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DISCUSSION PAPER

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Lessons From the EU Effort Sharing Decision for Supranational Climate Cooperation: A Firm-Level Analysis

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Lessons from the EU Effort Sharing Decision for supranational climate cooperation: a firm-level analysis

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Abstract: As an example of supranational climate policy coordination for sectors not covered by carbon trading, the European Effort Sharing Decision set national targets for emission reductions for the time period 2013-2020. Member States were free to decide the national policies to implement to achieve these objectives. This is the first quantification of the impact this regulation had on the emissions of the corresponding firms. We exploit the differences along three variables: a national-level treatment intensity, an exposure index defined at the firm level and a time dimension (before or after the introduction of the policy). We find that, even in countries with no stringent target, emissions from exposed firms tended to decrease more than emissions from non-exposed firms. In addition, each percentage point increase in the stringency of the treatment leads to a 6.1% reduction in emissions for an average exposed firm. This provides interesting insights for other supranational climate agreements.

Keywords: carbon emissions; effort sharing decision; firms; climate policy
JEL classification: D22, F53, L51, Q54, Q58

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1 Introduction

The European Union has been a pioneer in terms of supranational coordination for climate policy. Beside the well known Emissions Trading Scheme (EU ETS), the experience of which has been helpful for the design of other cap-and-trade systems in the world,[1] another series of regulation has tried to constrain emissions in the sectors not covered by the common carbon price. It is the Effort Sharing Decision (ESD) for the time period from 2013 to 2020, then followed by the Effort Sharing Regulation from 2021 to 2030.

It consists in an agreement between Member States to share the effort for reducing emissions in the sectors that are not included in the carbon market, in order to ensure reaching the aggregate EU emission reduction objective. Targets are heterogeneous across countries. Member States are free to decide the policies they implement domestically in order to comply with their respective targets under the agreement. The agreement involves relatively soft compliance and monitoring mechanisms. As not all countries in the world wish to use market instruments, the experience with the Effort Sharing can be inspiring for further international climate cooperation.

Our objective is to empirically examine whether this policy contributed to a reduction of the emissions from the firms in the corresponding economic sectors and, if so, to quantify this impact. We take advantage of the Carbon Disclosure Project which provides a global dataset of companies which voluntarily report emission related information on their activity for the years 2009-2016. We analyse the impact of the ESD on firm emissions in the covered sectors. We exploit the differences in three variables, considering a country-specific treatment and an exposure index at the firm level before and after the introduction of the policy.

We find that the Effort Sharing Decision did contribute to a decrease in the emissions of the firms in the sectors covered by this regulation. In the time period covered by our analysis, each percentage point increase in the stringency of the treatment at the national level led to a 6.1% reduction in emissions for an average exposed firm. In addition, even in countries with no stringent target, emissions from exposed firms tended to decrease more than emissions from non-exposed firms. This can be explained by the policies implemented in countries where the target was not necessarily stringent. It is possible that the ESD framework incentivized these policies and measures even in countries with loose targets.

Most of the existing literature on supranational cooperation in the field of climate policy so far has involved theory, simulations or laboratory experiments and focused more on the conditions for such cooperation to exist than on its actual impacts. For example, using theoretical models, Barrett (1994) show that international environmental agreements (IEAs) help little if the number of countries sharing a common resource (such as global climate) is large. Nordhaus (2015) suggests that, without sanctions against non-participating parties, stable IEAs achieving pollution abatement beyond a minimum level are not feasible. Many papers investigate determinants for stable and profitable IEAs (or coalitions in general) and stress the importance of, for instance, exclusive membership, a high degree of consensus (Finus and Rundshagen, 2009) or commitment and transfers (Carraro and Siniscalco, 1993).[2] Weitzman (2014) suggests that nego-

[1] The EU experience helped for the design of the Korean or Chinese ETSs.

[2] Other papers focus on more specific features that impact the stability of such agreements. For example, using a repeated game framework, Günther and Hellmann (2017) find that international environmental agreements (IEAs) are less stable under asymmetric

tiating a single internationally binding minimum carbon price would be better than negotiating quantities to address the global warming free rider externality. Most of the empirical literature on supranational climate cooperation has focused on carbon pricing and, in particular, on ETSs. A general overview on these studies is provided in Martin et al. (2016), where the authors particularly focus on the impact of the ETS on firms' emissions, economic performance and innovation.[3]

The EU Effort Sharing Decision, which is an example of climate supranational cooperation involving quantities, has been analyzed, but the corresponding studies are mostly descriptive or involve simulations, and they have focused much on the design of the sharing rule. For example, van den Berg et al. (2020) build a general model of effort-sharing and find a trade-off between fairness in the distribution of efforts and cost-optimality of emission reduction. Harmsen et al. (2011) describe an imbalance in the stringency of the ESD targets among the EU Member States. Babonneau et al. (2018) calculate the expected costs of complying to the ESD regulations for each country until 2030, and simulate scenarios for the period after 2030.[4]

Our study is the first one to conduct an empirical analysis of the ESD impacts, and in particular of its effects at the firm-level. Given some parallel features between the ESD and other supranational cooperation frameworks (compliance and monitoring mechanisms involving regular reporting and review processes for example), we think this study can provide interesting insights for other international environmental agreements.

The paper is structured as follows: After presenting the institutional background in Section 2 and the data in Section 3, we explain the identification strategy in Section 4 and discuss the results in Section 5. We finally conclude.

2 The Effort Sharing Decision

The EU emissions reduction objective is decomposed into one target for the sectors covered by the EU Emissions Trading Scheme (EU ETS) and one target for the rest of the economy, regulated under the Effort Sharing Decision for the time period from 2013 to 2020 (European Parliament, 2009) and under the Effort Sharing Regulation for the time from 2021 to 2030 (European Parliament, 2018). While the ETS has existed since 2005 and covers mostly energy intensive sectors, the ESD started in 2013 and has constrained emissions for the sectors that are not covered by the carbon market.

The ESD and ESR set annual national targets for these sectors (European Commission, 2013a,b). Delbeke and Vis (2015) explain how these targets were determined. The 2013 targets were defined as the average of a Member State's emissions over the years 2008, 2009 and 2010. The 2020 targets were for-

pollution spillovers. Marchiori et al. (2017) investigate how IEAs are affected by domestic politics—and find that, under certain conditions, lobbyism can actually lead to stable agreements and lower emissions.

