Internal Carbon Markets and Carbon Emissions

Abstract

Firms operating internal carbon markets in the European Union Emissions Trading System reallocate more carbon allowances from subsidiaries with generous free allowance allocated to those with modest free allowance allocated by the regulator, and vice versa, after allowances become relatively scarce. In response to allowance scarcity, subsidiaries of firms with internal carbon markets also become 15% more carbon intensive. The increase in carbon intensity is consistent with an agency conflict based explanation related to the reallocation of resources within a firm. I further document the negative effect of such agency frictions on emissions when the carbon markets are expanded. Overall, the paper highlights a novel mechanism that can undermine the effectiveness of market–based climate policies.

Keywords: Internal carbon markets, EU ETS, carbon trading, internal capital markets, climate policy

JEL classification: G30, G32, G34, G38, P18, Q54

1. Introduction

Carbon emissions trading is one of the most commonly used policy tools to tackle climate change. Such systems are already in place in Canada, China, the EU, the UK, the US (California cap-and-trade system and the Regional Greenhouse Gas Initiative), Switzerland and many more are under consideration.[1] Emissions trading systems are typically implemented as a cap-and-trade system where the participants trade carbon allowances based on their cap (or free allowances) and their actual emissions.

One unique feature of such a market is that free allowances are allocated to the installations (as opposed to a firm) by the regulator. Hence, if installations are owned by the same parent firm or Global Ultimate Ownner (GUO), it can operate an internal market by reallocating allowances within its firm boundary as shown in Figure 1.[2] This is important as roughly 50% of the firms that own an installation in European Union Emissions Trading System (EU ETS) have access to an internal market for trading carbon allowances, i.e., an internal carbon market (ICO_2M, hereafter). However, little is known about the role of ICO_2M in emissions reduction. In this paper, I study this unique feature of such ETSs and how it can influence the carbon emissions of firms operating in the ETS. I use regulatory changes in the EU ETS, the oldest and the largest emissions trading system in the world, as a laboratory for my analyses. The findings of the paper imply that ICO_2Ms are an important determinant for carbon emissions of firms operating in an ETS.

As a first step, I document that ICO_2Ms are relevant in the EU ETS and are actively used. I exploit a new allowance allocation policy (described in detail in Section 2) that introduced substantial heterogeneity in the allocation free allowances across installations based on their industrial sectors *within* the same GUO–year. Using this identifying variation, I find that subsidiaries that receive relatively generous (scarce) free allowances

[1] See: https://carbonpricingdashboard.worldbank.org/

[2] For example, row 3 of the figure demonstrates transaction between two subsidiaries belonging to the energy firm Iberdrola. Similarly, the last row in the figure demonstrates transaction between two subsidiaries of ExxonMobil located in different EU countries.

transfer 12.6% (receive 11.6%) of allowances internally *within a GUO–year* after the introduction of the mechanism compared to before. This evidence establishes a novel fact that ICO_2Ms are strategically used by firms in the EU ETS consistent with the existing literature in internal capital markets (e.g., Gopalan et al., 2007; Almeida et al., 2015; Buchuk et al., 2020) documenting that firms operating multiple business units support resource constrained divisions when facing external shocks.

Next, I build on the extensive literature on internal capital markets to investigate whether the emission behavior of firms with ICO_2Ms changes in response to shocks compared to other firms in the EU ETS. On the one hand, the bright side view in the context of internal resource allocation (e.g., Stein, 1997) would suggest that a GUO could reallocate emissions to firms where it is most efficient. On the other hand, by the "dark-side" view of internal resource reallocation, taking away resources from one division reduces the private benefits associated with that resource for the divisional managers under incomplete contracts. That is, when headquarters exercise its control rights it is impossible to compensate the divisional managers for the loss of their private benefits from controlling the allowances (Aghion et al., 2014). This expected reduction in private benefits could lead divisional managers to exert less effort ex-ante and discourage them to make any allowances available for reallocation ex-post (e.g., Stein, 1997; Brusco and Panunzi, 2005; Inderst, Roman and Laux, Christian, 2005; Seru, 2014). If such a mechanism is at play then firms belonging to an ICO_2M would have less efficient carbon emissions compared to other firms.

To test the above hypotheses, I exploit the transition from Phase II to Phase III of the EU ETS as a negative shock to the (expected) availability and/or higher prices of carbon allowances in the future, similar to Antoniou et al. (2020). Indeed, as compared to Phase II, when more than 90% of the allowances were given out for free, during Phase III only 43% of the allowances were freely allocated. In a difference-in-differences setting exploiting the transition, I find that compared to other firms, subsidiaries (or independent firms) that are part of an internal carbon market become 15% less carbon efficient after the transition to Phase III. I demonstrate that the result is robust to the inclusion of various fixed effects, samples and alternative definitions of the dependent variable. Additionally, I also document that the results are robust to using the difference-in-differences specification on a propensity score matched sample as well as scaling emissions by total assets instead of revenues.

I provide a conceptual framework behind the results using a simple model of decision-making for divisional managers (in Appendix Section A1). I compare a single-division and a division of a multi-division firm (operating an ICO_2M). Relocation of allocated allowances moves the control of these allowances away from the divisional managers. This could reduce the private benefits of the divisional managers in at least two ways. First, the managers could indirectly lose any private benefits associated with controlling more cash flows. When allowances are within the control of the managers, they could choose to sell the allowances when prices are more favorable (since EU ETS allow 'banking' of allowances from one year to the next). Second, there could be a direct loss of private benefit driven by the loss of control on corporate resources (Aghion et al., 2014), in this case, emission allowances itself. It is particularly important in this context as the allowance allocation mechanism designed by the European Commission, by definition, provides control rights to the divisional managers as the allowances are allocated to the facilities rather than to the headquarters. Hence, anticipating the loss of private benefits managers put less effort into abating emissions, thereby, making firms with ICO_2Ms more carbon intensive.

Consistent with this dark–side view of internal resource reallocation, the effects are largely driven by ICO_2Ms that are more difficult to monitor. I document this finding using four different proxies of monitoring difficulty. Furthermore, firms with ICO_2Ms that are relatively difficult to monitor also consume more free allowances during Phase III compared to other firms and as compared to Phase II. Hence, this evidence is consistent with the explanation that managers use up resources if there is a threat of reallocation of such resources by the headquarters ex-post. Consistent with such explanation, I further document that particularly those ICO_2Ms become more carbon intensive that face higher transaction costs (e.g., Zaklan, 2022; Hahn and Stavins, 2011; Jaraitė-Kažukauskė and Kažukauskas, 2015; Naegele, 2018; Baudry et al., 2021) in the external carbon market compared to others.

I consider two additional explanations to explain the main finding but do not find evidence supporting them. First, I consider a *favoritism* hypothesis. According to this view, the headquarters of the GUO would allocate more carbon allowances to managers with social ties or influence (e.g., Glaser et al., 2013; Duchin and Sosyura, 2013). Such allocation can be efficient if connections to the headquarters help alleviate information asymmetry. Alternatively, such allocation can be inefficient if the power play within an organization influences resource allocation decisions by the headquarters. Hence, the favoritism hypothesis would predict internal carbon markets those are more likely to be connected to the headquarters, would, either become less or more carbon efficient in response to the policy change. In my empirical tests, I proxy for such social ties if the ICO_2M is located in the same headquarters country as the GUO. I do not observe a statistically significant difference in emissions behavior associated with the connection to headquarters for firms with ICO_2Ms. Additionally, the favoritism hypothesis based on the inefficient allocation of resources would also predict that managers of ex-ante less efficient divisions would be the ones that would lobby for more resources (Scharfstein and Stein, 2000) and are also more inefficient after the shock. However, the empirical evidence speaks against it. In summary, the evidence documented in this paper is not consistent with a corporate favoritism based explanation.

The second hypothesis I consider is a *financially efficient* allocation of emissions within an ICO_2M. In one of the seminal papers, Montgomery (1972) demonstrates that a profit-maximizing firm can abate emissions until when the marginal cost of abatement is equal to the marginal benefit. If this is the case, one would expect that internal carbon markets help headquarters to reallocate emissions to subsidiaries that can abate at a lower cost and/or pass on the costs to consumers. This implies that with the increase in emissions there would be a corresponding reduction in emissions intensities for firms belonging to an ICO_2M as compared to other firms during Phase III. We might also observe an increase in revenue or profitability particularly for those firms in the ICO_2M that experience an increase in emissions intensity after the transition to Phase III. However, as I later document, I do not find evidence that would be consistent with such an explanation.

One potentially interesting aspect would be the interaction between the internal capital market (ICM) and the ICO_2M. It could be that transfer of resources through the ICM act as a substitute for transfer of carbon allowances. ICM–transfers can also act as a complement if such transfers generally proxy for a corporate policy to support a particular subsidiary. To investigate this, I create three proxies of ICM–transfers using the methodology of Rajan et al. (2000). I do not find evidence that ICM–transfers are related to the transfers allowances through the ICO_2M. Furthermore, I also do not find any evidence indicating the role that ICMs in moderating the effect of ICO_2Ms.

Finally, I investigate the implication of ICO_2Ms when carbon markets are expanded. The EU ETS expanded in 2008 by including Iceland, Lichtenstein, and Norway. Additionally, in 2013 Croatia joined the EU ETS. With such expansion, firms get access to additional facilities through which they can operate an ICO_2M. Hence, going by the previous results, one could expect that firms that operate the ICO_2Ms through the newly included countries would also increase their emission intensities. Exploiting Croatia's inclusion in the EU ETS, I find that non-Croatian facilities increase their emission intensities and increase the consumption of their free allowances compared to other firms that operate an ICO_2M in Eastern Europe. This result highlights additional policy implications for ICO_2Ms in the operation of carbon markets.

This paper is related to at least three strands of the literature. First, I add to the growing literature on climate finance, especially in corporate finance. As noted in Dai et al. (2021) a vast majority of the current literature in climate finance focuses on asset pricing and financial market implications. Most related to this paper is Bartram et al.

(2021) where the authors document that firms in the US relocate emissions to their facilities outside California in response to the California cap-and-trade emissions trading system. The role of firm boundaries has also been studied in Akey and Appel (2021), especially, how parents' limited liability protection impacts toxic chemical releases from subsidiaries. In a related theory paper, Heider and Inderst (2021) models how financial constraints can have implications on optimal environmental policy. I complement this growing literature in corporate finance by studying the internal carbon markets of firms.

