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Assessment of the European Emissions Trading System's Impact on Sustainable Development

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Preprint

1. Introduction

In today's technological, economic, and environmental transformations, the link between climate policies, sustainable development, and the circular economy is of paramount importance. Within the internationally shared and institutionally defined 2030 Agenda goals, the need for effective environmental policies [1] and robust governance [2] to internalize the environmental costs of economic activities has emerged. Carbon markets and mechanisms are deemed to play a remarkable role; their growth has been remarkable over the last decade. Carbon taxes and emissions trading systems (ETSs) reach has expanded significantly, with the share of global emissions covered increasing from 7% in 2013 to 23% in 2022. This growth trajectory is expected to continue as jurisdictions introduce new carbon pricing instruments and expand their scope.

Carbon pricing is a market approach that provides an economic signal to emitters by allowing them to decide through rational strategic decision logic based on opportunity costs whether to invest in projects to reduce emissions or delay the investment by continuing to emit and paying for excess emissions. If well defined, carbon pricing can be a valuable policy tool for flexibly achieving environmental goals and minimizing costs to society by being an incentive for investment in clean technologies, which is why it plays an essential role in formulating effective climate mitigation strategies [3,4].

This article analyzes the effects of environmental policy and its potential role in achieving the Sustainable Development Goals (SDGs). The European ETS, a well-known example fully integrated into the ecosystem of European environmental policy, was chosen as a reference [5], and a set of SDG-related variables was selected to test the link.

How effectively the ETS integrates the costs of carbon emissions is an important critical dimension [6]. In this regard, a recent study showed a gradual improvement [7] due to the various corrective actions implemented over the years to reduce the risk of carbon leakage. This phenomenon implies that emission reductions within the EU could be offset by a concomitant increase in emissions, although elsewhere, due to the shift of production to places with more permissive regulations [8,9]. To prevent such negative externalities, free allocations are provided for industries exposed to the risk of relocation [10,11].

The objectives of this study were twofold: to analyze the determinants of the correct allocation of environmental responsibility and to explore the relationship between the effectiveness of the ETS system and specific SDGs, which is a prominent topic [12]. The analysis was based on data from the European database on SDGs and the circular economy and data from the EU registry for verified emissions. The empirical analyses were performed on panel data containing information from 2016 to 2021 for industrial sectors based on the European statistical classification of economic activities NACE Rev. 2 of the European Union.

This study examined the connection between the effective allocation of environmental responsibility within the ETS and the achievement of specific SDGs. Two research questions were posed: how do determinants of emissions influence the appropriate distribution of environmental responsibility, and what is the correlation between the system's effectiveness and the SDGs it impacts?

The key findings included the need for balanced policies that consider the effects of international trade on emissions and the need to invest in clean technologies and encourage efficient production practices. In addition, the analysis showed how the ETS efficiency affects various aspects of sustainable development, including raw material consumption and the use of renewable energy sources, highlighting the complexity of the interactions between environmental policies and the SDGs.

Such findings contribute to the literature by providing new insights that are valuable to the scientific community, policymakers, and practitioners because they provide a basis for policy formulation to facilitate the transition into a green and sustainable economy by addressing the challenge of effectively balancing environmental efficiency with sustainable economic development.

This paper is organized as follows. Section 2 contains background information to properly frame the objective of this study. Section 3 refers to the research design and methods, including the definition of the variables and research questions (RQs). Section 4 summarizes the main findings discussed in Section 5, in which policy implications are also provided. The conclusions follow in Section 6.

2. Background

The European Union generates approximately 8% of global carbon emissions [13], and the European ETS is currently the world's largest carbon market [14]. A cap is imposed on the aggregate volume of emissions that can be produced annually, and it is consistently reduced over time [15] to reduce emissions in the medium and long term. Companies that fill installations within the ETS scope can buy or sell allowances [16] that are also allocated for free based on the allocation rules.

