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Exploring the Relationship between the EU Emissions Trading System and Renewable Energy Development in the EU

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Abstract: This research paper examines the impact of the EU Emissions Trading System (EU ETS) on the development of the renewable energy market in the European Union. Using regression analysis, the study investigates the relationship between the volume of emission permits, EU GDP, and the share of renewables in the overall energy balance. The results reveal that the EU ETS has a significant negative impact on the development of the renewable energy market in the EU, with an increase in the volume of emission permits corresponding to a decrease in the share of renewables. The study also finds that economic growth alone may not necessarily lead to an increase in the share of renewables; however, when combined with other policies and measures, economic growth may promote the development of renewable energy in the EU. The findings suggest that the EU ETS needs to be improved to encourage renewable energy development effectively, and policymakers should consider introducing additional policies and measures to promote the deployment of renewable energy. In addition to analysing the impact of the EU ETS on the renewable energy market, this paper provides an overview of the EU ETS and its challenges. As a cap-and-trade system covering over 11,000 installations across the European Economic Area, the EU ETS has faced challenges from the beginning due to an oversupply of emission allowances. This resulted in a low carbon price insufficient for driving climate change mitigation. To address these issues, the EU ETS Market Stability Reserve (MSR) was established to absorb excess allowances from the market and manage past surpluses. However, the MSR cannot handle sudden shocks or future surpluses. The paper also presents data on the distribution of emission allowances by country and sector. Germany has the most significant emissions under the EU ETS, followed by Italy, Poland, and the United Kingdom. The stationary installations sector, encompassing power plants and other large industrial emitters, received the most allowances, followed by the fuel combustion sector. The data indicates that energy and industry are the largest emitters and thus receive the most ETS allowances. This research contributes to the understanding of the EU ETS and its impact on the development of the renewable energy market in the EU. The results emphasise the need to improve the EU ETS to promote the deployment of renewable energy and suggest that policymakers should consider introducing additional policies and measures to facilitate the transition to a low-carbon economy.

Keywords: EU Emissions Trading System, Renewable energy, Regression analysis, Greenhouse gas emissions, Carbon pricing, Market Stability Reserve, Energy transition, Climate policy.

1. Introduction

The EU has long been a global leader in addressing climate change and implementing policies to mitigate its impacts. One of the key instruments in this fight against climate change is the EU ETS, the largest carbon market in the world, covering approximately 40 per cent of the EU's greenhouse gas emissions [14]. The EU ETS allocates a limited number of emission allowances to companies, which can then be traded with other companies. This creates an incentivising market for companies to buy and sell allowances based on their emissions.

Over the years, the EU has made several adjustments to the EU ETS to increase its effectiveness. Recently, the system was tightened by reducing the number of available allowances and introducing a market stability reserve better to regulate the market [5]. The EU ETS aims to provide a price signal that encourages companies to reduce their emissions and invest in low-carbon technologies, ultimately driving innovation and fostering the development of renewable energy sources.

Green energy, including wind, solar, and hydropower, is a crucial component of the EU's strategy to reduce greenhouse gas emissions and transition to a low-carbon economy [1]. However, the deployment of renewables has needed to be faster in some EU member states due to various factors, such as regulatory barriers, market design issues, and financing challenges [11]. Moreover, the interaction between the EU ETS and national support schemes for renewables has been complex, with some studies suggesting that the EU ETS might have a limited impact on promoting renewable energy development [3].

This paper addresses the following research questions: (1) What is the relationship between the EU ETS and the development of renewable energy sources (RES) in the EU? (2) How has the EU ETS impacted the deployment of RES across different EU member states? (3) What are the main factors influencing the varying levels of success in renewable energy deployment in different member states? By exploring these questions, we aim to understand better the EU ETS's effectiveness in promoting renewable energy development, assess its role in driving investment in green technologies, and identify potential improvements to the system to support the transition to a low-carbon economy further.

2. Object and subject of research

This research explores the relationship between the EU ETS and the development of RES in the European Union. In this context, "renewable energy development" refers to the growth, deployment, and integration of RES within the EU's energy system, such as wind, solar, and hydropower. A "low-carbon economy" is an economy that significantly reduces greenhouse gas emissions while maintaining economic growth and development. This paper addresses the following research questions: (1) What is the relationship between the EU ETS and the development of RES in the EU? (2) How has the EU ETS impacted the deployment of RES across different EU member states? (3) What are the main factors influencing the varying levels of success in renewable energy deployment in different member states? By exploring these questions, we aim to understand better the EU ETS's effectiveness in promoting renewable energy development, assess its role in driving investment in green technologies, and identify potential improvements to the system to support the transition to a low-carbon economy further.