Second, I complement the extensive literature studying the EU ETS. Perino et al. (2021), Cludius et al. (2021), Duscha et al. (2021), Perino et al. (2019), Perino and Willner (2017), Perino and Willner (2016), Ellerman et al. (2015) and Böhringer (2014) discuss various aspects of the EU ETS design. Trading behaviour in the EU ETS have been studied by Abrell et al. (2021), Schleich et al. (2020), Naegele and Zaklan (2016), Fan et al. (2016), Betz and Schmidt (2015), Jaraitė-Kažukauskė and Kažukauskas (2014), Martin et al. (2014b), and Zaklan (2013) among many others. A vast majority of these studies do not investigate the role of firm boundaries, except, Schleich et al. (2020), Betz and Schmidt (2015) and Zaklan (2013). Zaklan (2013) investigate the determinants of intra-firm transfers during the first two years of the EU ETS, i.e., 2005 and 2006 and finds that total value of emission allowance received by a firm is positively correlated with intra-firm transfers. Betz and Schmidt (2015) use trading data for the period 2005 to 2007 and find that vast majority of the installations hardly participate in trading. However, in these years the EU ETS was only in its trial phase. Similar findings have been documented by other studies such as Martin et al. (2014b). In a similar vein, Schleich et al. (2020) study the determinants of intra-firm transfers between 2005 and 2015 in the EU ETS and finds that, conditional on having higher free allocation than verified emissions in a given year, firms belonging to carbon leakage industries do not transfer more allowances internally. However, a crucial difference between this paper and Schleich et al. (2020) lies in the definition of firm boundaries. While, Schleich et al. (2020) considers transfers within a given subsidiary across multiple installations as intra-firm trades, I take the overall firm boundary into account. Overall, I complement this strand of literature by not only demonstrating strategic transfer of carbon allowances across subsidiaries, but I also document the effects of such possibility of ex-post allowance transfer on firm's carbon emissions in the EU ETS.

Finally, this paper builds on the large literature in internal capital markets (e.g., Stein, 1997; Rajan et al., 2000; Maksimovic and Phillips, 2002) reviewed in Maksimovic and Phillips (2013). The majority of the literature on internal capital markets studies the flow of capital between business units. For example, Buchuk et al. (2020), Almeida et al. (2015), Gopalan et al. (2007) study the internal monetary transactions of business groups among group affiliated firms in various emerging economies. Similarly, Glaser et al. (2013) study capital allocation in a large multinational conglomerate. I complement this literature by analyzing the flow of carbon allowances. Additionally, I complement the literature that investigates managerial effort provision at the mere prospect of having resources reallocated away from them via the internal capital markets (e.g., Brusco and Panunzi, 2005; Inderst, Roman and Laux, Christian, 2005; Inderst et al., 2007; Seru, 2014). I document that in the presence of an internal carbon market, firms are less likely to reduce their emissions so as to make surplus emission allowance available for other firms within the group.

2. Overview of the EU ETS

The EU ETS is the flagship climate policy tool of the EU. It was setup in 2005 as the world's first international carbon emissions trading system and covers approximately 45% of the carbon emissions of the EU from 11,000 installations across 31 countries. The EU ETS is currently in its fourth trading phase (2021–2030) with the first three trading phases covering the years 2005–2007, 2008–2012 and 2013-2020, respectively. The EU ETS operates as a cap-and-trade system. Phase I, 2005–2007, was a three year pilot of the ETS in order to prepare for the Phase II (2008–2012). It started with 28 EU member countries. As a pilot project, Phase I covered only CO_2 emissions from power generators and other energy intensive industries. Additionally, nearly all allowances were given out for free during this time. However, it provided policymakers valuable experience and it succeeded in establishing a robust infrastructure for monitoring, reporting and verification of carbon emissions across the EU countries. During the Phase II (2008–2012), three new countries (Iceland, Lichtenstein and Norway) joined the ETS. 90% of the allowances were still allocated for free.

In Phases I and II, the allocation of allowances was decentralized, with each country allocating allowances (according to its National Allocation Plan) to installations in its country based on "grandfathering", i.e., installations were allocated free allowances as per their historical emissions. However, this changed during trading Phase III. Beginning 2013, EU made a transition towards auctioning as the default mode of allocation and the allocation was centralized according to the Benchmarking Decision of the EU.[3]

The Benchmarking Decision makes free allocation available to installations based on their four digit NACE based industry or product benchmarks. The benchmark is defined as the 10% of the best performing installation for a given sector or product based on average CO_2 emissions per unit of output during the period 2007–2008. The allocation is determined based on the following formula:

$$Q_{i,j,t} = B_j \times HAL_{i,j} \times LRF_{j,t} \times CSCF_t \tag{1}$$

where, $Q_{i,j,t}$ is the free allowance received by the installation i, in industry j in year t. B is the benchmark in sector j, HAL is the historical activity level measured as the median activity level during 2005–2008 (or from 2009 until 2010, if larger) for the installation i in sector j. LRF is the linear reduction factor that goes down from 0.8 in 2013 to 0.3 in 2020 linearly. Finally, CSCF is the cross-sectional correction factor applied uniformly across all installations to align the total free allocation to the EU wide cap on emissions. As noted in Martin et al. (2014a), an important feature of this allocation methodology

[3]See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32011D0278&from=EN

is that the free allocation is based on production capacity prior to the trading phase and annual updates occur automatically via the LRF. The allocation is not tied to the actual production levels.

Importantly, the LRF takes the value of 1 for all installations belonging to the carbon leakage (CL) list. This essentially means that all such installations receive 100% of their benchmarked emission allowances for free. A sector is categorized at the risk of carbon leakage based on their carbon intensity (CI, measured as the ratio between total cost[4] and the gross value added of the sector) and/or trade intensity (TI, calculated as the ratio of total value of imports and exports with third countries to the total market size for the Community (annual turnover plus total imports from third countries)). If CI is greater than 5 percent and TI is greater than 10 percent, or either CI or TI is greater than 30 percent, then a sector is classified under the CL list. There are 154 granular NACE-based industries that are part of this list. The CL list is reviewed regularly and the criteria for inclusion under the CL list became stricter during Phase IV (2021–2030) of the EU ETS. Furthermore, starting 2013, electricity producers had to buy all carbon allowances from the market. Thus, for electricity producers LRF takes the value of zero.

3. Data description

The data for the study comes from primarily three sources. First, I get the carbon allowance trading data from the European Union Transaction Log (EUTL) database. The database provides information for each allowance that have been transacted in the EU ETS, either through an exchange or through over-the-counter transactions. It records the name of the organization that transfers the allowance along with the parent firm of the organization, the receiving organization, the parent firm of the receiving organization, date and time of the transaction, country of origin and destination, the type of transac-

[4]Both direct and indirect costs are included. Direct costs are calculated as the value of CO_2 emissions using a proxy price of 30 euros per ton of carbon emissions (Martin et al., 2014a).

tion and the quantity of allowances traded.[5] While the data is granular and rich with information, it has two limitations. First, the transaction prices are not disclosed. In my communication with the European Commission and also with many national authorities, it was made clear that prices for transactions are not recorded in the EUTL database. Second, the data is published with a three year delay. At the time of writing this draft, trading data was available until 2018.

Second database that I use for the analysis is the Monitoring, Reporting and Verification (MRV) database. This database reports installation wise yearly verified emissions, amount of free allocation that the installation received, the total amount of allowances the installation provided for its verified emissions. This database also provides the name of each installation, its location, the name of the firm owning the installation along with an unique national identifier of the firm.

Third database is the Orbis financials and ownership database that is offered by Bureau van Dijk, a Moody's company. Orbis is the largest cross-country firm-level database covering both public and private firms. It provides balance sheet and income statements as well as detailed information on firms' location, industry and crucially for this study, their ownership structures. In the following sub-section, I describe how I match the three datasets.

3.1. Linking Orbis to EU ETS databases

The first set of matching is done between the MRV database and Orbis. The process is made relatively less cumbersome due to the availability of the national identifiers. In many cases, the national identifier could be easily mapped uniquely to a particular firm. For some countries, like the United Kingdom, appending the two-letter country code, *GB* in this case, provides the corresponding Bureau van Dijk Identifier (BvDID). BvDID uniquely identifies a firm in the Orbis database. However for many other countries, for example Germany and Italy, this is not the case. Hence, for these countries, I manually

[5]See: https://ec.europa.eu/clima/ets/transaction.do

go through possible national identifiers in the database and assign the company for the corresponding identifier. In the cases where the national identifiers could not be found in the database, I do a manual name search to find out the BvDIDs. Additionally, there are some cases where national identifiers seems to be wrongly entered. This happens for simple formatting issues such as leaving out the leading zeros from the ID or an additional special character. I manually correct them to get their BvDIDs. By this process, I could match nearly all of the installations to Orbis through their BvDIDs.[6]

The second set of matching is done between the EUTL database and Orbis. This is more time consuming as the EUTL database does not always contain the national identifier of the firm. Hence, the matching between the EUTL database and Orbis is purely based on name matching. In order to ensure accuracy, I manually match each individual organization to Orbis taking into account their location in order to avoid ambiguities. Even though some organizations could not be mapped, a vast majority of transactions during my sample period could be mapped to firm listed in Orbis. One limitation of the EUTL database is that it does not track the full path of allowance flow, i.e., even though I could know that a firm is receiving or transferring certain number of allowances, many times it is often unknown from which installation (if at all) these allowances are coming from or going to.

3.2. Mapping Ownership

Once I get the BvDIDs for the owners of the installations in the MRV database and the counterparties involved in a transaction from the EUTL database, I map each BvDID, in each year, to the corresponding Global Ultimate Owner (GUO) in that year. A GUO is defined as a firm having more than 50% ownership of a subsidiary. I consider 50-50 joint ventures as independent firms. In the most recent data revisions, Bureau van Dijk provides vintage files for ownership links for each year for each BvDID. In the first step, I use this vintage ownership link files to map the BvDID for the GUO. However, I found

[6]I could not match very few installations belonging to Greece due to ambiguity in their names

that in many cases the ownership links were not complete. For example, PORSCHE HOLDING SE was mapped to a different identifier as compared to VOLKSWAGEN AG. In order to avoid such issues, I manually go through the mapping and check for all possible such cases and correct them. Furthermore, many cases, especially when installations are owned by private equity funds, are difficult to trace back to the same GUO as often times, they use different names or its abbreviations. For these cases, I use manual google searches to avoid any inconsistencies as much as possible.

For each firm, its subsidiaries and installations, I get their locations at the country level based on the information available in the EUTL database and the Orbis database. I also get industry information from Orbis based on the second revision of the statistical classification of economic activities (NACE Rev.2) as followed by the EU.

