes on carbon-containing goods to convert consumer buying behavior to ease the inclusion of CO_2 emissions (Karmaker et al., 2021). These modifications upgrade the entire business attitude in the matter of selling and buying commodities.

A parallel approach, such as an ecological tax, is carried forward with socioeconomic developers on high-consuming energy equipment to surge the accumulated production prices (Safi et al., 2021) but simultaneously boost the production of green technologies (Chien et al., 2021). Similarly, per capita income decreases because of financial accountabilities on tax raises (Qi et al., 2022). Even though barriers to environmental taxes depress tourism and trading activities in the short-run, positive advancements are sure in the long-run (Ibrahim and Ajide, 2021). Several studies declare that economies impose environmental taxes on fossil fuels with the help of a top-down energy demand model if they are proactive and financially stable to flourish green economic activities (Trencher et al., 2021). Thus, exerting these taxes combats the negative externalities of climatic issues (Bashir et al., 2021) and promotes the efficient production of green energies through nature-friendly technologies (Su et al., 2021).

Although perpetual demand for energy supply extremely haunts the preservation of natural resources, the only potential solution is the transition towards green energy via innovative technologies (Khan and Ulucak, 2020). Economies, such as China, the United States of America (USA), and Brazil, inaugurate green energy projects for hydropower, biomass, solar, wind, and geothermal energies to omit fossil-fuel-based ecology. Hence, it is essential to upgrade the systematic approach to green energy and several operationalizations, such as sophisticated resource management, optimized energy transformation systems, and stringent policies to mitigate the volume of CO_2 emissions (Wang et al., 2021). Therefore, green energy is vital in reducing economic externalities (Schelly et al., 2020). As a result, global sustainability plans direct countries to develop and invest in energy plants that utilize minimum carbon content and elevate the re-consumption of renewable resources to decrease the ratio of ecological footprint.

In this context, the research and development departments reveal substitutes for fossil fuels, such as renewable and nuclear energy (Hussain and Nishat, 2022). Also, it is worth noting that the significant association between green energy innovations and CO_2 emissions is inevitable; thus, concerning the statement of the World Economic Forum (WEF, 2022) that increasing or decreasing rates of environmental risk depends on the consumption of fossil-fuel energy, which varies among countries, like economic stability of 5 sovereign Nordic countries are moderately better than China, USA, and India because sustainable methods of economic progression are far better than the environmental degradation means of advancements. Against all the carbon-intensive industries, these nations are minimum producers of CO_2 emissions and still generate the highest gross domestic product (GDP) per capita income according to the last updated critical economic indicator of Nordic countries (OECD, 2022a). Fig. 1 shows the progress trend of CO_2 emissions, per capita income, green technology, green energy, environmental tax, and population.

Notes: Units for CO_2 Emissions, Income, Green Technology, Green Energy, and Environmental Taxes are per capita tons, per capita USA Dollar (USD), number of patents, per capita energy supply, and per capita tax for GDP, respectively.

Per capita CO_2 emissions of Nordic countries has a generally declining trend. Among all, Sweden and Iceland have the lowest per capita CO_2 emissions, whereas Finland and Norway have the highest (Fig. 1a). Also, the income level of all these countries has been increasing continuously. Specifically, per capita income in all these countries is above USD 36.000 and Norway has the highest per capita income with USD 55.193,5 (Fig. 1b). In terms of green technology, Denmark is leading, while Iceland is the pioneering country in green energy (Fig. 1c and 1d). In environmental tax, Denmark is leading (Fig. 1e). Moreover, Nordic countries have a relatively stable population, with which Sweden and Denmark have the highest (Fig. 1f).

Based on the explanations above, this study analyzes five sovereign Nordic countries (Denmark, Sweden, Finland, Norway, and Iceland) to investigate the role of green technology, environmental taxes, and green energy in a sustainable environment. According to Normann (2021), these countries possess the position of competitive capitalism in the market due to minimum wages gaps, high appointments rates, higher taxes, education, and security incentives, and these attributes entice this study to discover the difficulties and obstacles faced by these nations in mitigating the CO_2 emissions. The CO_2 emissions per capita is 6.7 metric tons in Norway, 5.1 metric tons in Denmark, and 3.4 metric tons in Sweden (OECD, 2022a). Thus, the current topic flourishes the novelty by assessing the pros and cons of environmental sustainability in Nordic countries that is not yet observed. However, socioeconomic factors, such as industrialization and globalization, have been widely studied before (Van and Bao, 2018). Still, this study exclusively integrates the potential variables (green technology, green energy, and environmental taxes) to CO_2 emissions to stimulate Nordic countries' environmental consequences. The motivation for these countries is rooted in the fact that these countries are highly integrated into trade and business. Thus, the emission of GHG affects per-capita income. These green growth factors prevent environmental degradation and scarcity of natural resources, as widely proved in previous studies (Ahmed et al., 2020). Hence, to describe the intellectual understanding of CO_2 emissions and their determinants, potential studies are identified to inscribe in the literature reviews section.

Additionally, various techniques are applied to extract reliable results that increase the constancy of the present research. For example, the authenticity of the analysis results augments after employing the techniques of Westerlund and Edgerton (2008) and Banerjee and Carrion-i-Silvestre (2017) to resolve the consequences of cross-section dependence. Another rationality of the research is characterized by the CS-ARDL method. This method illustrates the short-run and long-run dynamics of the variables outlined. Also, AMG and CCEMG are employed as robustness analyses. Therefore, this study provides a detailed discussion of the causalities of environmental pollution and enhances logical insights of Nordic policymakers to optimize their economic sustainability and secure the world from the disastrous effects of CO_2 emissions.

The sections of this study are summarized as follows: the present section delivers a detailed overview of the dependent variable and its determinants. Further elaborations are found in the

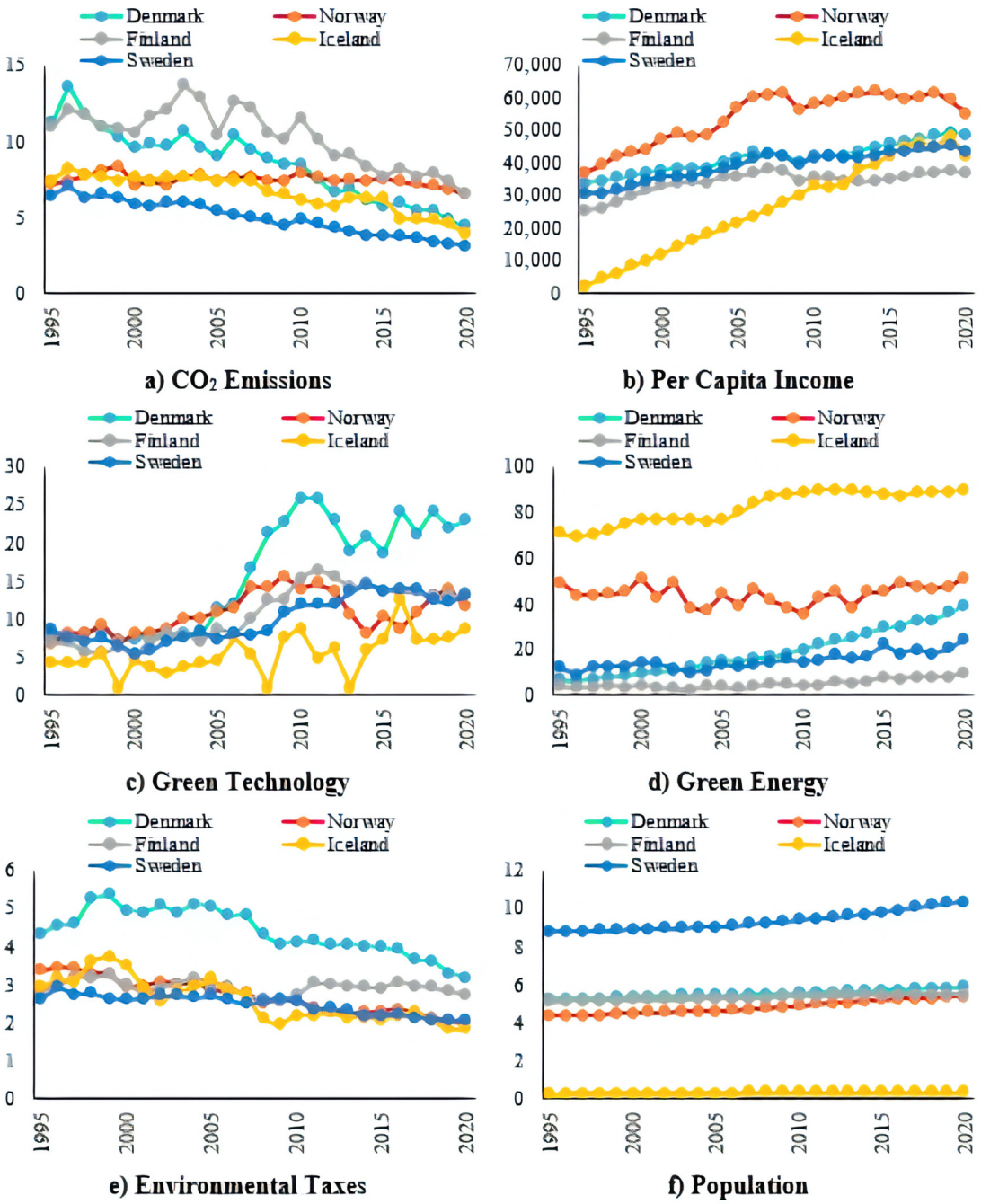


Fig. 1. Progress of Indicators in Nordic Countries.

literature section, which is the second section of the study. The third section explains the data and methodology. The fourth section presents empirical analysis and discussion by illustrating the results of CS-ARDL, the interpretation of these tables as well as the results of the alternative models (AMG and CCEMG) that are used for robustness checks. The last section covers the conclusion and policy implications.