3. Target of research

The main goal of this research is to provide a comprehensive analysis of the relationship between the EU ETS and the development of RES in the EU. To achieve this goal, the following tasks will be undertaken:

Analyse the current state of RES development in the EU and identify the challenges EU member states face in deploying renewables.

Investigate the role of the EU ETS in promoting RES and reducing greenhouse gas emissions in the EU.

Examine the effectiveness of the EU ETS in achieving its goals and identify areas for improvement.

Explore the potential for the EU ETS to address the challenges some EU member states face in deploying renewables and accelerating the transition to a low-carbon economy.

Provide recommendations for improving the EU ETS to promote RES and achieve the EU's climate goals.

Examples of specific tasks that can be undertaken to achieve these goals include:

• Conducting a literature review to analyse previous research on the relationship between the EU ETS and the development of RES in the EU.

• Examining the impact of the EU ETS on RES investments and deployment in different EU member states.

• Analyzing the effectiveness of the EU ETS in reducing greenhouse gas emissions and achieving its climate targets.

• Identifying the challenges some EU member states face in deploying renewables, such as regulatory barriers, market design issues, and financing challenges.

• Investigating how the EU ETS can be improved to address these challenges and better promote RES development in the EU.

• Analyzing the potential for new policy initiatives, such as carbon border adjustment mechanisms, to complement the EU ETS in promoting RES development and reducing greenhouse gas emissions.

Overall, the research aims to contribute to a better understanding of the relationship between the EU ETS and the development of RES in the EU and provide recommendations for improving the effectiveness of the EU ETS in achieving its climate goals.

4. Literature analysis

According to Rogge and Hoffmann [13], the EU ETS has significantly impacted the power generation technology sector. Their research found that the EU ETS mainly affects the rate and direction of technological change within the large-scale, coal-based power generation regime, which has added carbon capture technologies as a new technological trajectory. The impact of the EU ETS on corporate CO_2 culture and routines may also prepare the ground for transitioning to a low-carbon sectoral innovation system for power generation technologies. While these findings shed light on the effects of the EU ETS on technological change in the power generation sector, there needs to be more research on its direct impact on renewable energy development and deployment.

Pietzcker, Osorio, and Rodrigues [12] conducted research that concluded that tightening the EU ETS targets would accelerate the decarbonisation of the EU power sector by 3-17 years. This would be achieved through renewables contributing 74% of the electricity in 2030 and zero electricity generation emissions reached by 2040. Carbon prices within the EU ETS would increase to 129€/tCO_2 in 2030, reducing cumulated power sector emissions from 2017 to 2057 by 54%. The transformation would come at limited costs, with total discounted power system costs only increasing by 5%. This study highlights the potential benefits of a more stringent EU ETS; however, it does not delve into the specific factors influencing renewable energy deployment in different member states.

Landis and Heindl [10] researched the impact of renewable energy targets in power generation on EU ETS permit prices. They found that renewable energy targets reduced EU ETS permit prices, making net permit exporters and net permit importers better off. An increase in prices for energy commodities affects households in low-income quintiles the most. Revenues from climate policy can compensate households for losses, but this is limited for states with large allocations of auctionable permits. While this research provides insights into the interplay between renewable energy targets and EU ETS permit prices, it needs to address the role of the EU ETS in promoting renewable energy development.

Hoffmann [9] conducted research that found that companies in the German electricity sector integrate costs for CO_2 in their investment decisions. The EU ETS significantly impacts small-scale investments with short amortisation times more than large-scale investments. To increase the effectiveness of the EU ETS, policymakers should reflect on their long-term reduction intentions regarding the scarcity of allowances, provide more incentives to increase efficiency, and reduce regulatory uncertainty. This study offers valuable insights into investment decisions in the German electricity sector, but further research is needed to understand the broader implications for renewable energy development in the EU.

According to Yu, He, and Liu [15], the emissions trading system (ETS) positively affects renewable energy output. The authors also found that ETS has a trend effect on renewable energy output, and the growth of renewables has been successfully boosted through ETS. This research presents evidence for the positive impact of ETS on renewable energy output; however, it needs to address the challenges EU member states face in deploying renewables or the potential improvements to the EU ETS.

The existing literature offers valuable insights into the impact of the EU ETS on the power generation sector, carbon prices, and renewable energy output. However, there needs to be more literature concerning the specific relationship between the EU ETS and renewable energy development in the EU, the factors influencing the varying success of renewable energy deployment in different member states, and potential improvements to the system. This research aims to fill this gap by addressing these questions.