Companies that do not receive emission allowances for free or where the allowances received are insufficient to cover their emissions must buy allowances at auctions or from other companies. Conversely, those with emission allowances above their emissions can sell them. Companies facing difficulties in reducing their emissions can reduce them by investing in efficient technologies, purchasing the necessary allowances from auctions or the market, or combining the two options [17], ensuring that emissions are reduced cost-effectively. These transactions are based on strategic decisions and aspire to converge environmental and economic objectives [18]. Firms are supposed to innovate by embracing cleaner technologies, and these innovations will culminate in an overall decrease in carbon emissions [19]. For the mechanism to be efficient, carbon pricing plays a significant role [20] because it aims to internalize the external costs of emissions and link them to their sources through a price signal [21].

At the time of writing, the ETS covered approximately 45% of the European emissions generated by nearly 11,000 installations. Figure 1 shows the trends in the verified emissions and freely allocated allowances in European industry over the period covered by this analysis.

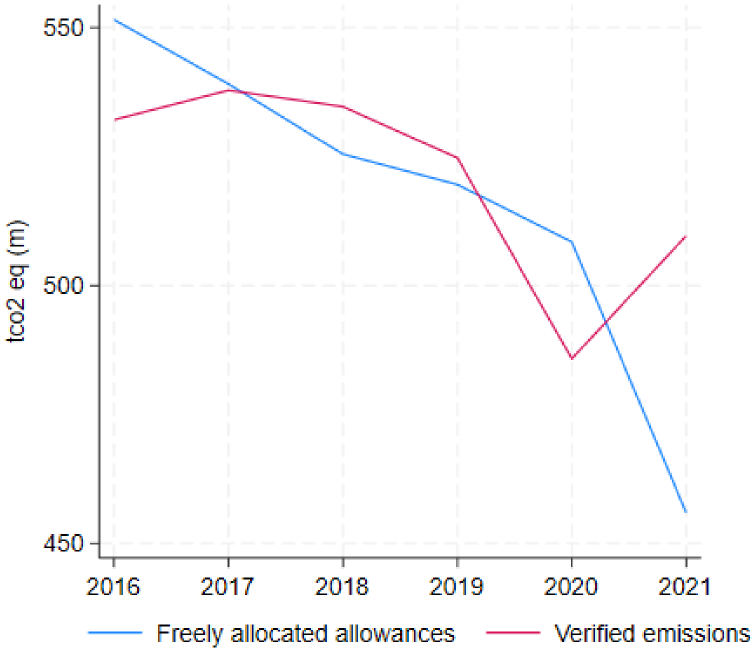

Figure 1. Verified emissions and free allocations. Source: Our own elaboration on the ETS data viewer and [13], and all the industrial sectors covered by the ETS, except combustions.

Recent regulatory and environmental policy developments have significantly impacted the system's development prospects and goals. For example, under the European Green Deal, which has given rise to a series of market regulation measures and policies aimed at promoting sustainability in various sectors of the economy [22], the European strategy aims to reduce greenhouse gas emissions by at least 55% by 2030 [23] to achieve decarbonization by 2050. Therefore, it is evident that steps must be taken to meet the goal, as the emission reduction path should accelerate. Figure 2 shows the trends in the ratio between free allowances and verified emissions in European industry.

