5th International Conference on Energy and Environment: bringing together Engineering and Economics
Porto, Portugal
2-3 June, 2022

EU ETS EFFECTS ON EMISSIONS OF EUROPEAN UNION INDUSTRIES

Mara Madaleno,[1*] Mónica Meireles[2] and Margarita Robaina[1]

[1] GOVCOPP, University of Aveiro, DEGEIT, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal
[2] Iscte – Instituto Universitário de Lisboa, Business Research Unit (bru_iscte), Avenida das Forças Armadas, 1649-026 Lisboa, Portugal

* Corresponding author: maramadaleno@ua.pt, University of Aveiro, Departamento de Economia, Gestão, Engenharia Industrial e Turismo (DEGEIT), Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

KEYWORDS
Carbon pricing, EU ETS, Environmental policy

ABSTRACT

This article contributes to the literature by analyzing how has the EU ETS allowance price affected the CO2 emissions of the EU industries, analyzing eight economic activity sectors for the three EU ETS phases (2005-2020). Estimations were performed using both a sample of 33 and 23 European countries through panel estimations. From the results, it was inferred that only in the sectors manufacture of paper and paper products (mpp) and manufacture of other non-metallic mineral products (monmp) the impact of CO2 allowances prices has lead to the reduction of emissions intensity significantly, meaning that they reduce the emissions amount whenever the price of these allowances goes up. Therefore, the effect of allowances prices on emissions intensity is heterogeneous among sectors and the implementation phase of the EU ETS is relevant to explain emissions intensity reductions (phase 3) or increases (phases 1 and 2). Policymakers, thus should devote more attention to the other sectors where prices do not reveal a negative nor significant impact on emissions intensity.

INTRODUCTION

The world is facing a big challenge in dealing with the excess greenhouse gas (GHG) emissions, in particular the increase in CO_2 emissions. Indeed, currently, these emissions have already resulted in climate change, like the increase in temperatures, extreme weather events, natural disasters, and changes in biodiversity. Therefore, several countries have recently adopted the Paris agreement, to commit themselves to achieving emissions abatement goals to keep the global average temperature below 1.5 degrees Celsius. As a response, at the European level, it was adopted the European Union Emissions Trading Scheme (EU ETS), one of the main emission abatement policies to reduce emissions from energy-intensive industrial and manufacturing producers. It was introduced in 2005 and it is currently the largest cap-and-trade program in the world (Dechezleprêtre et al., 2018). This policy consists in supplying emissions permits whose quantity is constrained to an upper limit of emissions, usually associated with the emissions reductions level that is intended to achieve. Then those permits can be traded according to each firm's needs. Therefore, the firms with an excess of permits can sell in the allowance market whereas the firms emitting more than the permits that they own can buy in the market. The price of the allowances is determined by the demand and supply of permits, creating daily-spot prices for allowances. This market-based instrument ensures that emissions reductions are achieved in a cost-effectively way.

Although there are studies that evidence the effectiveness of EU ETS in reducing emissions (as Ellerman and Buchner, 2008, Anderson and Di Maria 2011, Abrell et al., 2011 or Åberg, 2021), there are other studies that evidence different impacts on different sectors, that may cause problems, as the green paradox, the carbon leakage, or the cost pass through the consumers (Tavares and Robaina, 2021, Lise et al 2010). Indeed, as the EU ETS only covers European companies, carbon and energy-intensive companies can be injured in their competitiveness due to this partial implementation of climate policy. Moreover, other sectors can also be at a disadvantage, if they export to, or import from, regions that have not implemented a similar climate policy. This distortion depends on i) the carbon intensity of the production process, ii) the price for EU allowances (EUAs), iii) the significance of the additional carbon costs concerning other production costs, and iv) the extent to which these additional costs may be passed-through (Graichen, et al. 2008). Therefore, the EU ETS may lead to a shift in production or to the relocation of industrial production facilities to regions without stringent climate policies, and would hence imply carbon leakage. This phenomenon essentially occurs through the relocation of emitting companies (from different sectors) from countries within the capping mechanism to others without the same commitment, to reduce their private costs for pollution mitigation, or the acquisition of emission allowances (Eichner and Pethig, 2011, Tavares and Robaina, 2021).