5. Research methods

The methodology used in this research involves regression analysis to test the impact of the EU ETS on the development of the EU renewable energy market. Here is a detailed description of the methodology:

Dependent variable: The share of renewables in the overall balance (RES_share) will be chosen as the dependent variable. Data for this variable will be sourced from the Eurostat database [14], which provides comprehensive and reliable statistics on the renewable energy sector in the EU.

Independent variables: The independent variables will be the volume of emission permits (EUETS) and EU GDP (EU_GDP). EU_GDP is included as a control variable to show that the decrease in emissions is not a consequence of the decline in economic activity in the EU. Data for these variables will be collected from the European Union Transaction Log (EUTL) [7] for EUETS and Eurostat for EU_GDP [8].

The regression equation used in this research is:

$$RES\_share = \beta 0 + \beta 1 EUETS + \beta 2 EU\_GDP + \beta 3 sq\_EU\_GDP + \varepsilon \qquad (1)$$

Where:

β0 represents the constant term

β1 represents the coefficient of the EUETS variable

β2 represents the coefficient of the EU_GDP variable

β3 represents the coefficient of the square of the EU_GDP variable (sq_EU_GDP)

ε represents the error term

Assumptions of the least squares method: Before estimating the regression equation coefficients, the assumptions of the least squares method are ensured. In particular, it was found that there is a non-linear relationship between the dependent variable and EU_GDP. To address potential issues of multicollinearity, variance inflation factors (VIFs) will be calculated, and variables with VIFs greater than ten will be removed or modified. Additionally, tests for endogeneity and omitted variable bias will be conducted to ensure the validity of the results.

Estimation of several models: Several models will be estimated to account for different specifications, and the coefficients with the best fit will be selected. Sensitivity analysis will be performed to evaluate the robustness of the results, and the final model will be chosen based on a combination of goodness-of-fit measures, such as adjusted R-squared and Akaike Information Criterion (AIC).

This revised research methods section offers a more robust framework for understanding the relationship between the EU ETS and the development of renewable energy sources in the European Union by providing a detailed description of data sources and addressing potential issues with the regression analysis.

6. Research results

The EU ETS was introduced in 2005 and covers over 11,000 installations across the European Economic Area, accounting for approximately 40% of the region's greenhouse gas emissions [4]. It is a cap-and-trade system which aims to promote the development of renewable energy sources by creating a market incentive for companies to reduce their emissions. The total amount of greenhouse gas emissions that companies can produce is determined by a cap. Companies receive or purchase emission allowances through the cap, which is reduced annually, and they can trade these allowances as needed [5].

However, the EU ETS has faced challenges from the beginning due to an oversupply of emission allowances, resulting in a price that needs to be higher to drive climate change mitigation. This relationship between the EU ETS and renewable energy development is relevant for policymakers because a well-functioning emissions trading system can incentivise companies to invest in cleaner technologies, such as renewable energy sources, to reduce their emissions.

To address these issues, the EU ETS Market Stability Reserve (MSR) has been established to absorb excess allowances from the market and help cope with past surpluses. However, the MSR cannot deal with sudden shocks or future surpluses. Additionally, companies that have to pay for pollution still benefit from the EU ETS due to the free allocation of emission allowances. In 2021, the EU ETS began to change as part of the EU Green Deal, focusing on more ambitious targets, a more effective market stability reserve, and better alignment with other EU policies [6].

As shown in Figure 1, during the early years of the ETS, emission allowances were relatively large, leading to an oversupply of credits and a low carbon price. This is reflected in the data, where the value of the EU ETS started at 28.7 billion tonnes in 2005, peaked at 32.3 billion tonnes in 2006 and 2007, and then steadily declined until 2013.

In 2013. The ETS was revised - as mentioned above, a new Market Stability Reserve (MSR) was created to address the oversupply of allowances and the rising carbon price. As a result, the size of the EU ETS increased slightly in 2014 but continued to decline until 2018.

In 2018. The EU ETS stabilised and increased slightly in 2019. However, in 2020 and 2021, volumes dropped significantly, likely due to the COVID-19 pandemic and the associated economic downturn.

It can be assumed, and the data suggests, that the EU ETS will decline further in the coming years. This may be due to the ongoing economic impact of the pandemic, Russia's aggression against Ukraine, or other factors such as changes in energy consumption patterns, economic conditions, technological advances, regulatory changes, and shifting political priorities that still need to be fully understood.

The recent decline in cost, which we see in Fig. 1, suggests that further policy intervention is likely needed to support the transition to a low-carbon economy. This could include the introduction of more stringent emission reduction targets or the creation incentives for investment in renewable energy sources.

