

Drivers of Environmental Degradation in Nordic Nations: The Role of Financial Development, Economic Expansion, trade openness, and Natural Resources

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Abstract

The current study aims to analyze the effect of financial development, economic expansion, trade openness, and natural resources on the carbon emission situation in the Nordic countries over the span of 1980 to 2021. The study adopted the Panel Autoregressive Distributed Lag (ARDL) model to get insights on the relationship between the study variables in both the long and short run.

The findings indicate that in the long run, financial development increased carbon emissions, while economic growth and trade openness reduced it. However, in the short run, financial development mitigated the carbon emissions, contrary to the GDP, which further complicated the environmental situation. Furthermore, the Granger causality analysis indicated a one-way causality direction from financial development, economic expansion, and trade openness to carbon emissions.

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1. Introduction

Scholars over the last decades have shifted their intention to the environmental impact of the social and economic activities (Ahmad, et al., 2020; Wei & Nie, 2024; Yang, Wu, Sharif, & Uddin, 2023). Their current debates are on how we can achieve increasing and steady economic growth without harming the environment that we are living in, in other words, achieving long-term sustainability by reducing gas emissions. One of the factors that can be explored to mitigate the environmental degradation is financial development. The later variables have been found to reduce the environmental impact in several studies (Destek, Yildirim, & Manga, 2024; Rahman, Khan, Khan, & Tariq, 2023).

On the one hand, (Destek, Yildirim, & Manga, 2024) examined the role of financial development in enhancing environmental situations in the BRICS-T economies. The established that financial development has hindered the CO₂ emission, thus making the transition from the potential haven hypothesis into the halo hypothesis over the study time span. Similarly, results indicated that financial development significantly reduced carbon emission when (Zhou, Abbas, Najam, & Alvarez-Otero, 2023) explored the complex links among financial development and CO₂ emission in Asian emerging economies.

On the other hand, economic growth has also been well established to be one of the crucial drivers of carbon emissions (Alola, Celik, Awan, Abdallah, & Obekpa, 2023; Owusu, Chuanbo, & Qiao, 2024). However, the impact of economic growth is diverse. For instance, according to (Alola, Bekun, Obekpa, & Adebayo, 2024), who examined the impact of economic growth on carbon emissions in the Nordic countries during the pre-COVID-19 period, discovered that economic growth further worsens the environmental situation. In contrast, (Alola, Celik, Awan, Abdallah, & Obekpa, 2023) evaluated the effect of economic growth on environmental degradation in Denmark, Finland, Norway, and Sweden and found out that greenhouse gas emissions are decreased by economic expansionary policies that push for faster economic growth. Furthermore, other scholars suggested that trade openness (Ashraf, Ashraf, & Javed, 2023; Su, Wang, Li, & Wang, 2022) and natural resources (Khan, et al., 2020; Li, Li, Zheng, & Si, 2023; Yang, Wu, Sharif, & Uddin, 2023) have an important role in mitigating or aggravating the environmental situation.

Based on the aforementioned, aims to analyze the effect of financial development, economic growth, trade openness, and natural resources on the environmental situation in the Nordic countries over the span of 1980 to 2021. The study adopted the Panel Autoregressive Distributed Lag (ARDL) model to get insights on the relationship between the study variables in both the long and short run.

Following the introduction, the remainder of this research is organized as follows. In Section 2, past literature related to this topic is reviewed. The methodology and data sources are covered in Section 3. The empirical findings and their discussion are presented in Section 4. Finally, section 5 contains the conclusions and policy recommendations.

2. Literature review

2.1 Financial development and environment degradation

(Destek, Yildirim, & Manga, 2024) assessed the role of financial development in enhancing environment situation in the BRICS-T economies from 1995 to 2020. The findings suggested the presence of cross-sectional problem between the countries in addition to a long run cointegration relationship between financial development and carbon emission timeseries, which motivated the authors to apply cross-sectional ARDL approach for long and run analysis. It was established that the financial development has hindered the CO₂ emission thus making transition from potential haven hypothesis into the halo hypothesis over the study time span. As per (Rahman, Khan, Khan, & Tariq, 2023), The degree to which a collective financial development would shape the environmental situation in newly industrialized countries in the short run is unclear due to the low statistical significance. However, in the long run, financial development has increased the energy intensity hence leading to the rise in carbon emission. Causality analysis revealed a two-way granger causality between financial development and carbon emission through energy intensity. The influence of financial development and renewable energy on environment degradation was explored by (Wei & Nie, 2024). Employing the panel ARDL, Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) techniques the empirical findings exhibit that carbon emission did not impact by the financial development nor the renewable energy, this result was further validated by the granger causality test. In different study, (Hu, Alola, Tauni, Adebayo, & Abbas, 2023) conducted a novel wavelet local multiple correlation method in the case of Canada using quarterly data from 1984Q1 to 2021Q4. The suggested that financial development reduced environment degradation in short and long run. (Zhou, Abbas, Najam, & Alvarez-Otero, 2023) explore the complex links among financial development and gas emission in Asian emerging nations from 2010 to 2021 by the means of pane ARDL methodology. Results indicated that financial development significantly reduced carbon emission.