To mitigate these risks, the majority of the allowances were initially distributed for free, in the first two trading periods (2005–2012). However, major revisions were undertaken for the third trading period (2013–2020), to strengthen the EU ETS especially concerning the allowance allocation and included: a single union-wide cap, instead of national caps, harmonizing the ambition between the Member States and therefore the level of allocation to their industries; allowances became to be auctioned, reducing the percentage of free allowances; coherent rules for free allocation based on (emission performance) benchmarks (for products and fallback approaches for heat and fuels) standardized the approach for installations within each sector or sub-sector (Healy et al., 2018).

Given these changes, installations covered by the EU ETS may now be at a greater risk of carbon leakage than in the past. Despite the increased efforts by third countries to implement more ambitious climate change policies, the European Commission (2015) concluded that no comparable action was being taken by them. As a consequence, it was considered necessary to continue to protect those sectors or sub-sectors at risk of carbon leakage via the provision of a higher share of free allowances in the third trading period in comparison to other industrial installations. These sectoral impacts require that more studies should be made at the sectoral level. Most of the studies focus on the impacts on the energy companies (as Pietzcker et al. 2021, Neuhoff et al, 2006, or Lise et al 2010), but there is a scarcity of studies that incorporate other sectors, or even that compare the EU ETS effects in different sectors. Therefore, this paper intends to provide policy analysis on how the EU ETS allowance prices are affecting the industrial CO_2 emissions in the EU countries. Furthermore, it assesses whether there are differences among sectors regarding emissions patterns and whether these changes are due to the EU ETS allowance price. Hence, this study seeks to answer the following question: How has the EU ETS allowance price affected the CO_2 emissions of the EU industries? The results might be helpful for policymakers to make sector-specific adjustments to achieve the overall policy efficiency.

LITERATURE OVERVIEW

According to the European Commission (2021), the EU ETS has proven to be an effective tool in driving emissions reductions cost-effectively. Installations covered by the ETS reduced emissions by about 35% between 2005 and 2019.

Several studies tried to access if the EU ETS and its associated carbon price are being effective in reducing CO_2 emissions. Methodologically, this is a tough mission as it requires comparing actual emission levels under the EU ETS with emission levels that would occur if the EU ETS would never be implemented (Hovi et al., 2003, Bayer and Aklin, 2020). Some studies used econometric modeling to estimate EU ETS-associated emissions reductions, as the ones by Ellerman and Buchner (2008), Delarue et al. (2008), Anderson and Di Maria (2011), Abrell et al. (2011), or Egenhofer et al. (2011). Åberg (2021) states that existing literature points to attributable emission savings in the range 40 – 80 MtCO2/yr, annual average to date, which means about 2-4% of the total capped emissions, which is much bigger than the impact of most other individual energy-environmental policy instruments.

Still, there is some skepticism about the EU ETS effectiveness due its low price compared to the social cost of carbon. Green (2021) surveyed studies that relate the carbon price to emissions and stated that the general results show that the carbon prices are not high enough to cause significant decreases in emissions. Moreover, Jaraite-Kažukauske and Di Maria (2016) concluded that although a slight decrease in emission intensity was identified, the EU ETS did not lead to a reduction in CO_2 emissions, concerning Lithuanian firms between 2003-2010.

Nevertheless, Bayer and Aklin (2020) assessed through a statistical model with panel data, whether the EU ETS has reduced CO_2 emissions despite its low prices, and concluded that it saved about 1.2 billion tons of CO_2 between 2008 and 2016 (3.8%). Indeed, they state that a carbon market can be effective if it becomes more stringent in the future. Firms might cut emissions even though market prices are low. In effect, low prices can be a signal that the demand for carbon permits weakens. Thus, low prices are compatible with successful carbon markets.