[3]For example, Abrell et al. (2011) investigate the effectiveness of the ETS in reducing firms' emissions. Petrick and Wagner (2014) analyze the impact on fuel efficiency of manufacturing plants in Germany, Martin et al. (2014) the effect on firms' propensity to relocate or to reduce employment, Hintermann et al. (2020) the repercussion on firms' productivity, and Germeshausen (2020) the consequences for power plants in Germany.

[4]Babonneau et al. (2018) focus on the consequences of Brexit for the welfare impacts of the ESD on EU Member States.

mulated as a percentage change in comparison to 2005. Targets for the years between 2013 and 2020 were deducted by linear interpolation between the 2013 and 2020 targets. To have member states accept the ESD, together with the whole EU 2020 Climate and Energy Framework, distributional aspects needed to be taken into account. For this reason, as shown in Figure 5.2 in Delbeke and Vis (2015), the 2020 percentage reduction objectives nearly follow a linear function of national GDP per capita. Member States with a GDP per capita above the EU average in 2005 were asked to reduce their emissions by a maximum of 20%. Member States with lower per capita GDP were required to reduce emissions by less than the EU average. Thirteen Member States were even allowed to increase their emissions.

In this framework, Member States are free to decide the domestic measures to implement in order to achieve their respective objectives. The ESD involves a monitoring and compliance system that requires Member States to report annual greenhouse gas inventories, including information on planned additional national policies and measures to meet commitments. An annual review of these inventories is carried out by a team of technical experts contracted by the European Commission and coordinated by a secretariat from the European Environment Agency. The review process leads to a Commission Implementing Decision[5] that takes into account technical corrections and revised estimates calculated during the review. Afterwards countries have four months to use flexibilities under Articles 3 and 5 of the ESD (borrowing or buying of allocations or international project credits) to ensure compliance with their ESD targets. In practice the use of such flexibilities was rarely needed. If a Member State does not comply with its annual target, the excess emissions are multiplied by 1.08 and this penalty is added to the objective for the following year. In practice the use of such penalties was never needed.

This climate policy framework is an interesting example of supranational cooperation with coexistence of a common market-based instrument (the EU-ETS) and a mechanism involving a joint emission target but domestically defined policies - which are not necessarily market-based - for the non-ETS sectors (the Effort Sharing Decision). The ESD shares some comparable features with other international environmental agreements, for example the definition of a joint objective to which countries contribute heterogeneously depending on their own circumstances, compliance and monitoring mechanisms involving regular reporting and review processes, and the use of flexibility mechanisms.

3 Data

3.1 The CDP data

We exploit a rich dataset from the Carbon Disclosure Project (CDP). This is the largest worldwide registry of firm-level GHG emissions and related information. The data available to us covers the time period from 2009 to 2016. The CDP dataset differentiates scope 1 emissions (direct emissions from owned or controlled sources)[6], scope 2 emissions (indirect emissions from the generation of purchased energy,

[5] See, for example, European Commission (2021) for the 2019 emissions.

[6] Emissions from generators owned by the company are also included in scope 1 emissions.

be it electricity, steam, heating or cooling for own use)[7] and scope 3 emissions (all indirect emissions not included in scope 2 and that occur in the economic activity, e.g. business travel emissions).[8] It also contains quantitative information such as energy consumption, and qualitative information such as the participation in a national or regional emissions trading scheme, and information on the sector.[9] Companies report to CDP voluntarily but, in many cases, disclosure is requested by investors, which induces a substantial reputational incentive for participation. We discuss the potential impact of this on our results in Section 4. Based on the collected data, the CDP also provides a ranking of environmental performance that is made available to its institutional investors (over 475 as of 2009). In total, over 7000 companies (thereof the majority of the Global 500 firms) from more than 90 countries report to the CDP.

3.2 Data preparation

The use of the CDP data required a substantial amount of preliminary data preparation to select the variables of interest and build a consistent panel from the yearly data provided. A significant share of firms have branches in several countries. We hence use the firm-country level of disaggregation (i.e. each unit of observation is at the firm-country level). We want to conduct our analysis on European firms not covered by the EU ETS. We hence drop all non-European and Croatian firms (Croatia only joined the EU in 2013 and was not an EU member for the entire period of observation) as well as all EU ETS firms. We define a firm to be an ETS firm if it reported ETS coverage for at least one period.[10] We remove all firms in the Air Transportation sector because this sector has been covered by the European Union Emissions Trading Scheme (EU ETS) since 2012. We only include observations with non-missing values in both scope 1 and scope 2 emissions in 2010. Finally, we drop all firms with missing values in the sector variable. The geographical and sectoral distributions of all firms included in our final data are presented in Figures 1 and 2, respectively. The temporal distribution of our observations as well as the distribution of the number of observations per firm and country are reported in Figures 3[11] and 4 respectively in appendix.

[7] From 2016 onwards, firms can choose to report their scope 2 emissions as location- or market-based emissions. According to Sotos (2015), the location-based method measures scope 2 emissions using the average emissions intensity of the grid on which energy consumption occurs, while the market-based method uses contractual instruments, i.e. firms report, for instance on the amount of electricity they have purchased from their suppliers. We use the location-based scope 2 emissions.

[8] Since 2007, the CDP data has also included environmental data on supply chains (reporting companies can become "supply chain members", which means they will request their suppliers to report environmental data through the CDP questionnaires).

[9] CDP has also collected environmental information on cities and regions since 2008, and on water and forests since 2012.

[10] Note that energy intensive firms that are below the threshold for being regulated under the ETS are covered by the ESD, but not necessarily targeted by specific national sectoral measures.

[11] The number of observations decreases over time. This sample attrition is due to the fact that we define exposure on the share of scope 1 emissions over the sum of scope 1 and 2 emissions in 2010. As a consequence, the sample contains only firms who participated in 2010 and the number of these firms naturally declines over time after 2010. This should have no impact on our estimations as the dropping out of the sample is not correlated with emission trends in the other years.