2.2 Economic growth and environment degradation

(Alola, Bekun, Obekpa, & Adebayo, 2024) examined the impact of economic growth on the carbon emission in the Nordic countries pre covid-19 period by employing robust panel estimation technique and discovered that economic growth further worsens the environment situation. Moreover, this result was confirmed by the Granger causality analysis framework that revealed the existence of a one-way causality direction going from economic growth to CO₂ emission. Using yearly data from 1995 to 2020, (Alola, Celik, Awan, Abdallah, & Obekpa, 2023) evaluated the effect of economic growth on environment degradation in Denmark, Finland, Norway, and Sweden. Driscoll- Kraay's standard errors for RE with individual effects results show that the Nordic region's greenhouse gas emissions are decreased by economic expansionary policies that push for faster economic growth. By emphasizing the region's existing strong position as a driving force in seeking a sustainable environment and carbon neutrality, this finding advances the green transition and the creation of a sustainable economy. According to research conducted by (Owusu, Chuanbo,

& Qiao, 2024), economic growth has enhanced the environmental situation only in Denmark and Finland where in Iceland, Norway, and Sweden economic expansion has increased considerably the gas emission. The Granger causality analysis made by the authors revealed that there is a one-way causality from economic growth to gas emission.

2.3 Trade openness and environment degradation

In the framework of environmental pollution for 116 economies, (Su, Wang, Li, & Wang, 2022) assessed the role of trade openness. The findings showed that the rise in per capita use of renewable energy is influenced by trade structure, or trade openness. Hence leading to less carbon emission. According to (Rahman, Khan, Khan, & Tariq, 2023), Long-term trade openness lowers energy intensity, but not immediately. Furthermore, the Granger causality analysis indicated that energy intensity causes trade openness and not the other way around. (Ashraf, Ashraf, & Javed, 2023) explore the complex intercorrelation links between trade openness and carbon emission in 75 Belt and Road Initiative countries between 1990 and 2019. Findings using spatial econometric framework reveal that trade openness has a positive effect on carbon emission.

2.4 Natural resources and environment degradation

(Yang, Wu, Sharif, & Uddin, 2023) investigated the influence of natural resources exploration and other macroeconomic variables on the ecological footprint in the Nordic countries by employing Method of the Moments Quantile Regression (MMQR), which is a novel quantile-based regression method to reveal asymmetric effect between the model variables. The results suggested that natural resources further worsen the environment degradation situation in the Nordic countries across all quantiles. Furthermore, the authors confirm these results by employing Common Correlated Effect Mean Group (CCEMG) and Augmented Mean Group (AMG). According to (Ahmad, Pata, Ahmed, & Zhao, 2024) the results of direct and indirect analysis regression demonstrated that natural resources abundance considerably reduced the CO₂ emission in twenty-five European union countries. Using dynamic ordinary least square and (DOLS), fully modified ordinary least square (FMOLS), and canonical cointegration regression (CCR) approaches (Li, Li, Zheng, & Si, 2023) assessed the role of natural resource rent on environmental situation in upper-middle income countries between 1984 and 2021. According to the empirical results natural resources have positive and significant effect on carbon emission. By employing panel ARDL (Ahmad, et al., 2020) revealed that in both long and short run natural resources increase CO₂ emission, hence worsen the environment situation in the case of emerging countries. In the case of BRICS economies (Khan, et al., 2020) adopted AMG, and FM-LS panel approaches and have arrived to the same conclusion as the previous studies. Furthermore, the Granger causality analysis made by (Li, Li, Zheng, & Si, 2023) in the case of upper-middle income countries and (Ahmad, et al., 2020) in the case of emerging countries both revealed that the two variables have a bidirectional causality.