Haites (2018) studied the performance of carbon pricing policies concerning emission abatements and cost-effectiveness and found that carbon taxes in Europe have made overall reductions up to 6,5% over several years. The author also concluded that in the countries enrolled in the EU ETS, the CO_2 mitigation happens more quickly than in those with only a carbon tax. Indeed, Murray and Maniloff (2015) compared the emissions reductions associated with EU ETS to the ones associated with other factors, such as additional environmental programs, recession, and lowered natural gas prices, using econometric models. They concluded that the emissions would have been 24% higher without the EU ETS, supporting its efficiency. Particularly, Kotnik et al. (2014) found that an increase in carbon price by 1 euro results in a 0,014-ton decrease in emissions per year in industrial processes.

Concerning sectoral studies, we can point specific studies for the electricity sector. For instance, Pietzcker et al, 2021 say that shrinking the EU ETS target would speed up the transformation by 3–17 years for different parts of the electricity system, with renewables contributing 74% of the electricity in 2030, EU-wide coal use almost completely phased-out by 2030 instead of 2045, and zero electricity generation emissions reached by 2040. The European Court of Auditors (European Union, 2020) assessed the reduction in the carbon intensity of the energy sector of countries eligible for free allocation, compared to the same data for countries that do not benefit from this allocation, and the results show a much smaller decrease in carbon intensity in the Member States that received free allowances to modernize the energy sector. A recent study (Sandbag, 2019) on the reduction of coal as a basis for energy production in 2019 also confirms this trend. Except for ten lower-income Member States, the ETS excluded the electricity sector from the allocation of free allowances, as this sector was able to pass the costs on to its customers, so it was not exposed to the risk of carbon leakage (European Union, 2020). When a free allocation is not properly targeted, it can lead to situations where sectors can shift carbon costs even when they receive this type of allowance. As a result, free allowances imply a financial transfer from consumers (or customer industries) to energy-intensive industries, which would give rise to what is often referred to as "windfall profits" (European Commission, 2015). Still, for the energy sector, Weigt et al. (2013) present an interesting conclusion. The authors state that the emission reduction would be larger with higher CO_2 prices. However, the bigger factor in explaining the reduced demand for allowances is the direct reduction of CO_2 emissions by renewable energy (RE) injections, that is, these injections are more effective in reducing CO_2 emissions than the EUA price. Although a carbon price tends to substitute coal generation for lower-emitting gas generation, RE injections displace whatever is on the relevant margin with a zero-CO_2-emitting source. The displacement occurs without regarding to the carbon content of the displaced generation, but in the existing electricity systems this is nearly always CO_2-emitting fossil generation. Hence, this explains the large abatement effect and consequent reduction in the demand for allowances within the EU ETS. Moreover, Lise et al (2010) state that emissions trading and the resulting pass-through of carbon cost to electricity prices reduce CO2 emissions significantly by affecting not only producers' decisions—through a re-dispatch or change in the merit order of generation technologies—but also consumer' decisions, through reducing power demand in response to ETS-induced increases in electricity prices, that is, if power demand is price responsive (mainly in the medium or long run), the pass-through of carbon costs to higher electricity prices for end-users can be a major contributor to the goal of reducing CO2 emissions in the medium or long term.

Other studies were made for other specific sectors, such as aviation (Meleo et al., 2016, Anger and Köhler, 2010, Faber and Brinke, 2011, Girardet and Spinler 2013, Malina et al. 2012) pulp and paper sectors (Fontini and Pavan, 2014) or cement and aluminum sectors (Healy et al., 2018).

Comparing several sectors, we can point out the studies of Robaina-Alves et al. (2011) and Robaina and Gonçalves (2019) for the first and second phases of EU ETS respectively, both applied to Portugal. Both studies point out the not uniform distribution across all companies and sectors, as they do not have the same level of pollution, as well as other factors such as technology, fuel substitution capacity, the flexibility of adaptation, and economic vulnerability. Only the thermoelectric generation sector has had significant negative balances (in 2005, 2008, and 2009), but even this sector was long in Phase I as a whole. The sectoral bias in the allotment of emissions is also clear at the European level, where the Power and Heat sector stands out for its net short positions in all periods (Kettner et al., 2008). Some possible reasons for this bias are worries about competitiveness in tradable sectors and carbon leakage, as well as the apparent availability of cheaper abatement options in the sector. Interestingly, for Portugal the results for thermoelectric generation are seen to be highly dependent on weather conditions, namely precipitation, due to the necessity of replacing hydropower, which accounts for the most significant part of domestic energy production, when hydrological conditions are dry. A final point regarding the thermoelectric sector is that unlike what has happened in many EU countries, price pass-through has not been a significant feature in the strongly-regulated Iberian market. For the first period, most installations in all sectors may have gained from EU ETS participation, with firms in sectors like ceramic and cogeneration showing considerable potential for additional revenues, with emissions far below the received licenses.