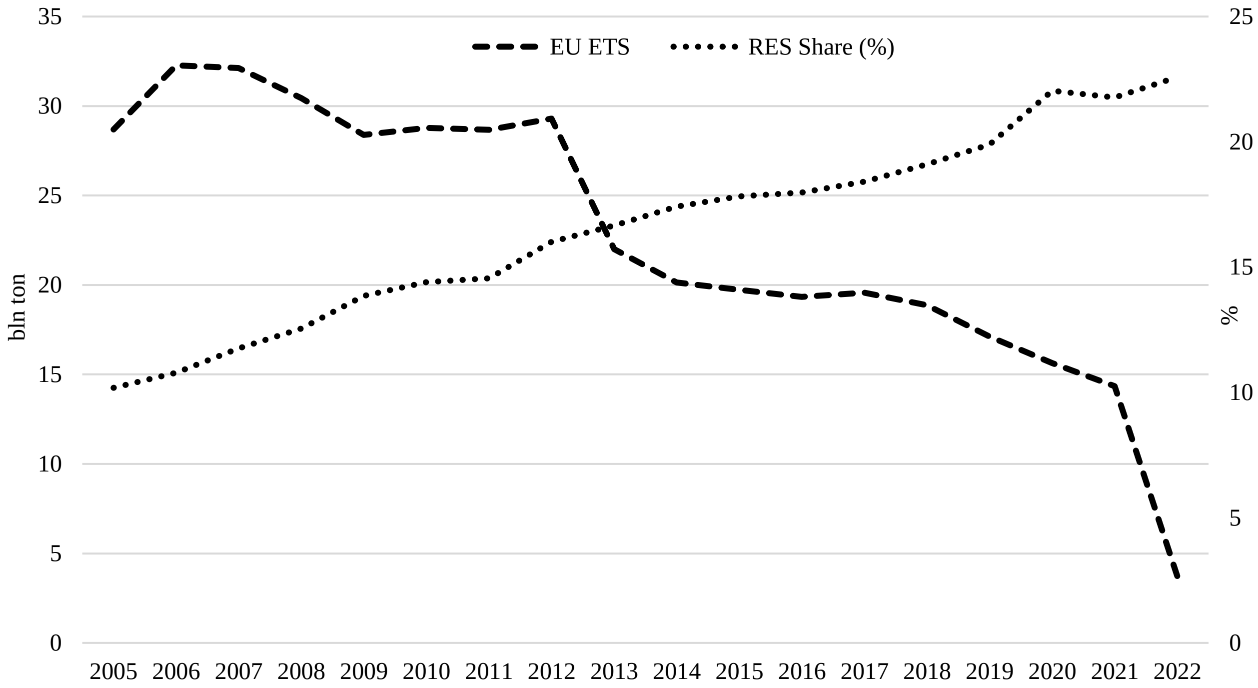

Figure 1. Emissions trading system in the European Union (billion tonnes) and share of RES (%), 2005-2022 [7; 14].

Figure 2 shows that Germany (DE) has the most significant number of emissions under the EU ETS, followed by Italy (IT), Poland (PL) and the United Kingdom (GB). We attribute their emissions to a higher level of industrial activity. On the other hand, smaller countries such as Luxembourg (LU), Iceland (IS) and Malta (MT) have relatively lower values for the EU ETS. This may indicate that these countries have less industrial activity and lower emissions, resulting in lower allowance requirements.

It is worth noting that we added the value of NER300 - 1.2 billion tonnes in addition to countries. Of course, it is not comparable to other countries, as the number of allowances allocated to a specific initiative to finance low-carbon technologies. Still, the programme is directly related to our research topic.

In general, NER300 is a funding programme established by the European Commission to support the demonstration of innovative low-carbon technologies. The name "NER300" is derived from the 300 million allowances of the EU Emissions Trading System's New Entrant Reserve (NER) allocated to the programme.

The programme ran from 2012 to 2020 and covered large-scale demonstration projects for innovative renewable energy and carbon capture and storage (CCS) technologies. The projects had to demonstrate that they could significantly reduce carbon dioxide emissions cost-effectively 3.

The NER300 programme was essential to the EU's efforts to combat climate change and transition to a low-carbon economy. It was also intended to help overcome the so-called "valley of death" that many innovative technologies face at commercialisation [2].

Looking at Figure 3, it can be seen that Germany receives the largest ETS allocation each year, followed closely by Italy and Poland. However, all six countries show a downward trend in ETS allocations over time, with a particularly sharp decline in 2019-2020.

It is also interesting to note the impact of the COVID-19 pandemic on the distribution of ETSs. In 2020, all countries saw a decrease in the allocation of ETSs, which may be due to the economic downturn caused by the pandemic.

