Green Economy Transition in Europe: Balancing Trade Competitiveness and Carbon Emission Reduction

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Abstract
As the world transitions to renewable energy using different policies to ensure compliance, there is a need to understand how these affect several aspects of the economy. This research explored green economy transition in Europe and its impact on trade competitiveness and carbon emission reduction. The Panel ARDL and cointegration was used to analyse the data from different Europian countries from 1991 to 2023. The green transition strategy was capured using carbon pricing. The relevant data was obtained from the World Bank Group. The result revealed that carbon pricing had a negative and significant impact on reducing carbon emissions, while energy consumption and industrial output had a positive and significant impact on carbon emissions. Carbon pricing was also discovered to have a positive relationship with trade balance, which suggests that carbon pricing may not necessarily affect trade balance negatively in the selected countries. The study recommends priotisation of policies that encourage investments in clean energy infrastructure and innovation.

Keywords: green economy, carbon pricing, carbon emmission, energy consumption, renewable energy, trade balance

1. Introduction

1.1 Background to the Study

Over the years, global warming has driven a set of changes to the Earth's climate and weather systems. This continuous increase in temperature is associated with the emission of greenhouse gases (GHG). According to the International Energy Agency (IEA, 2023), the global total carbon dioxide emissions were 37.4 gigatons as of 2024. This raises concerns and the need to develop strategies to achieve net-zero emissions (Song *et al*., 2023). As the world adopts these strategies, it is important to assess their effectiveness in reducing carbon emissions (Gu *et al*. 2023).

Emissions are still rising in many parts of the world. While several countries like Denmark and Sweden have managed to cut their emissions in recent decades. However, other countries like still depend heavily on fossil fuel. Non-renewable energy sources (fossil fuels) have continued to dominate the energy system for decades. In 2023, fossil fuels comprising petroleum, natural gas, and coal amounted to about 83% of total U.S energy consumption (EIA 2024). This dependence on fossil fuels for energy poses numerous challenges, including imbalances between supply and demand in the domestic energy market, risk of depletion of oil reserves, and the huge contribution to greenhouse gas emissions (McLellan R, 2014). Due to the large volume of CO2 emission from the non-renewable (fossil fuels) sources, there has been a huge in increase in the global temperature by roughly 1.0C above the pre industrial level and the temperature is predicted to climb by 1.5 ◦C between 2030 and 2052 (Meng, *et al*, 2018, Fawzy, 2020 and Xiao, *et al*, 2019).

Conversely, the EU has witnessed a significant decline in carbon emissions in the last two decades (Dechezleprêtre et al., 2023). According to Bianco et al. (2024), Carbon emissions in the EU 27 reduced by 689 Mt from 1995 to 2019 (Bianco et al., 2024), which may be due to the different policies adopted over the years. In 2005, the European Union launched the Emission Trading Scheme (Ellerman et al., 2016), which was designed to reduce greenhouse gas emissions by putting a price on carbon dioxide (CO2) and other emissions (Jin et al., 2016).

One of the problems with implementing fully efficient environmental policies is their impact on international trade competitiveness in the manufacturing sector, which represents a tradeoff between environmental quality and income (Wiedmann and Lenzen, 2018). These strict policies may increase the cost of production; thus, firms move their production plants to countries with less strict environmental policies (Brännlund and Lundgren, 2009). This shift reduces domestic production capacity and exports and increases imports, leading to a trade deficit. Over time, the deficit may affect other macroeconomic indicators, including reduced domestic employment in manufacturing sectors, lower GDP growth rates, and adverse economic stability impacts.

Although European countries have made significant progress in adopting green growth policies, they face challenges in maintaining a competitive edge in global trade. Aside from this, there is limited research analysing how green growth policies affect the trade competitiveness of countries in Europe. This study aims to address this gap and provides possible polices that will facilitate a sustainable and competitive green economy transition in Europe.

1.2 Hypothesis

Hypothesis 1

H_{10}: Carbon pricing has no significant effect on carbon emissions in European countries.

$H_{11:}$ Carbon pricing significantly reduces carbon emissions in European countries (negative

Hypothesis 2

$H_{20::}$ Carbon pricing has no significant effect on trade balance in European countries.