METHODS AND DATA

The EU ETS is built on an auctioning principle, ensuring that the allowances prices are the equilibrium prices that come out from the demand and supply matching. However, the supply of allowances is fixed by policymakers as they decide the cap of allowed emissions. Thus, a lower cap results in lower supply and higher prices. Increased demand also pulls allowances prices up. But, if allowances prices are lower than the cost of production adjustments to pollute less, it is simpler to buy allowances than to adjust production levels to be more environmentally friendly. Thus, allowances prices must always be higher than the cost of adjusting production to lower production levels. Our empirical research uses panel regression analysis to investigate how the industrial emissions of various EU countries are affected by the price of emissions permits. The chosen period is that of the available data from 2005-2020 (covering the first trading period: 2005-2007; the second period of allowances trading: 2008-2012; and the third trading period: 2013-2020), limited to eight industries (Manufacture of paper and paper products (mpp); Manufacture of coke and refined petroleum products (mcrpp); Manufacture of chemicals and chemical products (mccp); Manufacture of other non-metallic mineral products (monmp); Manufacture of basic metals (mbm); Manufacture of fabricated metal products, except machinery and equipment (mm); Electricity, gas, steam and air conditioning supply (elec); Air transport (at). This choice is due to data availability but also to the European Commission classification: "The EU ETS covers the following sectors and gases, focusing on emissions that can be measured, reported and verified with a high level of accuracy: carbon dioxide (CO2) from electricity and heat generation, energy-intensive industry sectors including oil refineries, steelworks, and production of iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic

chemicals, commercial aviation within the European Economic Area (information retrieved from: https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_pt#ecl-inpage-685)). The air emissions intensities by NACE Rev. 2 activity is the dependent variable, measured in terms of Kilograms per euro, at current prices, which is the ratio between tons of CO2 emissions and the gross value added, both by the economic activity sector. The data of emissions, gross value added and emissions intensity (retrieved from the website: https://ec.europa.eu/eurostat/
databrowser/view/ENV_AC_AEINT_R2/default/table?lang=en&category=env.env_air.env_air_aa) from the various sectors and countries were collected from Eurostat (2021) and the European Environment Agency, EEA (2021). The independent variable of interest used is the data of allowance prices, collected from Ember (2021) and confirmed through sendeco (https://www.sendeco2.com/es/precios-co2), adjusted to mean annual data since it originally covered weekly spot-price data of EU ETS allowances in euros. Variable trade phase (years) were included in the regression analysis as dummy variables (3 in total). Robust standard error specification is used to control for any possible heteroscedasticity. Simple fixed effects panel data models were run, one for each economic activity sector. Thus, as explanatory, we will have EUA price (EUR / t CO2-eq) by year and the trading phase dummies. As for the countries included in the analysis, initially, we will have 33 countries (Belgium; Bulgaria; Czechia; Denmark; Germany; Estonia; Ireland; Greece; Spain; France; Croatia; Italy; Cyprus; Latvia; Lithuania; Luxembourg; Hungary; Malta; Netherlands; Austria; Poland; Portugal; Romania; Slovenia; Slovakia; Finland; Sweden; Iceland; Norway; Switzerland; United Kingdom; Serbia; Turkey), some with missing data, and to adjust these series we end up removing 10 countries from the sample (with at least one series missing for one of the economic activity sectors of interest for all years, we had to remove the countries Ireland, Lithuania, Luxembourg, Malta, Norway, Poland, Serbia (this one only had data for all the eight sectors during 2010-2014 and was as such removed as well), Sweden, Switzerland, and Turkey).