Overall, the database constructed in this way is a relatively clean dataset mapping installations and trading counterparties in the EU ETS to their corporate parents, even though it may not be 100% accurate.

3.3. Summary Statistics

The unit of observation of my analysis is at a subsidiary-year level. For independent firms, this automatically translates to parent firm-year level observations. For each subsidiary (or parent firm, in case of independent firms) in a given year, I calculate the total emissions by aggregating the verified emissions for all stationary installations covered under the EU ETS under the control of a given subsidiary or firm. In a similar way, I calculate the total amount of free allowances allocated across all installations for a given subsidiary/firm by aggregating installation specific free allocation. The MRV database for Phase II and Phase III additionally comes with four-digit NACE Rev. 2 codes for each a vast majority of installations. I identify electricity producing installations and installations belonging to the CL list from these granular industry descriptions. For the installations that do not have any industry associated with them, I follow a conservative approach and mark them as not belonging to either of the two categories. This measurement error is likely to introduce more noise in estimating the regression specifications mentioned above and is likely to bias the results of the estimations towards zero. Additionally, I collect firm-year level annual financials from Orbis as mentioned above.

Insert Table 1 here

Table 1 provides summary statistics of the variables used in the study for the period 2008-2019. The variable *TRFICM* is percentage of carbon allowance a particular subsidiary transfers to other subsidiaries for firms with an internal carbon market. By definition, this variable is only measured for firms with at least two or more separate subsidiaries operating installations covered by the EU ETS. The variable *OE* is a dummy variable indicating if a firm/subsidiary is emitting emissions more than its allocation. This variable is measured by excluding emissions from the electricity producing installations as they do not receive any free allocation from Phase III. A mean of 0.256 suggests that 25.6% of subsidiary/firm-year observations are with more emissions than their free allocation levels during the sample period. Additionally, the variable ICO_2M suggests that 61.4% of subsidiary/firm-year level observations are associated with an internal carbon market. In a similar vein, mean of ICO_2M_{NonLoc}, ICO_2M_{mf}, ICO_2M_{divgeo} suggests that 31.7%, 49.1% and 35.7% of observations are associated with non-local, multi-firm and geographically diversified internal carbon markets, respectively. The variable *ROA* is return on assets defined as revenues over total assets of firms/subsidiaries. *CHE* is the total cash holding of firms/subsidiaries scaled by total assets. *Log_Emissions* and *Log_Allocation* are the natural logarithm of the total verified emissions and free allocation for a given firm/subsidiary, respectively.

4. Identification Strategy & Empirical Results

4.1. Relevance of Internal Carbon Markets

The literature on internal capital markets (ICMs) document that firms reallocate capital from one division to another when facing external capital market frictions (e.g., Gopalan et al., 2007; Glaser et al., 2013; Almeida et al., 2015; Buchuk et al., 2020). If firms take advantage of their ICO_2Ms in a similar way, one would expect firms to reallocate carbon allowances to subsidiaries that receive less from the ones that receive more generous allocations. In the parlance of the literature on ICMs, one can think of firms that receive more generous allocation of free allowances to be less resource constrained than others.

It is difficult to proxy which firms receive generous or modest allowances as compared to their requirements. Hence, I consider two extreme variations induced by the Phase III allocation mechanism to establish whether firms actively use their ICO_2Ms. Specifically, according to the Benchmarking Decision, firms with facilities belonging to the CL list received a generous allocation of allowances. For example, Martin et al. (2014a) documents that the Phase III allocation rules overcompensated for the carbon leakage risk. Additionally, starting from Phase III, power producers stopped receiving any free allowances. Hence, subsidiaries with CL list (electricity producing) installations would be less (more) resource constrained than other subsidiaries within the parent firm.

If firms use their ICO_2M, then I hypothesize that:

H1: *Compared to Phase II of the EU ETS, more carbon allowances to flow from (to) subsidiaries associated with CL list (electricity producing) installations to (from) subsidiaries without them within a parent firm, during Phase III.*

In order to test the hypothesis, I use the following specification:

$$\begin{aligned} TRFICM_{i,j,k,t} = {} & \beta_1 \times CLEAK_{i,t} + \beta_2 \times POST_t + \beta_3 \times POST_t \times CLEAK_{i,t} + \\ & \gamma \times X_{i,t} + \delta_i + \eta_j + \theta_t + \zeta_k + \epsilon_{i,j,k,t} \end{aligned} \tag{2}$$

In the above equation, *TRFICM* is defined as the amount if CO_2 allowances transferred from a given subsidiary (i) as a percentage of its yearly emissions in a given year (t) belonging a GUO (j) in a specific industry (k). Depending on the specifications, the variable $CLEAK$ takes the value of 1 if the subsidiary has at least one CL list installation or an electricity producing installation and zero, otherwise. Alternatively, I replace $CLEAK$ with $ELECT$ if the subsidiary has at least one electricity producing installation. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012, X is a vector of subsidiary/firm level time varying control variables. δ, η, ζ and θ are subsidiary, parent firm, industry and year fixed effects, respectively. In some specifications I use parent firm×year fixed effects as well.

The results of estimating equation 2 is presented in Table 2. Panel A (Panel B) of the table tests whether parent firms having subsidiaries with at least one CL list (electricity producing) installation transfers (receives) more carbon allowances to other subsidiaries belonging to the same parent firm during the first three year of Phase III of the EU ETS as compared to the last three year of Phase II (*Hypothesis 1*).

In Panel A, The coefficient of interest is on the interaction term $CLEAK \times POST$. As can be seen, the coefficient is always positive and statistically significant at the conventional levels. This suggests that, indeed, within a parent firm, during Phase III, subsidiaries having at least one CL list installations transfer more carbon allowances to other group firms who are possibly more resource constrained. The relationship is robust to various fixed effects. Importantly, when we look at a given subsidiary with a particular parent firm in a give year, i.e., $ParentFirm \times Year$ fixed effect in column (4) of the table, the effect seems to get stronger. This also accounts for any firm-year level unobserved heterogeneity that might confound with these internal transfers. In terms of economic magnitude, the coefficient of 0.126 in column (4) suggests that a subsidiary with a CL list installation transfers 12.6% of its yearly total emissions more in carbon allowances to other subsidiaries belonging to the same parent firm during Phase III as compared to Phase II.

Insert Table 2 here

In a similar vein, in Panel B, the coefficient of interest is on the interaction term $ELECT \times POST$. The coefficients are always negative and except column (1), they are statistically significant at conventional levels. As before, the results seem to get stronger when applying $ParentFirm \times Year$ fixed effect in column (4). The coefficient in column (4) suggests that a subsidiary having at least one electricity producing installation receives

11.6% of its yearly total emissions more from other subsidiaries belonging to the same parent during Phase III as compared to Phase II of the EU ETS.

These results are consistent with the extensive literature in internal capital markets documenting that firms seem to support resource constrained units or divisions by reallocating resources within their firm boundaries. These results indicate that the threat of reallocation of resources, carbon allowances in the context of this paper, is credible and real for all managers in a firm operating an internal carbon market within the EU ETS. Hence, going forward, I explore whether such threat of reallocation of allowances away from firms impacts carbon emissions and achieving firm-specific climate policy targets as stipulated by the EU ETS allocation mechanism.

4.2. Effects of Internal Carbon Markets: Transition to Phase III

Having established the relevance of ICO_2Ms in the EU ETS, I explore its effect on carbon emissions. Literature in internal capital markets suggests various ways by which ICO_2Ms can impact the emissions behavior of firms. According to the bright side view (e.g., Stein, 1997), in response to shocks that make resources scarce, the headquarters can allocate available resources to their best use within the firm boundaries. This happens as headquarters will have information about the true nature of each project within the firm. If this is the case, then one could expect that facing the transition from Phase II to Phase III after carbon allowances become relatively scarce, firms belonging to an ICO_2M will become more carbon efficient than other firms without an internal carbon market. Hence, the bright side view based argument would suggest the following hypothesis:

H2a: *Compared to Phase II of the EU ETS, firms with ICO_2M in the EU ETS are becoming* ***more*** *carbon efficient during Phase III as compared to other firms.*

However, the dark side view builds on the idea that various frictions within an organization inhibit the efficient allocation of resources. One such friction is the headquarters' preference for corporate socialism, i.e., supporting (weaker) divisions by reallocating resources from stronger divisions. Anticipating such reallocation ex-post, the divisional managers within an organization reduce effort so that any such resource is not available for reallocation in the first place. An important assumption here is that the headquarters cannot compensate the divisional managers enough for the loss of any possible private benefit (as such benefits are, by definition, private or unobservable) that the divisional managers would have derived if the resources were under their control. Additionally, potential information asymmetry between the divisional managers and the headquarters could further exacerbate the problem as more information asymmetry would enable the divisional managers to shirk. In the setting of internal carbon markets, this would mean that firms associated with ICO_2Ms are becoming less carbon efficient after the transition to Phase III. Hence, going by the dark side view, one would expect the following hypothesis:

H2b: *Compared to Phase II of the EU ETS, firms with ICO_2M in the EU ETS are becoming **less** carbon efficient during Phase III as compared to other firms.*

To test the above hypothesis, I employ the following specification:

$$CO_2INT_{i,j,c,k,t} = \beta_1 \times ICO_2M_{i,j,c,k,n,t} + \beta_2 \times POST_t + \beta_3 \times POST_t \times ICO_2M_{i,j,c,k,t} + \gamma \times X_{i,t} + \delta_i + \eta_j + \zeta_c + \omega_k + \theta_t + \epsilon_{i,j,c,k,t} \tag{3}$$

ICO_2M is a dummy variable that takes the value of one for subsidiaries belonging to the same GUO with at least two installations (or a single independent firm operating more than one installation) covered by the EU ETS in a given year during the sample period, and zero, otherwise. The main dependent variable, CO_2INT, is a measure of carbon intensity as calculated by total carbon emissions scaled by revenue of the firm in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012, X is a vector of subsidiary/firm level time varying control variables. I employ subsidiary/firm fixed effects (δ_i), parent firm fixed effects (η_j), country fixed effects (ζ_c), industry (NACE 2-digit) fixed effects (ω_k) and year fixed effect (θ_t).

Table 3 presents the results of estimating equation 3 in order to test Hypothesis 2. The coefficient of interest is the coefficient on the double interaction term $ICM \times POST$. If the prospect of having resources relocated away from subsidiaries affect their incentive to reduce emissions below the free allocation level and make unused allowances available for other subsidiaries belonging to the firm, we expect to see a positive coefficient on $ICO_2M \times POST$. This is indeed what we find across various specifications in Table 3.