2. Literature review

With the growing externalities of these nature-exploiting gases, environmentalists need to invent precautionary strategical plans to elevate the genuine version of green growth (Rockstrom et al., 2018). Due to this course, a substantial and detailed discussion on variables enhances knowledge of the current happenings. It becomes more accessible for researchers to engrave unique perspectives of the "win-win growth frame" (Tilsted et al., 2021). For instance, this study targets Nordic countries and components, which impact their sustainability, so with the help of different research topics, samples, and methodologies, the broad and distinct relationship status is scrutinized between them. Hence, the below sections individually inspect the energy technology, environmental taxes, and green energy with CO_2 emissions.

2.1. Green technology and sustainable environment

The mounting era of technologies transforms the economies entirely (Solanki and Nayyar, 2019; Mona et al., 2020), and con-

temporary ways of living standards stimulate flexibility as well as adversities. The same happens when technical developments boost, environmental dilapidation increases, and diminutions of natural resources seem obvious (Hussain et al., 2022). Therefore, Shan et al. (2021) are renowned economists, who raise this global issue by inciting a negative affiliation of green technology with environmental pollution. Like, Ulucak (2020) analyzes the mechanism through which environmental technologies affect green growth. The findings highlight the consumption of carbon-intensive materials in BRICS countries and incorporate guidance over renewable and non-renewable energy depletion. The results support that environmental technologies contribute toward green growth in a positive way, renewable energy causes a significant increase in green growth, while non-renewable energy is found to have a detrimental effect on green growth. Also, Kılıç and Ç ankaya (2020) direct a similar contribution that BRICS and G7 countries need to devise techniques and innovations in their renewable energy sector to expand the eco-friendly environment.

Although it is phenomenal that higher environmental-related technologies positively combat the negative aftermaths of climate, limited studies seconds this fact (Hishan et al., 2019; Song et al., 2019). Moreover, some studies show a contrary opinion. For instance, the influence of green technological changes on CO_2 emissions varies from region to region due to financial and political conditions (Yasin et al., 2021). Besides these approaches, Sharif et al. (2022) emphasize that nourishments of educational and skills-preparing sectors are essential, even locally and internationally, to gather the knowledge of adapting green technology mechanisms. Similarly, Du and Li (2019) conduct a study to determine the phenomenon through which innovations in green technology effects carbon productivity and reveal a difference between development and innovations in green technology. Jahanger (2022) propose that green technology innovations should be encouraged worldwide to attain a carbon-neutral economy.

Moreover, Kirikkaleli and Adebayo (2021) investigate whether partnerships such as public as well as private can affect consumption-based CO_2 emissions in India. From the results, it is devised that policies should discourage non-renewable and encourage renewable energy so that consumption-based CO_2 emissions can be reduced in India. Therefore, countries become more technology-oriented via green technical ways (Capasso et al., 2019) to compete against environmental challenges.

On the other hand, Hao et al. (2021) opine that the green revolution and low emissions due to carbon in G7 countries from 1991 to 2017. It focuses on the function of green growth in endorsing sustainable surroundings by using second-generation techniques. The fallouts show that CO_2 emissions could be mitigated by linear and non-linear terms of green growth. Moreover, it is declared that renewable energy, environmental tax, and human capital help improve the environment, parallel demonstrations signified in the research by Sharma et al. (2021). A positive change in atmospheric weather is recognized after the adaptation of green technology. Additionally, the cost minimization of products raises customer loyalty and buying power and decreases the global ecological footprint in turn.

According to Mishra et al. (2020), carbon tax and cap guidelines are the sources of subsiding carbon-based emissions and usage of non-renewable energies. Also, panel data results explain that carbon tax and cap model for sustainable economic production quantity has been suggested for a controlled carbon secretions rate by financing green technology with and without scarcity conditions. However, a contradicted view is stated by Lv et al. (2019) that technological advancement increases medical problems and inflation rates, and even green technical change initially spread negative consequences on the eco-friendly environment. Moreover, these explorations are supported in the same view by Amiri et al. (2021). They also add that developed nations increase their per capita income and introduce green technological plants, but simultaneously deteriorate the other countries via exporting carbon-emitting technologies.

Khan et al. (2020) demonstrate the impact of technological revolutions and investments in green technology on a sustainable environment in China. Public and private investments are both focused on in the study. Hence, the results show a cointegrating relationship between renewable energy, exports, and technological innovations that are found to be beneficial in sinking (consumption-based carbon emissions) activities. However, Zhang (2021) finds that financial funds and capital investments (public and private) in energy-intensive businesses cause carbon emissions in China. Moreover, Wang et al. (2020) direct a study to define how sustainable growth is being fed in China. The study observes that the abduction of fossil fuels and dependability on green investment significantly affect production-based carbon emissions, so it is declared that both variables could contribute to sustainable growth.

After analyzing the association between a sustainable environment and green technology by inspecting the last shreds of evidence, it is observed that without adaptation or transformation towards green technology, it is impossible to eradicate the repercussions of CO_2 emissions (Razzaq et al., 2021). However, studies are unclear about the external operations of integrated countries that employ trading businesses and spread extreme consequences of CO_2 emissions. Another gap identified is that few researchers enlighten the green planetary actions for developed economies considering their collaborations with developing countries. Hence, the circle of CO_2 remains consistent because of low stringent policies followed globally to mitigate CO_2 emissions. However, the need for practical ideologies and solutions is significant to elevate sustainability via adapting complicated approaches to green technology.

2.2. Green energy and sustainable environment

Renewable green energy and recycling are elementary factors to mitigate climate deterioration and support a sustainable environment. The significant factor of green energy is receiving valuable attention in this era of industrialization (Ahmed et al., 2020) because pollution-intensive developments, especially in the USA, China, and India, continuously detriment natural resources and disturb the organic environment globally. In recent times, numerous studies have explored the utilization of solar energies, conversions of biomass and geothermal energies, and literature (Sun et al., 2019) emphasizes the varieties of energy transition systems to eradicate the impacts of GHG emissions. For instance, Cerqueira et al. (2021) explore the data collected between 2000 and 2016 from 28 OECD countries to observe the circular economy paradigm (circular interconnection) happening between renewable energy, recycling, and economic development. Similarly, Hsu et al. (2021) use the quantile ARDL method to examine the short-run and long-run relationship between green energy and its effect on the sustainable environment in China. They observe that financial factors play an essential role in utilizing green energy, which directly targets achieving technological sustainability in the environment. The critical determinant factors of this research are ecological innovation, globalization, environmental taxes, and renewable energy. Findings reveal that ecological innovation, environmental taxes, and renewable energy negatively control CO_2 emissions, whereas similar factors help reduce pollution rates in the long-run. Moreover, it is concluded that globalization significantly affects the rate of CO_2 emissions. Dong et al. (2021) explore that energy poverty surges the utilization of CO_2 emissions in China as the increasing rate of the population develops more energy

demand, whereas Noussan et al. (2020) argue that the financial conditions of undeveloped nations are immature to tackle the expenditures of green energy transitions or by planting projects of renewable energies.

On the other hand, Kahia et al. (2021) declare that as financially stable and has potential energy production areas, it is predicted that Saudi Arabia effectively will produce energy base alternatives to acquire power sustainability by 2030. Even though, Jebli et al. (2020) demonstrate that green energy is necessary for all types of business, whether it is agriculture, industrial, service-based, or whatsoever the eminent role of energy exists. Thus, these business sectors must accommodate green energy systems to enhance organizational productivity and GDP income. Additionally, prior literature also focuses on green logistic operations, Khan et al. (2018) research 43 countries to find the relationship between green energy demand, green logistic operations, economic growth, and sustainable environment. Logistic operations utilize fossil-fuel, and non-green energy and causing a detrimental effect on the environment and degrading economic growth. The findings conclude that using green energy reduces the negative impact of the logistic operation.

Therefore, the benefic effect of green energy on regional and well as global levels are undeniable to sustain environmental stability (Nazir et al., 2020). The multifarious ways of green energy attract scholars to investigate the in-depth scenarios of endorsing green energy attributes to prevent environmental pollution and the effect of GHG emissions (Naqvi et al., 2022). Renewable green energy and recycling are elementary factors to mitigate climate deterioration and increase the sustainable environment. The theoretical view over green energy significantly affects environmental sustainability. Chau et al. (2022) observe the secondary data collected from the WDI or World Bank indication of G7 countries from 2001 to 2019. The examination takes place while using the methods of moment quantile regression (MMQR) method. The results prove that green exportation and consumption highlight a significant positive effect on the sustainability of natural environmental resources. Also, Bigerna et al. (2021) embrace the positive affiliation of green energies concerning CO_2 emissions in long-run equilibrium. Considerably, the literature shows that green energy significantly affects environmental suitability in short-run and long-run estimates.

In a nutshell, newly invented procedures (solar, wind, geothermal, biomass, and non-renewable renewable resources) substantially fulfill green energy demands and are highly compatible with spreading an environmentally friendly environment (Sharma et al., 2022). Although continuous evolutions make past literature a little ineffective, thus employing typical procedures and tactics of green energy operations, the proper guidance and policy implications are still needed to normalize the standards of green energies.