2.5 Research gap

According to the aforementioned literature, no researchers have yet conducted studies on how five Nordic nations' economies, economic growth, financial development, trade openness, natural resources, and environmental sustainability interact. Scholars have made some attempts to investigate different fields, but the results of their research have not been methodically combined. Earlier studies have found a number of gaps. Interestingly, no thorough investigation of the connection between financial development and carbon emission in the Nordic economies. The current paper investigates this unexplored research area by analyzing the effect of the financial development on environmental degradation using panel ARDL framework. Moreover, this empirical investigation consists of economic growth while accounting for other significant drivers such as trade openness and natural resources, considerably adding knowledge to the established academic literature. Additionally, there is a critical necessity for further research leveraging the causality analysis to examine the direction of causality between endogenous variable and exogenous variables. This study equips policymakers and stakeholders with the insights needed to craft policies that are precisely aligned with the distinct environmental and socioeconomic contexts of the targeted regions, fostering sustainable development and resilience.

3. Methodology strategy

3.1 Variables and data sources

Relaying on yearly observations, the current study examined how the Nordic countries namely Denmark, Finland, Iceland, Norway, and Sweden environment degradation (CO_2) were affected between 1980 and 2021 by economic growth (GDP per capita), financial development (FD), trade openness (TR), and natural resources exploration (NR). The data was collected from the world development indicators (WDI) database except for the financial development index it was gathered out of the database of International Monetary Fund (FMI). Table below offers a more detailed description of the chosen variables, unit of measurement, their assigned abbreviations, and their data repository.

Table 1. Variable's definition and measurement

Variables	Description	Scale of measurement	Reference source
CO_2	CO_2 emission per capita	Tones per person	WDI
GDP	Gross Domestic Product	GDP per capita in constant 2015US\$	WDI
FD	Financial development index	Index	IMF
TR	Trade openness	Trade (% of GDP)	WDI
NR	Natural Resources	Total natural resources rents (% of GDP)	WDI

Source: Authors' own construction

3.2 Theoretical framework

Following the previous empirical literature review on environmental degradation, we employ the following equation:

$$CO2_{nt} = \alpha_0 + \alpha_1 GDP_{nt} + \alpha_2 FD_{nt} + \alpha_3 TR_{nt} + \alpha_4 NR_{nt} + \varepsilon_{nt} \quad (1)$$

Where $CO2_{nt}$ reflects the environment degradation, GDP_{nt} is the gross domestic product per capita to control for the effect of population in addition it is in the constant US dollars to account for inflation, FD_{nt} is the financial development index, TR_{nt} is the trade openness measured as fraction of GDP, NR_{nt} is natural resources as a percentage of GDP, and ε_{nt} is the error term.

3.3 Econometric framework

This study aims to analyze the impact of economic growth, financial development, trade openness, and natural resources on the environmental degradation in the Nordic countries. To this end, the short and long run analysis and causality analyses are employed to get insights on the dynamic relationship between the latter variables. Given that the Nordic countries are located close to each other and they have roughly similar economic and social structure, there is the possibility of spillover effect between them, which may lead to the existence of cross-sectional problem. The use of CSD testing is necessary since a shock in one nation might have a quick impact on others. The slope homogeneity test, which is a crucial step when working with panel data, will be applied next. Thirdly, we will use either the first-generation unit root tests or the second-generation unit root tests following the verification of the cross-sectional dependence and slope consistency findings. Fourth, the existence of cointegration between the time series will be evaluated using the proper tests once the results of the CSD tests have been verified and the sequence of time series integration has been established. Fifth, in order to get the most dependable and efficient outcomes, we will select the best ARDL model. Finally, we will examine the path of causation between the endogenous and exogenous variables.

3.4 Cross sectional dependency tests

The initial step in our econometric analyses involves conformation the existence of cross-sectional dependency between the countries in our sample. The CSD issue requests to be addressed to guarantee the robustness of model parameters. To this end, the (Pesaran, Shin, & Smith, 2021) and (Pesaran, 2007) CSD test is applied to the data. Regardless of whether T is larger than N or N is bigger than T, this test yields reliable findings. The following formula displays the test statistics for the CSD test (Pesaran, Shin, & Smith, 2021):

$$CSD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N K_{ij} \right) \quad (2)$$

Where T denotes the temporal dimension in the panel, in our case it's the time period from 1980 to 2021, whereas N stands for the cross-sectional dimension, currently the Nordic countries, and the

Ordinary Least Squares (OLS) correlation estimates among the module estimated residuals of notation i and j as determined by the variable K_{ij} .