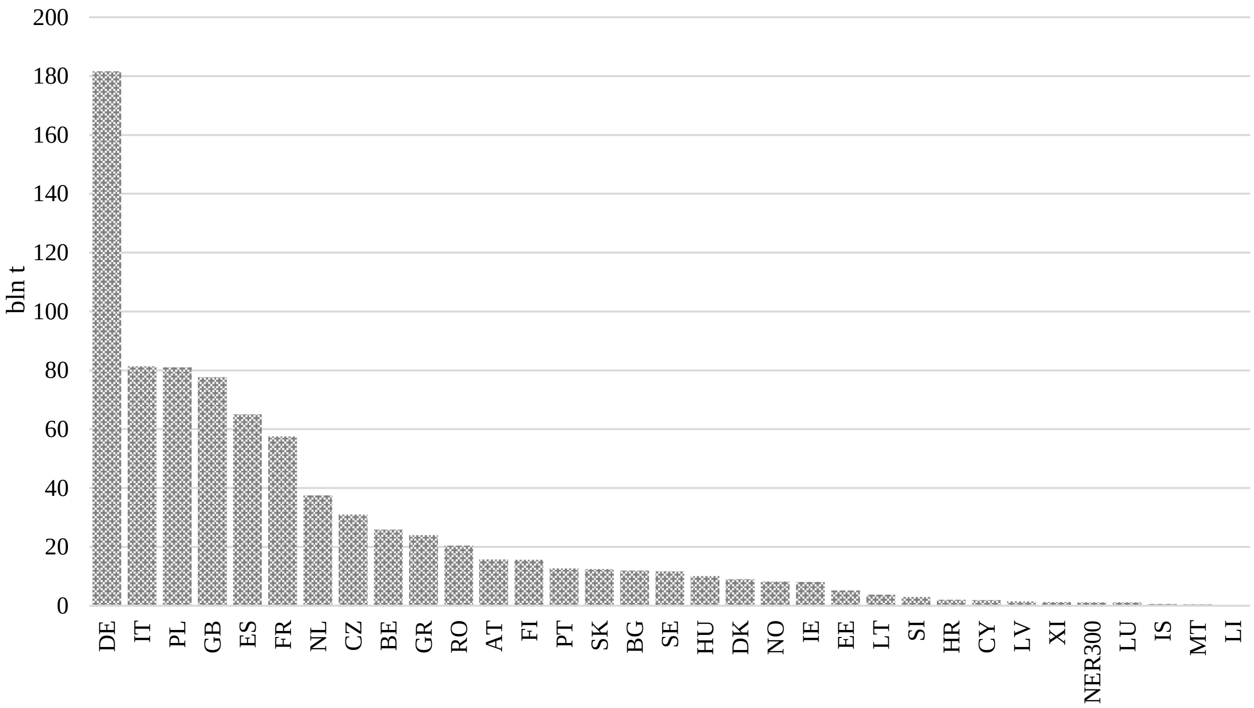

Figure 2. EU ETS by country, 2005-2022, billion tonnes of CO2 [6].

Fig. 4 shows the distribution of allowances by significant sectors of activity. Thus, the stationary installations sector, including power plants and other large industrial emitters, received the most considerable allowances - 389.89 million. The fuel combustion sector, which includes smaller power plants, received the second largest allocation - 200.82 million AAUs.