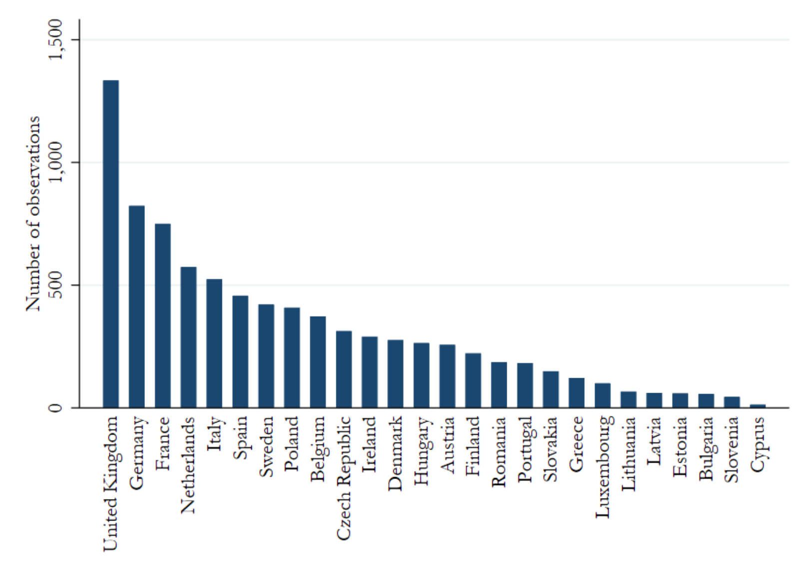

Figure 1: Geographical distribution of the firms

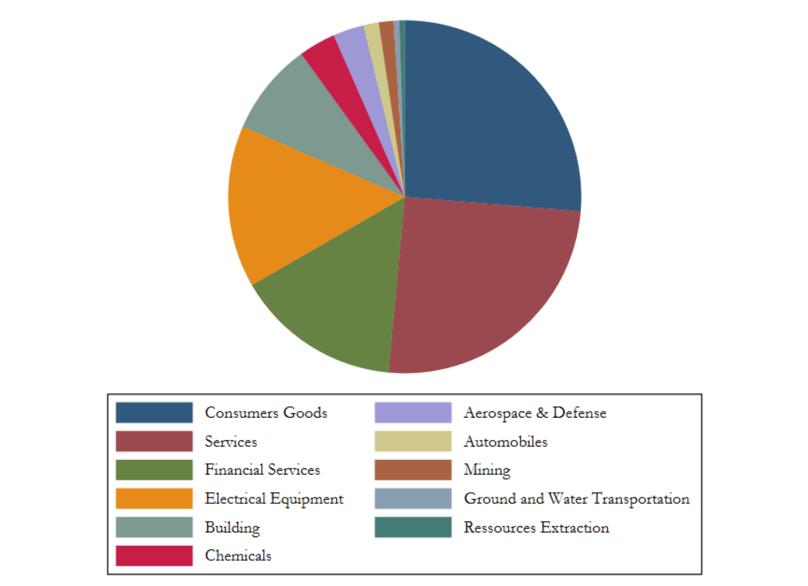

Figure 2: Sectoral distribution of the firms

4 Empirical Framework

We want to analyze whether the Effort Sharing Decision and its associated national targets contributed to a reduction of the emissions from the firms in the corresponding economic sectors and, if so, to quantify this impact. In the spirit of Acemoglu et al. (2004), one initial idea could be to exploit the variation in the policy stringency among countries to examine the impact of the ESD on firm emissions, comparing these before and after the introduction of the ESD in 2013.[12] We would then define a continuous treatment variable

[12]To examine the impact of female labor supply on wages during World War II, Acemoglu et al. (2004) employs a two-way interaction model where the treatment (national mobilization rate of men) is continuous and does not have zero values.

T_c that would reflect the required annualized change in ESD allocations from 2013 to 2020, corrected for pre-trends in country c:

$$T_c = (\psi_c - \delta_c) * 100 \tag{1}$$

where ψ_c and δ_c are defined such that

$$Emissions_{c,2011} = Emissions_{c,2005} * (1 + \psi_c)^6 \tag{2}$$

$$Target_{c,2020} = Target_{c,2013} * (1 + \delta_c)^7 \tag{3}$$

with $Target_{c,t}$ and $Emissions_{c,t}$ being the ESD target and country-wide emissions[13] from ESD sectors in country c and year t, respectively. Such a treatment variable captures by how many percentage points a country has to deviate from the percentage growth in its pre-ESD emission path in order to comply with its emission targets. It is an indicator of the stringency of the treatment. For instance, if the emissions of country c grew with a yearly rate of 1% ($\psi_c = 0.01$) between 2005 and 2011, and the ESD requires this country to reduce emissions by a yearly rate of 1% ($\delta_c = -0.01$) between 2013 and 2020, then the stringency variable would be $T_c = 2$. The values of T for all countries are reported in Table 2 in appendix. T_c is on average negative (-1.33). The larger it is, the more stringent the target. As noticed by Harmsen et al. (2011), the stringency of ESD targets is heterogeneous across member states.

A first naive estimation considering this two-way interaction between the stringency and the binary time variable (see estimation equation in appendix) indicates a positive treatment effect, which would suggest an increasing effect of the policy on emissions (see results in Table 6 in appendix). However, given our definition of the stringency, it is possible that this positive coefficient only reflects the correlation between the treatment and pre-trends (see Figure 5 in appendix). This correlation is related to the differences in the industrial structure among Member States.

To address this, we introduce a third variable, the exposure index which characterizes the exposure of each firm to the ESD policy as a function of its scope 1 and scope 2 emissions. We then estimate a three-way interaction model with two continuous variables. Since the ESD targets scope 1 emissions, firms with larger shares of scope 1 emissions are considered more exposed to the ESD, i.e. their emissions are expected to be reduced more strongly in response to the ESD. As we employ panel data in which the individual unit is a specific firm in a specific country, this exposure indicator is at the firm-country level. The summary statistics for the main variables used in the estimations are reported in Table 3 in appendix.