3.5 Slope homogeneity diagnostics

The slope homogeneity test is employed to assess whether the slope coefficients in a regression model are equal across all countries in a panel dataset. For the current research, we employ the slope homogeneity test developed by (Pesaran & Yamagata, 2008) sometimes referred to as “Delta test”. This test examines whether the slopes are homogeneous across all countries and it takes into account the problem of CSD, hence, it gives robust results. The mathematical formula of delta assessment is derived by employing the following equations:

$$\Delta = \sqrt{N \frac{N^{-1}S-K}{\sqrt{2K}}}; \Delta_{adj} = \sqrt{N \frac{N^{-1}S-K}{\sqrt{\frac{2K(T-K-1)}{T+1}}}} \quad (3)$$

3.6 First and second generation panel unit root tests

To assess the stationarity characteristics of our time series under investigation, we can employ panel first generation unit root tests such as the Im, Pesaran, and Shin test proposed by (Im et al., 2003) or Levin, Lin, and Chu (LLC) developed by (Levin et al., 2002) or several others commonly known by the first generation tests. Moreover, we can adopt the Augmented Im, Pesaran, and Shin (CIPS), which is an augmented version of Im, Pesaran, and Shin test, and Cross-sectionally Augmented Dickey-Fuller (CADF) developed by Pesaran (2007). The main difference between the previous two generations tests is that the second-generation unit root tests are more powerful and robust in the case of CSD problem and slope heterogeneity. The CADF formula is expressed mathematically as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \theta \bar{y}_{t-1} + \sum_{j=1}^p \gamma_{ij} \Delta y_{it-1} + \sum_{j=0}^p \delta_{ij} \Delta \bar{y}_{t-j} + d_{it} + \varepsilon_{it} \quad (4)$$

Where t stands for the time dimension, α_i is the intercept, y_{it} are the variables, Δ is the difference operator, and ε_{it} is the error term. The CIPS statistic, in turn, is calculated by taking the average the CADF values for each and every i . The corresponding equation is:

$$CIPS(N, T) = \frac{1}{N} \sum_{i=1}^N t_i(N, T) \quad (5)$$

3.7 Co integration tests

Several cointegration can be applied to test the long run relationship between panel time series. One of the commonly used panel cointegration test by econometricians is the one proposed by Westerlund and Edgerton (2007). This test is more reliable when CSD problems appears because it allows for dependence in both between and inside CSD units. The test generates four panel cointegration statistics that do not impose common factor limitation and are derived from structural

dynamics rather than residual dynamics. The first two tests provide insights wither some panels are cointegrated. The other two, test if the panel as whole is cointegrated. This test examines the null hypothesis of no cointegration by relaying on error correction model. Statistically the model is written as shown:

$$y_{nt} = \lambda_{0n} + \lambda_{1nt} + \alpha_n D_{nt} + x_{nt} \beta_n + (D_{nt} x_{nt})' \gamma_n + \omega_{nt} \quad (6)$$

Where n is the cross-sectional dimension, t stands for time dimension, λ_{0n} and α_n are unknown parameters vectors.

3.8 Panel ARDL model

Popular approach to explore the symmetric relationship in the long and mid term between time series variables scholars uses ARDL bound test approach. This approach was first proposed by (Pesaran, 2007) and later proposed by (Pesaran, Shin, & Smith, 2021) as an effective approach to explore the long and short run relationship between times series. In this study, we adopt the ARDL approach to investigate the impact of economic growth, financial development, trade openness, and natural resources on the environmental degradation in the Nordic countries. One of the strong features of panel ARDL that it allows for heterogeneity across units thus allowing for the capture of social, economic, and technological differences between five countries in our sample.

In contrast to the other panel data approaches, panel Autoregressive Distributed Lag (ARDL) permits diverse lag structure across all variables in the model, thereby making it possible to capture the unique temporal dynamics for each country. Such flexibility is key to understand the effect of economic growth, financial development, trade openness, and natural resources on the environmental degradation across our sample. Additionally, panel ARDL is capable of accommodating variables of different integration orders (I (0) and I (1)) and endogeneity issues. Furthermore, the error correction model in the Autoregressive Distributed Lag approach gives robust estimation on the rate of convergence to long-run equilibrium, providing valued economic insights on how effectively Nordic nations can tackle environmental degradation challenges. As shown in equation below, the long run ARDL estimate is calculated as follows:

$$\begin{aligned} CO2 = & \alpha_0 + \alpha_1 CO2_{t-1} + \alpha_2 GDP_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 TR_{t-1} + \alpha_5 NL_{t-1} + \\ & \sum_{i=1}^m \beta_1 \Delta CO2_{t-i} + \sum_{i=1}^m \beta_2 \Delta GDP_{t-i} + \sum_{i=1}^m \beta_3 \Delta FD_{t-i} + \sum_{i=1}^m \beta_4 \Delta TR_{t-i} + \\ & \sum_{i=1}^m \beta_5 \Delta NR_{t-i} + \varepsilon_t \end{aligned} \quad (2)$$

The null hypothesis that assumes no cointegration is evaluated against the alternative hypothesis that suggests the presence of cointegration. The null hypothesis, which states that all β_i are equal, is dismissed if the F-statistic is larger than the lower and upper bounds.