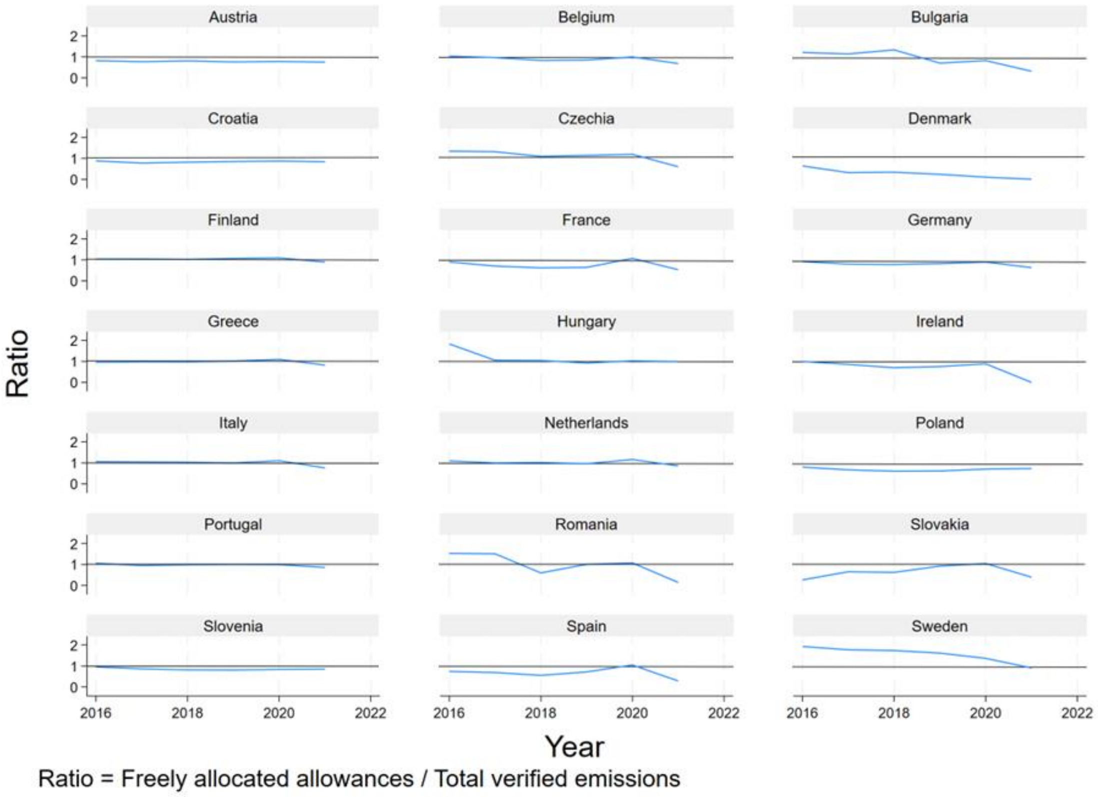

Figure 2. Ratio between free allowances and verified emissions. Source: Our own elaboration on the ETS data viewer and [13], and all industrial sectors, except combustions.

This article discusses the link between the ETS and related SDGs. The goal was to highlight potential areas where environmental and industrial policies could focus to increase sustainability and a circular economy [24]. This was done by introducing the variables obtained from the European database on sustainable development and the circular economy into our analysis.

3. Research Design

The variables selected for the regression analysis and elasticity estimation, the research questions to be tested, and the model are described in this section. The sample contains data from the manufacturing installations aggregated by country and economic activity for the years 2016 to 2021.

3.1. Variables

The data on verified emissions and free allowances were obtained from the European ETS data viewer, and merged with other databases containing data on emissions, turnover, imports, and exports of economic sectors classified using the classification of economic activities. In addition, we added data on the SDGs to create a functional dataset for the econometric analyses to answer the RQs.

The variables used to develop the model were selected among those related to climate issues available in the EU dataset and are as follows: *gap* measured the difference between the total carbon emissions generated by domestic demand and verified emissions; thus, it was a measure that captured emissions not accounted for by the system. Table 1 summarized the variables used in the models: *cint* was the emission intensity, i.e., the ratio of carbon emissions to turnover; *csh* represented the percentage of sector verified emissions to total emissions and was thus a proxy for the relative size of the industry in terms of emissions; *eua* was the price of allocations; and *open* served as a measure for capturing international openness, taking into account the size of the sectoral economy. Then, *cbal* defined the balance between carbon imports and exports, *cbali* represented the balance of the interaction between carbon imports and the sectoral dimension and the interaction between carbon exports and the sectoral relative size, *depen* was the interaction between energy dependence and the emissions generated by domestic demand, and finally "gdpop" described the interaction between GDP and population, where "pop" is population and "year" is the year.

Table 1. Descriptive statistics.

Variables		**Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
cint	%	1382	248.50	585.37	0.01	7495.36
csh	%	1492	15.70	35.96	0.00	269.94
eua	€	1492	21.66	16.27	5.35	53.55
open	index	1152	5577.44	13,608.87	0.00	154,801
cbal (m)	ton	1132	−0.10	1.04	−5.83	5.90
cbali (m)	ton	1132	−16.30	113.00	−804.00	394.00
depen(m)	ton	1492	82.70	203.00	0.02	2210.00
gdpc	€ pc	1492	0.03	0.02	0.01	0.11
pop	n	1492	25.10	26.40	0.58	83.20
year	n	1492	2018.50	1.71	2016.00	2021.00

Source: Our own elaboration.