2.3. Environment taxes and sustainable environment

To address severe environmental issues, governmental authorities ensure measures to prevent explosive carbon activities (Ulucak and Kassouri, 2020), by implementing sometimes stringent environmental policies such as subsidies, regulation on privatization, and environmental taxes. As per the recent study relevance, the component of environmental taxes is discussed widely to comprehend the impact of these taxes on negative externalities of the environment. However, some scholars analyze a severe downfall in economic growth due to the tariffs on carbon content (Bashir et al., 2021). But simultaneously, bundles of research find that seconds the positive relationship between environmental taxes on global warming and CO_2 emissions. Kang and Lee (2021) reveal that although the government of friendly environmental countries has all the modern instrument to reduce pollution, they are still struggling; evidence confirms that green taxes and zero-carbon energies are essential in reducing CO_2 emissions to get a healthier environment and progressive approach should be taken by imposing environmental taxes and promoting renewable-based energies.

Resembling that, Ma et al. (2021) accompany research to find the nexus between CO_2 emissions and technology and energy investments in China. For this purpose, they utilize the macroeconomic determinants of China's carbon-neutrality target. Moreover, it is also found that expenditure on research and development and emission taxes support the ease of CO_2 emissions. A similar study is conducted by He et al. (2021) in Finland and Malaysia in addition to China. In this study, the nexus is found between the similar factors (CO_2 emissions, technology, and energy investments) utilized by Ma et al. (2021) and economic growth. Moreover, a panel-ARDL approach is used in this research. Observations of the results depict an N-shaped relation between CO_2 emissions in volumetric measures and the GDP of the understudy countries. Furthermore, it is also found that in all those countries, environmental taxes have a double dividend effect in the long-run. So, it is concluded that environmental taxes can potentially mitigate CO_2 emissions in Finland and Malaysia and can be generalized as a reference for China.

On the contrary, CO_2 emissions are enhanced or boosted by regional growth and development in the tertiary sector (Nosheen et al., 2021). So, it is concluded that innovative measures for abating CO_2 emissions, investments in research and development, and environmental taxes are necessary. Such regulation may decrease the GDP per capita income as analyzed through the MMQR method but increase sustainability further (Farooq et al., 2022). Instead, Ulucak and Kassouri (2020) assess the non-linear properties of environmental taxation on CO_2 emissions. The results recommend that an environmental tax diminishes CO_2 emissions at increasing degrees of globalization. At increasing degrees of globalization, the non-linear influence of environmental-related technology and patents on CO_2 emissions is also beneficial.

Globally, it is perceived that environmental taxes sustain the demand and supply of energy-related goods (Ahmed et al., 2022). In this regard, Doğan et al. (2022) investigate the impact of an environmental tax on CO_2 emissions for the G7 nations from 1994 to 2014. Also, they explain the relationship between aspects, such as natural resources and economic complexity that cause CO_2 emissions. As per analysis, environmental taxes and their regulatory role control energy consumption and CO_2 emissions. However, the results demonstrate how environmental taxes can effectually conquer a carbon-free economy. If an adequately determined environmental tax law is implemented, it will automatically shift business production toward uncontaminated methods. Shahzad et al. (2021) support the identified results.

Similarly, Wolde-Rufael and Mulat-Weldemeskel (2022) assess the efficacy of environmental taxes in dipping CO_2 in 18 Latin America and the Caribbean (LAC) countries from 1994 to 2018. Environmental taxes may minimize not only CO_2 emissions but also enhance the usage of renewable energies. According to Du and Li (2019), the progressive growth of the economies depends on formulating rules and regulations. However, economic taxes cut off the lavish standards of life but gradually decreased the ecological footprint.

2.4. Evaluation of the literature

While studies on the carbon-income nexus are quite large, there is a paucity of documentation on carbon-income analysis via the channel of green technology, environmental taxes, and green energy, of which each provides inconclusive outcomes. Shahzad et al. (2020) take place among the few studies exploring the role of green technology growth from environmental taxes on its miti-

gating role on CO_2 emissions in the case of European Union (EU) economies. A similar positive trend of the contribution of green technologies via the channel of renewable energy consumption is highlighted in BRICS economies, as seen in the study of Ulucak (2020). This is contrary to the findings of Hishan et al. (2019) and Song et al. (2019). Thus, the pertinent role of adopting green growth technologies on environmental sustainability is limited in the extant literature as previously outlined, especially for Nordic countries. To this end, this study advances the extant literature on the following fronts:

First, this study incorporates green technology, environmental taxes, and green energy in the stochastic impacts by regression on population, affluence, and technology framework for the first time in the extant literature for Nordic countries between 1995 and 2020. The current study variable model is motivated and draws strength from the SDGs agenda, which is very limited for the study area investigated.

Second, this study advances the extant literature in scope (Nordic countries). In retrospect, it is revealed in the literature that environmental taxes quickly transform consumer behavior toward carbon-related commodities. Also, the production cost of energy-related items escalates due to the observed reduction in CO_2 emissions. Hence, the significant effect between environmental taxes and CO_2 emissions validates the findings of Miremadi et al. (2019) and Ahmed et al. (2022), but still, countries hesitate to impose taxes on exports, tourism, and carbon-related goods because these taxes significantly decrease the per capita income. Therefore, practical approaches must be proposed to impose environmental taxes without harming green ecological growth to fill this gap.

Additionally, this study leverages recent and state-of-the-art econometrics modeling tools such as Westerlund and Edgerton's in conjunction with Banerjee and Carrion-i-Silvestre's (2017) cointegration test, CS-ARDL, AMG, and CCEMG are known to circumvent for the shortcomings of first-generational techniques. All the estimators are robust to cross-sectional and heterogeneity issues as they are superior to the first generational estimators. Hence, this study relies on second-generation econometric models for robustness and soundness of estimates and coefficients for adequate policy crafting.

3. Data and methodology

3.1. Model and data

Concerning environmental quality, a STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model, which is a modified version of the model IPAT explored by Dietz and Rosa (1994, 1997), is used to assess the practicalities of the current topic. For example, variables of population and income per capita are extracted from the STIRPAT to support the other econometric factors of the study.

The STIRPAT model is indicated in Equation (1) below:

$$CO_{2i,t} = f\left(GTI_{i,t}, ET_{i,t}, GEN_{i,t}, PI_{i,t}, POP_{i,t}\right) \quad (1)$$

The extracted data sources of Nordic countries range from 1995 to 2020 to investigate the inter-relationship among green technology (GTI), environmental taxes (ET), and green energy (GEN) on CO_2 emissions by also considering population (POP) and per capita income (PI). The dominant economies are Nordic countries (Denmark, Norway, Finland, Iceland, and Sweden). Hence, the data of supporting variables (PI and POP), are from World Bank (WB, 2022). The data on GTI, ET, and GEN is extracted from the website of OECD (2022b). The number of patents related to the environment represents green technology. Green energy is measured via renewable energy and sustainable environment parameter by the indicator of CO_2 emissions from the web page of British Petroleum (BP, 2022).

3.2. Methodology flow

Fig. 2 presents the methodology followed up in the empirical examination.

In the context of the empirical examination, the following steps are applied. First, data are collected from the data sources. Second, descriptive statistics of the variables, normality, and correlation coefficient are examined. Third, CD and SH are tested. Fourth, the unit-roots of variables are controlled. Fifth, a cointegration test for the panel and single countries is applied. Sixth, long-run and short-run coefficients are estimated. Seventh, the results are checked for robustness via alternative panel data approaches. Lastly, discussion and implications as well as limitations and future directions are presented based on the empirical results obtained.

3.3. Cross-sectional dependency, slope homogeneity, and unit root test

The primary objective of the econometric analysis is to identify the existence of cross-sectional dependence (CD). The detection of cross-sectional dependency is necessary to avoid inefficient information in the form of bias stationarity and cointegration results (Salim et al., 2017). The CD occurs due to the engagements of the economic and financial activities, externalities, and countries' dependency on each other. However, this test is helpful to scrutinize the complete unit root test process (first, second, and third generation tests); hence Pesaran's (2015) CD test is applied to the data to check the issues of CD.

After testing CD, the non-stationarity with the homogenous panel of the data is extracted via the second generation, introduced by Choi (2001) and Levin et al. (2002); on the other hand, heterogeneity in the data is checked by (Im et al., 2003). Correspondingly, problems of structural breaks sort out through the testing approach introduced by Carrion-i-Silvestre et al. (2005). Still, somehow these techniques are unsuccessful in resolving the issues of CD. At last, Moon and Perron (2012) successfully overcome the complications of structural breaks, data distortion, and issues related to homogenous and heterogeneous panel data between the determinants. However, suppose the problems of structural breaks arise due to extreme variations in global and local events. In that case, the third generation of the unit root test suggested by Bai and Carrion-i-Silvestre (2009) runs on the data to resolve CD problems. Therefore, this study adopts the techniques of Pesaran (2015) and Bai and Carrion-i-Silvestre (2009) unit root tests to accomplish the practicalities of CD that would have been unsolved previously, and Carrion-i-Silvestre et al. (2005) test is used for each cross-section to interpret the effect of time interval dimension structural breakages.