The error correction term and short run coefficients are evaluated using the error correction model (ECM), which was put out by **Invalid source specified..** The short-term interactions between the model variables are represented by the panel ARDL estimate using error correction representation in the following equation:

$$CO_2 = \beta_0 + \sum_{i=1}^m \beta_1 \Delta CO_{2,t-i} + \sum_{i=1}^m \beta_2 \Delta GDP_{t-i} + \sum_{i=1}^m \beta_3 \Delta FD_{t-i} + \sum_{i=1}^m \beta_4 \Delta TR_{t-i} + \sum_{i=1}^m \beta_5 \Delta NR_{t-i} + \theta ECT_{t-i} \varepsilon_t \quad (3)$$

Where θ is the change rate.

3.9 Causality test

Understanding the causal relationship between environmental degradation, economic growth, financial development, trade, and natural resources exploration can provide valuable insights to the academic debate and useful information to policymakers. For this reason, we employ causality analysis framework Formulated by **Invalid source specified**. to explore the existence and direction of causality, primarily focusing on the causality direction between endogenous variable and exogenous variables in our model. This test is more robust than panel Granger causality test in case of CSD between the G-7 countries. Statistically the **Invalid source specified**. is written as follows:

$$y_{it} = \alpha_i + \sum_{j=1}^j \beta_i^j y_{i(t-j)} + \sum_{j=1}^j \gamma_i^j x_{j(t-j)} + \varepsilon_{it} \quad (9)$$

Where y and x are the variables in the model, β_i^j stands for the autoregressive parameters, and γ_i^j is the estimations of regression parameters.

4. Results and discussion

4.1 Descriptive statistics

Table 2 presents the primary descriptive univariate statistics for both the dependent and independent variables. Based on the central tendency and dispersion indicators, the CO₂ emission variable has a mean of 8.86 with a standard deviation of 2.20. FD variables and TR averages are 0.53 and 74.19 with a standard deviation of 0.16 and 13.21, respectively. Economic growth's variable and NR averages are 8.86 and 1.78 with a standard deviation of 2.20 and 2.89, respectively. In addition, measures of asymmetry are provided.

Table 2. Descriptive statistics

	CO ₂	GDP	FD	TR	NR
Mean	8.868	25.672	0.537	74.198	1.7826
Median	8.884	26.184	0.550	71.225	0.4765
Maximum	14.228	27.070	0.810	111.89	12.617
Minimum	3.544	22.652	0.130	43.481	0.000
Std. Dev.	2.203	1.287	0.164	13.219	2.897
Skewness	-0.181	-1.323	-0.300	0.649	1.965
Kurtosis	2.495	3.185	2.251	3.458	5.726
Observations	210	210	210	210	210

Source: Authors' own construction

4.2 Cross-sectional dependency tests

Before any further statistical analyses, it is essential to test the presence of CSD. Three main cross-sectional dependency are employed in this study namely Breusch-Pagan LM, Pesaran CD, and Pesaran scaled LM. The main hypothesis tested is the absence of cross-sectional dependency. The results showed in table 3 showed that the calculated statistic of Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD are 124.02, 25.49, and 7.49, respectively. All calculated p-values for the three tests are less than 0.01% this result leading to the rejection of the null hypothesis. In other words, confirming the existence of cross-sectional dependency problem between the countries dues to the strong evidence against the null hypothesis.

Table 3. Cross-sectional dependency results

Test	Statistic	d.f.	p-value
Breusch-Pagan LM	124.0213	10	0.0000
Pesaran scaled LM	25.49594		0.0000
Pesaran CD	7.493		0.0000

Source: Authors' own construction

4.3 Slop homogeneity test

Testing for slop homogeneity is crucial after the confirmation of the existance of cross-sectional dependence between the sample countries. The purpose of this statistical test is to determine if the slope coefficients in various regressions are the same in each nation, as well as in our study throughout the Nordic nations. Table 4 displays the findings of the test (Pesaran & Yamagata, 2008), which examines the null hypothesis of slop homogeneity. The findings provide compelling evidence that slops varied among the Nordic countries over the research period.

Table 4. Slop homogeneity results

Delta	p-value
15.460	0.000
16.699	0.000

Source: Authors' own construction

4.4 Unit root tests

Since there is a cross-sectional dependency problem in our yearly data, the first-generation tests of unit root tests are not compatible with the data characteristics and it can lead to a non-reliable outcome. Hence, second-generation unit root tests are more suitable for our time series because they take into consideration the cross-sectional dependency between variables. The CIPS and CADF unit root test, as shown in table 5, indicates that none of the study variables is integrated of the second order. Moreover, the results indicate that the variables have an integrated order of one. Meaning that the application of panel ARDL is possible.