Our three-way interaction model writes as :

[13]For the country-wide emissions on ESD sectors, we use the data from the European Environment Agency (EEA).

$$Y_{ict} = \delta T_c * BA_t * expos_i + \beta_1 T_c * expos_i + \beta_2 T_c * BA_t + \beta_3 expos_i * BA_t + \beta_4 T_c + \beta_5 expos_i + \beta_6 BA_t + \beta_0 + \mu_{ic} + \tau_t + \epsilon_{ict} \quad (4)$$

where

Y_{ict} is the outcome variable and can be either the logarithmic scope 1 or scope 2 emissions of firm i in country c in year t;

T_c is the country-level treatment indicator;

BA_t the before-after indicator (= 0 before 2013, = 1 from 2013 onwards)

and $expos_i = \frac{scope1_i^{2010}}{scope1_i^{2010}+scope2_i^{2010}}$ is the exposure indicator at the firm-country level (the exposure to the ESD is measured by the firm's share of scope 1 emissions in the sum of its scope 1 and scope 2 emissions in 2010). We also include firm-country fixed effects μ_{ic} and year fixed effects τ_t. ϵ_{ict} is the standard error term clustered at the firm level.[14] We find it plausible that the correlation between unobservables is most likely to occur within firms. Therefore, based on Abadie et al. (2017), we consider clustering at the firm level appropriate. We check the robustness of our approach to this specification by using firm-country clustering instead and find negligible deviations (see Table 7 in appendix). For the result interpretation, we rely on Dawson and Richer (2004).

To check the absence of spillovers, i.e. that the policy in treated countries does not impact emissions of firms in non-treated countries, we conduct a robustness check by conducting the estimations without multinational companies (see Table 8 in appendix). This however reduces the number of observations by a factor 10. We discuss the results at the end of Section 5. A remaining challenge is that there could be a concern of selection bias: we might wonder if firms reporting to CDP are not firms that already undertake more rigorous measures to lower their emissions. If that is the case, it means such firms would not necessarily be affected by the ESD. We follow Dechezleprêtre et al. (2022) who argue that this risk is mitigated by the fact that, as the CDP survey is looked at by potential investors, there is a strong incentive for companies to participate (refusal to do so could be perceived as a negative signal by investors). Finally, to address a potential anticipation effect, we conduct two robustness checks for the estimations: one without the 2012 data and one with the 2012 data considered as "after" (BA_t = 1 from 2012 onwards instead of 2013). The results are presented in Tables 9 and 10 in appendix and discussed at the end of Section 5.

5 Results and discussion

We present the estimation results of our three-way interaction model of the impact of the Effort Sharing Decisions on the firm emissions in Table 1. The outcome variable is logarithmic scope 1 emissions for regressions (1) and (3) and logarithmic scope 2 emissions for regressions (2) and (4). Emissions are in tons

[14]This specification is inspired from the approach used by Garthwaite et al. (2014) to estimate the effect of public health insurance on labor supply.

of CO2 equivalent. (1) and (2) do not include year fixed effects while (3) and (4) do. Note that, due to collinearity (for example the exposure index is time invariant), some of the coefficients are not identifiable. These are hence not reported in the table of results.

The estimated coefficient associated with the triple interaction term is -0.154. The fact that it is negative and significant tends to confirm the impact of the ESD on emissions of the firms in the sectors covered by this policy. Isolated from the other coefficients, this coefficient means that, for firms with maximum exposure (firms that would have no scope 2 emissions but only scope 1 emissions, i.e. $expos = 1$), each percentage point increase in the stringency of the treatment at the national level (difference between the growth rate of country-level emissions imposed by the ESD targets and the pre-2011 emission trend as defined in Equation 1) leads to a 15.5% reduction in scope 1 emissions. For example, if a country had reduced its emissions by 1% each year between 2005 and 2011, while the ESD required an annual emission reduction of 2% between 2013 and 2020, this policy lowers the emissions of a hypothetical 100% exposed firm by 15.5%. Given an average exposure of 0.3922, this effect amounts to 6.1% for an average firm. For scope 2 emissions, the coefficient associated with the triple interaction term is not significantly different from zero. This is consistent with the fact that the ESD targets scope 1 emissions while scope 2 emissions are rather regulated under the ETS.

Table 1: The effect of the ESD targets on firms' scope 1 and scope 2 emissions

	(1) Scope 1	(2) Scope 2	(3) Scope 1	(4) Scope 2
T × BA × expos	-0.154**	0.00686	-0.154**	0.00654
	(0.0651)	(0.0739)	(0.0652)	(0.0738)
T × BA	0.111***	0.00902	0.111***	0.00880
	(0.0409)	(0.0247)	(0.0409)	(0.0247)
expos × BA	-0.854***	0.108	-0.853***	0.106
	(0.181)	(0.167)	(0.181)	(0.165)
BA	0.384***	-0.190**		
	(0.116)	(0.0745)		
Constant	6.595***	6.970***	6.553***	7.009***
	(0.0213)	(0.0146)	(0.0745)	(0.0320)
R2	0.0160	0.0131	0.0195	0.0160
Observations	7644	8001	7644	8001
Year FE	no	no	yes	yes
Firm-Country FE	yes	yes	yes	yes

Standard errors, clustered at the firm level, are reported in parentheses. *, ** and *** respectively refer to the 10%, 5% and 1% significance level of the estimated coefficients.

The estimated coefficient associated with $expos * BA$ indicates the difference between the change in emissions of maximally exposed ($expos = 1$) and non-exposed firms ($expos = 0$) over time (in countries where the treatment involves no actual constraint). In most countries, the ESD targets require emissions to decrease between 2013 and 2020. The negative and significant coefficient that we find here (-0.854) shows that, after 2012, even in countries without stringent target, scope 1 emissions from exposed firms tend to decrease more than emissions from non-exposed firms. This could be explained by the fact that many of those countries whose ESD targets we consider non-stringent, still implemented a number of new environmental policies in the framework of the ESD (see detailed explanations on these policies in appendix). Germany, for instance, created a special fund for energy efficiency improvements in small and medium-sized enterprises: the KfW, a publicly financed investment bank, covers the cost for consulting and investment related to increasing energy efficiency (Eichhammer, 2012); a similar policy was implemented in Bulgaria. Many EU member states subsidize electric mobility: The United Kingdom, for example, introduced an electric car grant (a subsidy of initially up to £5000 for the purchase of an electric vehicle) in 2011 (Morris et al., 2012). This grant did not only apply to private buyers but was also valid for up to 1000 business vehicles (plug-in vans, trucks and taxis) per organisation each year. Other policies included programmes addressing emissions in the agricultural sector (for example in Denmark) or voluntary agreements between governments and companies for a joint energy efficiency improvement target (for example in the Netherlands or Finland).