Insert Table 3 here

Column (1) includes subsidiary fixed effects, *Country* fixed effects and year fixed effects. In, Column (2), we further introduce a set of time-varying control variables. Column (3) includes additional NACE 2-digit industry level fixed effects and finally, column (4) includes GUO fixed effects. The point estimate of 0.060 in column (4) suggests that for a given subsidiary within a GUO, it emits 6% more carbon emissions per unit of revenue during Phase III as compared Phase II. The economic magnitude remains relatively stable across all the specifications. Additionally, Figure 2 plots the results dynamically. Specifically, it shows the dynamic treatment effects pertaining to the specification of column (4) in Table 3. Figure 2, does not seem to suggest any obvious pre-trend and the effect is solely concentrated during the treatment period, i.e., after 2013. This further strengthens a causal interpretation of the results.

Overall, the results in Table 3 are consistent with the adverse effects of internal carbon markets on carbon emissions. Based on the existing literature, such adverse effects could be a manifestation of agency conflicts within the firm boundaries in various ways. In the following sub-sections, I analyse possible ways in which agency conflicts could hinder efficient usage of carbon allowances.

4.3. Why are Internal Carbon Markets Less Efficient?

The inefficient working of an internal market for resource allocation could be explained by different ways how agency costs are manifested within the firm boundaries.

4.3.1. Evidence Consistent with Agency Issues

One way how ICO_2Ms can lead to inefficient carbon emissions is through adverse incentives induced by the threat of reallocation of excess carbon allowances from one subsidiary of the firm to the other. Anticipating that the headquarters could relocate any excess carbon allowances in the future, managers operating ICO_2Ms could provide less effort to reduce emissions and/or consume the available allowances so that less allowances are available for reallocation. Such adverse effect of internal resource reallocation has been discussed in Gertner et al. (1994), Stein (1997), Brusco and Panunzi (2005), Seru (2014) among many others. In this context, one can think of carbon allowances as a corporate resource which provides private benefits to the divisional managers and by reallocating carbon allowances reduces the private benefits associated with it and hence reduces incentives to exert effort. To formalize this intuition, I present a conceptual framework in Section A1 in the appendix.

Where can one expect to find such effects? Managers could put less effort in firms those are difficult to monitor. Hence, ICO_2Ms that are difficult to monitor emit more carbon and specifically in such a way so as to make the free allowances endowed to them not available for the headquarters to reallocate. Hence, we would expect to see that specifically in ICO_2Ms that are more difficult to monitor are the ones that are becoming more carbon intensive and/or using up more free allowances allocated to them compared to other firms.

To proxy for information asymmetry, I use four different proxies motivated by the existing literature. I categorize ICO_2Ms that are diversified either across multiple industries (ICO_2M_{divind}) or across multiple countries (ICO_2M_{divgeo}) as being more difficult to monitor (Berger and Ofek, 1995; Denis et al., 2002). Another proxy I use is whether ICO_2Ms span countries that are *not* in the headquarter–country of the parent firm (ICO_2M_{nonLoc}). I consider such ICO_2Ms as difficult to monitor compared to ICO_2Ms that span the headquarter–country of the parent firm. Finally, I use whether the ICO_2Ms are decentralized following Stein (2002). I consider ICO_2Ms that are spread across multiple subsidiaries (ICO_2M_{mf}) as being more difficult to monitor compared to other ICO_2Ms.

Insert Table 4 here

In Table 4, I first document whether ICO_2Ms that are more difficult to monitor are the ones that are also becoming more carbon intensive. Each column in the table represents a separate regression. For example, In column (1), I split the ICO_2M into two groups based on industrial diversification as described above. The coefficient on $ICO_2M_{divind} \times POST$ and $ICO_2M_{nondivind} \times POST$ are the two coefficients of interest. For brevity, I do not report coefficients on other variables in the regression. Column (1) documents that both industrially diversified and non-diversified ICO_2Ms became more carbon intensive during Phase III. However, the point estimate only on the diversified ICO_2Ms ($ICO_2M_{divind} \times POST$) is statistically significant. In terms of economic magnitude, diversified ICO_2Ms became 5.5% more carbon intensive while the non-diversified ICO_2Ms became 2.2% more intensive. We can observe similar and more pronounced differential patterns across the other columns, except, column (4).

In column (4), we do see that the point estimate on $ICO_2M_{Loc} \times POST$ is statistically significant and economically larger than the point estimate on $ICO_2M_{NonLoc} \times POST$. This suggests that local ICO_2Ms became more carbon intensive compared to the non-local ones during Phase III of the EU ETS, inconsistent with am information asymmetry based explanation. This evidence can also be consistent with a "favoritism hypothesis" that I discuss in detail in the next sub-section. To further disentangle this issue, I provide two additional pieces of evidence. In columns (5) and (6), I further categorize local and non-local ICO_2Ms into diversified and non-diversified ICO_2M, either based on industry (in column (5)) or based on geography (in column (6)). We see that in both columns, the results are primarily driven by diversified ICO_2Ms.

Next, I analyze *how* do these ICO_2Ms increase emissions. ICO_2Ms can increase emissions if they have more allowances available. However, if agency conflicts are driving the results, we should observe that ICO_2Ms that are difficult to monitor are increasing emissions proportionately more compared to the free allowances that are allocated to them. Hence, to examine this specific mechanism, I analyze whether emissions increase particularly with respect to free allowances available to each subsidiary within a ICO_2M

in Table 5.

Insert Table 5 here

The dependent variable in this analysis is the amount of emissions above the free allocation level (scaled by the free allocation level) that is emitted by a firm. As before, I employ the four proxies of information asymmetry. As can be seen the point estimates on the double interaction terms proxying for more information asymmetry (ICO_2M_{divind}, ICO_2M_{divgeo}, ICO_2M_{mf}, ICO_2M_{Loc}) is always positive and statistically significant for ICO_2M_{Loc}. At the same time, we also observe that the point estimates on the double interaction terms proxying for ICO_2Ms with lower information asymmetry ($ICO_2M_{nondivind}$, $ICO_2M_{nondivgeo}$, ICO_2M_{sf}, ICO_2M_{NonLoc}) is negative and statistically significant for all specifications except for the first column.

In economic terms, these results indicate that ICO_2Ms that are difficult to monitor do not decrease (or in some cases, even increase) their usage of allowances. The opposite is true for ICO_2Ms that are relatively easier to monitor. The point estimates are also economically meaningful. For example, in the second column, the point estimate on $ICO_2M_{nondivgeo} \times POST$ suggests that industrially non-diversified ICO_2Ms decrease their emissions in such a way that they consume approximately 17% less of the free allowances allocated to them during Phase III compared to a firm without an ICO_2M. However, diversified ICO_2Ms do not decrease their allowance consumption. Additionally, the point estimate on $ICO_2M_{divgeo} \times POST$ is also statistically different from $ICO_2M_{nondivgeo} \times POST$ as confirmed by the Wald-test with a $p-$value of 0.001. Similar inferences apply to the results of the remaining columns.

4.3.2. Additional Evidence from Transaction Costs

Transaction costs play an important role in the EU ETS. As noted in Naegele (2018), transaction costs can be fixed costs such as administrative costs and variable trading costs. They can also be variable such as liquidity, search and bargaining frictions, information asymmetry among other things. If ICO_2Ms alleviate such costs (Stavins, 1995), then, the threat of reallocation of allowances will be higher, specifically in those ICO_2Ms where the transactions costs are high. Hence, managers in those ICO_2Ms would have lower incentives to abate their emissions beyond the free allocation levels.

However, transactions costs are difficult to measure. The literature in the EU ETS have argued that small emitters face higher transaction costs Zaklan (2022). Hence, headquarters of ICO_2Ms with smaller emitters might find it favorable to reallocate emissions internally before transacting with the external carbon market, thereby, increasing the threat of reallocation of allowances through the internal carbon market. This would mean that these ICO_2Ms who are smaller emitters would become more carbon intensive and/or use more free allowances allocated to them compared to others.

For this analysis, I split up parent firms operating an ICO_2M into two groups – one with greater than median average emissions of their subsidiaries from the period 2008 to 2012 (ICO_2M_{hiE}) and the other group with lower than median average emissions for the same period (ICO_2M_{loE}). I apply the same difference-in-differences specification as before for the estimation.

Insert Table 6 here

The results of the estimation are shown in Table 6. In Panel A, the dependent variable is the emissions intensity. The coefficients of interest are on the double interaction terms $ICO_2M_{hiE} \times POST$ and $ICO_2M_{loE} \times POST$. We see that the coefficient on $ICO_2M_{hiE} \times POST$ is positive and statistically significant across most of the specifications. A Wald-test also rejects the null hypothesis that the two coefficients are statistically different from each other. Hence, the evidence is consistent with the explanation that higher transaction costs in the external market increases the possibility of reallocation of resources in the internal market which, in turn, makes subsidiaries more carbon–intensive.

Overall, results in this section are consistent with an agency conflicts based explanation introduced by the adverse effects of the ex-post threat of reallocation of corporate resources on the managerial incentives to effort in making these resources available ex-ante.

4.3.3. Corporate Favoritism

One strand of literature has emphasized the role of *corporate favoritism* in the allocation of resources. Scharfstein and Stein (2000) models an internal capital market where divisional managers waste resources in influence activities to increase their bargaining power with the headquarters. Empirically, looking at the capital budgeting decisions of a large conglomerate, Glaser et al. (2013) finds that managers with connections to the CEO receive more cash after unexpected exogenous cash windfalls. Such cash flows are also ex-post inefficiently allocated. Similar findings have been documented in Duchin and Sosyura (2013) in the presence of weak governance. If such favoritism–based allocation is at play, then one could expect more carbon allowances are allocated to socially connected subsidiaries compared to other subsidiaries in an ICO_2M, and/or these firms could be more carbon intensive during Phase III compared to Phase II.

Insert Table 7 here

To investigate whether this mechanism could be an explanation behind the main result, I classify subsidiaries that belong to the same country as the headquarter of the GUO as being socially connected. The results are documented in Table 7. In Panel A, the dependent variable is the amount of carbon allowances that a subsidiary transfers to other subsidiaries that belong to the same GUO in a given year as a percentage of that subsidiary's emissions in that year. The variable *Local* takes the value of 1 for subsidiaries that have their headquarters in the same country as the headquarters of the GUO and zero otherwise. As before, $POST$ takes the value of one for the Phase III years and zero otherwise. We observe that in general the coefficients on *Local* are negative suggesting that subsidiaries that are possibly socially connected receive more allowances internally. However, the coefficients are not statistically significant consistently. Interestingly, the coefficients on the double interaction term $Local \times POST$ is positive and statistically significant suggesting that subsidiaries that are possibly socially connected to the headquarters *transfer* more allowances to other group firms during Phase III compared to Phase II. Additionally, Panel B documents that these local subsidiaries also reduce their emission intensities compared to other group subsidiaries during Phase III compared to Phase II. Hence, these findings are opposite to what a corporate favoritism based inefficiency in resource allocation would predict.