Table 5. Panel unit root tests results

	I(0)		I(1)		Decision
	CADF test	CIPS test	CADF test	CIPS test	
CO2	-2.157	-3.601	-3.778 ***	-6.420 ***	I(1)
GDP	-0.801	-1.202	-3.611 ***	-5.632 ***	I(1)
FD	-2.291	-3.101	-3.381 ***	-6.405 ***	I(1)
TR	-2.109	-2.357	-3.489 ***	-5.088 ***	I(1)
NR	-1.984	-2.612	-3.341 ***	-5.893 ***	I(1)

Note: ***, **, and * stands for 10%, 5%, and 1% significance level respectively.

Source: Authors' own construction

4.5 panel cointegration tests

Table 6 presents the results of (Westerlund & Edgerton, 2007) test for cointegration, which takes in account the presence of cross-sectional dependency between variables. We examined the presence of cointegration both for individual panels and across all panels, and the empirical finding confirmed the existence of cointegration at the 5% significance level. This indicates that the variables time series share a long-run relationship with one another.

Table 6. Cointegration results

Co-integrating vector	Test	Stat.	p-value	Decision
Some panels are co-integrated	Variance ratio	-1.8652	0.0311	The series are co-integrated
All panels are co-integrated	Variance ratio	-1.4780	0.0437	

Source: Authors' own construction

4.6 Estimation of panel ARDL

Table 7 displays the estimated results for both panel ARDL short- and long-run findings. The results indicate that while financial development has a negative and statistically significant effect on carbon emission in the near-term analysis, it shows a statistically significant positive impact in the long-term analysis. Precisely, a one percent increase in financial development is associated with a 13.71 unit increase in CO2 emission. (Destek, Yildirim, & Manga, 2024) established that the financial development has hindered the CO2 emission, thus making transition from potential haven hypothesis into the halo hypothesis over the study time span. Similarly, (Rahman, Khan, Khan, & Tariq, 2023) concluded that in the long run, financial development has increased the energy intensity hence leading to the rise in carbon emission. As per the short run results, they are in line with the findings of (Hu, Alola, Tauni, Adebayo, & Abbas, 2023) and (Zhou, Abbas, Najam, & Alvarez-Otero, 2023). They found that financial development reduced environmental degradation in short run. However, our findings indicate that while short-term policies designed to reduce the

effects of financial development on carbon emission may yield near-term results, they are inadequate for addressing long-term challenges.

The estimations suggested that while economic expansion has significantly raised on the carbon emission in the near-term analysis, it exhibits a negative influence in the long-term analysis. Exactly, a one percent rise in economic growth raises the carbon emission by 9.33 units in the short run. However, in the long run, this impact reverses, with a 1% increase leading to a -8.08 unit decline in CO₂ emission in the Nordic nations. These results are statistically significant in both long and short relationships. The outcomes of the short run relationship align with those of (Alola, Bekun, Obekpa, & Adebayo, 2024) who examined the impact of economic growth on the carbon emission in the Nordic countries pre covid-19 period and discovered that economic growth further worsens the environment situation. In contrary, the long run results are contrast with the previous studies. Notably, (Alola, Celik, Awan, Abdallah, & Obekpa, 2023) results show that the Nordic region's greenhouse gas emissions are decreased by economic expansionary policies that push for faster economic growth. By emphasizing the region's existing strong position as a driving force in seeking a sustainable environment and carbon neutrality, this finding advances the green transition and the creation of a sustainable economy.

The results also indicate that while the trade openness has a negative statistically insignificant effect on carbon emission in the short run, it shows a negative and statistically significant impact in the long run. Specifically, a 1% increase in trade openness reduces CO₂ emission by -0.11 units in the long term. These long-run findings align with those of (Rahman, Khan, Khan, & Tariq, 2023) for newly industrialized countries, where the author established that long-term trade openness lowers energy intensity, but not instantly. Accordingly, (Su, Wang, Li, & Wang, 2022) found the same results in a large econometric study that included 116 countries all around the world. Our study's findings showed that trade structure, or trade openness, influences the rise in the amount of renewable energy consumed per person. Hence leading to less carbon emission in the Nordic countries.