The estimated coefficient associated with $T * BA$ is positive and significant (0.111). It reflects the difference between the change in emissions from firms in treated and non-treated countries over time if only non-exposed firms were in the sample. By construction, non-exposed firms have zero scope 1 emissions. The positive coefficient for scope 1 emissions indicates that firms with very small scope 1 emissions in 2010 were more likely to have an increase in scope 1 emissions after 2013 in countries with more stringent targets. This coefficient may capture the correlation between the target stringency and the pre-trend mentioned in Section 4. The coefficient associated with this interaction term is not significant for scope 2 emissions, which suggests that changes in energy emissions from non-exposed firms are not significantly different between treated and non treated countries.

In the regressions without year fixed effects, the estimated coefficient associated with BA indicates the change in emissions after 2013 for non-exposed firms ($expos = 0$) in countries where the treatment is not stringent (i.e. assuming pre-2013 emission paths would simply continue). It is is positive (0.384) for scope 1 emissions and negative for scope 2 emissions (-0.190). The positive sign for scope 1 emissions suggests that average annual emissions from the non-exposed firms in the time period 2013-2016 in countries where there is no stringent treatment tend to be 38% higher than the corresponding emissions in the time period 2010-2012. As scope 2 emissions represent emissions from energy consumed by the companies, the negative sign might reflect the effect of the ETS on emissions from energy production (decreasing cap).

As explained in Section 4, we check the robustness of our results to the standard-error clustering approach by using clustering at the firm-country level instead of clustering at the firm level. The results are reported in Table 7 in appendix. They are very similar.

To conclude on these results, the negative coefficient associated with the triple interaction term tends to confirm the impact of the ESD on emissions of the firms that are regulated within this framework: the effort sharing decision—reflected by the interaction between the firm-level exposure index, the national treatment intensity, and the before/after 2012 term—is associated with a decrease in the scope 1 emissions of the firms that fall into the scope of this regulation. To give an order of magnitude, each percentage point increase in the stringency of the treatment at the national level (difference between the growth rate of country-level emissions imposed by the ESD targets and the pre-2011 emission trend) leads to a 6.1% reduction in scope 1 emissions for an average exposed firm. The negative sign associated with the double interaction term $expos * BA$ is also interesting: after 2012, even in the absence of stringent targets, scope 1 emissions from exposed firms tend to decrease more than emissions from non-exposed firms. This can be explained by the policies implemented in countries where the target was not necessarily stringent, like in Germany or the United Kingdom. It is possible that the ESD framework incentivized these policies and measures even in countries with loose targets. This seems to be an interesting insight for the international climate negotiations, and in particular the Paris Agreement, in the context of which the stringency of the national targets is rather heterogeneous among countries.

Robustness checks

In order to account for a potential anticipation effect, we conduct two robustness checks for the estimations. First we consider the 2012 data in the "after" time period (BA_t = 1 from 2012 onwards instead of 2013). The results are presented in Table 9 in appendix. The estimation results are comparable to those obtained in the main analysis. The coefficient associated with the triple interaction term is just a bit smaller: -0.101 instead of -0.154. Second we consider 2012 as a transition period and we exclude the 2012 data from the analysis (see results in Table 10 in appendix). The estimated coefficients are also comparable to those obtained in the main analysis. The coefficient associated with the triple interaction term is -0,144 instead of -0.154.

Regarding the robustness of the results when we conduct the estimations without multinational companies (results in Table 8), we find that the signs of the coefficients obtained for scope 1 emissions are the same but the coefficients lose significance. This should be nuanced by the fact that the exclusion of multinational companies reduce the number of observations by a factor 10, in comparison with the other estimations. The coefficient associated with the triple term interaction is twice larger in absolute value than in Table 1 (-0.317 instead of -0.154). The coefficients associated with $T * BA$ and with $expos * BA$ are of comparable magnitude (0.134 in comparison with 0.111, and -0.872 in comparison with -0.854 respectively). The coefficient associated with BA is reduced (0.183 instead of 0.384).

Surprisingly the coefficients for the estimations of scope 2 emissions change a lot. The coefficient associated with the triple term interaction is much larger (0.669 instead of 0.00686) and becomes significant at the 1% level. This could hint towards an electrification of exposed firms in treated countries: for example, instead of buying fossil fuel and burning it on site for part of their industrial processes, some companies may decide to electrify some of these processes, which would result in the corresponding emissions to be counted in scope 2 emissions (they are then likely covered by the ETS). The coefficient associated with $expos * BA$ could hint towards a similar trend for exposed firms even in countries where the target is not stringent. This coefficient is indeed ten times larger than in the main analysis and it becomes significant at the 5% level (1.219 instead of 0.108). This electrification trend would then happen for all exposed firms and would even be stronger in countries where the target is stringent. This hypothesis would be consistent with the negative coefficients associated with $T * expos * BA$ and $expos * BA$ for the estimations of scope 1 emissions: by electrifying some of their processes, exposed firms reduce their own emissions (scope 1 emissions) and increase their scope 2 emissions, the latter being likely regulated by the ETS. The estimated coefficient associated with the BA variable is stronger here than in the main analysis (-0.645 instead of -0.190) and still significant at the 1% level. This decreasing trend in scope 2 emissions is consistent with the EU objective to reduce emissions from energy intensive industries, and in particular from the electricity sector, via the ETS.[15]

6 Conclusion

We conduct the first analysis of the impact the EU Effort Sharing Decision had on emissions of firms in the covered sectors. We estimate a three-way interaction model considering an indicator of the stringency of the policy at the national level, combined with a firm-level exposure index.