Overall, the evidence in this section together with the evidence presented in the previous section is not consistent with a corporate favoritism based hypothesis explaining the main findings.

4.3.4. Financially Efficient Emissions Abatement

Another explanation for the baseline findings is that firms with ICO_2Ms are increasing their emissions as they could reallocate emissions to firms where their marginal abatement cost is the least and/or they can share the increasing costs of emissions with the consumers, thereby, earning higher revenues or profits. This would follow from modeling the behavior of a profit-maximizing firm operating under an emissions trading scheme (Montgomery, 1972). If reallocation is done in such a way, one would expect that emissions intensities are particularly low for firms belonging to an internal carbon market where they also emit more. Additionally, if firms are able to pass on the costs to consumers, one could expect to observe that revenues are more for firms where they are *more* carbon-intensive. Finally, if firms are able to do *both* cost minimization and revenue maximization, one could also observe an increase in profitability for internal carbon market firms that are becoming more carbon-intensive after the transition to Phase III.

To test if this is indeed what we observe, I estimate the following equation:

$$\begin{aligned}\Delta Y_{i,j,c,k,t} = {} & \beta_1 \times ICO_2M_{i,j,c,k,t} + \beta_2 \times POST_t + \beta_3 \times POST_t \times ICO_2M_{i,j,c,k,t} + \\ & \beta_4 \times POST_t \times \Delta Z_{i,j,c,k,t} + \beta_5 \times POST_t \times \Delta Z_{i,j,c,k,t} \times ICO_2M_{i,j,c,k,t} + \\ & \gamma \times X_{i,t} + \delta_i + \eta_j + \zeta_c + \omega_k + \theta_t + \epsilon_{i,j,c,k,t}\end{aligned} \tag{4}$$

In the above equation, the coefficient of interest would be β_5. The variable Y is any of the following: natural logarithm of emissions per unit of revenue (CO_2INT), the natural logarithm of revenue (REV), profit before taxes (PBT), and, operating margin defined as earnings before interest and taxes ($EBIT$). I use PBT and $EBIT$ as two measures of profitability. Δ denotes a year-on-year change in a variable. The variable Z denotes natural logarithm of total emissions (CO_2E) or emissions intensity (CO_2INT). If firms are emitting more in subsidiaries where they can most efficiently abate emissions, one would expect that emissions intensity goes down in firms that are part of an ICO_2M with higher emissions as compared to other firms (not part of an ICO_2M). Hence, β_5 would be negative when the dependent variable is CO_2INT and the variable Z is CO_2E. Similarly, if firms can pass the costs of higher emissions to consumers, then one would expect the β_5 is positive when the dependent variable is the increase in revenue of firms and the variable Z is CO_2INT. Finally, following a similar logic, if ICO_2Ms allow headquarters to shift emissions to firms that could abate emissions at the lowest cost as well as pass on some of the costs to the consumers, this would translate to a positive β_5 when the dependent variable is either PBT or $EBIT$.

Insert Table 8 here

The results of the estimation are shown in Table 8. In the first column, we observe that the double interaction term $ICO_2M \times \Delta CO_2E$ has a negative coefficient indicating that, indeed, firms with ICO_2Ms reallocate emissions to firms that are less carbon-intensive. We also observe that firms having higher carbon emissions also tend to have higher emissions intensity. However, for the triple interaction term, $ICO_2M \times POST \times \Delta CO_2E$ we do not observe a statistically significant point estimate. In columns (2)-(4) of the table, we again observe the point estimates on the triple interaction term, $ICO_2M \times POST \times \Delta CO_2INT$, are not statistically significant.[7] Overall, the results in this section are not consistent with a financially efficient reallocation of emissions within an internal carbon market.

[7]It must be noted that the signs of the point estimate are also in the opposite direction than expected.

4.4. Role of Internal Capital Markets

Does internal capital market (ICM) play any role in allocation of carbon allowances? Additionally, does the presence of ICM have any impact on the emissions behaviour of firms driven by ICO_2M? To answer these questions, I follow Rajan et al. (2000) to construct a proxy for internal transfer of resources within an internal capital market. However, Orbis does not have capital expenditure data for majority of firm–years. Hence, instead of using capital expenditures, I use three different proxies of internal transfer of resources within a parent firm, namely, cash and cash equivalents, shareholder funds and fixed assets. I closely follow Rajan et al. (2000) and create an industry-adjusted measure of transfers from ICM for each of these variables. As with Rajan et al. (2000), a positive (negative) industry-adjusted number would indicate a receipt (transfer) for any of these variables.

After I create these proxies for internal transfers or receipts through ICM, first, I explore whether ICM transfers are related to the allocation of carbon allowances internally. ICM–transfers could be either complements or substitutes to the $\mathrm{ICO_2M}$–transfers. For example, headquarters of a firm could fund the purchase of additional allowances instead of supplying them through internal transfers or, the headquarters could provide support in addition to providing carbon allowances if the subsidiaries are particularly resource constrained. To investigate this, I employ a regression specification similar to Equation (2) by introducing an additional double interaction term between one of the three ICM transfer proxies and $POST$.

Insert Table 9 here

The results are shown in Table 9, Panel A. As can be seen, there is no significant relationship between ICM transfers and reallocation of carbon allowances via the $\mathrm{ICO_2M}$ after the introduction of Phase III compared to before. Additionally, we the coefficients on $CLEAK \times POST$ remains almost identical to Table (2). Hence, there is no evidence that ICM–transfers are associated with carbon allowance reallocation through the $\mathrm{ICO_2M}$. In unreported results, I find similar results for electricity producing $\mathrm{ICO_2M}$s.

Next, I examine whether ICMs play any role in moderating the relationship between ICO_2M and carbon emissions after the introduction of Phase III. Going by the results in Panel A, if ICM–transfers are not related to carbon allowance reallocation, then one might not expect that ICMs play any role in moderating the relationship between ICO_2M and carbon emissions. On the contrary, ICM–transfers could also proxy for a general corporate policy of supporting their subsidiaries. If this is the case, then presence of ICM–transfers could alleviate part of the negative effect of ICO_2M as the divisional managers could expect support from the headquarters through the ICM if they provide allowances to the headquarters for internal reallocation.

I investigate this by employing a specification similar to the one in Table 6. I categorize ICO_2Ms into two groups. One group where the *absolute* amount of transfers is greater than median among all the ICO_2Ms in a given year. The other group is the one where the amount of transfers is below median.

The results of the analysis is shown in Panel B of Table 9. The estimates in columns (1) and (3) suggest that ICO_2Ms with lower than median ICM–transfers have larger increases in emissions intensity compared to ICO_2Ms with higher ICM–transfers during Phase III. This is consistent with the explanation that the possibility of ICM–transfers can alleviate some of the negative effect of ICO_2Ms on carbon emissions. However, one caveat is that a Wald test cannot reject the null hypothesis that the point estimates, $ICM_{hi} \times POST$ and $ICM_{low} \times POST$ ate statistically different from each other. Additionally, the point estimates in column (2) would suggest the contrary. Hence, the results in Panel B, can be considered as a relatively weak evidence suggesting a moderating role of internal capital markets.

Overall, results in this section demonstrate that potential transfer from internal capital markets are not correlated with the transfer of allowances during Phase III. Additionally, such internal capital market transfers cannot explain the increaase of carbon intensities for firms belonging to ICO_2Ms.

4.5. Robustness Tests

4.5.1. Matched Sample Difference-in-Difference

One concern could be that my results are driven by comparing dissimilar firms with each other. This is similar to the concern noted for the internal capital markets literature in Hund et al. (2012). Hence, to alleviate such concerns, I re-run my analyses using a matched sample difference-in-difference estimation. For the transition to Phase III, I predict the likelihood of a given firm to be included in the internal carbon market or not, based on firm size as of 2012. Additionally, I match firms within the same 2-digit NACE industries. I employ an three nearest neighbor matching based on propensity scores from a probit model. I keep a firm only once in the final matched sample.

Insert Table 10 here

The results of the analysis is shown in Table 10. The results are qualitatively same as those documented in Table 3. The last column in the table suggests that firms with ICO_2Ms increase their carbon intensities by approximately 3% in Phase III as compared to Phase II. As before, I plot the dynamics of the treatment effect in Figure 3. As before, we do not see a visible pre-trend and we could see that emissions intensities starts to increase after 2013.

Additionally, in Tables A1 and A2 in the appendix, I document that main results behind the economic mechanism remain qualitatively unaltered when using the matched sample. Finally, in Table A3 I document that the baseline result is also robust to using other dependent variable, namely, emissions scaled by total assets. Hence, the stability of these results lend credence to the causal interpretation of the main findings.

5. Discussion of Policy Implications

What could be the implication of carbon policies? First, the results imply that agency-induced frictions in allocating corporate resources could undermine the effectiveness of market–based climate policies. Hence, regulators could, for instance, limit the internal reallocation of carbon allowances and encourage trading primarily through the secondary market.

A second implication could be the expansion of carbon trading markets. For example, EU ETS expanded in 2008 to include Iceland, Liechtenstein, and Norway. In 2013, EU ETS was further expanded to include Croatia. What such expansion essentially does is to create (or increase) the operation of an ICO_2M. Hence, considering the results so far, one could argue that such expansion of carbon markets negatively impacts the emissions abatement of firms that now can operate their ICO_2Ms through facilities they own in these newly included countries.

To explore this possibility, I perform a similar difference-in-difference analysis where I consider all firms operating an ICO_2M in Eastern European countries including Croatia. I consider (subsidiaries of) firms as treated if they operate a facility in Croatia after 2013 as well as a subsidiary in another country in Eastern Europe. All other firms are in the control group. With this setting, I explore whether non-Croatian firms (or non-Croatian subsidiaries of firms) that are operating an ICO_2M having facilities in Croatia increase their emissions intensities compared to other firms operating an ICO_2M in Eastern Europe.[8]

Insert Table 11 here

The results of the analysis is shown in Table 11. In Panel A, the point estimate on the double interaction coefficient $ICM_{Croatia} \times POST$ suggests that there is an increase in emissions intensities for non-Croatian firms, that after 2013, whose ICO_2Ms spanned Croatia. Even though the point estimates are not always statistically significant, they are economically meaningful. In Panel B, I further document that non-Croatian firms with ICO_2Ms span Croatia increased their consumption of allowances after 2013 compared to before consistent with the economic mechanism documented above.