H_{21}: Carbon pricing significantly improves trade balance in European countries

1.3 Structure of the Research

This research is divided into five sections. The first sections introduce the research topic, problem and hypothsis. The second section provides a comprehensive analysis of the empirical and theoretical literature. The third section specifies the models and estimation methods used to analyse the hypothesis. The fouth section presents and discuss the result while the last section provides the conclusion and recommendations.

2. Literature Review

2.1 Empirical Literature

As the world takes different measures to achieve net-zero emissions by 2050, it is important to understand how these policies to reduce carbon emissions affect macroeconomic dynamics. While several policies have been implemented over the years, one major policy used is Carbon pricing (Narassimhan *et al*., 2022). Carbon pricing is a policy tool to lower emissions of carbon dioxide and other greenhouse gases through carbon taxes or emissions trading schemes (ETS) (Baranzini *et al*., 2017). While these policies have been adopted widely, ex-post analyses and research on their impact have been limited. Green (2021) conducted a systematic review of the literature to understand the impact of Carbon pricing on reducing greenhouse gas emissions. It was discovered that most studies suggest reductions between 0% and 2% per year, with carbon taxes generally performing better than ETSs. Using structural equation modelling on survey data from 4,800 respondents, Lonescu (2019) discovered that carbon taxes can reduce carbon emissions. However, the study used a survey analysing public opinions on carbon pricing, which may not reflect reality.

Using a cross-country analysis of 142 countries, Li and Jia (2019) discovered a positive relationship between carbon pricing and emission reduction: with each additional euro per tonne of CO_2 in carbon price, emissions growth declines by approximately 0.3 percentage points. In the EU, Dechezlêpretre *et al*. (2018), using the Difference-in-difference approach, found an Average annual reduction of 1.42% per year between 2005 and 2012. Likewise, Wagner *et al*. (2014) found a decrease in emissions by 13.5% to 19.8% from 2008 to 2012 in French manufacturing firms. However, these two studies were based on the regulated sectors directly subject to carbon regulations, such as manufacturing, power generation, and heavy industries. This confirms the argument of Cullenward and Victor (2020) that sectoral analysis provides a more practical method in analysing emission reduction as different industries face different decarbonization challenges.

Carbon prices may also have a significant effect on growth and economic inequality in a nation. In China, Lia and Jia (2019) argued that GDP will reduce more with increasing ETS price level. Mengesha and Roy (2025) also identified a regressive effect of carbon pricing, which disproportionately affects low-income populations and creates political resistance. However, this may be addressed through the addition of redistributive policies (such as carbon dividends or subsidies for clean energy). While the argument on capital pricing's negative effect has been on the increase, Driscoll (2020) discovered no significant effect on economic growth in the USA.

Uncoordinated carbon pricing policies could undermine climate action, lead to trade tensions and increase carbon leakage (WTO, 2022). According to Levinson and Taylor (2008), changes in environmental compliance costs have been estimated to account for 10 per cent of the change in US trade flows to Canada and Mexico. Using OECD and G20 countries, Ellis *et al*. (2019) found no significant relationship between carbon pricing or energy prices and net imports. However, Kurz and Rubínová (2024) discovered that a 10% increase in carbon prices leads to a decrease in export capability in the most carbon-intensive industry by 0.3% to 0.7%. Aldy and Pizer (2015) discovered that a Carbon tax of $15 per ton would increase net imports by up to 0.8 per cent for the most energy-intensive industries.

2.2 Theoretical Litrature

The relationship between green economy transition, trade competitiveness and the reduction in carbon emissions can be explained using different theories. One of these theories is the Porter Hypothesis (Porter and Van der Linde, 1995). According to the theory, well-crafted and well-enforced environmental regulations would benefit both the environment and the firm. Since firms face market imperfections, strict environmental regulations would make companies pursue innovations that have been neglected, thus overcoming market imperfections (Rubashkina *et al*., 2015). These innovations reduce the cost of compliance, increasing the firm's efficiency and productivity. Hence, this creates a win-win situation. Using carbon taxes or emission trading systems makes companies invest in cleaner technologies, leading to increased efficiency and long-term economic benefits (Fadly *et al*., 2020). This increase in productivity may increase firm competitiveness, thus increasing exports.