3.4. Cointegration test

In this process, the test of Pesaran and Yamagata (2008), which is a modified version of Swamy's (1970) test, is used to analyze the presence of slope heterogeneity in the data stream; thus, the null hypothesis assumes the homogenous and alternative as heterogeneous slope parameters. Although Larsson et al. (2001) disqualify eases the issues of CD, hence the existence of CD creates a problematic situation in the data size demonstration and is unable to scrutinize the best possible estimations. Due to this course, with the help of Banerjee and Caarion-i-Silvestre (2017), disruption of slope heterogeneity structural breaks and non-stationarity issues incorporate but again, the unusual gaps in the data occur problems in rejecting the null hypothesis of no cointegration. Based on this

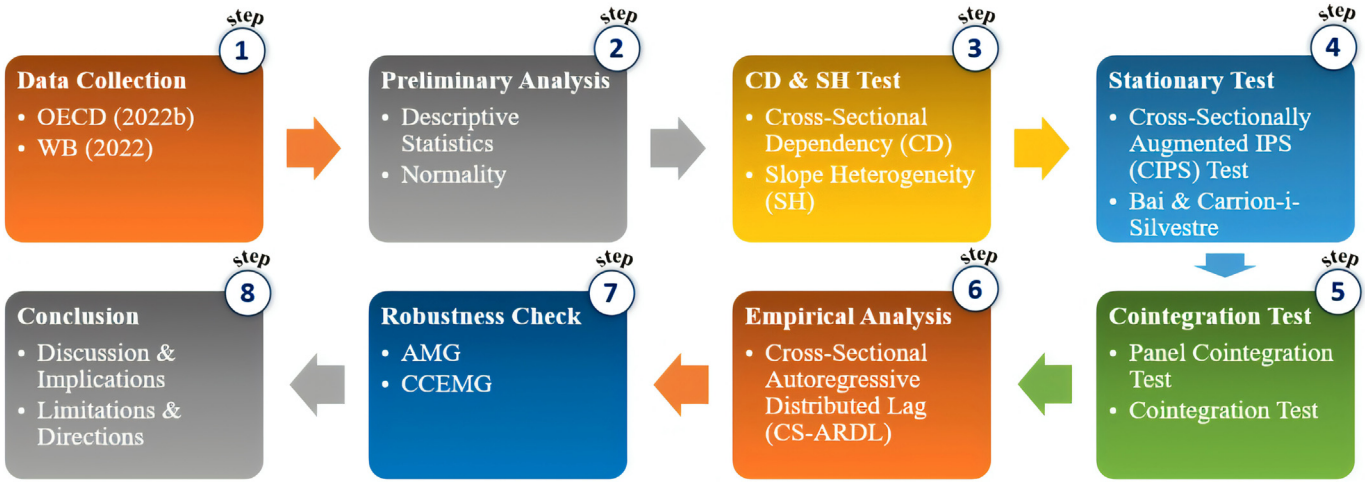


Fig. 2. The methodology.

scenario, Westerlund and Edgerton (2008) analytically resolve the sudden effect of possible structural breaks with all the homogenous and heterogeneous issues and errors of correlations. After this, Banerjee and Caarion-i-Silvestre (2017) surpass the cointegration analysis using the assistance of the CCEMG between the variables. This approach provides a precise estimation of cross-sectional dependence even if the statistics are weak or strong, stationarity or non-stationarity issues, and handles slope heterogeneity and specious parameters perfectly in the panel data. Thus, this study chooses these methods to check the cointegration among the selected econometric factors.

3.5. CS-ARDL model

CS-ARDL is the statistical procedure that satisfies the issue of CD and slope heterogeneity; however, this study needs to tackle the issue of CD; thus, the CS-ARDL method effectively tackles these complications because of its familiar correlated effect estimators (Yao et al., 2019). Initially, Equation (2) is given below to start the CS-ARDL process;

$$U_{it} = \sum_{I=0}^{p_U} \gamma_{I,i} U_{i,t-I} + \sum_{I=0}^{p_W} \beta_{I,i} W_{i,t-I} + \varepsilon_{i,t} \tag{2}$$

Furthermore, to explain the ARDL model, the extended Equation (2) in the form of cross-section averages of each regressor is mentioned below, which deals with the inconsistency and misleading parameters that happen due to the occurrence of cross-section dependency (Chudik and Pesaran, 2015). But if we use equation (4) to carry out the existing process, the issue of cross-section remains constant.

$$U_{it} = \sum_{I=0}^{p_U} \gamma_{I,i} U_{i,t-I} + \sum_{I=0}^{p_W} \beta_{I,i} W_{i,t-I} + \sum_{I=0}^{p_V} \alpha'_{i} I\bar{V}_{i,t-I} + \varepsilon_{i,t} \tag{3}$$

In Equation (3), the regressors of dependent and independent variables are stated as $\bar{V}_{i,t-I} = (U_{i,t-1}, W_{i,t-I})$, and p_U, p_W,p_V signifies the lags of each factor. Whereas U_{it} supports the dependent variable (CO_2 emissions) and W_{it} indicates the factors such as green technology, environmental taxes, and green energy. Finally,$\bar{V}$ specifies the averages of CD that exert a spillover effect on the selected data. After this, the long-run figures are extracted from the coefficient of the short-run; thus, the mean estimator is given below,

$$\pi_{CS-ARDL,i} = \frac{\sum_{I=0}^{pW} \widehat{\beta}_{I,i}}{1 - \sum I = 0}^{PU} \gamma_{I,i} \tag{4}$$

Moreover, the mean group is mentioned as,

$$\pi_{MG} = \frac{1}{N} \sum_{i=0}^{N} \widehat{\pi}_i \tag{5}$$

And short-run coefficient is reported as,

$$U_{i,t} = \vartheta_i [U_{i,t-1} - \pi_i W_{i,t}] - \sum_{I=1}^{PU-1} \gamma_{I,i}, \Delta_I U_{i,t-1} + \sum_{I=0}^{PW} \beta_{I,i}, \Delta_I W_{i,t} + \sum_{I=0}^{p_V} \alpha'_{i} I\bar{V}_{i,t} + \varepsilon_{i,t} \tag{6}$$

Here.$\Delta_I = t - (t-1)$

$$\widehat{\tau}_i = -\left(1 - \sum_{I=1}^{pU} \widehat{\gamma}_{I,i}\right) \tag{7}$$

$$\widehat{\pi i} = \frac{\sum_{I=0}^{PW} \widehat{\beta}_{I,i}}{\widehat{\tau}_i} \tag{8}$$

$$\bar{\widehat{\pi}} MG = \frac{1}{N} \sum_{i=0}^{N} \widehat{\pi}_i \tag{9}$$

Alike pooled group mean treated for the CS-ARDL method, in a similar way error correction mechanism (ECM (-1)) is adjusted by using the equation toward the equilibrium point.

3.6. Robustness check

The most effective ways to deal with non-stationary variables are the AMG by Teal and Eberhardt (2010) and the CCEMG by Pesaran (2006) approaches. The main advantage of CCEMG is overcoming the identification issue by considering slope heterogeneity constraints that are unnoticeable because of time variations. The calculation is carried out by taking the average of determinants for all cross sections to eliminate the spillover effect uprooted by CD but not containing trends (or time dummies) (Liddle, 2018). This is the resilient solution for both weak and robust factors to deal with the uncertain jolt worldwide (Pesaran and Tosetti, 2011; Chudik et al., 2011). The substitute style of AMG and CCEMG deals not only with heterogeneity, cross-section dependence, and structural breaks but also includes year copies. So, overcoming the unobservable factors is not inconvenient but also a substantial process (Teal and Eberhardt, 2010).

4. Empirical analysis and discussion

Fig. 3 presents the preliminary statistics and Box-Whisker plots.

Fig. 3 shows that values of CO_2 range from 3.12 to 13.67 and the mean value is 7.56. The coefficient of variation statistics, which stands for how much its values vary from the mean, is around 30 and it has few outliers. In addition, the Jarque-Bera test reveals there is no significant evidence to reject the null hypothesis which assumes data is normally distributed. Besides, values of POP, PI, GTI, ET, and GEN range from 0.27 to 10.35, from 2,624.47 to 62,002.88, from 0.96 to 25.83, from 1.82 to 5.36, and from 2.56 to 89.87, respectively. Moreover, the coefficient of variation statistics for POP, GTI, and GEN are relatively higher than others, because they have many outliers. Once skewness and kurtosis statistics are examined, it is seen that CO_2, PI, GTI, ET, and GEN have a platykurtic distribution. Although POP has many outliers, it is normally distributed. On the other hand, PI, GTI, ET, and GEN are not normally distributed based on Jarque-Bera test results.

After examination of preliminary statistics and correlations between variables. Firstly, the existence of cross-dependency is tested via Pesaran's test (2015) and the results are presented in Table 1.

Suppose, it is initially ignored the possibility of false figures generated due to bias cointegration and unit root analysis. Hence, Table 1 illustrates that variables (CO_2, POP, PI, GTI, ET, and GEN) rejected the null hypothesis with a significance level of 1%, 5%, and 10%, which means the presence of cross-section dependence is confirmed in Nordic countries, based on this estimation authors further investigate Pesaran (2007) and Bai and Carrion-i-Silvestre (2009) test of stationarity under the availability of CD, heterogeneity, and structural breaks.