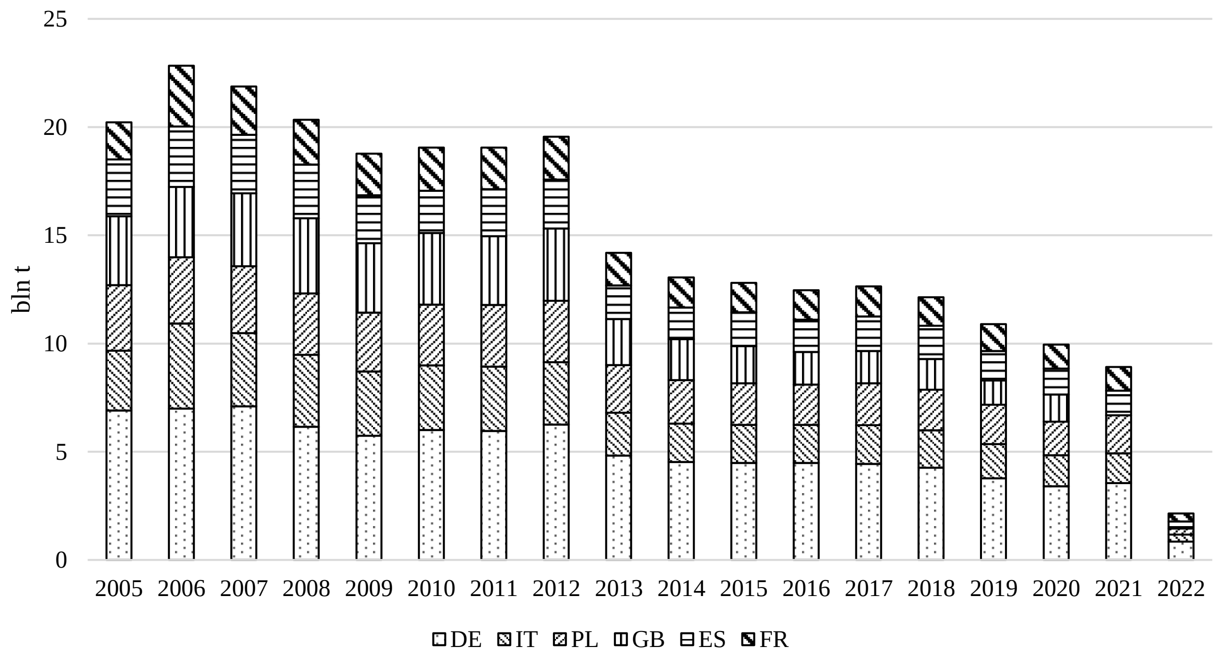

Figure 3. Breakdown of the European Union Emissions Trading System by country and year for the six main EU countries [6].

The industrial installations (excluding combustion) sector received 111.91 million ETS allowances. This sector includes various industries such as food and beverage, chemicals, and metalworking. The iron and steel sector received 27.33 million in subsidies, and the cement clinker sector received 25.58 million. The oil refining sector received 23.58 million ETS units.

The aviation sector received 6.24 million ETS units, while lime production or calcination of dolomite/magnesite and inorganic chemicals production received 5.99 million ETS units each. Finally, the paper and paperboard production sector received 4.59 million ETS units.

This data shows the allocation of ETS allowances to different sectors. ETS allowances are distributed based on the number of emissions each sector produces. The data shows that energy and industry are the largest emitters and receive the most significant ETS allowances.

Let's now explore the connection between the EU ETS and the development of renewable energy in the EU. As shown in Figure 1, there appears to be an inverse relationship between the EU ETS and the share of renewable energy sources in the overall energy balance. In the early years of the EU ETS, from 2005 to 2008, there was a slight increase in the share of renewables from 10.2% to 12.5%. However, as the EU ETS matured and the price of carbon credits decreased, the percentage of renewables also declined, hitting a low of 15.6% in 2020. This decline could be attributed to the fact that the EU ETS imposes a cost on carbon, making greenhouse gas emissions more expensive for companies. Consequently, some businesses have switched to renewable energy sources to reduce emissions and save money. However, as the cost of carbon decreased, it became more cost-effective for companies to continue using fossil fuels instead of investing in renewable energy.