[8]Since CO_2 emissions data for Croatian facilities are not available before 2013, I could only examine the emissions of non-Croatian facilities during my entire sample period.

These results suggest that agency issues within a firm can inhibit the effectiveness of climate policies and expansion of carbon markets.

6. Conclusion

In this paper, I investigate internal carbon markets that firms operate within the European Union's Emissions Trading System. First, I establish the relevance of such an internal market by documenting that firms tend to transfer allowances to subsidiaries that receives fewer allowances from the regulators. Next, I exploit whether the threat of such internal resource reallocation away from subsidiaries has an impact on their carbon emissions. Firms that are part of an internal carbon market become more carbon intensive after allowances become scarce, specifically, in internal markets that are difficult to monitor. These firms become more carbon intensive in such a way so that they do not have to share their free allowances to other group firms. Finally, I document that such frictions can also undermine the expansion of carbon markets. These results are consistent with the literature in corporate finance highlighting the prospect of resource reallocation away from business units or divisions adversely impact managers' incentives to exert effort ex-ante and make such resources available. Overall, I highlight a potentially important friction in designing market based climate policies such as an emissions trading system.

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Figure 1 – Example of Transactions in Internal Carbon Market

The picture below provides some examples of Internal Carbon Markets (ICO_2Ms). For example, the third row shows a transaction between two subsidiaries of Iberdola in Spain transacting in carbon allowances worth 1.2 million tonnes of CO_2. This picture is a snapshot of the carbon trading registry as provided by the European Commission. In this picture, rows number 3 and rows 5 to 10 are examples of transactions in an ICO_2M.

Transferring Registry	Transferring Account Name	Transferring Account Holder	Acquiring Registry	Acquiring Account Name	Acquiring Account Holder	Nb of units
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Energyworks Vitvall, S.L.	ENERGYWORKS VIT-VALL, S.L.	136766
Italy	INDUSTRIA LATERIZI VOGHERESE S.p.A.	ILV INDUSTRIA LATERIZI VOGHERESE S.r.l.	Italy	iCASCO - Trading	i.CA.S.CO. S.p.A	14000
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Iberdrola Generación Térmica, S.L.U. – Central Térmica de Velilla, grupos 1 y 2	Iberdrola Generación Térmica, S.L.	1117083
Estonia	Renergypro account	Strolia Arturas	Slovenia	BELEKTRON EKOTRADING d.o.o	BELEKTRON EKOTRADING d.o.o.	5000
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Iberdrola Generación Térmica, S.L.U. – Ciclo Combinado de Aceca, grupo 3	Iberdrola Generación Térmica, S.L.	196066
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Iberdrola Generación Térmica, S.L.U. – Central de Ciclo Combinado de Arcos	Iberdrola Generación Térmica, S.L.	347602
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Iberdrola Generación Térmica, S.L.U. – Ciclo Combinado de Castellón, grupos 3 y 4	Iberdrola Generación Térmica, S.L.	584118
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Energyworks Monzón, S.L.	Energyworks Monzón, S.L.	56126
Spain	Iberdrola Clientes España, S.A.U.	Iberdrola Clientes España, S.A.U.	Spain	Iberdrola Generación Térmica, S.L.U. – Ciclo Combinado Escombreras, grupo 6	Iberdrola Generación Térmica, S.L.	141282
Belgium	176 Esso Raffinaderij	Exxonmobil Petroleum & Chemical	France	ERSAS PJG	ESSO RAFFINAGE	88000

Figure 2 – Plotting Dynamic Effects

This table plots the dynamic treatment effect of having an internal carbon market on the emissions intensity (= $Total\ Emissions/Revenue$ during Phase III of the EU ETS as compared to the Phase II. The $x{-}axis$ plots the yearly time period relative to year 2013 ($t = 0$). The y-axis plots the coefficient on the interaction term $POST \times ICO_2M$ in Equation 3 for each year with the year 2012 as the reference year. Standard errors are clustered by the parent firm. Confidence intervals are at the top/bottom 5%.

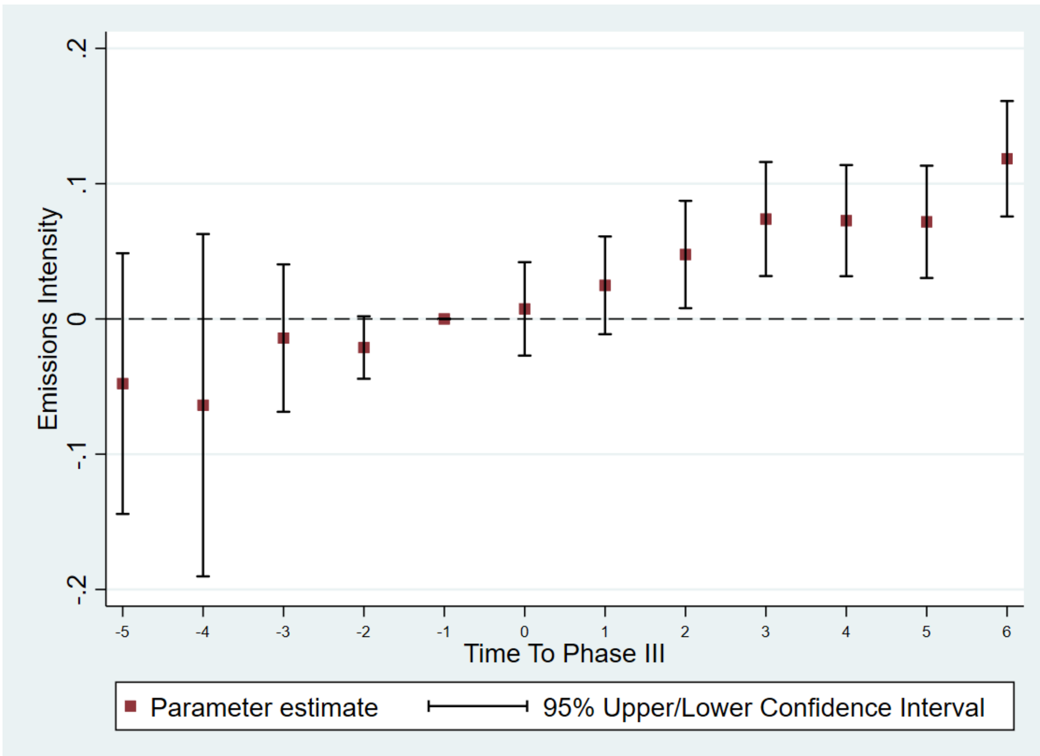

Figure 3 – Plotting Dynamic Effects: Propensity Score Matching Statistics
This table plots the dynamic treatment effect of having an internal carbon market on the emissions intensity ($Total\ Emissions/Revenue$ during Phase III of the EU ETS as compared to the Phase II based on a propensity score matched sample. The $x{-}axis$ plots the yearly time period relative to year 2013 ($t = 0$). The y-axis plots the coefficient on the interaction term $POST \times ICO_2M$ in Equation 3 for each year with the year 2012 as the reference year. Standard errors are clustered by the parent firm. Confidence intervals are at the top/bottom 5%.