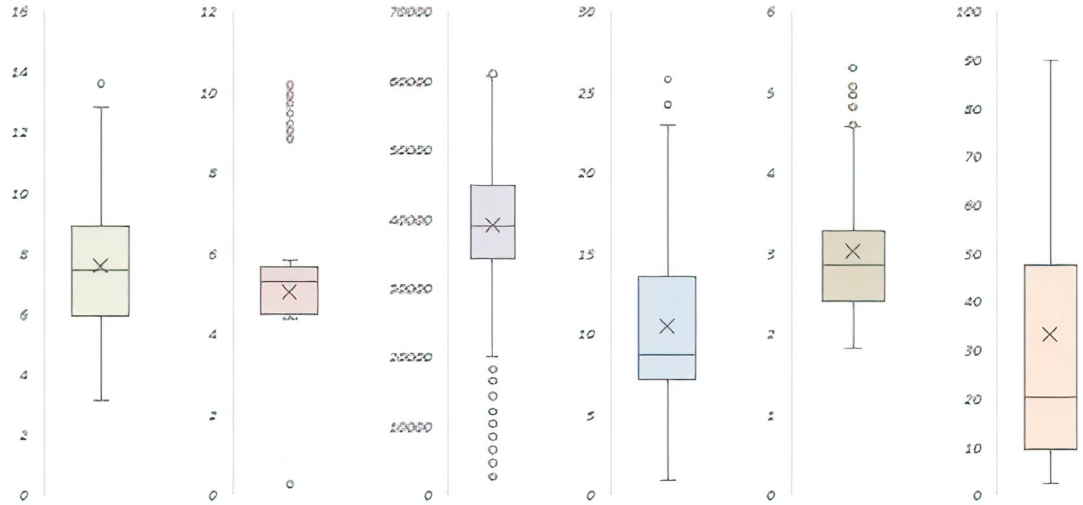
Table 1
CD analysis results.

Variable	Test Statistics (p-values)
CO_2	19.134*** (0.000)
POP	44.017*** (0.000)
PI	38.152*** (0.000)
GTI	23.060*** (0.000)
ET	18.181*** (0.000)
GEN	31.075*** (0.000)

Also, in Table 2, a modified version of Swamy's (1970) test is used to detect the slope heterogeneity; this altered version was proposed by (Pesaran and Yamagata, 2008).

The test indicates the presence of homogenous or heterogeneity in the panel data. Alike when acceptance of the null hypothesis confirms the homogenous data is supposed which causes misleading information, well if the rejection of the alternative idea approves the existence of slope heterogeneity is confirmed. Thus, the results support slope heterogeneity.

Moreover, empirical outcomes of the unit root test under the existence of multiple issues of structural halts, stationarity, and heterogeneity are presented in Table 3.



	CO_2	POP	PI	GTI	ET	GEN
Mean	7.56	5.06	39,132.50	10.50	3.02	33.08
Standard Deviation	2.36	2.90	12,052.06	5.28	0.83	28.47
Coefficient of Variation	31.22	57.27	30.80	50.32	27.50	86.07
Minimum	3.12	0.27	2,624.47	0.96	1.82	2.56
Q_{25}	5.96	4.52	34,310.65	7.22	2.45	9.71
Median	7.42	5.30	38,849.36	8.69	2.86	20.40
Q_{75}	8.78	5.64	44,775.45	13.52	3.27	47.28
Maximum	13.67	10.35	62,002.88	25.83	5.36	89.87
Skewness	0.16	-1.28	0.05	0.30	0.04	0.45
Kurtosis	-0.35	0.78	-0.73	-1.75	-1.26	-1.08
Jarque-Bera	0.86	0.84	0.93	0.81	0.82	0.66
Probability	0.0822	0.3312	0.0044	0.0000	0.0000	0.0002
Observations	130	130	130	130	130	130

Fig. 3. Preliminary statistics.

Table 2
Slope heterogeneity analysis results.

Statistics	Test value (p-value)
Delta tilde	83.175*** (0.000)
Delta tilde Adjusted	67.203*** (0.000)

Table 4
Panel Cointegration Analysis Results (Westerlund and Edgerton, 2008).

Test	No break	Mean shift	Regime shift
$Z_{\varphi}(N)$	−6.032***	−6.242***	−5.168***
P-value	0.000	0.000	0.000
$Z_{\tau}(N)$	−8.659***	−8.105***	−8.237***
P_{value}	0.000	0.000	0.000

In Table 3, empirical outcomes confirm the first difference in stationarity at I(I) in all determinants such as CO_2, POP, PI, GTI, ET, and GEN. Although at the start of Pesaran's (2017) and Bai and Carrion-i-Silvestre levels declare unsuccessful to reject the null hypothesis, even the issues of CD and structural breaks also get stuck after considering Bai and Carrion-i-Silvestre still represent a rejection of the null hypothesis of non-stationarity. Later, Pesaran (2015) signifies stationarity at level I (I). However, when Bai and Carrion-i-Silvestre (2009) apply first-order differencing, the consequences got rejection of the null hypothesis and non-stationarity in the unit root test. They accepted the alternative view of all factors under the misconception of CD, heterogeneity, and formal breaks. overall, all results confirm stationarity, as mentioned above.

Another estimated effect of Westerlund and Edgerton (2008) is reported in Table 4, which elaborates on the rejection of the null hypothesis and seconds the cointegration among all variables of the study with no breaks, mean shift, and regime shift. This test checks the integration among the variables under the presence of CD issues, heterogeneity, and serialized correlation.

Similarly, empirical findings in Table 5, the cointegration analysis proposed by Banerjee and Carrion-i- Silvestre (2017), are considered the confirmatory test for cointegration among the variables. Since the figures are significant at 1%, the factors are highly integrated or correlated with each other. Even the entire sample and data of Nordic countries depend on each other and represent cointegration with the dependent variable (CO_2 emissions). The results are previously supported by Sarfraz et al. (2022). However, the presence of cointegration directs the authors to stimulate the finding of a long-run and short-run analysis using the CS-ARDL technique.

In Table 6, the accumulated results of the CS-ARDL model in the long-run are scrutinized.

According to the predicted variables, population and per-capita income are the supporting elements and represent a positive correlation with CO_2 emission, in the long-run, having coefficient values of (0.173) and (0.264). However, come to actual indicators such as GTI, ET, and GEN empirically found significant negation with CO_2 emissions. For instance, GTI reports a coefficient of (-0.282), which is also significant at 1%; hence it is interpreted that a 1% increase in green technology negatively influences the CO_2 emissions with the ratio of (0.282). This interprets that, in Nordic countries, developmental procedures of green technology positively enhance the green growth of the economy and maintain its sustainability if the production of green technical equipment, machinery, and engines is encouraged. Also, (Ma et al., 2021; Khan et al., 2020) signify the positive relationship between green technology and CO_2 emissions. Once Karmaker (2021) elaborates that, to gain competitive advantages, economies urge for sustainability in their operations, and the only possible way is to regulate the mechanism of developing green technologies.

Likewise, the component of ET reported a negative association with CO_2 emissions due to the coefficient of (-0.335), this states that a 1% increase in environmental taxes significantly decreases the emission of carbon content with the proportion of (0.335) in Nordic countries. The reason behind negative affiliation is because of the imposed taxes on carbon-intensive goods. However, in the selected panel data of Nordic countries, a negative collaboration is confirmed between ET and CO_2 emissions. Previously, Bashir et al. (2021) and Ahmed et al. (2022) also support the positive output of environmental taxes on the consequences of global warming and ecological footprint as Doğan et al. (2022) analyze the same results and show his intellectuals that due to imposed tariffs, consumers' perception of buying fluctuates and shifts towards non-tax substitutes. Hao et al. (2021) contribute that environmental taxes rapidly decreases the imports and sometimes exports of carbon-based products, hurting the yearly GDP growth but instantly cleaning the environment. However, in the panel data of Nordic countries, a negative affiliation is confirmed between ET and CO_2 emissions.

Compared to green technology and environmental taxes, the wonders of green energy are highly appreciated in Nordic countries due to their negative association with CO_2 emissions. Like, a 1% rise in green energy leads to a (-0.240) decrease in emission of CO_2 emissions. Such scenarios represent that if Nordic countries are compatible enough to implant sources of green energy production, then in the longer run, sustainability in the environment is

Table 3
Unit Root Test Analysis Results (Pesaran, 2007; Bai and Carrion-i-Silvestre, 2009).

	Level I(0)			First Difference I(1)		
Variables	**CIPS**	**M-CIPS**			**CIPS**	**M-CIPS**
CO_2	−6.015***	−4.128**			–	–
POP	−3.179***	−3.157**			–	–
PI	−5.068***	−6.016**			–	–
GTI	−4.155***	−5.082**			–	–
ET	−6.010***	−3.169**				
GEN	−5.049***	−4.135**			–	–
Bai and Carrion-i-Silvestre (2009)						
	Z	P_m	*P*	*Z*	P_m	*P*
CO_2	0.165	0.243	16.183	−5.048***	3.185***	56.174***
POP	0.327	0.168	20.062	−3.163***	5.062***	74.082***
PI	0.184	0.315	17.154	−6.020***	4.174***	62.153***
GTI	0.239	0.172	22.071	−4.141***	6.035***	86.041***
ET	0.175	0.236	18.143	−5.065***	3.169***	55.190***
GEN	0.228	0.159	24.030	−4.172***	5.080***	71.065***

Table 5
Cointegration Analysis Results (Banerjee and Carrion-i-Silvestre, 2017).

Countries	No deterministic specification	With constant	With trend
Full Sample	−6.013***	−4.145***	−5.026***
Denmark	−3.151***	−3.176***	−3.154***
Finland	−5.042***	−6.008***	−6.004***
Iceland	−4.136***	−3.195***	−4.138***
Norway	−6.009***	−5.043***	−5.027***
Sweden	−3.157***	−4.129***	−3.145***

Table 6
CS-ARDL Long-Run Analysis Results.