RESULTS

Panel regression results presented in Table 1, allow us to conclude that all variables in the model have a statistically significant influence on emissions, but not for all sectors. When significant, prices have a negative impact on emissions intensity, usually with a common pattern regarding economic activity sectors. The other independent variables included, besides the allowances price, are the dummies representative of trading periods or phases in allowances. Since these are all dummies, we cannot use all the three at once in estimations. So, and to derive conclusions about their effects, we decided to individually include two by two (by order: phases 2 and 3; phases 1 and 2; phases 1 and 3). We can infer from the full sample that using time trading representatives in equations is relevant.

Table 1: Regression results for 33 countries and 23 countries samples

Full sample: 33 countries								
Sector	elec	mpp	mcrpp	mccp	monmp	mbm	mm	at
co2 price	-0.0215	-0.0031**	-0.2519	0.0009	-0.0278**	0.0236	-0.0004	0.0735
D2p	-0.8825*	0.0531	-2.6040	0.1042	-0.5930**	0.3207	-0.0949	4.3218
D3p	-3.2158***	-0.1818	1.6147	-0.5757**	-0.9966***	-0.2843	-0.1600	-2.6202
const	8.5891***	0.8076***	11.7532*	2.1383***	5.0318***	2.8862***	0.2916***	6.3852
NºObs.	436	392	328	370	390	401	401	365
F test stat	15.36***	6.88***	0.24	3.02**	10.24***	5.80***	2.28*	1.10
Sector	elec	mpp	mcrpp	mccp	monmp	mbm	mm	at
co2 price	-0.0215	-0.0031**	-0.2519	0.0009	-0.0278**	0.0236	-0.0004	0.0735
D1p	3.2158***	0.1818	-1.6147	0.5757**	0.9966***	0.2843	0.1600	2.6202
D2p	2.3333***	0.2349***	-4.2187	0.6799**	0.4036	0.6050**	0.0650**	6.9420
const	5.3733***	0.6258***	13.3678*	1.5626***	4.0351***	2.6019***	0.1316***	3.7650
NºObs.	436	392	328	370	390	401	401	365
F(3,31)	15.36***	6.88***	0.24	3.02**	10.24***	5.80***	2.28*	1.10
Sector	elec	mpp	mcrpp	mccp	monmp	mbm	mm	at
co2 price	-0.0215	-0.0031**	-0.2519	0.0009	-0.0278**	0.0236	-0.0004	0.0735
D1p	0.8825*	-0.0531	2.6040	-0.1042	0.5930**	-0.3207	0.0949	-4.3218
D3p	-2.3333***	-0.2349***	4.2187	-0.6799**	-0.4036	-0.6050**	-0.0650**	-6.9420

const	7.7066***	0.8607***	9.1491**	2.2425***	4.4388***	3.2069***	.1967***	10.7071***
NºObs.	436	392	328	370	390	401	401	365
F(3,31)	15.36***	6.88***	0.24	3.02**	10.24***	5.80***	2.28*	1.10
Reduced sample: 23 countries								
Sector	elec	mpp	mcrpp	mccp	monmp	mbm	mm	at
co2 price	-0.0221	-0.0034**	-0.2737	0.0028	-0.0299*	0.0254	-0.0003	0.0981
D2p	-0.6907	0.0515	-3.0006	0.1500	-0.6331**	0.2265	-0.0852	5.1209
D3p	-3.2606***	-0.1814	1.7850	-0.6020**	-0.9748***	-0.2153	-0.1665	-3.1042
const	8.6794***	0.8755***	12.5442*	2.0500***	5.1078***	2.5948***	0.3204***	6.8001
NºObs.	324	314	298	317	314	314	314	314
F test stat	15.86***	5.07***	0.24	3.38**	8.99***	5.51***	2.19	1.16