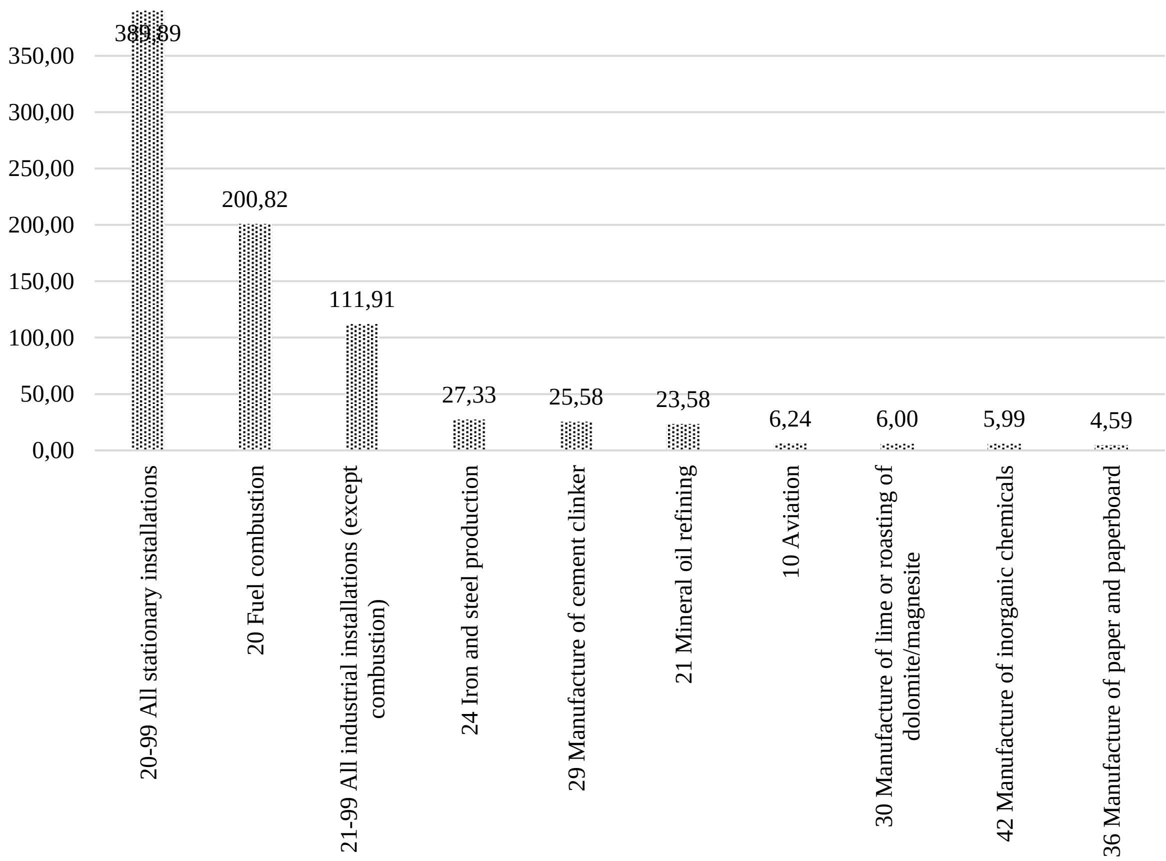

Figure 4. Main activity sectors and their respective ETS values [6].

To better understand the relationship between the EU ETS and renewable energy development, we can analyse the data presented in Figure 1. There is an inverse relationship between the EU ETS and the share of renewable energy sources in the overall energy balance. In the early years of the EU ETS, from 2005 to 2008, there was a slight increase in the share of renewables from 10.2% to 12.5%. However, as the EU ETS matured and the price of carbon credits decreased, the share of renewables also declined, hitting a low of 15.6% in 2020. This decline could be attributed to the fact that the EU

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It is important to note that the COVID-19 pandemic could have affected the data for 2020 and 2021, as it resulted in a decrease in economic activity and energy demand, which could have impacted the share of renewable energy in the overall energy mix.

The relationship between the EU ETS and renewable energy development is essential for policymakers as they seek to accelerate the transition to a low-carbon economy. The data suggests that the EU ETS's current design may not provide a strong enough incentive for companies to invest in renewable energy sources. Further policy interventions may be needed to address this issue.

We will use regression analysis to test the impact of the EU ETS on developing the EU renewable energy market. The dependent variable chosen will be the share of renewables in the overall balance (RES_share), and the independent variables will be the volume of emission permits (EUETS) and EU GDP (EU_GDP). We added EU_GDP as a control variable to demonstrate that the decrease in emissions is not solely due to the decline in economic activity in the EU. Including GDP as a control variable can help capture macroeconomic factors' influence on renewable energy development.

We assume a linear functional form for the regression model, which simplifies the interpretation of the coefficients and provides a baseline model for comparison with more complex models. If needed, we can explore alternative functional forms in further research.

Although we initially expected a linear relationship between RES_share and EU_GDP, our preliminary analysis indicated a possible non-linear relationship. This could be due to diminishing returns to scale, saturation effects, or other complex interactions between economic growth and renewable energy development. However, further research and literature review are needed to confirm and explain this non-linear relationship.

To address potential endogeneity issues in our analysis, we first assessed the possibility of omitted variable bias by including relevant control variables such as EU_GDP. We also examined the Durbin-Watson statistic to check for autocorrelation in the residuals. The statistic of 1.865 indicates no significant autocorrelation, suggesting that errors are independent and no important variable was omitted from the model. Although our current analysis does not directly address potential endogeneity concerns, such as reverse causality or simultaneity bias, future research could employ techniques like instrumental variables or panel data methods to tackle these issues more thoroughly.

Before we estimate the regression equation coefficients, we will ensure that the assumptions of the least squares method are met. In particular, we found a non-linear relationship between the dependent variable and EU_GDP. We estimated multiple models and selected the coefficients with the best fit, as seen in Table 1. The resulting regression model has a high index of determination of 0.944, meaning that 94.4% of the dependent variable (RES_share) variation can be explained by the independent variables (EUETS, sq_EU_GDP, and EU_GDP) in the model. The adjusted R-squared value of 0.931 indicates that the model is not overfitted and that the independent variables are excellent predictors of the dependent variable.