Variables	Coefficients	t-statistics	p-values
POP	0.173***	6.676	0.000
PI	0.264***	7.853	0.000
GTI	−0.282**	−2.141	0.042
ET	−0.335***	−3.169	0.000
GEN	−0.240***	−4.828	0.000

complementary. Even though Naqvi et al. (2020) and Jebli et al. (2020) emphasize while investigating the USA's contribution to carbon emission, advancing the transition towards green energy resources must eradicate the exploitation of natural resources and provide non-carbon-based sources of energy consumption. In addition, the negative relationship between GER and CO_2 emissions is predicated by Kahia et al. (2021). Thus, traditional methods of fulfilling energy demands are detrimental to the organic environment and highly unappreciated in acquiring a zero-carbon economy.

To continue with the approaches of the CS-ARDL method, Table 7 reports the analysis of short-run equilibrium by considering the panel data of Nordic countries.

The empirical investigation also illustrates that the chief determinants of GTI, ET, and GEN significantly share a negative bond with CO_2 emissions in the short-run. In addition, the ECT (-1) signifies the adjustment speed of equilibrium to extract genuine figures. However, it is analyzed that industrialization through destructive means of carbon emissions in Nordic countries is nature-damaging-damaging. For example, urbanized procedures of technical innovation raise the toxicity of carbon emissions

Table 7
CS-ARDL Short-Run Analysis Results.

Variables	Coefficients	t-statistics	p-values
POP	0.086***	5.045	0.000
PI	0.043*	1.683	0.094
GTI	−0.059***	−8.191	0.000
ET	−0.102***	−5.062	0.000
GEN	−0.068***	−9.800	0.000
ECT(-1)	−0.277***	−3.551	0.000

(Song et al., 2021), but as per the results, a 1% increase in GTI resulted in a (-0.059) decrease in CO_2 emissions. Similarly, a 1% increase in ET leads to a reduction in CO_2 emissions by (-0.102), and a 1% rise in GEN, decreases CO_2 emissions by (-0.068) in Nordic countries. These suggestions are seconds by previous scholars (Sharif et al., 2022); they all commended policymakers for strategizing financial investments plans, collection of funds, or monetarization of green technical projects to develop green energy plants such as solar, wind, and geothermal energies, as these energies are highly compatible with the recreation of natural resources and decrease the externalities of adverse climatic change.

Lastly, Table 8 reports the empirical findings of the AMG and CCEMG models that are applied for robustness check.

In Table 8, a section of AMG illustrates that variables of green technology, environmental taxes, and green energy represent the coefficient values of −0.174, −0.310, and −0.272, which state that a 1% rise in these variables decreases the emission of CO_2 with respective figures. Similar results are reported in CCEMG. For instance, a 1% increase in GTI reduces the CO_2 emissions by −0.169, a 1% growth in ET drops CO_2 emissions by −0.257, and a 1% increase in GEN decreases CO_2 emissions by −0.240. Hussain et al. (2021), Kang and Lee (2021), and Sharma et al. (2022) support these statistical results. However, these records also second the extracted results of short-run and long-run analysis of the CS-ARDL approach.

As following up a comprehensive econometric examination approach, Fig. 4 presents a summary of the empirical results obtained.

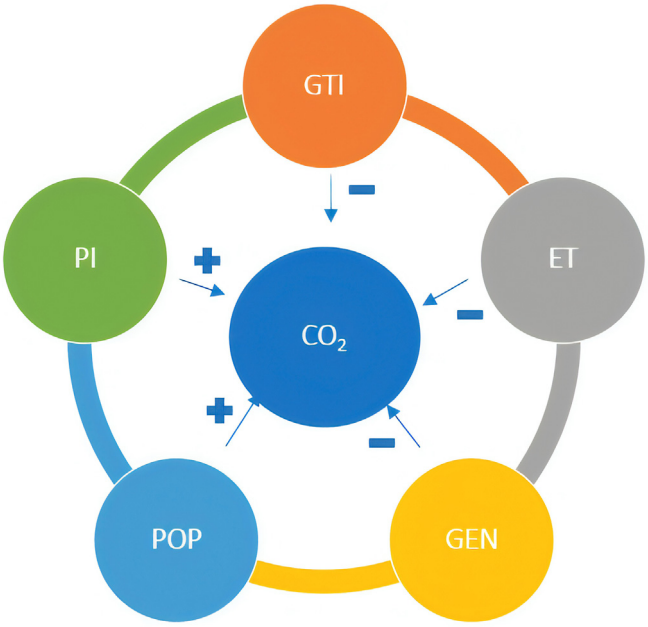


Fig. 4. Summary of empirical results.

Table 8
Robustness Check Results by AMG and CCEMG Approaches.

Variable	AMG			CCEMG		
	Coefficients	t-statistics	p-values	Coefficients	t-statistics	p-values
POP	0.185***	5.051	0.000	0.250***	5.754	0.000
PI	0.230***	5.119	0.000	0.125***	11.138	0.000
GTI	−0.174***	−3.687	0.000	−0.169***	−6.152	0.000
ET	−0.310***	−4.194	0.000	−0.257**	−2.064	0.048
GEN	−0.272***	−3.065	0.000	−0.240***	−6.671	0.000
Wald test	–	16.611	0.000	–	23.981	0.000

5. Conclusion and policy implications

The benefits of green growth are undeniable because the requirement of a balanced, resource-abundant, and urbanized market attracts all economies. Likewise, green strategical approaches are the subset of sustainable development. Therefore, this study comprehensively analyzes the role of green technology, environmental taxes, and green energy toward a sustainable environment in 5 sovereign Nordic countries with the help of the cross-sectional augmented autoregressive distributed lag method. The top authentic articles are reviewed analytically to accumulate relatively recent knowledge over the variables regarding carbon dioxide emissions; the authors extracted the Nordic countries' data from 1995 to 2020 to test the short-run and long-run compatibilities of these variables on carbon dioxide emissions. Also, the first, second, and third generations of unit root tests verify data to resolve the issue of cross-section dependence. Hence, the empirical estimations imply a negative association between green technology, environmental taxes, and green energy on carbon dioxide emissions in the short-run and long-run. In addition, tools for robustness (augmented mean group and common correlated effects mean group) report similar findings with the cross-sectional augmented autoregressive distributed lag.

Based on these identifications, practically sustainable policies are developed to enhance the green ecological system in Nordic countries. Primarily, the variable of green technology illustrates the negative impact on carbon dioxide emissions. Thus, engineers and developers optimize their operations by transmitting green strategical approaches globally via the mediums of imports and exports, foreign direct investments, and licensing from developed to under-developed nations. By implementing this, uneven market stability decreases, and sustainability increases universally. Also, through growth-oriented monetary plans, income per capita increases. Based on this, Nordic countries initiate educational programs and skill learning schemes to produce zero-carbon consuming technologies that will benefit in mitigating carbon dioxide emissions. Correspondingly, scholars stress the significance of environmental taxes in fortifying the severe consequences of environmental pollution. As per this estimation, governmental authorities should impose high taxes on carbon-containing products and abandon private organizations for startup businesses that utilize non-renewable energies. In addition, with the assistance of tax collections, ecologically friendly awareness programs, donations, and knowledge must be standardized. Similarly, the transport sector of Nordic countries is a great contributor to carbon dioxide emissions. Thus, an organized tax framework will impose to minimize the consumption of fossil fuels and promote low-emission vehicles. By doing so, Nordic countries can achieve the agreed target with European Union countries to increase the market share of biofuels to 10% or more.

Since the negative impact of green energy on the emission of carbon dioxide is identified, thus the potential policy implications are suggested in favor of green energy in the Nordic countries. Firstly, Nordic countries obtain cheap and excellent storage facilities from huge hydro reserves. These storage options are effectively utilized. As per the consumption, in, companies will require chemical storage in the form of hydrogen-based fuels or batteries in the future capture and storage play a vital role in reducing industrial carbon dioxide emissions. Moreover, they also reduce carbon dioxide emissions when applied to biomass. Even low-income households are rarely given energy subsidies in the Nordic countries; instead, they are helped by social welfare measures that allow them to satisfy their heating needs with the help of biofuels, and heat pumps, while maintaining incentives that motivate everyone to use less energy. These are beneficial and progress-making tactics for the Nordic countries to attain a sustainable environment.

Finally, this study has some limitations. Because this study considers only Nordic countries, future studies can include more countries from different regional data, such as the group of seven countries, emerging seven countries, BRICS, and MINT countries. Also, some other advanced econometric methodologies, such as methods of moment quantile regression and nonlinear panel autoregressive distributed lag, can be used in future studies.

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7. Authors' Contributions

The authors have contributed equally to this work. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Ahmed, N., Sheikh, A.A., Hamid, Z., Senkus, P., Borda, R.C., Wysokińska-Senkus, A., Glabiszewski, W., 2022. Exploring the causal relationship among green taxes, energy intensity, and energy consumption in Nordic countries: Dumitrescu and Hurlin causality approach. Energies 15 (14), 5199.

Ahmed, Z., Asghar, M.M., Malik, M.N., Nawaz, K., 2020. Moving towards a sustainable environment: The dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China. Resour. Policy. 67, 101677.

Amiri, M.M., Kazemian, M., Motaghed, Z., Abdi, Z., 2021. Systematic review of factors determining health care expenditures. Health Policy Techn. 10, (2) 100498.