Only sectors manufacture of paper and paper products (mpp) and manufacture of other non-metallic mineral products (monmp) evidence a negative and significant impact of CO2 allowances prices, meaning that they will reduce the emissions amount whenever the price of these allowances goes up. This happens independently of the EU ETS phase of implementation and independently of the sample of countries, we are analyzing. For the full sample of 33 countries, we even observe that the amount of emissions of the electricity, gas, steam and air conditioning supply (elec) sector amount of emissions depends negatively on phases 2 and 3, but positively on phases 1 and 2. Inclusively, phase 1 always allowed an increase in the intensity of emissions, whereas phase 3 led to the reduction of the emissions intensity in this sector. and the output of production (GVA) has a positive effect on emissions. There may be results that are extremely high due to the underlying bias from the limitations within the dataset and the model. Other factors and circumstances have an impact on emission reductions of European EU ETS industries. Moreover, the limited data turned impossible to perform an analysis by country.

The significant reduction of the intensity of emissions is also verified during phase 3 in the sectors manufacture of chemicals and chemical products (mccp), and monmp whereas the effect of phase 1 leads to the increase in emissions intensity in these same sectors, significantly. When estimating the impact of the allowances price over the intensity of emissions considering solely phases 1 and 3, we also observe that phase 3 reduced significantly the emissions intensity of sectors manufacture of basic metals (mbm), manufacture of fabricated metal products, except machinery and equipment (mm) and mpp. This has a reasonable and simple explanation. The positive signs associated with phases 1 and 2 coefficients (significant or not) may be explained by the allocation of the free allowance provided during those phases. Moreover, Phase I and II was widely believed to have been over allocated. Kettner et al. (2010) show that the market was long overall, as the number of allowances was 3.2% higher than the emissions. The authors also state that for the EU as a whole, the Power and Heat sector was the only one to have a short position, while the other industrial sectors were all long, often by large percentages (around 20% for ceramic, iron, steel and coke, and pulp and paper). The underlying reasons for this uneven distribution of allowances among sectors appear to have been: the fear of loss of competitiveness for GHG-intensive tradable sectors, carbon leakage and also the cheaper abatement options available to the power sector. As a result, the National Allocation Plans were generous in the number of allowances allocated except for the Power and Heat sector. In contrast, in phase 3 the most pollutant economic activity sectors included in the EU ETS started to pay more for the allowances they needed when the total emissions surpassed the allocated allowances. Indeed, Phase III is a little different from the previous ones and is based on much more specific and strict rules, with some of the changes being the substantial reduction of the total cap and the fact that licenses are not granted free of charge, but through the sale at auction (more than 40% of emission allowances were auctioned). Even so, we do not observe the negative price effect in all economic activity sectors in a significant way, although the coefficient sign seems to be negative in most of these sectors. No relevant conclusions, in general, may be taken from sectors manufacture of coke and refined petroleum products (mcrpp), manufacture of chemicals and chemical products (mccp), and air transport (at). Considering the effect of the phases, for the smallest sample of 23 countries, we have only included the phases 2 and 3 dummies into estimations (Table 1).

CONCLUSIONS AND FURTHER RESEARCH

The results of this article make relevant contributions to the scientific debate. The findings of a significant negative effect of the EU ETS allowance price on industrial emissions (in some sectors at least) are contributing to the discussion about price effects in this field of study, where no consensus has yet been reached. Moreover, some sectors do not seem to be affected by the changes in the EU ETS allowance price. Thus, results from this study evidence heterogeneity for both countries and industries, which should be further enhanced and explored. There may be results that are extremely high/small due to the underlying bias from the limitations within the dataset and the model. Other factors and circumstances have an impact on emission reductions of European EU ETS industries and were unable to be included in this analysis. Moreover, the limited data turned impossible to perform an analysis by country.

Acknowledgments
The support of the Research Unit on Governance, Competitiveness and Public Policy (UIDB/04058/2020), funded by national funds through FCT - Fundação para a Ciência e a Tecnologia is acknowledged.