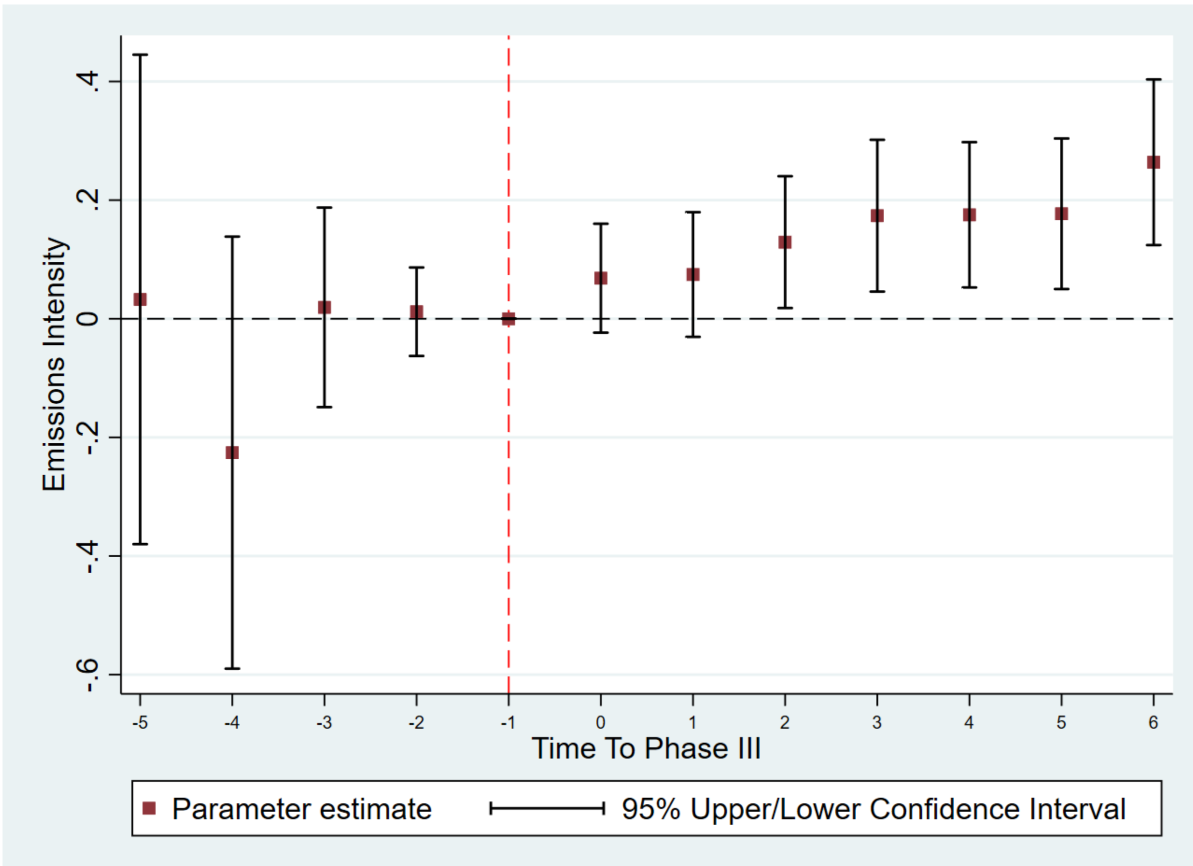

Table 1 – Summary Stats

This table provides the descriptive statistics for the variables used in the study. *TRFICM* is the total amount of carbon allowances transferred by a given subsidiary in a given year to other subsidiaries controlled by the same parent firm scaled by the total verified emissions of the subsidiary. *OE* is defined as (*Emissions−Allocation*)/*Allocation* for a given firm/subsidiary in a given year. CO_2INT is total verified emissions for a given firm/subsidiary in a given year scaled by revenues. ICO_2M is a dummy variable taking the value of 1 if the subsidiary/firm is part of a parent firm owning at least two installations covered by the EU ETS. ICO_2M_{Loc} (ICO_2M_{NonLoc}) is a dummy variable taking the value of 1 if the internal carbon market is located in foreign countries (in the headquarters country) as compared to the headquarters country of its GUO and zero, otherwise. ICO_2M_{mf} (ICO_2M_{sf}) is a dummy variable taking the value of 1 if the internal carbon market of a parent firm covers multiple subsidiaries (housed in a single firm) and zero, otherwise. ICO_2M_{divgeo} ($ICO_2M_{nondivgeo}$) is a dummy variable taking the value of 1 if the internal carbon market of the parent firm spans multiple countries (single country) and zero, otherwise. ICO_2M_{divind} ($ICO_2M_{nondivind}$) is a dummy variable taking the value of 1 if the internal carbon market of the parent firm spans multiple (single) 2-digit NACE Rev.2 industries and zero, otherwise. *ROA* is total revenues of a firm/subsidiary scaled by total assets. *CHE* is similarly total cash holding of a firm/subsidiary scaled by total assets. *Log Assets* is the the natural logarithm of total assets of a firm/subsidiary. The sample period is from 2008-2019. All non-logarithmic variables are winsorized at 1% and 99%-ile.

Variables	#Observations	Mean	Std.Dev	Min	Median	Max
$TRFICM$	41634	-0.009	0.137	-0.883	0.000	0.687
OE	36645	0.433	22.318	-1.000	-0.190	1457.165
CO_2INT	45201	1.252	2.310	0	0.234	10.126
ICO_2M	50953	0.522	0.499	0.000	1.000	1.000
ICO_2M_{Loc}	50953	0.384	0.486	0.000	0.000	1.000
ICO_2M_{NonLoc}	50953	0.138	0.345	0.000	0.000	1.000
ICO_2M_{divind}	50953	0.347	0.476	0.000	0.000	1.000
$ICO_2M_{nondivind}$	50953	0.242	0.428	0.000	0.000	1.000
ICO_2M_{divgeo}	50953	0.394	0.488	0.000	0.000	1.000
$ICO_2M_{nondivgeo}$	50953	0.395	0.489	0.000	0.000	1.000
ICO_2M_{hi}	50953	0.300	0.458	0.000	0.000	1.000
ICO_2M_{low}	50953	0.133	0.340	0.000	0.000	1.000
ICO_2M_{mf}	50953	0.502	0.500	0.000	1.000	1.000
ICO_2M_{sf}	50953	0.502	0.500	0.000	1.000	1.000
ROA	45168	1.030	0.863	0.001	0.831	4.942
$LogAssets$	47926	10.949	2.246	-6.696	10.982	22.225
CHE	43620	0.064	0.112	0.000	0.0170	0.635

Table 2 – Evidence of Internal Carbon Markets

This table presents the evidence of internal carbon markets by exploiting cross sectional variation in allocation of free allowances based on industrial activity. In Panel A, *CLEAK* is a dummy variable that takes the value of 1 if the subsidiary belonging to a parent firm with an internal carbon market has at least one installation belonging to the CL list and zero, otherwise. *POST* takes the value of 1 for the years 2013-2018 and zero for the years 2008-2012. In Panel B, *ELECT* is a dummy variable taking the value of 1 if the subsidiary belonging to a parent firm with an internal carbon market has at least one electricity producing installation and zero, otherwise. Other variables are defined in Table 1. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Dep. Variable:	TRFICM	TRFICM	TRFICM	TRFICM
Panel A: Relocation of Allowances *from* CL list subsidiaries				
CLEAK	-0.016	0.026	0.006	0.071
	(-0.236)	(0.422)	(0.103)	(0.579)
CLEAK × POST	0.026**	0.031**	0.034**	0.126***
	(2.319)	(2.360)	(2.485)	(3.990)
ROA			-0.013**	-0.016**
			(-2.379)	(-1.908)
Log of Assets			-0.008	-0.012
			(-1.353)	(-1.367)
CHE			0.004	0.023
			(0.114)	(0.466)
Constant	-0.004	-0.027	0.093	0.066
	(-0.115)	(-0.898)	(1.242)	(0.628)
Panel B: Relocation of Allowances *to* Electricity producing subsidiaries				
ELECT	-0.060	-0.072	-0.013	0.041
	(-1.204)	(-1.198)	(-0.232)	(0.568)
ELECT × POST	-0.023	-0.029*	-0.035**	-0.116***
	(-1.580)	(-1.696)	(-2.073)	(-2.676)
ROA			-0.014**	-0.017**
			(-2.468)	(-2.059)
Log of Assets			-0.009	-0.013
			(-1.467)	(-1.508)
CHE			0.003	0.023
			(0.099)	(0.468)
Constant	0.019	0.023	0.127*	0.177*
	(1.245)	(1.286)	(1.681)	(1.693)
Observations	19074	18819	15426	11081
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	Yes	Yes	No
Country×Ind FE	Yes	Yes	Yes	Yes
Parent Firm×Year FE	No	No	No	Yes
Year FE	Yes	Yes	Yes	No

Table 3 – Effect of Internal Carbon Markets: Baseline

This table presents the baseline results showing the effects of internal carbon markets on the carbon emissions of firms. The dependent variable is total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. *POST* takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The standard errors are clustered at the GUO level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. *t*-statistics are displayed in parenthesis.

Dep. Variable:	($Total\ Emissions/Revenue$)			
ICO_2M	-0.021	-0.002	-0.005	-0.115
	(-0.495)	(-0.054)	(-0.110)	(-1.626)
ICO_2M × POST	0.194***	0.190***	0.188***	0.152***
	(5.266)	(5.185)	(5.116)	(3.476)
ROA		-0.248***	-0.252***	-0.331***
		(-5.688)	(-5.704)	(-6.147)
Log of Assets		-0.169***	-0.173***	-0.251***
		(-3.457)	(-3.513)	(-3.951)
CHE		-0.426***	-0.449***	-0.359**
		(-2.900)	(-3.035)	(-2.249)
Constant	1.184***	3.321***	3.379***	4.479***
	(64.330)	(5.879)	(5.916)	(6.000)
Observations	45113	41068	40881	37801
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	No	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes

Table 4 – Internal Carbon Markets and Monitoring Difficulty

This table investigates whether the baseline results are driven by ICO_2Ms that are more difficult monitor. The dependent variable is total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The standard errors are clustered at the GUO level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Dep. Variable:		$(Total\ Emissions/Revenue)$		
$ICO_2M_{nondivind}$ × POST	0.138***			
	(2.76)			
ICO_2M_{divind} × POST	0.159***			
	(3.23)			
$ICO_2M_{nondivgeo}$ × POST		0.069		
		(1.25)		
ICO_2M_{divgeo} × POST		0.193***		
		(4.14)		
ICO_2M_{sf} × POST			0.115*	
			(1.72)	
ICO_2M_{mf} × POST			0.156***	
			(3.46)	
ICO_2M_{Loc} × POST				0.135***
				(2.93)
ICO_2M_{NonLoc} × POST				0.194***
				(3.46)
Observations	37,739	37,739	37,739	37,739
Controls	Yes	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 5 – Agency Issues based Explanation in Carbon Allowance Usage

This table investigates whether results are consistent with agency conflicts based explanation for resource allocation. The dependent variable is $(Emissions{-}Allocation)/Allocation$ of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1 and are same as defined in previous tables. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Dep. Variable:	$(Emissions{-}Allocation)/Allocation$			
$ICO_2M_{nondivind}$ × POST	-0.051			
	(-1.19)			
ICO_2M_{divind} × POST	0.046			
	(1.09)			
$ICO_2M_{nondivgeo}$ × POST		-0.164***		
		(-2.89)		
ICO_2M_{divgeo} × POST		0.083**		
		(2.14)		
ICO_2M_{sf} × POST			-0.191***	
			(-3.22)	
ICO_2M_{mf} × POST			0.037	
			(1.05)	
ICO_2M_{Loc} × POST				-0.071*
				(-1.81)
ICO_2M_{NonLoc} × POST				0.219***
				(4.73)
Observations	29,635	29,635	29,635	29,635
Controls	Yes	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 6 – Evidence based on Transaction Costs
This table investigates whether results are consistent with a transaction cost based explanation for resource allocation. The dependent variable in Panel A is carbon intensity defined as total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. The dependent variable in Panel B is $(Emissions{-}Allocation)/Allocation$ of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. ICO_2M_{hiE} (ICO_2M_{loE}) is a dummy variable identifying ICO_2Ms that have greater (lower) than median average emissions across all its subsidiaries over the years 2008–2012. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012.. Other variables are defined in Table 1. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Panel A, Dep. Variable:	$(Total\ Emissions/Revenue)$			
ICO_2M_{hiE}	-0.006	0.018	0.017	0.001
	(-0.12)	(0.36)	(0.34)	(0.01)
ICO_2M_{hiE} × POST	0.152***	0.128***	0.126***	0.116**
	(3.68)	(3.11)	(3.06)	(2.38)
ICO_2M_{loE}	-0.218***	-0.213***	-0.215***	-0.200**
	(-5.37)	(-5.03)	(-5.04)	(-2.29)
ICO_2M_{loE} × POST	0.238***	0.240***	0.240***	0.222***
	(5.78)	(5.77)	(5.75)	(4.42)
Observations	44,847	40,995	40,808	37,739
Panel B, Dep. Variable:	$(Emissions{-}Allocation)/Allocation$			
ICO_2M_{hiE}	0.074**	0.044	0.044	0.060
	(2.50)	(1.40)	(1.38)	(0.95)
ICO_2M_{hiE} × POST	-0.083***	-0.045	-0.045	-0.043
	(-2.80)	(-1.40)	(-1.40)	(-1.09)
ICO_2M_{loE}	-0.096**	-0.123***	-0.121***	-0.112*
	(-2.54)	(-3.10)	(-3.05)	(-1.92)
ICO_2M_{loE} × POST	0.129***	0.154***	0.152***	0.141***
	(3.31)	(3.72)	(3.65)	(2.82)
Observations	36,503	30,603	30,498	29,635
	For Both Panels			
Controls	No	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	No	No	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 7 – Corporate Favoritism based Explanation