Banerjee, A., Carrion-i-Silvestre, J.L., 2017. Testing for panel cointegration using common correlated effects estimators. J. Time Ser. Anal. 38(4), 610-636.

Bai, J., Carrion-I-Silvestre, J.L., 2009. Structural changes, common stochastic trends, and unit roots in panel data. Rev. Econ. Stud. 76 (2), 471–501.

Bashir, M.F., Ma, B., Komal, B., Bashir, M.A., 2021. Analysis of environmental taxes publications: A bibliometric and systematic literature review. Environ. Sci. Pollut. R. 28 (16), 20700–20716.

Bigerna, S., Bollino, C.A., Polinori, P., 2021. Convergence in renewable energy sources diffusion worldwide. J. Environ. Manage. 292, 112784.

BP., 2022. Energy Data. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html, August 10, 2022.

Capasso, M., Hansen, T., Heiberg, J., Klitkou, A., Steen, M., 2019. Green growth-A synthesis of scientific findings. Technol. Forecast. Soc. 146, 390–402.

Carrion-i-Silvestre, J.L., del Barrio-Castro, T., Lopez-Bazo, E., 2005. Breaking the panels: An application to the GDP Per Capita. Econom. J. 8 (2), 159–175.

Cerqueira, P.A., Soukiazis, E., Proença, S., 2021. Assessing the linkages between recycling, renewable energy and sustainable development: Evidence from the OECD countries. Environ. Dev. Sustain. 23 (7), 9766–9791.

Chau, K.Y., Moslehpour, M., Tu, Y.T., Tai, N.T., Tien, N.H., Huy, P.Q., 2022. Exploring the impact of green energy and consumption on the sustainability of natural resources: Empirical evidence from G7 countries. Renew. Energ. 196, 1241–1249.

Chien, F., Ananzeh, M., Mirza, F., Bakar, A., Vu, H.M., Ngo, T.Q., 2021. The effects of green growth, environmental-related tax, and eco-innovation towards carbon neutrality target in the US economy. J. Environ. Manage. 299, 113633.

Choi, I., 2001. Unit root tests for panel data. J. Int. Money Financ. 20 (2), 249–272.

Chudik, A., Pesaran, M.H., 2015. Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. J. Econometrics. 188 (2), 393–420.

Chudik, A., Pesaran, M.H., Tosetti, E., 2011. Weak and strong cross-section dependence and estimation of large panels. Econom. J. 14 (1), 45–90.

Doğan, B., Chu, L.K., Ghosh, S., Truong, H.H.D., Balsalobre-Lorente, D., 2022. How environmental taxes and carbon emissions are related in the G7 economies? Renew. Energ. 187, 645–656.

Dong, K., Jiang, Q., Shahbaz, M., Zhao, J., 2021. Does low-carbon energy transition mitigate energy poverty? The case of natural gas for China. Energ. Econ. 99, 105324.

Dietz, T., Rosa, E.A., 1994. Rethinking the environmental impacts of population, affluence and technology. Hum. Ecol. Rev. 1 (2), 277–300.

Dietz, T., Rosa, E.A., 1997. Effects of population and affluence on CO_2 emissions. P. NatlÇ AcadÇ SciÇ Usa. 94 (1), 175–179.
Du, K., Li, J., 2019. Towards a green world: How do green technology innovations affect total-factor carbon productivity. Energy Policy 131, 240–250.
Farooq, U., Ahmed, J., Akhter, W., Tabash, M.I., 2022. Environmental regulations and trade credit activities of corporate sector: A new panel data evidence. J. Clean. Prod. 132307.
Ghazouani, A., Jebli, M.B., Shahzad, U., 2021. Impacts of environmental taxes and technologies on greenhouse gas emissions: Contextual evidence from leading emitter European Countries. Environ. Sci. Pollut. R. 28 (18), 22758–22767.
Ghazouani, A., Xia, W., Ben Jebli, M., Shahzad, U., 2020. Exploring the role of carbon taxation policies on CO_2 emissions: Contextual evidence from tax implementation and non-implementation European countries. Sustainability. 12 (20), 8680.
Hao, L.N., Umar, M., Khan, Z., Ali, W., 2021. Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? Sci. Total Environ. 752, 141853.
He, P., Ya, Q., Chengfeng, L., Yuan, Y., Xiao, C., 2021. Nexus between environmental tax, economic growth, energy consumption, and carbon-dioxide emissions: Evidence from China, Finland, and Malaysia based on a panel-ARDL approach. Emerg. Mark. Financ. Tr. 57 (3), 698–712.
Hishan, S.S., Khan, A., Ahmad, J., Hassan, Z.B., Zaman, K., Qureshi, M.I., 2019. Access to clean technologies, energy, finance, and food: Environmental sustainability agenda and its implications on sub-saharan African countries. Environ. Sci. Pollut. R. 26 (16), 16503–16518.
Hsu, C.C., Zhang, Y., Ch, P., Aqdas, R., Chupradit, S., Nawaz, A., 2021. A step towards sustainable environment in China: The role of eco-innovation renewable energy and environmental taxes. J. Environ. Manage. 299, 113609.
Hussain, A., Nishat, A.S., 2022. The energy challenge: Moving from fossil fuels to biofuels, hydrogen, and green energy sources. https://academicworks.cuny.edu/ny_pubs/910, August 10, 2022.
Hussain, M., Mir, G.M., Usman, M., Ye, C., Mansoor, S., 2022. Analysing the role of environment-related technologies and carbon emissions in emerging economies: A step towards sustainable development. Environ. Technol. 43 (3), 367–375.
Ibrahim, R.L., Ajide, K.B., 2021. Disaggregated environmental impacts of non-renewable energy and trade openness in selected G-20 countries: The conditioning role of technological innovation. Environ. Sci. Pollut. R. 28 (47), 67496–67510.
IEA., 2018. World Energy Outlook 2018, IEA, Paris. https://www.iea.org/reports/world-energy-outlook-2018, August 10, 2022.
Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. J. Econometrics. 115 (1), 53–74.
Jahanger, A., 2022. Impact of globalization on CO_2 emissions based on EKC hypothesis in developing world: The moderating role of human capital. Environ. Sci. Pollut. R. 29 (14), 20731–20751.
Jebli, M.B., Farhani, S., Guesmi, K., 2020. Renewable energy, CO_2 emissions and value added: Empirical evidence from countries with different income levels. Struct. Change. Econ. D. 53, 402–410.
Kahia, M., Omri, A., Jarraya, B., 2021. Green energy, economic growth and environmental quality nexus in Saudi Arabia. Sustainability. 13 (3), 1264.
Kang, S.J., Lee, S., 2021. Impacts of environmental policies on global green trade. Sustainability. 13 (3), 1517.
Karmaker, S.C., Hosan, S., Chapman, A.J., Saha, B.B., 2021. The role of environmental taxes on technological innovation. Energy 232, 121052.
Khan, D., Ulucak, R., 2020. How do environmental technologies affect green growth? Evidence from BRICS economies. Sci. Total Environ. 712, 136504.
Khan, S.A.R., Zhang, Y., Anees, M., Golpîra, H., Lahmar, A., Qianli, D., 2018. Green supply chain management, economic growth and environment: A GMM based evidence. J. Clean. Prod. 185, 588–599.
Khan, Z., Ali, M., Kirikkaleli, D., Wahab, S., Jiao, Z., 2020. The impact of technological innovation and public-private partnership investment on sustainable environment in China: Consumption-based carbon emissions analysis. Sustain. Dev. 28 (5), 1317–1330.
Kılıç, E., Çankaya, S., 2020. Oil prices and economic activity in BRICS and G7 countries. Cent. Eur. J. Operat. Res. 28 (4), 1315–1342.
Kirikkaleli, D., Adebayo, T.S., 2021. Do public-private partnerships in energy and renewable energy consumption matter for consumption-based carbon dioxide emissions in India? Environ. Sci. Pollut. R. 28 (23), 30139–30152.
Larsson, R., Lyhagen, J., Löthgren, M., 2001. Likelihood-based cointegration tests in heterogeneous panels. Economet. J. 4 (1), 109–142.
Levin, A., Lin, C.F., Chu, C.S.J., 2002. Unit root tests in panel data: Asymptotic and finite-sample properties. J. Econometrics. 108 (1), 1–24.
Liddle, B., 2018. Consumption-based accounting and the trade-carbon emissions nexus. Energ. Econ. 69, 71–78.
Liu, Q., Zhu, Y., Yang, W., Wang, X., 2022. Research on the impact of environmental regulation on green technology innovation from the perspective of regional differences: A quasi-natural experiment based on China's new environmental protection law. Sustainability. 14 (3), 1714.
Lv, L., Liu, Z., Xu, Y., 2019. Technological progress, globalization and low-inflation: Evidence from the United States. PLoS One 14 (4), e0215366.
Ma, Q., Murshed, M., Khan, Z., 2021. The nexuses between energy investments, technological innovations, emission taxes, and carbon emissions in China. Energy Policy 155, 112345.
Miremadi, I., Saboohi, Y., Arasti, M., 2019. The influence of public R&D and knowledge spillovers on the development of renewable energy sources: The case of the Nordic countries. Technol. Forecast. Soc. 146, 450–463.
Mishra, U., Wu, J.Z., Sarkar, B., 2020. A sustainable production-inventory model for a controllable carbon emissions rate under shortages. J. Clean. Prod. 256, 120268.
Mona, S., Kumar, S.S., Kumar, V., Parveen, K., Saini, N., Deepak, B., Pugazhendhi, A., 2020. Green technology for sustainable biohydrogen production (waste to energy): A review. Sci. Total Environ. 728, 138481.
Moon, H.R., Perron, B., 2012. Beyond panel unit root tests: Using multiple testing to determine the nonstationarity properties of individual series in a panel. J. Econometrics. 169 (1), 29–33.
Naqvi, B., Rizvi, S.K.A., Hasnaoui, A., Shao, X., 2022. Going beyond sustainability: The diversification benefits of green energy financial products. Energ. Econ. 106111.
Nazir, M.S., Bilal, M., Sohail, H.M., Liu, B., Chen, W., Iqbal, H.M., 2020. Impacts of renewable energy atlas: Reaping the benefits of renewables and biodiversity threats. Int. J. Hydrogen. Energ. 45 (41), 22113–22124.
Normann, S., 2021. Green colonialism in the Nordic context: Exploring southern Saami representations of wind energy development. J. Community. Psychol. 49 (1), 77–94.
Nosheen, M., Iqbal, J., Abbasi, M.A., 2021. Do technological innovations promote green growth in the European Union? Environ. Sci. Pollut. R. 28 (17), 21717–21729.
Noussan, M., Raimondi, P.P., Scita, R., Hafner, M., 2020. The role of green and blue hydrogen in the energy transition-A technological and geopolitical perspective. Sustainability. 13 (1), 298.
OECD, 2022a. Organisation for Economic Co-operation and Development. https://www.oecd.org, August 10, 2022.
OECD, 2022b. Environmental Related Tax Revenue. https://data.worldbank.org, August 10, 2022.
Pesaran, M.H., 2006. Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica 74 (4), 967–1012.
Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. J. Appl. Economet. 22 (2), 265–312.
Pesaran, M.H., 2015. Testing weak cross-sectional dependence in large panels. Econometric. Rev. 34 (6–10), 1089–1117.
Pesaran, M.H., Tosetti, E., 2011. Large panels with common factors and spatial correlation. J. Econometrics. 161 (2), 182–202.
Pesaran, M.H., Yamagata, T., 2008. Testing slope homogeneity in large panels. J. Econometrics. 142 (1), 50–93.
Qi, Y., Shao, S., Tian, Z., Xu, Y., Yin, J., 2022. Environmental consequences of fair competition: Evidence from China's corporate income tax merger policy. Ecol. Econ. 195, 107365.
Razzaq, A., Wang, Y., Chupradit, S., Suksatan, W., Shahzad, F., 2021. Asymmetric inter-linkages between green technology innovation and consumption-based carbon emissions in BRICS countries using quantile-on-quantile framework. Technol. Soc. 66, 101656.
Rockstrom, M.D., Chen, L., Taishi, P., Nguyen, J.T., Gibbons, C.M., Veasey, S.C., Krueger, J.M., 2018. Tumor necrosis factor alpha in sleep regulation. Sleep Med. Rev. 40, 69–78.
Safi, A., Chen, Y., Wahab, S., Zheng, L., Rjoub, H., 2021. Does environmental taxes achieve the carbon neutrality target of G7 economies? Evaluating the importance of environmental R&D. J. Environ. Manage. 293, 112908.
Salim, R., Yao, Y., Chen, G.S., 2017. Does human capital matter for energy consumption in China? Energ. Econ. 67, 49–59.
Sarfraz, M., Naseem, S., Mohsin, M., Bhutta, M.S., 2022. Recent analytical tools to mitigate carbon-based pollution: new insights by using Wavelet coherence for a sustainable environment. Environ. Res. 212, 113074.
Schelly, C., Bessette, D., Brosemer, K., Gagnon, V., Arola, K.L., Fiss, A., Halvorsen, K.E., 2020. Energy policy for energy sovereignty: Can policy tools enhance energy sovereignty? Sol. Energy. 205, 109–112.
Shahzad, U., 2020. Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications. Environ. Sci. Pollut. R. 27 (20), 24848–24862.
Shahzad, U., Radulescu, M., Rahim, S., Isik, C., Yousaf, Z., Ionescu, S.A., 2021. Do environment-related policy instruments and technologies facilitate renewable energy generation? Exploring the contextual evidence from developed economies. Energies 14 (3), 690.
Shan, S., Genç, S.Y., Kamran, H.W., Dinca, G., 2021. Role of green technology innovation and renewable energy in carbon neutrality: A sustainable investigation from Turkey. J. Environ. Manage. 294, 113004.
Shao, X., Zhong, Y., Liu, W., Li, R.Y.M., 2021. Modeling the effect of green technology innovation and renewable energy on carbon neutrality in N-11 countries? Evidence from advance panel estimations. J. Environ. Manage. 296, 113189.
Sharif, A., Saqib, N., Dong, K., Khan, S.A.R., 2022. Nexus between Green Technology Innovation, Green Financing, and CO_2 Emissions in the G7 Countries: The Moderating Role of Social Globalisation. Sustain. Dev. https://doi.org/10.1002/sd.2360.
Sharma, A., Surana, K., George, M., 2022. Do clean energy trade duties generate employment benefits? Renew. Sust. Energ. Rev. 159, 112104.
Sharma, G.D., Shah, M.I., Shahzad, U., Jain, M., Chopra, R., 2021. Exploring the nexus between agriculture and greenhouse gas emissions in BIMSTEC region: The role of renewable energy and human capital as moderators. J. Environ. Manage. 297, 113316.
Solanki, A., Nayyar, A., 2019. Green internet of things (G-IoT): ICT technologies, principles, applications, projects, and challenges. In: Handbook of research on big data and the IoT. IGI Global, pp. 379–405.