REFERENCES

Åberg, S. (2021). The effect of the EU ETS on emissions of Swedish industries – a price effect estimation approach. Economics and Management Programme – Sustainable Development. Degree project/SLU, Department of Economics, 1391. ISSN 1401-4084.
Abrell J, Ndoye-Faye A. and Zachmann G. (2011). Assessing the impact of the EU ETS using firm level data. Bruegel Working Paper 2011/08, Brussels.
Anderson B. and Di Maria C. (2011). Abatement and Allocation in the Pilot Phase of the EU ETS. Environmental and Resource Economics 48 (1) 83-103.
Anger A.and Köhler, J. (2010) Including aviation emissions in the EU ETS: Much ado about nothing? A review, Transp. Policy, vol. 17, no. 1, pp. 38-46.
Bayer, P. and Aklin, M. (2020). The European Union Emissions Trading System reduced CO2 emissions despite low prices, PNAS, 8804–8812, vol. 117, |no. 16.
D. Girardet and S. Spinler, (2013). Surcharge management of kerosene and CO2 costs for airlines under the EU's emission trading, J. Air Transp. Manag., vol. 26, pp. 25-30.
Dechezleprêtre, A., Nachtigall, D. and Frank Venmans (2018). The joint impact of the European Union emisisons trading system on carbon emissions and economic performance. OECD Economics Department Working Papers No. 1515
Delarue E, Voorspools K and D'haeseleer W. (2008). Fuel Switching in the Electricity Sector under the EU ETS: Review and Prospective. Journal of Energy Engineering 134(2) 40-46.
EEA (2021) – European Environment Agency in https://www.eea.europa.eu/data-and-maps, accessed on November 2021.
Egenhofer C, Alessi M, Georgiev, A, Fujiwara N. (2011). The EU Emissions Trading System and Climate Policy towards 2050: Real incentives to reduce emissions and drive innovation?, Report, Centre for European Policy Studies, Brussels.
Ellerman, A. D. and Buchner B. K. (2008). A preliminary analysis of the EU ETS based on the 2005-06 emissions data. Environmental and Resource Economics 41(2): 267-87.
Ember (2021) in https://ember-climate.org/, accessed on November 2021.
European Commission (2015). Ex post investigation of cost pass through in the EU ETS – an analysis of six sectors. CE Delft e Oeko Institut, doi: 10.2834/612494.
European Union (2020). Special Report 18/2020 - Emissions Trading System: Guiding the allocation of free allowances. Available in https://op.europa.eu/webpub/eca/special-reports/emissions-trading-system-18-2020/pt/ (accessed in February 2022).
European Commission (2021) in https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en, accessed on November 2021.
Eurostat (2021) in https://ec.europa.eu/eurostat/data/database, accessed on November 2021.
Faber J. and Brinke, L., (2011). The Inclusion of Aviation in the EU Emissions Trading System: An Economic and Environmental Assessment, Geneva, Switzerland.
Fontini F. and Pavan G., (2014). The European Union Emission Trading System and technological change: The case of the Italian pulp and paper industry, Energy Policy, vol. 68, pp. 603-607, Mai. 2014.
Freitas C. and Silva, P. (2015). European Union emissions trading scheme impact on the Spanish electricity price during phase II and phase III implementation", Util. Policy, vol. 33, pp. 54-62.
Graichen, V., Schumacher, K. Matthes, F. Mohr, L., Duscha, V., Schleich, J.and Diekmann, J.. (2008). Impacts of the EU Emissions Trading Scheme on the industrial competitiveness in Germany. Environmental Research Of The Federal Ministry Of The Environment, Nature Conservation And Nuclear Safety, Federal Environment Agency, Research Report 3707 41 501, 2008, UBA-FB 001177, ISSN 1862-4359.
Green, J. F. (2021). Does carbon pricing reduce emissions? A review of ex-post analyses. Environmental Research Letters.
Haites, E. (2018). Carbon taxes and greenhouse gas emissions trading systems: what have we learned?. Climate Policy, 18(8), 955-966.
Healy, S., Schumacher, K. and Eichhammer, W. Analysis of Carbon Leakage under Phase III of the EU Emissions Trading System: Trading Patterns in the Cement and Aluminium Sectors. Energies 2018, 11, 1231. https://doi.org/10.3390/en11051231.
Heinrichs, H., Jochem P. and Fichtner, W. (2014).Including road transport in the EU ETS (European Emissions Trading System): A model-based analysis of the German electricity and transport sector, Energy, vol. 69, pp. 708-720.
Hovi, J., Sprinz, D. F. and Underdal, A. (2003). The Oslo-Potsdam solution to measuring regime effectiveness: Critique, response, and the road ahead. Global Environ. Polit. 3, 74–96.
Jaraite-Kažukauske, J., and Di Maria, C. (2016). Did the EU ETS make a difference? An empirical assessment using Lithuanian firm-level data. The Energy Journal, 37(1).
Kettner, C., KÖPPL, A., Schleicher, S.P., Thenius, G (2008). Stringency and distribution in the EU Emissions Trading Scheme: First evidence. Climate Policy, 8 (1), pp. 41-61. doi: 10.3763/cpol.2007.0394.
Kotnik, Z., Klun, M., and Skulj, D. (2014). The effect of taxation on greenhouse gas emissions. Trans. Rev. Admin. Sci. 10 168–85.