We find that the EU Effort Sharing Decision did contribute to a reduction of the emissions of firms in the sectors included in the regulation. In the time period considered for the econometric estimation, each percentage point rise in the stringency of the treatment at the national level led to a 6.1% reduction in emissions for an average exposed firm. In addition, even in countries with no stringent target, emissions from exposed firms tended to decrease more than emissions from non-exposed firms. Even in these countries, emission reduction policies were implemented in these sectors. The ESD framework is likely to have incentivized such measures in all EU Member States and the effect has been stronger in countries where the official emission reduction target was stringent. Complementary estimations on the emissions of the electricity these firms bought on the local grid suggest the above mentioned reduction in installation emissions may be associated with the electrification of part of the industrial processes of the firms.

The EU Effort Sharing Decision is an interesting experience of supranational climate cooperation for economic sectors that are not covered by a common carbon price. In a way it may provide valuable insights for the international climate negotiations in a context where national targets are rather heterogeneous and countries keep their sovereignty for the policies they implement, or for more regional climate agreements between countries who do not employ market-based instruments. The compliance and monitoring mechanisms used in the ESD require national inventories and a review process at the EU level each year. The finding that this framework did contribute to emission reductions would tend to support the use of such regular reporting and review processes in other supranational climate governance frameworks.

[15] Besides this trend, the coefficient associated with $T * BA$ becomes negative and significant (-0.188 instead of 0.00902). This is more puzzling. We make the hypothesis that strictly national companies in treated countries increase their energy efficiency over time more than comparable companies in non-treated countries (such an improvement in energy efficiency would tend to reduce their need for purchased electricity if they do not switch from fossil fuel to electricity for part of their processes at the same time).

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Appendices

Summary Statistics

Table 2: Stringency T of the ESD targets (a positive sign reflects a stringent target, as defined in Section 5)

	T
Austria	-1.138
Belgium	-0.540
Bulgaria	-2.921
Cyprus	1.098
Czech Republic	-1.522
Denmark	1.192
Estonia	-0.737
Finland	-0.287
France	-0.621
Germany	-0.145
Greece	-2.777
Hungary	-5.212
Ireland	0.446
Italy	-1.806
Latvia	-0.959
Lithuania	-3.032
Luxembourg	1.553
Netherlands	0.012
Poland	0.019
Portugal	-3.010
Romania	-3.716
Slovakia	-3.201
Slovenia	-0.450
Spain	-1.514
Sweden	-0.997
United Kingdom	-3.114
Total	-0.997

Table 3: Summary statistics of the key variables

	Mean	Standard Dev.	1st Quartile	Median	3rd Quartile
Log Scope 1 Emissions	6.563	2.529	4.984	6.677	8.237
Log Scope 2 Emissions	7.101	2.642	5.401	7.322	8.948
Exposure	0.402	0.292	0.143	0.353	0.639
T	-1.352	1.504	-3.010	-0.997	-0.145

Note: Emissions are in tons of CO2 equivalent.

Table 4: Median of the key variables by country

	Log Scope 1 Emissions	Log Scope 2 Emissions	Exposure
Austria	5.768	4.745	0.529
Belgium	6.932	5.574	0.502
Bulgaria	6.534	7.317	0.260
Cyprus	7.996	8.415	0.640
Czech Republic	6.014	7.313	0.273
Denmark	6.715	6.935	0.389
Estonia	5.800	7.776	0.066
Finland	6.397	8.062	0.191
France	7.004	6.148	0.603
Germany	7.220	7.863	0.348
Greece	6.454	5.823	0.372
Hungary	6.928	6.236	0.418
Ireland	6.551	7.119	0.231
Italy	6.465	7.107	0.266
Latvia	6.105	4.712	0.617
Lithuania	7.088	5.572	0.388
Luxembourg	6.218	4.608	0.327
Netherlands	6.729	6.671	0.435
Poland	6.720	8.228	0.222
Portugal	6.177	7.181	0.274
Romania	6.003	6.485	0.302
Slovakia	6.480	5.136	0.511
Slovenia	5.198	5.303	0.412
Spain	6.000	6.998	0.143
Sweden	5.677	5.782	0.500
United Kingdom	7.193	8.393	0.232
Total	6.682	7.140	0.339

Note: Emissions are in tons of CO2 equivalent.

Table 5: Median of the key variables by sector

	Log Scope 1 Emissions	Log Scope 2 Emissions	Exposure	T
Aerospace & Defense	6.505	7.280	0.352	-0.621
Automobiles	6.900	8.289	0.246	-1.514
Building	6.933	7.327	0.500	-0.621
Chemicals	7.166	7.408	0.499	-0.621
Consumers Goods	6.654	7.235	0.401	-0.997
Electrical Equipment	6.301	7.185	0.311	-0.737
Financial Services	6.050	7.101	0.211	-1.514
Ground and Water Transportation	7.670	8.236	0.234	-1.514
Mining	8.387	8.936	0.323	-0.621
Resources Extraction	9.020	7.409	0.501	-3.114
Services	7.086	6.701	0.310	-0.959
Total	6.682	7.140	0.339	-0.997

Note: Emissions are in tons of CO2 equivalent.