The Environmental Kuznets Curve (EKC) hypothesis (Grossman and Krueger, 1991) also provides a framework explaining the relationship between economic growth and environmental quality (Sulaiman *et al*., 2013). As developing economies grow, they relax their trade and environmental policies, thus using their natural resources and energy to fuel economic growth, which pollutes the environment (Mahmood *et al*., 2023). After this, the communities cared for the environment while the government developed different environmental regulations to reduce pollution. This regulation may be counterproductive, leading to carbon leakage. Carbon leakage occurs when a company transfer its production from a country with strict environmental regulation policies to another country with relaxed environmental regulation (Yang *et al*., 2023). This may reduce the trade balance in the developed country with a stricter environmental regulation policy.

3. Methodology

3.1 Model Specification

Carbon pricing is the major mechanism used to regulate emissions, which could be in the form of carbon taxes and emissions trading systems (ETS). This research adopted a panel data analysis across selected European countries from 1991 to 2023. These countries include Denmark, Estonia, Finland, France, Ireland, Iceland, Latvia, Norway, Poland, Slovenia, Spain, Switzerland, and Ukraine. The data for this analysis were obtained from the World Bank Group.

3.2 Trade Balance and Carbon Emissions

The trade balance (TB) represents the net exports of a country.

$$TB = X - M \quad (1)$$

Where is "X" Exports and "M" is Imports. The carbon pricing may affect trade balance or competitiveness through two channels. This includes the cost-push effect and the leakage effect. According to the Pollution Haven Hypothesis, firms relocate their production units from countries with high regulation to countries with weaker environmental laws to minimise compliance costs. This is generally termed as carbon leakage. Taking the functional relations of this equation,

$$TB = f(CP, GDPG, EC, IO) \quad (2)$$

Where "CP" is the Carbon price (cost per ton of CO_2 emissions), "GDPG" is GDP Growth Rate (an indicator of economic activity), "EC" is Energy Consumption per capita, "IO" is the Industrial Output contribution to GDP.

$$TB_{it} = \beta_0 + \beta_1 CP_{it} + \beta_2 GDPG_{it} + \beta_3 EC_{it} + \beta_4 IO_{it} + \varepsilon_{it} \quad (3)$$

Introducing the interaction between economic growth and energy consumption. GDPG*EC.

$$TB_{it} = \beta_0 + \beta_1 CP_{it} + \beta_2 GDPG_{it} + \beta_3 EC_{it} + \beta_4 IO_{it} + \beta_5 (GDPG_{it} * EC_{it}) + \varepsilon_{it} \quad (4)$$

"β_1" is expected to be negative because higher carbon prices reduce the trade balance due to increased production costs. "β_2" is expected to be positive because GDP growth positively influences the trade balance. "β_3" Is expected to be positive as Higher energy consumption signals industrial activity, affecting trade. "β_4" can either be negative or positive, depending on whether industrial output is export-driven or fossil fuel-intensive.

3.3 Carbon Pricing and Carbon Emission Model

This model examines how the transition to a green economy is achieved through different policies adopted in Europe. The Cobb-Douglas functional form was used to describe the relationship.

$$CE = ACP^{\gamma_1} GDPG^{\gamma_2} EC^{\gamma_3}, IO^{\gamma_3}) \quad (5)$$

Where "A" is the Efficiency parameter "CE" is Carbon emission (CO_2 emissions), "CP" is the Carbon price (cost per ton of CO_2 emissions), "GDPG" is GDP Growth Rate (an indicator of economic activity), "EC" is Energy Consumption per capita, "IO" is the Industrial Output contribution to GDP.

$$CE_{it} = \gamma_0 + \gamma_1 CP_{it} + \gamma_2 GDPG_{it} + \gamma_3 EC_{it} + \gamma_4 IO_{it} + \mu_{it} \quad (6)$$

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$$CE_{it} = \gamma_0 + \gamma_1 CP_{it} + \gamma_2 GDPG_{it} + \gamma_3 EC_{it} + \gamma_4 IO_{it} + \gamma_5 (GDPG_{it} * EC_{it}) + \mu_{it} \quad (7)$$

Where "γ_1" is expected to be negative because Higher carbon prices should reduce emissions. "γ_2" is expected to be positive because GDP growth can lead to increased emissions. "γ_3" Is expected to be positive as Higher energy consumption leads to more emissions. "γ_4" can either be negative or positive, depending on whether industrial output is fossil fuel-based or green energy-based.