We explored this issue using the following approach based on a regression analysis, as formalized in Equation (1).

$$\mathrm{y_{it}} = \beta_0 + \beta_1\mathrm{x_{1it}} + \beta_2\mathrm{x_{2it}} + \cdots + \beta_k\mathrm{x_{kit}} + \mathrm{u_i} + \varepsilon_{\mathrm{it}} \quad (1)$$

where $\mathrm{y_{it}}$ is the dependent variable, $\mathrm{x_{1it}}, \mathrm{x_{2it}}, \cdots, \mathrm{x_{kit}}$ are the independent variables for unit i at time t, $\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients to be estimated, $\mathrm{u_i}$ is the unique random effect that captures unobserved influences that are constant over time for each unit, and $\varepsilon_{\mathrm{it}}$ is the error term. Therefore, Equation (2) formalized our model.

$$\mathrm{gap}_{it} = \beta_0 + \beta_1\mathrm{cint}_{it} + \beta_2\mathrm{csh}_{it} + \beta_3\mathrm{eua}_{it} + \beta_4\mathrm{open}_{it} + \beta_5\mathrm{cbal}_{it} + \beta_6\mathrm{cbali}_{it} + \beta_7\mathrm{dep}_{it} + u_i + \varepsilon_{it} \quad (2)$$

After estimating the model on the basis of Equation (1), we calculated the vector of residuals between the dependent variable and the estimate of the same variable on the basis of the model. We then used the model results to answer the RQs underlying this paper.

However, this research methodology had some limitations due to the estimations needed to align the data due to discrepancies between the European Economic Activity Nomenclature codes, the verified emissions register, and the database containing the emissions used to estimate the emissions generated by household demand. After assessing the model, we calculated a measure of effectiveness based on Equation (3).

$$X_{it} = 1 - \left(\frac{1}{1 + e^{-\mathrm{resi}}}\right) \quad (3)$$

This formula used the model residuals, i.e., the difference between the actual value of the variable *gap* and the predicted values, to generate an efficiency measure named *X*, as was commonly done [25,26]. In the second stage of the analysis, we proceeded in two ways. First, we correlated the variable X with the SDG variables, and then we calculated the elasticity of these variables concerning the X variable.

The selection of the variables was straightforward (Table 2). Environmental taxation is a prominent instrument for implementing EU energy and climate policies [27]. Similarly, there is a growing interest in climate-related economic losses following the Paris Climate Conference, which enshrined loss and damage as a permanent feature of the global climate regime [28]. Regarding the use of raw materials, many key industries require increasing quantities of raw materials [29], especially considering green transition policies along with the value added in environmental goods and services [30]. The circular material use rate is one of the leading indicators of circular economy progress [31]. The following three variables relate to energy, where the first is the final energy consumption [32], given that the factors influencing these variables fit this paper. The second variable relates to the energy import dependency [33], whereas the third is renewable energy in the final energy consumption, which has increased and has become a central target of EU countries' climate plans [34].

Table 2. Descriptive statistics of the sustainable development variables.

Label		**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
entax	%	1492	6.815	1.646	3.61	11.66
losspc	€ pc	1038	60.985	115.943	0.05	859.53
rawpc	pc	1492	17.005	6.938	7.335	47.737
vaegs	m	1492	2.309	1.073	0.59	6.92
cmu	%	1492	10.854	7.235	1.3	33.8
fec	toe	1492	2.303	0.854	1.13	7.16
eid	%	1492	55.812	17.632	1.208	96.28
resfc	%	1492	20.254	8.855	5.364	43.939

Source: Our own elaboration.

This approach is useful for identifying the possible areas of improvement for environmental policies to address climate change at the lowest cost to society and to test the linkage with the SDGs by providing valuable insights for policymakers.