The results indicate that natural resources exploration has a statistically insignificant diverse effect on carbon emission in both mid and long terms. The short run insignificant influence is in line with the work of (Yang, Wu, Sharif, & Uddin, 2023) and (Ahmad, Pata, Ahmed, & Zhao, 2024). This means that the Nordic countries transition policies from nonrenewable energies to green energy are working but needs more time and corrections for a better result. According to the error correction term, which is negative and statistically significant at the one percent level, the correction time is around 0.13 units.

Table 7. Short and long run panel ARDL outcomes

Variable	Coeff.	S.D.	t-Statistic	P-value.*
Panel A: Long Run estimations				
GDP	-8.0892	2.6719	-3.03	0.002
FD	13.7116	4.3308	3.17	0.002
TR	-0.1193	0.0354	-3.37	0.001
NR	-0.1338	0.2534	-0.53	0.598
Panel B: Short Run estimations				
COINTEQ01	-0.1273	0.0323	-3.93	0.000
D(CO2(-1))	-0.1863	0.0881	-2.11	0.035
D(GDP)	9.3355	2.4852	3.76	0.000
D(GDP(-1))	-0.0053	1.7110	-0.00	0.997
D(FD)	-3.3347	1.5246	-2.19	0.029
D(FD(-1))	-0.3358	1.2966	-0.26	0.796
D(TR)	-0.0109	0.0092	-1.19	0.235
D(NR)	243.2325	242.4796	1.00	0.316
C	27.9575	7.3008	3.83	0.000

Source: Authors' own construction

4.7 Causality analyses

As a final step to conclude our empirical investigation and after establishing a long and mid-term relationship among our endogenous and exogenous variables, we proceed to causality analyses. The D-H causality test, as shown in table 8, outputs revealed that there is a significant unidirectional causality between financial development and carbon emission at the 1% level. Our results are contradictory to the ones reported by (Rahman, Khan, Khan, & Tariq, 2023), who reported a bidirectional causation between these variables, indicating a reciprocity impact between financial development and carbon emissions. This variation could be due to variations in methodological approaches, selection for included data, or context specific to the regions or time ranges for which the study was conducted. However, even though our findings highlight the need to be mindful of the direction of causality in formulating policies for the mitigation of carbon in the atmosphere via financial development initiatives.

Similarly, a unidirectional causality is established between both economic growth and carbon emission at the 5% level. This result is in line with (Alola, Bekun, Obekpa, & Adebayo, 2024) and (Owusu, Chuanbo, & Qiao, 2024), their results confirmed the existence of a one-way Granger causality from economic expansion to carbon emission. Additionally, a unidirectional causality is established between trade openness and carbon emission at the 5% level, which is resembling to the findings of (Rahman, Khan, Khan, & Tariq, 2023). Additionally, there is significant one-way causality between carbon emission and natural resources. These findings imply that more CO₂ emission, often resulting from industrial activities or transportation, set in motion environmental degradation, such as deforestation or loss of biodiversity in the Nordic countries, which in turn

reduces natural resources. This conclusion highlights the significance of undertaking carbon emissions as a crucial driver of environmental degradation and the need for strategies that mitigate emissions to protect natural resources.

Table 8. D-H causality results

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
$CO_2 \Rightarrow GDP$	0.3893	-0.9566	0.3388
$GDP \Rightarrow CO_2$	2.8382	2.5598	0.0105
$CO_2 \Rightarrow FD$	1.98014	1.32762	0.1843
$FD \Rightarrow CO_2$	3.52317	3.54328	0.0004
$CO_2 \Rightarrow TR$	1.29263	0.34042	0.7335
$TR \Rightarrow CO_2$	2.55010	2.14604	0.0319
$CO_2 \Rightarrow NR$	2.92949	2.69081	0.0071
$NR \Rightarrow CO_2$	1.48046	0.61012	0.5418

Note: $\Rightarrow$ is the direction of causality.

Source: Authors' own construction

5. Conclusion

The current study aims to analyze the effect of financial development, economic growth, trade openness, and natural resources on the environmental situation in the Nordic countries over the span of 1980 to 2021. The study adopted the Panel Autoregressive Distributed Lag (ARDL) model to get insights on the relationship between the study variables in both the long and short run. Before the selection of the ARDL model, three main cross-sectional dependency are employed in this study namely Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD. The main hypothesis tested is the absence of cross-sectional dependency. Second, the findings of the test slop homogeneity provided compelling evidence that slops varied among the Nordic countries over the research period. Third, the CIPS and CADF unit root test, as shown indicated that none of the study variables is integrated of the second order. Forth, the results of test for cointegration confirmed the existence of cointegration at the 5% significance level.