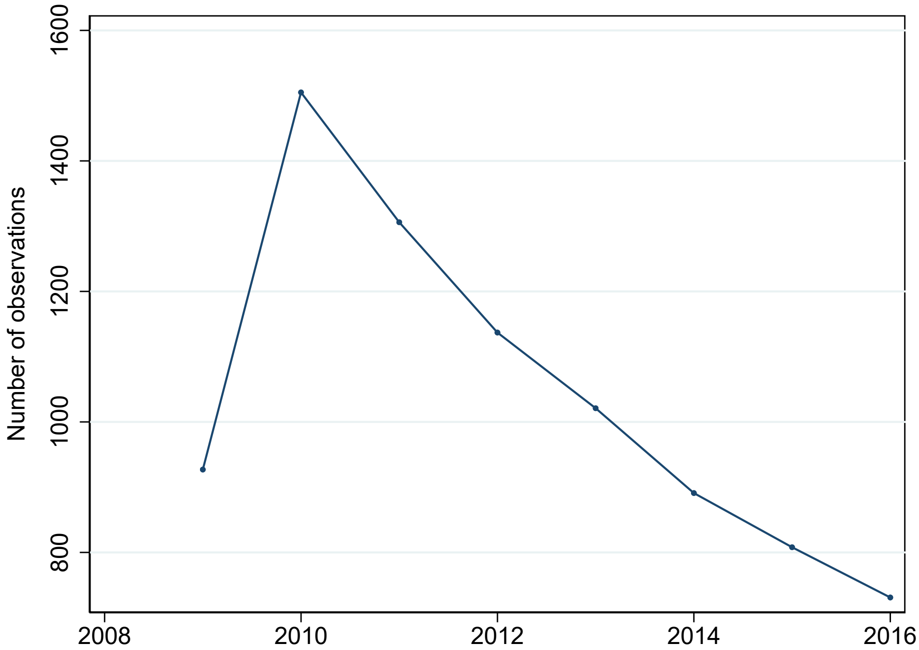

Figure 3: Number of observations over time

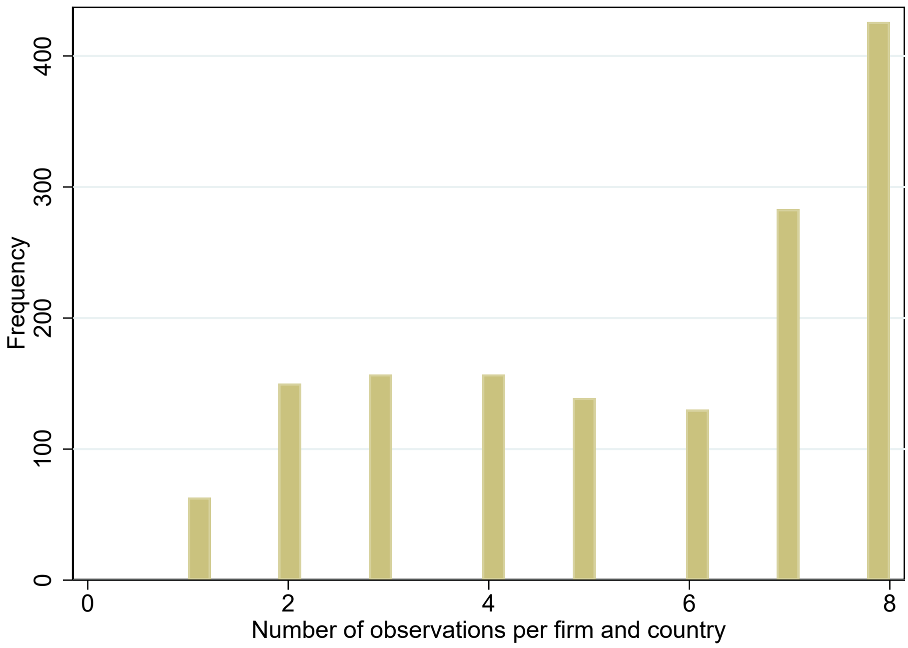

Figure 4: Distribution of numbers of observations per firm and country

Two-way interaction model with continuous treatment

The two-way interaction model writes as:

$$Y_{ict} = \delta T_c * BA_t + \beta_1 BA_t + \beta_0 + \mu_{ic} + \tau_t + \epsilon_{ict} \quad (5)$$

where

Y_{ict} is the outcome variable and can be either the logarithmic scope 1 or scope 2 emissions of firm i in country c in year t;

T_c is the country-level treatment indicator;

BA_t the before-after indicator (= 0 before 2013, = 1 from 2013 onwards);

μ_{ic} are the firm-country fixed effects;

τ_t are the year fixed effects;

and ϵ_{ict} is the standard error term clustered at the firm level.

Due to collinearity, the coefficient associated with T_c is not identifiable. It is hence omitted in the estimation.

Table 6: The effect of the ESD targets on firms' scope 1 and scope 2 emissions—
Two-way interaction with continuous treatment

	(1)	(2)	(3)	(4)
	Scope 1	Scope 2	Scope 1	Scope 2
T × BA	0.0388*	0.0126	0.0388*	0.0122
	(0.0201)	(0.0164)	(0.0202)	(0.0163)
BA	0.0151	-0.147***		
	(0.0657)	(0.0471)		
Constant	6.598***	6.970***	6.555***	7.009***
	(0.0215)	(0.0146)	(0.0736)	(0.0319)
R2	0.00167	0.0127	0.00519	0.0157
Observations	7644	8001	7644	8001
Year FE	no	no	yes	yes
Firm-Country FE	yes	yes	yes	yes

Standard errors, clustered at the firm level, are reported in parentheses. *, ** and *** respectively refer to the 10%, 5% and 1% significance level of the estimated coefficients.

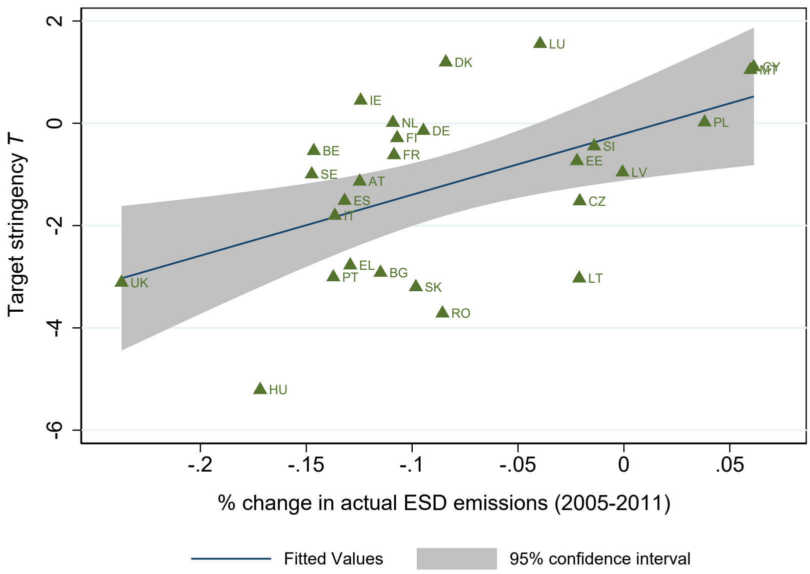

Figure 5: Relationship between the target stringency T and pre-trends in emissions from ESD sectors (computed with EEA data)

Examples of policies implemented in countries for which we consider the ESD target non-stringent

In 2008, Germany introduced a special fund for energy efficiency in small and medium size enterprises (SMEs) (Eichhammer, 2012). This fund is managed by the public reconstruction bank ("Kreditanstalt für Wiederaufbau", KfW) and covers the cost for consulting and investment related to energy efficiency improvement in SMEs. This could contribute to the reduction of both their scope 1 and 2 emissions.