3.2. Research Questions

This study investigated the connection between the proper allocation of environmental responsibility in the ETS and achieving specific SDGs. The research questions were as follows. RQ 1: How do the determinants of emissions affect the proper allocation of environmental responsibility? This RQ was based on the fact that environmental policy prevents and repairs environmental externalities while minimizing the cost to society. The idea was that the proper allocation of costs to mitigate environmental externalities from carbon emissions should be consistent with the polluter pays principle [10,11]. The hypothesis to be tested was that there is scope for improving the allocation of environmental liability so that the party responsible for the externality can bear the costs of prevention or remediation based on the actual magnitude of the externality produced. The alternative hypothesis was that cost allocation is already efficient.

RQ2: What is the relationship between the effectiveness of the system and some SDG variables that it affects? The intuition was that there is a link between ETS effectiveness, specifically in allocating costs based on the polluter pays principle, and the identified SDG variables. By answering the RQs, this paper provides an in-depth understanding of the dynamic between carbon pricing policies and sustainability, thus contributing to the existing literature and offering useful guidance for the formulation of more effective environmental policies.

4. Results

In this section, we report the results of the first stage of the analysis, i.e., the model results formalized in Equation (1), and the second stage of the study, in which the model result was used to test the linkage with the SDGs. The results of Equation (2) using a linear panel model with random effects are summarized in Table 3. The econometric analysis provided a detailed overview of the relationship between the economic and environmental variables and ETS effectiveness. Specifically, model 1 analyzed 1132 observations, which were grouped into 236 different entities (id), from 1460 initial non-aggregated data extrapolated from the union registry of the ETS. The model explained a high percentage of the observed variance of the gap being the variables included in the model indicative of the factors affecting the gap, as also confirmed by the Wald X^2 value (6164.88) with *p*-value (Prob > X^2 = 0.000). Analyzing the regression coefficients provided crucial insights into how the different factors influenced the carbon emission gap. The disparity between the intragroup and individual variances suggested that the between-group variance was higher than the within-group variance, indicating that a substantial portion of the total variance could be attributed to group differences.

Table 3. Regression analysis.

Variables	Model (1)	Model (2)
cint	−399.3 ***	−439.3 ***
	-81.66	-82.91
cshare	−127,141 ***	−125,224 ***
	-1959	-2044
eua	6444 ***	7087 ***
	-674.5	-2587
open	8.615 **	12.44 ***
	-4.258	-4.471
cbal	0.660 ***	0.649 ***
	-0.0654	-0.0655
cbali	−0.0059 ***	−0.0058 ***
	-0.00067	-0.00067
depen	0.0139 ***	0.0143 ***
	-0.00034	-0.00036
gdpc		−5.959 m
		(4.065 m)
pop		−0.00810 **
		-0.00325
year		−2410
		-27,325
Constant	−200,250 **	4.956 m
	-82,654	(55.080 m)
R^2	Overall: 0.978	Overall: 0.977
Observations	1132	1132
Number of id	236	236

Source: Our own elaboration. Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$.

On the basis of the assumption that the greater the supply of free allowances to installations in a given sector, the more significant the reduction in the gap, allocations may have mitigated the cost of emissions for ETS-covered installations.

It was observed that an increase in the energy intensity in a sector was correlated with a decrease in the carbon gap, which suggested that industries with a higher energy intensity fell more effectively under ETS accounting, as opposed to those with a lower energy intensity. Thus, the monitoring mechanism appeared to be more effective in energy-intensive sectors. An increase in the relative size of an industry was associated with a reduction in the gap. This indicated that the sectors with a more significant impact on total emissions also had a smaller relative gap. The combination of the first two variables highlighted how well the mechanism worked.

The higher the price of allowances, the wider the gap, indicating that higher carbon prices may not directly translate into reduced emissions without proper control mechanisms. Below, we considered three variables related to international trade.

An increase in a sector's international openness corresponded to an increase in the gap, suggesting that industries more exposed to global trade may be subject to competition and environmental dumping practices, negatively affecting the accuracy of emissions monitoring. An increase in the net balance between carbon imports and exports was also associated with an increase in the gap. The sectors that import more carbon than they export were a critical issue.