Lise, W., Sijm, J. and Hobbs, B.F. (2010). The Impact of the EU ETS on Prices, Profits and Emissions in the Power Sector: Simulation Results with the COMPETES EU20 Model. Environ Resource Econ 47, 23–44 https://doi.org/10.1007/s10640-010-9362-9.

Löschel, A., Lutz, B. and Managi, S. (2019). The impacts of the EU ETS on efficiency and economic performance – An empirical analyses for German manufacturing firms, Resource and Energy Economics, Volume 56, Pages 71-95, ISSN 0928-7655, https://doi.org/10.1016/j.reseneeco.2018.03.001.

Malina, R., McConnachie, D., Winchester, N., Wollersheim, C., Paltsev S. and Waitz, I. (2012). The impact of the European Union Emissions Trading Scheme on US aviation", J. Air Transp. Manag., vol. 19, pp. 36-41.

Meleo, L., Nava, C. and Pozzi, C., (2016). Aviation and the costs of the European Emission Trading Scheme: The case of Italy", Energy Policy, vol. 88, pp. 138-147.

Murray, B. C., and Maniloff, P. T. (2015). Why have greenhouse emissions in RGGI states declined? An econometric attribution to economic, energy market, and policy factors. Energy Economics, 51, 581-589.

Neuhoff, K., Martinez K. and Sato, M. (2006). Allocation, incentives and distortions: the impact of EU ETS emissions allowance allocations to the electricity sector, Climate Policy, 6:1, 73-91, doi: 10.1080/14693062.2006.9685589.

Pietzcker, R., Osorio, S. and Rodrigues, R. (2021). Tightening EU ETS targets in line with the European Green Deal: Impacts on the decarbonization of the EU power sector, Applied Energy, Volume 293, 116914, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2021.116914.

Robaina M. and Goncalves, M. (2019). Sectorial and Regional Impacts of the European Carbon Market in Portugal: Second Phase, 16th International Conference on the European Energy Market (EEM), pp. 1-5, doi: 10.1109/EEM.2019.8916399.

Robaina-Alves, M., Rodríguez, M. and Roseta-Palma, C. (2011). Sectoral and regional impacts of the European carbon market in Portugal, Energy Policy, Volume 39, Issue 5, Pages 2528-2541, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2011.02.018.

Sandbag (2019) The Great Coal Collapse of 2019 — Mid year analysis of the EU power sector. In https://ember-climate.org/project/coal-collapse/ (accessed in February 2022)

Weigt, H., Ellerman, D., Delarue, E. (2013). CO2 abatement from renewables in the German electricity sector: Does a CO2 price help?, Energy Economics, Volume 40, Supplement 1, Pages S149-S158, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2013.09.013.

Zhang Y.-J. and Wei, Y.-M (2010). An overview of current research on EU ETS: Evidence from its operating mechanism and economic effect, Appl. Energy, vol. 87, no. 6, pp. 1804-1814.