Table 1. Results of Regression Analysis

Dependent Variable: RES_share

Independent Variables	Coefficient	Standard Error	t-Statistic	p-value
const	-35.0513	22.5593	-1.554	0.1442
EUETS	-0.5076	0.0427	-11.90	<0.0001 ***
sq_EU_GDP	-0.2621	0.1080	-2.428	0.0305 **
EU_GDP	8.1853	3.1281	2.617	0.0213 **

Continued table 1

Model Fit Statistics	
Average Number of Shifts	16.185
Shift Control Room Open	3.6207
Amount of Square Balances	11.7355
R-squared	0.944
Adjusted R-squared	0.9311
F-statistic	73.118
Prob (F-statistic)	2.15e-08
Information Criteria	
Log Likelihood	-20.9719
Akaike info criterion	49.9437
Schwarz criterion	53.2766
Hannan-Quinn criterion	50.2750
Autocorrelation	
Rho parameter	0.0278
Durbin-Watson Statistic	1.8651

Note: ***p<0.001, **p<0.05 indicate statistical significance levels of the coefficients in the regression analysis.

The results suggest that the EU ETS hurts the development of the renewable energy market in the EU. The volume of emission permits (EUETS) has a significant negative relationship with the share of renewables in the overall balance (RES_share), meaning that the increase in the volume of emission permits corresponds to a decrease in the share of renewables. This suggests that the EU ETS may not effectively promote the development of renewable energy in the EU.

Moreover, the square of EU GDP (sq_EU_GDP) also has a significant negative relationship with RES_share, indicating that economic growth alone may not necessarily lead to an increase in the share of renewables. However, EU GDP had a significant positive relationship with RES_share, indicating that economic growth in combination with other policies and measures may help to promote the development of renewable energy in the EU.

The regression analysis results suggest that the EU ETS needs to be improved to promote renewable energy development in the EU. Policymakers may need to consider introducing additional policies and measures to encourage deploying renewable energy in the EU.

Overall, this study provides valuable insights into the impact of the EU ETS on the development of the renewable energy market in the EU. The findings have important implications for policymakers, indicating that the EU ETS needs to be improved to promote renewable energy development in the EU. Policymakers may need to consider introducing additional policies and measures to encourage the deployment of renewable energy in the EU, such as providing incentives for investment in renewable energy technologies, implementing carbon pricing mechanisms, or promoting energy efficiency measures.

In conclusion, our regression analysis demonstrates that the EU ETS has not been as effective in promoting renewable energy development in the EU as intended. While economic growth, as measured by EU GDP, has a significant positive relationship with the share of renewables in the overall balance, the square of EU GDP and the volume of emission permits show a significant negative relationship. These findings suggest that the current design of the EU ETS may need to be improved and that additional policies and measures should be implemented to support the development of the renewable energy market in the EU.

7. Prospects for further research development

Further research could explore the effectiveness of various policies and measures in promoting the development of renewable energy in the EU. This may include examining the impact of national and regional policies and sector-specific measures targeting transportation, industry, and residential sectors. Investigating the role of technological advances and changes in energy consumption patterns in developing renewable energy in the EU is also essential.

Additionally, the research could investigate the impact of the EU ETS on specific renewable energy technologies and sectors, such as wind, solar, and biomass. Exploring alternative policies and measures like feed-in tariffs, renewable energy targets, and subsidies could provide valuable insights. Furthermore, the potential of international cooperation and coordination in promoting renewable energy development and the role of private sector investment and innovation should be examined.

Finally, the research could explore the implications of emerging technologies, such as energy storage and carbon capture and storage, on developing renewable energy in the EU. This comprehensive approach will contribute to a better understanding of the factors that influence the growth of renewable energy in the region.

8. Conclusions

The research employed regression analysis to examine the impact of the EU ETS on developing the EU renewable energy market. The results demonstrated that the EU ETS has not been as effective in promoting renewable energy development as intended. The increase in the volume of emission permits corresponded to a decrease in the share of renewables. The square of EU GDP (sq_EU_GDP) showed a significant negative relationship with the share of renewables, indicating that economic growth alone may not necessarily lead to an increase in the share of renewables. However, EU GDP had a significant positive relationship with RES_share, suggesting that economic growth combined with other policies and measures could promote the development of renewable energy in the EU.

These findings imply that the current design of the EU ETS may need to be improved, and additional policies and measures should be implemented to support the development of the renewable energy market in the EU. Policymakers may need to consider introducing more stringent emission reduction targets or creating incentives for investment in renewable energy sources. Improving the effectiveness of the EU ETS and aligning it with other EU policies, such as the EU Green Deal, is crucial to support the transition to a low-carbon economy. The research contributes to the ongoing debate on climate change mitigation and renewable energy development in the EU.

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