Song, M., Fisher, R., Kwoh, Y., 2019. Technological challenges of green innovation and sustainable resource management with large scale data. Technol. Forecast. Soc. 144, 361–368.
Song, W., Mao, H., Han, X., 2021. The two-sided effects of foreign direct investment on carbon emissions performance in China. Sci. Total Environ. 791, 148331.
Swamy, P.A., 1970. Efficient inference in a random coefficient regression model. Econometrica, 311–323.
Su, Y., Huang, C., Lai, C., Yong, Q., 2021. Green solvent pretreatment for enhanced production of sugars and antioxidative lignin from poplar. Bioresource Technol. 321, 124471.
Sun, C.H., Fu, Q., Liao, Q., Xia, A., Huang, Y., Zhu, X., Chang, H.X., 2019. Life-cycle assessment of biofuel production from microalgae via various bioenergy conversion systems. Energy 171, 1033–1045.
Teal, F., Eberhardt, M., 2010. Productivity analysis in global manufacturing production. University of Oxford, Working Paper, No. 515.
Tilsted, J.P., Bjørn, A., Majeau-Bettez, G., Lund, J.F., 2021. Accounting matters: Revisiting claims of decoupling and genuine green growth in Nordic countries. Ecol. Econ. 187, 107101.
Trencher, G., Truong, N., Temocin, P., Duygan, M., 2021. Top-down sustainability transitions in action: How do incumbent actors drive electric mobility diffusion in China, Japan, and California? Energy Res. Soc. Sci. 79, 102184.
Ulucak, R., Kassouri, Y., 2020. An assessment of the environmental sustainability corridor: Investigating the non-linear effects of environmental taxation on CO_2 emissions. Sustain. Dev. 28 (4), 1010–1018.
Ulucak, R., 2020. How do environmental technologies affect green growth? Evidence from BRICS Economies. Sci. Total Environ. 712, 136504.
Van, D.T.B., Bao, H.H.G., 2018. The role of globalization on CO_2 emission in Vietnam incorporating industrialization, urbanization, GDP per capita and energy use. J. Energy Econ Policy 8 (6), 275.
Wang, L., Su, C.W., Ali, S., Chang, H.L., 2020. How China is fostering sustainable growth: The interplay of green investment and production-based emission. Environ. Sci. Pollut. R. 27 (31), 39607–39618.
Wang, M., Liu, X., 2021. Applications of red mud as an environmental remediation material: A review. J. Hazard. Mater. 408, 124420.
Wang, M., Li, X., Wang, S., 2021. Discovering research trends and opportunities of green finance and energy policy: A data-driven scientometric analysis. Energy Policy 154, 112295.
WB, 2022. Open Data for Indicators. https://data.worldbank.org, August 10, 2022.
WEF, 2022. Renewables Were the World's Cheapest Source of Energy in 2020, New Report Shows. https://www.weforum.org/agenda/2021/07/renewables-cheapest-energy-source, August 10, 2022.
Westerlund, J., Edgerton, D.L., 2008. A simple test for cointegration in dependent panels with structural breaks. Oxford B. Econ. Stat. 70 (5), 665–704.
Wolde-Rufael, Y., Mulat-Weldemeskel, E., 2022. The moderating role of environmental tax and renewable energy in CO_2 emissions in Latin America and Caribbean countries: Evidence from method of moments quantile regression. Environ. Chal. 6, 100412.
Yao, Y., Ivanovski, K., Inekwe, J., Smyth, R., 2019. Human capital and energy consumption: Evidence from OECD Countries. Energ. Econ. 84, 104534.
Yasin, I., Ahmad, N., Chaudhary, M.A., 2021. The impact of financial development, political institutions, and urbanization on environmental degradation: Evidence from 59 less-developed economies. Environ. Dev. Sustain. 23 (5), 6698–6721.
Zhang, D., 2021. Fiscal policy benefits and green recovery of firms: An experimental exploration of Chinese listed firms in Post-Covid-19. Econ Change Restruct. https://doi.org/10.1007/s10644-021-09344-6.