The UK put in place an electric car grant in 2011 (Morris et al., 2012): buyers of electric vehicles were given a subsidy of up to £5000 (this subsidy was reduced afterwards). This was valid for up to 1000 business vehicles (plug-in vans, trucks and taxis) per organisation each year. Similar programs have been adopted in many other member states. The UK's Department for Transport has also provided ecodriving training for companies' employees since 2008 and covers about half of the cost of the training. These measures may have contributed to reducing emissions of company vehicles.

Denmark introduced the Rural Development Programme aimed at, among others, increasing energy efficiency and reducing emissions in the agricultural sector (van Doorn et al., 2012).

The Bulgarian government gives loans to banks that on-lend them to private companies for industrial energy-efficiency projects.(Eichhammer, 2012) For these, companies may also benefit from free consultancy services, including energy pre-assessment, financial analysis, risk assessment or development of business plans.

Several countries such as Germany, the Netherlands and Finland settled voluntary agreements with companies (Eichhammer, 2012). For example, in the Netherlands, such agreements were made with SMEs not covered by the ETS for a joint energy efficiency improvement target (30% between 2005 and 2030). This goal was even largely exceeded.

Robustness checks

Table 7: The effect of the ESD targets on firms' scope 1 and scope 2 emissions—sensitivity check with firm-country clustering

	(1)	(2)	(3)	(4)
	Scope 1	Scope 2	Scope 1	Scope 2
T × BA × expos	-0.154**	0.00686	-0.154**	0.00654
	(0.0663)	(0.0691)	(0.0663)	(0.0691)
T × BA	0.111***	0.00902	0.111***	0.00880
	(0.0394)	(0.0275)	(0.0394)	(0.0275)
expos × BA	-0.854***	0.108	-0.853***	0.106
	(0.157)	(0.135)	(0.157)	(0.135)
BA	0.384***	-0.190***		
	(0.0953)	(0.0631)		
Constant	6.595***	6.970***	6.553***	7.009***
	(0.0122)	(0.0105)	(0.0385)	(0.0251)
R2	0.0160	0.0131	0.0195	0.0160
Observations	7644	8001	7644	8001
Year FE	no	no	yes	yes
Firm-Country FE	yes	yes	yes	yes

Standard errors, clustered at the firm level, are reported in parentheses. *, ** and *** respectively refer to the 10%, 5% and 1% significance level of the estimated coefficients.

Table 8: The effect of the ESD targets on firms' scope 1 and scope 2 emissions (multinational companies exluded)

	(1) Scope 1	(2) Scope 2	(3) Scope 1	(4) Scope 2
T × BA × expos	-0.317	0.669***	-0.319	0.654***
	(0.219)	(0.233)	(0.218)	(0.234)
T × BA	0.134	-0.188**	0.136	-0.183*
	(0.0908)	(0.0937)	(0.0904)	(0.0942)
expos × BA	-0.872*	1.219**	-0.889*	1.190**
	(0.496)	(0.548)	(0.494)	(0.551)
BA	0.183	-0.645***		
	(0.230)	(0.238)		
Constant	7.595***	8.530***	7.453***	8.565***
	(0.0447)	(0.0471)	(0.102)	(0.107)
R2	0.0200	0.0428	0.0424	0.0468
Observations	601	617	601	617
Year FE	no	no	yes	yes
Firm-Country FE	yes	yes	yes	yes

Standard errors, clustered at the firm level, are reported in parentheses. *, ** and *** respectively refer to the 10%, 5% and 1% significance level of the estimated coefficients.

Table 9: The effect of the ESD targets on firms' scope 1 and scope 2 emissions—2012 considered in the treatment group

	(1) Scope 1	(2) Scope 2	(3) Scope 1	(4) Scope 2
T × BA × expos	-0.101*	0.0316	-0.101	0.0310
	(0.0611)	(0.0690)	(0.0612)	(0.0690)
T × BA	0.0868**	0.00662	0.0866**	0.00558
	(0.0386)	(0.0242)	(0.0387)	(0.0243)
expos × BA	-0.753***	0.210	-0.751***	0.210
	(0.181)	(0.168)	(0.182)	(0.166)
BA	0.333***	-0.206***		
	(0.107)	(0.0696)		
Constant	6.602***	6.985***	6.554***	7.008***
	(0.0259)	(0.0184)	(0.0747)	(0.0323)
R2	0.0142	0.0125	0.0176	0.0172
Observations	7644	8001	7644	8001
Year FE	no	no	yes	yes
Firm-Country FE	yes	yes	yes	yes

Standard errors, clustered at the firm level, are reported in parentheses. *, ** and *** respectively refer to the 10%, 5% and 1% significance level of the estimated coefficients.

Table 10: The effect of the ESD targets on firms' scope 1 and scope 2 emissions—2012 excluded

	(1) Scope 1	(2) Scope 2	(3) Scope 1	(4) Scope 2
T × BA × expos	-0.144**	0.0235	-0.144**	0.0236
	(0.0728)	(0.0827)	(0.0728)	(0.0825)
T × BA	0.113**	0.00827	0.113**	0.00780
	(0.0465)	(0.0283)	(0.0465)	(0.0283)
expos × BA	-0.928***	0.182	-0.926***	0.182
	(0.211)	(0.197)	(0.211)	(0.195)
BA	0.418***	-0.228***		
	(0.131)	(0.0838)		
Constant	6.621***	6.995***	6.570***	7.019***
	(0.0275)	(0.0188)	(0.0758)	(0.0313)
R2	0.0189	0.0164	0.0226	0.0185
Observations	6605	6894	6605	6894
Year FE	no	no	yes	yes
Firm-Country FE	yes	yes	yes	yes

Standard errors, clustered at the firm level, are reported in parentheses. *, ** and *** respectively refer to the 10%, 5% and 1% significance level of the estimated coefficients.

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