Five, the ARDL (1,1,1,0,0) model was selected to estimate the effect between our variables. The findings indicate that in the long run, financial development increased carbon emissions, while economic growth and trade openness reduced it. However, in the short run, financial development mitigated the carbon emissions, contrary to the GDP, which further complicated the environmental situation. Specifically, while financial development has a negative and statistically significant effect on carbon emission in the near-term analysis, it shows a statistically significant positive impact in the long-term analysis. Explicitly, a one percent increase in financial development is associated with a 13.71 unit increase in CO₂ emission. Moreover, the estimations suggested that while economic expansion has increased the carbon emission in the near-term analysis, it exhibits a negative influence in the long-term analysis. Precisely, a one percent rise in economic growth raises the carbon emission by 9.33 units in the short run. However, in the long run, this impact reverses, with a 1% increase leading to a -8.08 unit decline in CO₂ emission. Finally, the Granger

causality test revealed a one-way causality direction from financial development, economic growth, and trade openness to carbon emissions. These findings provide comprehensive insights for the policymakers.

6. Bibliography List

Ahmad, M., Jiang, P., Majeed, A., Umar, M., Khan, Z., & Muhammad, S. (2020). The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: an advanced panel data estimation. *Resources Policy*, 69, 101817.

Ahmad, M., Pata, U. K., Ahmed, Z., & Zhao, R. (2024). Fintech, natural resources management, green energy transition, and ecological footprint: Empirical insights from EU countries. *Resources Policy*, 92, 104972.

Alola, A. A., Bekun, F. V., Obekpa, H. O., & Adebayo, T. S. (2024). Explaining the environmental efficiency capability of energy mix innovation among the Nordic countries. *Energy Reports*, 11, 233-239.

Alola, A. A., Celik, A., Awan, U., Abdallah, I., & Obekpa, H. O. (2023). Examining the environmental aspect of economic complexity outlook and environmental-related technologies in the Nordic states. *Journal of Cleaner Production*, 408, 137154.

Ashraf, J., Ashraf, Z., & Javed, A. (2023). The spatial spillover effects of energy transition and trade openness on CO2 emissions. *Energy and Buildings*, 292, 113167.

Destek, M. A., Yildirim, M., & Manga, M. (2024). High-income developing countries as pollution havens: Can financial development and environmental regulations make a difference? *Journal of Cleaner Production*, 436, 140479.

Hu, B., A. A., Tauni, M. Z., Adebayo, T. S., & Abbas, S. (2023). Pathway to cleaner environment: How effective are renewable electricity and financial development approaches? *Structural Change and Economic Dynamics*, 67, 277-292.

Khan, A., Muhammad, F., Chenggang, Y., Hussain, J., Bano, S., & Khan, M. A. (2020). The impression of technological innovations and natural resources in energy-growth-environment nexus: a new look into BRICS economies. *Science of The Total Environment*, 727, 138265.

Li, J., Li, Y., Zheng, Z., & Si, X. (2023). Environment and natural resources degradation under COVID-19 crises: Recovery post pandemic. *Resources Policy*, 83, 103652.

Owusu, S. M., Chuanbo, F., & Qiao, H. (2024). Examining economic policy uncertainty's impact on environmental sustainability: Insights from nordic nations. *Journal of Cleaner Production*, 449, 141688.

- Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of applied econometrics*, 22(2), 265-312.
- Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics*, 142(1), 50-90.
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2021). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, 16(3), 289-326.
- Rahman, M. M., Khan, Z., Khan, S., & Tariq, M. (2023). How is energy intensity affected by industrialisation, trade openness and financial development? A dynamic analysis for the panel of newly industrialized countries. *Energy Strategy Reviews*, 49, 101182.
- Su, M., Wang, Q., Li, R., & Wang, L. (2022). Per capita renewable energy consumption in 116 countries: The effects of urbanization, industrialization, GDP, aging, and trade openness. *Energy*, 254, 124289.
- Wei, Z., & Nie, C. (2024). The dynamics of natural resources, renewable energy, and financial development on achieving ecological sustainability. *Resources Policy*, 95, 105093.
- Westerlund, J., & Edgerton, D. L. (2007). A panel bootstrap cointegration test. *Economics letters*, 97(3), 185-190.
- Yang, B., Wu, Q., Sharif, A., & Uddin, G. S. (2023). Non-linear impact of natural resources, green financing, and energy transition on sustainable environment: A way out for common prosperity in NORDIC countries. *Resources Policy*, 83, 103683.
- Zhou, P., Abbas, J., Najam, H., & Alvarez-Otero, S. (2023). Nexus of renewable energy output, green technological innovation, and financial development for carbon neutrality of Asian emerging economies. *Sustainable Energy Technologies and Assessments*, 58, 103371.