Before estimating the models, the data were checked for stationarity using the Im, Pesaran and Shin (IPS) Test. If the variables are stationary at level (I(0)), then we proceed to Fixed Effects (FE) and Random Effects (RE). However, if these variables are integrated at different orders (I(0) and I(1)), then we estimate Panel ARDL or Cointegration Tests. To check for cross-sectional dependence, the Breusch-Pagan LM Test will be estimated. If cross-sectional dependence exists, the Driscoll-Kraay standard errors or Common Correlated Effects (CCE) models will be adopted.

4. Results

This section provides a critical analysis of the findings from the data analysis.

4.1 Unit Root Test

The Unit Root Test was conducted using the Im, Pesaran and Shin W-stat Unit root test. This permits heterogeneity across cross-sectional units and is also suitable for moderate or large numbers of cross-sectional units and periods (Dumrul and Kilicarslan, 2018).

Table 1. Im, Pesaran and Shin W-stat Unit root test

Variables	Level		First difference		I(d)
	T-Statistics	Prob.	T-Statistics	Prob.	
CE	-0.38798	0.3490	-11.5057	0.0000***	**I(1)**
CP	-3.51021	0.9998	-9.54793	0.0000***	**I(1)**
EC	-0.98040	0.1634	-11.0548	0.0000***	**I(1)**
GDPG	-8.13091	0.0000***	-15.7573	0.0000***	**I(0)**
IO	0.33438	0.6310	-7.49355	0.0000***	**I(1)**
TB	-2.14113	0.0161**	-11.0674	0.0000***	**I(0)**

Notes: ***, **, and * signify statistical significance at the 1%, 5%, and 10% levels.

The results indicate mixed integration orders among the variables. While the CE, CP, EC, and IO variables were stationary after the first difference, the TB and GDPG variables were stationary at levels (integrated of order zero, I(0)). The two models include variables that are stationary at both levels and first differences. This suggests a need to adopt an estimation technique that can accommodate this. Therefore, the Panel ARDL will be used to examine short-run and long-run relationships. However, before this, the panel cointegration tests will be conducted to confirm the long-run relationship between the variables.

4.2 Cointegration Analysis

The panel cointegration can be estimated using the Pedroni, Kao, or Johansen-Fisher Panel Cointegration Tests. Nevertheless, the Johansen Fisher Panel Cointegration Test was adopted for this analysis due to the panel data setup (with multiple European countries, multiple variables, and possibly complex interactions). Aside from this, the Johansen Fisher Panel Cointegration Test is suitable for larger panels and can detect multiple cointegration vectors compared to the Pedroni and Kao tests, which are suitable for smaller panel data.

Table 2. Panel Cointegration Test Results for Carbon Emissions

No. of Cointegration Equations	Fisher Stat (Trace Test)	p-value	Fisher Stat (Max-Eigen Test)	p-value
None	221	0.0000***	131.7	0.0000***
At most 1	106.8	0.0000***	72.72	0.0000***
At most 2	53.81	0.0011***	45.44	0.0105**
At most 3	27.34	0.3917	19.73	0.8043
At most 4	47.5	0.0062***	47.5	0.0062***

Notes: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels.

The result from the cointegration analysis revealed that the hypothesis of no cointegration (None) is strongly rejected at the 1% level for the two models. This confirms the existence of a long-run relationship between Carbon Emission (CE) and the explanatory variables (CP, EC, GDPG, IO). Subsequent hypotheses (at most 1, 2, and 4) also indicate additional cointegrating relationships, suggesting that multiple long-run relationships likely exist among the variables

Table 3. Panel Cointegration Test Results for Trade Balance Models

No. of Cointegration Equations	Fisher Stat (Trace Test)	p-value	Fisher Stat (Max-Eigen Test)	p-value
None	243.5	0.0000***	153	0.0000***
At most 1	112	0.0000***	74.79	0.0000***
At most 2	56.72	0.0005***	32.13	0.1887
At most 3	43.34	0.0178**	27.86	0.3653
At most 4	59.98	0.0002***	59.98	0.0002***

Notes: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels.