The increase in the interaction between carbon imports and the sectoral size was related to a decrease in the gap, highlighting that the sectors with more significant imports and a greater sectoral size showed a smaller discrepancy in the emissions balance than smaller sectors. Similarly, it was observed that higher levels of energy dependence corresponded to a greater gap, which was consistent with what was found on the import of emissions; that is, imports from countries with a less clean energy mix than European countries had a negative impact on the accuracy of the system. The results presented in Table 3 confirm the hypothesis behind RQ1 and provide insights for policymakers. To check the robustness of the model, an extended version was developed, as shown in model 2 in Table 3, containing additional exogenous variables.

In the second stage of the analysis, we focused on the link between the efficiency of the ETS mechanism and the key variables of sustainable development. Table 4 presents the correlations between these variables, including those derived from the model expressed in Equation (1).

Table 4. Correlations between the SDG variables and the proxy for ETS efficiency.

Variables	X	entax	losspc	rawpc	vaegs	cmu	fec	eid	resfc
X	1								
entax	0.013	1							
losspc	−0.092	−0.177	1						
rawpc	0.016	−0.005	−0.100	1					
vaegs	−0.054	−0.038	−0.069	0.651	1				
cmu	−0.022	−0.094	0.171	−0.549	−0.151	1			
fec	−0.018	−0.337	0.221	0.316	0.364	0.304	1		
eid	0.001	−0.175	0.237	−0.407	−0.183	0.238	0.203	1	
resfc	−0.044	0.164	−0.037	0.572	0.648	−0.525	−0.042	−0.133	1

Source: Our own elaboration.

To estimate the elasticity of the various sustainable development variables concerning the efficiency of the ETS mechanism, we proceeded by regressing X against each variable of interest. These variables were transformed into logarithms to ensure interpretation in terms of percentage changes. This approach facilitated an understanding of the degree of sensitivity of the efficiency of carbon pricing-based climate policy to changes in the sustainable development variables. The results shown in Table 5 highlight the elasticities of the environmental and sustainable development variables concerning the ETS efficiency.

Table 5. Elasticity.

	entax	losspc	rawpc	vaegs	cmu	fec	eid	resfc
ETS Effect	−0.022	−0.846	0.041	−0.043	0.002	0.02	0.053	−0.013
Std. Err	−0.011	0.248	0.011	0.014	0.024	0.005	0.025	0.019
p-value	0.054	0.001	0	0.002	0.908	0	0.039	0.501
	*	***	***	***		***	**	

Source elaboration. Values in logarithms. Standard errors in parentheses, *** p < 0.01, ** p < 0.05, * p< 0.1.

An increase in efficiency was correlated with a decrease in environmental taxes (−0.022 *), confirming that a more efficient ETS positively affected environmental taxation. An efficient system was associated with a significant reduction in climate-related economic losses (−0.846 ***), indicating the effectiveness of the ETS for mitigating the economic impacts of climate change. However, an increase in the consumption of raw materials was observed with a more efficient ETS (0.041 ***), raising questions about the sustainable use of resources, as was marked with the environmental value added (−0.043 ***). In this case, a potential trade-off between the efficiency and growth of services aimed at decarbonization emerged. No significant relationship was observed between the ETS efficiency and the use rate of circular materials (0.002). The relationship between the final energy consumption (0.020 ***) was interesting and consistent with what was reported in Table 3, as it was with energy dependence (0.053 **). Finally, no significant relationship was found between the renewable energy sources and final consumption (−0.013). The above confirmed the hypothesis that there was a connection between the efficiency of climate policy based on carbon pricing and the SDGs.

5. Discussion

Our research sought to understand the impact of the ETS and its intersection with environmental policies and sustainable development. The results of our analysis provided critical insights into these complex relationships. Here, we discuss the implications in the context of the existing literature. Our results share some similarities with other studies that examined the implications of carbon pricing mechanisms and noted that while such tools have successfully contributed to substantial emission declines, they are also associated with undesirable phenomena regarding healthy competition [35]. As the European Court of Auditors pointed out, free allowances still account for a remarkable share of all available allowances and have not been appropriately targeted [36]. Similar to previous studies, we recognize that carbon pricing has successfully contributed to substantial emission reductions [37]. However, we also identified some challenging issues regarding jointly evaluating it with SDGs.