The result from the cointegration analysis revealed that the hypothesis of no cointegration (None) is strongly rejected at the 1% level for the two models. This confirms the existence of a long-run relationship between Trade balance (TB) and the explanatory variables (CP, EC, GDPG, IO). Subsequent hypotheses (at most 1 and 4) also indicate additional cointegrating relationships, suggesting that multiple long-run relationships likely exist among the variables. The long-run relationship discovered in the two models suggests that policy interventions or shocks to explanatory variables like carbon prices (CP), energy consumption (EC), GDP growth (GDPG), and industrial output (IO) have sustained impacts on carbon emissions and trade balance. Hence, the use of the Panel ARDL Model to estimate both the long- and short-term relationship in the two models is highly appropriate.

4.3 Panel ARDL Analyses

Report any other analyses performed, including subgroup analyses and adjusted analyses, indicating those that were pre-specified and those that were exploratory (though not necessarily in the level of detail of primary analyses). Consider putting the detailed results of these analyses on the supplemental online archive. Discuss the implications, if any, of the ancillary analyses for statistical error rates.

Table 4. Long Run–Panel ARDL Carbon Emission

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
CP	-187736.2	55137.21	-3.404891	0.0008***
EC	342105.7	79473.57	4.304648	0.0000***
GDPG	357999.4	307000.1	1.166121	0.2448
IO	1124020.	462459.4	2.430527	0.0159**
GDPG*EC	-20159.60	7216.476	-2.793553	0.0057***

Notes: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels.

The Panel ARDL carbon emission model shows that carbon pricing has a negative and significant impact on carbon emissions in the long run. This aligns with the Porter Hypothesis that environmental policy improves the environment as it motivates industries and economies at large to reduce emissions (Fadly *et al*., 2020). This shows that carbon pricing is an effective policy to balance economic growth with sustainable environmental outcomes. As expected, energy consumption has a positive relationship with carbon emissions in Europe. Increased energy consumption, especially from traditional fossil fuels, escalates carbon emissions. This signifies the urgent need for energy transition policies to promote renewable and cleaner energy sources. Interestingly, GDP growth (GDPG) had no significant impact on carbon emissions in the long run.

The insignificant relationship may be due to differences in technological innovation among the countries analysed. It also reflects he degree of decoupling and the ability of European countries to improve growth with limited incremental environmental damage. The significant positive relationship between industrial output (IO) and emissions shows that increased industrial activities, especially in the energy-intensive sectors, increase carbon emissions. The interaction term (GDPG*EC) yields a significant negative impact, which suggests that increasing growth and energy consumption may not necessarily increase carbon emissions if accompanied by energy efficiency or technological progress.

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Table 5. Short Run–Panel ARDL Carbon Emission

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
COINTEQ01	0.020117	0.018323	1.097873	0.2734
D(CE(-1))	-0.234222	0.064491	-3.631845	0.0003***
D(CP)	-10319592	8597870.	-1.200250	0.2313
D(CP(-1))	1391215.	2904924.	0.478916	0.6325
D(EC)	152315.0	31188.70	4.883659	0.0000***
D(EC(-1))	40888.28	19078.44	2.143166	0.0332**
D(GDPG)	339953.3	1890660.	0.179807	0.8575
D(GDPG(-1))	545538.8	2596008.	0.210145	0.8337
D(IO)	-1593571.	1023936.	-1.556318	0.1210
D(IO(-1))	1477892.	1221308.	1.210089	0.2275
D(EC*GDPG)	-1800.751	1539.517	-1.169685	0.2434
D(EC(-1)*GDPG(-1))	-3224.686	3244.070	-0.994025	0.3213
C	-2254319.	3099910.	-0.727221	0.4678

Notes: *, **, and * represent statistical significance at the 1%, 5%, and 10% levels,**

From the short-run equation, the one-period lag of carbon emission has a negative and significant impact on carbon emission. The correction in the short run may be associated with cyclical economic behaviours, seasonal changes, or reactive short-term regulatory actions by governments or industries. While carbon pricing reduced carbon emissions in the long run, the short-run changes in carbon prices (D(CP) and D(CP(-1))) are both statistically insignificant. This suggests that it takes a longer time for the carbon pricing mechanism to influence emissions behaviour in Europe.

Energy consumption per capita (D(EC) and D(EC(-1))) also showed a positive and significant impact on energy emission, which aligns with the long-run positive and significant impact discovered. The positive lag effect indicates a sustained short-run impact that extends beyond the immediate period. GDP growth rate, industrial output and their respective lag values were found to have an insignificant impact on short-run carbon emission. This indicates that short-term variations in economic growth rates alone do not significantly alter carbon emissions. The negative sign of the immediate industrial output change (D(IO)) coefficient, although insignificant, contrasts with long-run results, suggesting a short-term reduction or efficiency gain not captured fully by statistical significance.

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Table 6 Long Run–Panel ARDL Trade Balance

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
CP	2.61E+09	5.77E+08	4.528617	0.0000***
EC	1.92E+08	5.00E+08	0.385090	0.7005
GDPG	-2.56E+10	1.30E+10	-1.961034	0.0511*
IO	-2.34E+08	1.25E+09	-0.187859	0.8512
GDPG*EC	1.68E+08	68461744	2.449608	0.0151**

Notes: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels.

The long-run Panel ARDL results for the trade balance model indicate that carbon pricing had a positive and significant impact on trade balance during the period under consideration. Although this appears counterintuitive, as higher carbon costs typically raise production costs, potentially reducing competitiveness. However, this aligns with the Porter Hypothesis, which argues that strict environmental regulations, such as robust carbon pricing mechanisms, stimulate innovation and efficiency. The constant use of these policies increases competitiveness and productivity, thereby improving the trade performance of domestic firms. Energy consumption per capita (EC), on the other hand, exhibited a positive and insignificant impact on trade balance. This may be due to the energy mix (fossil vs. renewable) and efficiency improvements, which vary significantly across industries and countries.

GDPG and Industrial output (IO) show an insignificant impact and a negative relationship with the trade balance. This negative effect may be due to the GDP growth being primarily consumption-driven, potentially leading to increased imports that surpass the growth of exports, thus negatively impacting the trade balance. The interaction between GDP growth and energy consumption (GDPG*EC) was also found to have a positive and significant impact on trade balance. Higher energy consumption and increases in GDP growth led to enhanced industrial productivity and export capacity. This indicates that the growth accompanied by energy transition strengthens the trade positions of countries through improved competitiveness in energy-intensive exports.

Table 7 Short Run–Panel ARDL Trade Balance

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	-0.130609	0.132795	-0.983539	0.3264
D(CP)	-1.60E+10	1.39E+10	-1.155024	0.2493
D(CP(-1))	2.07E+09	1.23E+09	1.683023	0.0937*
D(EC)	4.69E+08	4.75E+08	0.986909	0.3247
D(EC(-1))	-1.51E+08	1.76E+08	-0.858146	0.3917
D(GDPG)	1.39E+09	6.85E+09	0.203262	0.8391
D(GDPG(-1))	8.36E+09	1.18E+10	0.708661	0.4793
D(IO)	7.19E+08	3.41E+09	0.210708	0.8333
D(IO(-1))	-6630063.	1.00E+09	-0.006625	0.9947
D(EC*GDPG)	1473142.	12414178	0.118666	0.9056
D(EC(-1)*GDPG(-1))	-51453084	58938744	-0.872993	0.3836
C	-3.45E+09	6.71E+09	-0.514335	0.6075

Notes: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels.

The short-run analysis does not show a significant result. Policy-wise, it emphasises the need for targeted long-term interventions to improve the region's trade balance.

5. Conclusion and Recommendation

As the world transitions toward clean energy, it is important to ensure that the policy measures adopted are sustainable and achieve the desired goal. This research, using the Panel ARDL approach, examined critically the complex dynamics between carbon emissions, trade competitiveness, and the transition toward a green economy in Europe. The result aligns with the Porter Hypothesis, which argues that strict environmental regulations drive innovation and productivity. Carbon Pricing was found to have a negative and significant impact on reducing carbon emissions, while energy consumption and industrial output had a positive and significant impact on carbon emissions, emphasising the environmental challenges posed by industrial activities and fossil energy consumption. The positive relationship between carbon pricing and trade balance also suggests that carbon pricing may not necessarily affect trade balance negatively in the selected countries. In conclusion, this study highlights the critical importance of carbon pricing and renewable energy transition policies in simultaneously achieving environmental sustainability and international trade competitiveness. Given the findings, it is important to expand and sustain carbon pricing instruments like carbon taxes or emissions trading schemes to accelerate the energy transition. The government should also prioritise policies that encourage investments in clean energy infrastructure and innovation. This will help curb the emissions impact from traditional energy sources.

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