The results offered several important insights for designing environmental policies and regulating carbon emissions. The negative association between energy intensity and the gap may indicate that incentives to increase energy efficiency in sectors could be an effective strategy for improving monitoring accuracy and reducing carbon emissions. This implies investing in clean technologies and encouraging more energy-efficient production practices [38]. In addition, the observed negative correlation between the relative sector size and the gap indicated that the sectors with higher emissions were effectively monitored [13]. There may be value in intensifying monitoring and regulatory efforts in industries with fewer emissions, which may escape effective tracking. The increase in the gap associated with rising carbon prices was linkable to the fact that higher carbon price policies may not always effectively reduce total emissions, highlighting the need to balance carbon pricing policies with measures that limit the risk of carbon leakage [39,40], such as investment in technological innovation and international cooperation. The positive association between international openness and the gap suggested that integrating global markets can complicate efforts to reduce carbon emissions. Therefore, policies should consider the effects of international trade on emissions and explore mechanisms to mitigate the negative environmental impact of trade [41,42]. Finally, the influence of energy dependence confirmed the importance of an energy transition [43] to cleaner sources [44] and the need to support investments in green technologies. Policies promoting renewable energy use and reducing dependence on fossil fuels can help reduce the gap and achieve more ambitious climate goals, provided an appropriate level playing field is maintained.

The analysis of the relationship between ETS efficiency and sustainable development variables offers important insights into environmental policies. Reducing environmental taxes and climate-related economic losses with a more efficient ETS confirms that the system can be an effective environmental policy tool. However, the association between an increase in raw material consumption and final energy consumption poses challenges regarding sustainable resource management and reduction in overall energy use. The absence of a significant relationship between the use of circular materials and renewable energy sources suggests the need to integrate environmental policies with other measures, such as market reforms, to promote the circular economy [45] and energy transition. Finally, attention is drawn to the need for policies that balance efficiency with energy security and independence [46,47], given recent crises that have seriously undermined the resilience of the European economy.

Although this study offers valuable insights, it is important to acknowledge the limitations associated with data harmonization. While the novel finding of a direct link between the efficiency of the ETS and SDGs is noteworthy, a more comprehensive analysis should consider overlapping alternative policies to fully comprehend the impact.

This study has policy implications. Integrating environmental policies with market reforms is vital, as is the diversification of policy instruments that carefully manage overlapping [48,49]. We argue that complementary policies can achieve better results. This is consistent with previous studies, providing further support for the claim that the diversification of policy instruments can advance climate governance [50]. Regular evaluation of carbon pricing mechanisms is critical as is the integration of environmental policies with sustainable development.

6. Conclusions

This study analyzed the determinants of the correct allocation of environmental responsibility and explored the relationship between the effectiveness of the ETS system and specific SDGs. The results showed that energy intensity and the relative size of the sector in terms of emissions were crucial factors affecting the effectiveness of the ETS. It was also observed that higher allocation prices and international sector openness can negatively affect the accuracy of emission monitoring. These results suggest that targeted policies and a balanced approach are essential for improving the effectiveness of the ETS and addressing the challenges of climate change.

The link between the ETS efficiency and key sustainable development variables was also explored. The analysis revealed that a more efficient ETS could positively impact aspects such as reducing environmental taxes and climate-related economic losses. However, challenges have emerged, emphasizing the need for a holistic approach that integrates carbon pricing with sustainable development policies.

A combination of policies, including improvements in energy efficiency, targeted regulations, balanced carbon pricing policies, international trade considerations, and an energy transition to cleaner sources, is essential to effectively address the carbon emissions challenge.

Future research could comparatively analyze the effectiveness of the ETS on the SDGs in different regions, explore the potential of circular economy and resource efficiency, and assess the distributional effects on socioeconomic groups.

In addition, long-term scenarios should be developed to examine the evolution of the ETS by evaluating its potential contribution to achieving the sustainability goals through different economic and technological pathways, minimizing social and economic costs.

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