This table investigates whether results are consistent with a favoritism based explanation for resource allocation. The dependent variable is total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. ICO_2M_{Loc} indicates those ICO_2Ms that are only present in the headquarter country of the GUO and ICO_2M_{NonLoc} indicates those ICO_2Ms that are present only across non-headquarter countries. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Panel A, Dep. Variable:	Transfer of Allowances from a Subsidiary			
Local	-0.015	-0.015	-0.044**	-0.036
	(-1.39)	(-1.38)	(-2.57)	(-1.48)
Local × POST	0.017**	0.017**	0.018*	0.032*
	(2.03)	(2.01)	(1.96)	(1.82)
Observations	14,161	14,118	14,059	13,193
Panel B, Dep. Variable:	(*Total Emissions/Revenue*)			
Local	0.085	0.079	0.080	0.092
	(1.40)	(1.30)	(1.32)	(1.35)
Local× POST	-0.173***	-0.132***	-0.133***	-0.129**
	(-3.27)	(-2.60)	(-2.64)	(-2.34)
Observations	20,707	18,048	18,000	17,937
	For Both Panels			
Controls	Yes	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	No	Yes	Yes
Parent Firm × Year FE	No	No	No	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 8 – Financially Efficient Carbon Emissions
This table investigates whether results are consistent with an financially efficient resource allocation based explanation. The dependent variables columns (1) - (4) are year-on-year changes in: emissions intensity defined as emissions per unit revenue (ΔCO_2INT), natural logarithm of one plus revenue ($\Delta Revenue$, profit before taxes (ΔPBT), and earnings before interest and taxes ($\Delta EBIT$), respectively in a given year for a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. ΔCO_2E is the natural logarithm of one plus the total emissions of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The point estimates on the control variables are omitted for brevity. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Dep. Variable:	ΔCO_2INT	$\Delta Revenue$	ΔPBT	$\Delta EBIT$
ICO_2M	-0.000	0.025	9.802	17.865
	(-0.014)	(0.495)	(0.286)	(0.428)
ICO_2M × POST	0.005	-0.019	1.134	-3.340
	(0.335)	(-0.751)	(0.055)	(-0.141)
ΔCO_2E	0.132***			
	(4.525)			
$ICO_2M \times \Delta CO_2E$	-0.061			
	(-1.635)			
ΔCO_2E × POST	-0.051*			
	(-1.730)			
ICO_2M × POST × ΔCO_2E	0.034			
	(0.929)			
ΔCO_2INT		-0.496***	0.277	0.257
		(-4.460)	(1.636)	(1.475)
$ICO_2M \times \Delta CO_2INT$		-0.284	0.692	-0.256
		(-1.527)	(0.658)	(-0.493)
ΔCO_2INT × POST		0.166	-4.997	-4.974
		(1.223)	(-1.027)	(-1.023)
ICO_2M × POST × ΔCO_2INT		-0.023	2.734	4.123
		(-0.106)	(0.521)	(0.841)
Constant	1.564***	-2.553***	16.667	16.867
	(2.683)	(-4.498)	(0.624)	(0.709)
Observations	32702	32511	30773	30796
Other Controls	Yes	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 9 – Role of Internal Capital Markets

This table investigates the role of internal capital markets in moderating the relationship between internal carbon markets (ICO_2Ms) and transfer of allowances as well as carbon emissions. The dependent variable in Panel A is the total amount of carbon allowances transferred by a given subsidiary in a given year to other subsidiaries controlled by the same parent firm scaled by the total verified emissions of the subsidiary in that year. The dependent variable in Panel B is emissions intensity defined as $TotalEmissions/Revenue$ of a firm (or a subsidiary if the subsidiary belongs to a parent firm) in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Columns (1), (2) and (3) use *Shareholder Funds*, *Cash* and, *Fixed Assets* as the financial variables used to calculate a proxy for transfers related to internal capital market following Rajan et al. (2000). In Panel B, across all columns, ICM_{hi} (ICM_{low}) denotes all subsidiaries belonging to a parent firm whose transfers are more (less) than the median in the cross-section among all firms belonging to ICO_2Ms using the respective proxy of internal transfer. All variables are defined in Table 1. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Panel A, Dep. Variable:	Transfer of Allowances from a Subsidiary		
ICM–variable:	Shareholder Funds	Cash	Fixed Assets
ICM × POST	0.000	0.001	-0.000
	(0.93)	(1.37)	(-1.30)
CLEAK × POST	0.066***	0.064***	0.07***
	(4.44)	(4.37)	(4.53)
Observations	14,131	13,838	11,081
Sub-FE	Yes	Yes	Yes
Parent Firm FE	No	No	No
Country×Ind FE	Yes	Yes	Yes
Parent Firm×Year FE	Yes	Yes	Yes
Year FE	No	No	No

Panel B, Dep. Variable:	($Total\ Emissions/Revenue$)		
ICM–variable:	Shareholder Funds	Cash	Fixed Assets
ICM_{hi}× POST	0.154***	0.158***	0.148***
	(3.32)	(3.38)	(3.16)
ICM_{low}× POST	0.156**	0.131**	0.176***
	(2.39)	(2.32)	(3.04)
Observations	28471	37801	37801
Controls	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes
Parent Firm FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Table 10 – Robustness – Propensity Score Matched Diff-in-Diff
This table presents the results of estimating the difference-in-difference specifications of Table 3 using a propensity score matched sample. The matching is done as of 2012. The dependent variable in Panel A is carbon intensity defined as total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. Hence, *POST* takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. *t*-statistics are displayed in parenthesis.

Dep. Variable:	*Total Emissions/Revenue*			
ICO_2M	-0.000	0.017	0.017	-0.048
	(-0.02)	(0.38)	(0.38)	(-0.69)
ICO_2M × POST	0.141***	0.133**	0.133**	0.105**
	(3.64)	(3.50)	(3.50)	(2.34)
ROA		-0.124***	-0.124***	-0.120***
		(-4.249)	(-4.249)	(-4.036)
Log of Assets		-0.101***	-0.101***	-0.096***
		(-3.083)	(-3.083)	(-2.639)
CHE		-0.229***	-0.229***	-0.191***
		(-3.278)	(-3.278)	(-2.604)
Constant	0.576***	1.847***	1.771***	1.771***
	(65.293)	(4.674)	(4.082)	(4.082)
Observations	32,399	31,153	31,153	29,035
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	No	No	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 11 – Implications of ICO_2M – Expansion of Carbon Markets
This table presents the results of estimating the difference-in-difference specifications of Table 3 on a sample of firms operating their ICO_2Ms in Eastern Europe including Croatia. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. $ICM_{Croatia}$ is a dummy variable indicating non-Croatian subsidiaries of firms that operated an ICO_2M spanning Croatia after 2013. The dependent variable in Panel A is carbon intensity defined as total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. The dependent variable in Panel B is $(Emissions{-}Allocation)/Allocation$ of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. Other variables are defined in Table 1. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Panel A, Dep. Variable:	$TotalEmissions/Revenue$			
$ICM_{Croatia}$	0.223	0.045	0.077	
	(1.491)	(0.258)	(0.438)	
$ICM_{Croatia}$ × POST	0.074	0.115*	0.112*	0.092
	(1.146)	(1.749)	(1.688)	(1.311)
Observations	10,371	9,212	9,179	9,120
Panel B, Dep. Variable:	$(Emissions{-}Allocation)/Allocation$			
$ICM_{Croatia}$	-0.359**	-0.281**	-0.298**	
	(-3.173)	(-2.971)	(-2.981)	
$ICM_{Croatia}$ × POST	0.448***	0.383***	0.383***	0.362***
	(4.007)	(3.913)	(3.919)	(3.534)
Observations	9,181	7,997	7,970	7,902
	For Both Panels			
Controls	No	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	No	No	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Appendix

A1. Conceptual Framework

In order to formalize the mechanism behind the hypothesis of the study, I provide a simple conceptual framework. I compare a single division of a multi-division firm (that is, this division is part of a possible ICO_2M) to a single-division firm operating under the cap-and-trade system. I assume both the divisions have K units of capital with productivity z. Each of the divisions has emissions e if it is not abated. The divisional managers can choose a non-negative fraction, $\alpha < 1$, of the capital K for emissions abatement. Additionally, both divisions are allocated with a_1 free allowances. The market price of each unit of carbon allowance is P. Each division can reduce emissions by r and generate excess allowances if and only if the division invests in abatement. Following Heider and Inderst (2021), I assume that the division is able to reduce emissions by r if they spend $c(r)$ in abatement, where, $c()$ is an abatement function such that $c(0) = c'(0) = 0, c''(r) > 0, c'(e) = \infty$. For the division with a single-division firm, the divisional manager and the headquarters (HQ) are the same. For the division with the multi-division firm, the HQ makes is the ultimate decision maker for the allocation of emission allowances across its divisions. However, the divisional manager in the ICO_2M–division also has the discretion to allocate capital for normal operating activities and abatement activities. Finally, each divisional manager derives private benefits from the cash flows generated by the division's activity, and by nature, they are unobservable to the HQ.

An interesting feature of the cap-and-trade policy is the "banking" of allowances. That is, a division operating under the cap-and-trade policy could keep any excess allowance with it and sell them at a future date at more favorable prices or, consume these allowances in the future when might they require them. While both divisions can do so, the ICO_2M–division suffers from a potential agency problem that the other division doesn't face. Given the corporate HQ's preference for corporate socialism (Matvos and Seru, 2014; Seru, 2014), the divisional manager knows that any (or part of the) excess allowance that a division generates by investing in the abatement technology will be reallocated by the HQ to other divisions that faces a shortage of allowances. At the very least, such an intervention by the HQ would imply a "loss of control" Aghion et al. (2014) over a corporate resource This, in turn, implies that the divisional manager will not be able to derive the full utility from having any excess allowance generated by exerting effort at the division level, thereby, leading to lower effort provision by the manager in the first place.

A1.1. Baseline Scenario: Non–Constraining Allowances

When the supply of allowances are not (expected to be) constraining, then each division has sufficient supply of allowances to cover their unabated emissions, e. In this case, for both divisions, the profit function would be: $\Pi_{nc} = K \times z$. Thus, firms do not invest in abatement and the market in carbon allowances does not come into play. This is consistent with critics of the design of the EU ETS where in Phases I and II, more than 90% of the allowances were allocated for free, resulting is over–supply of allowances and very low carbon price.

A1.2. Constraining Allowances

The difference in the profit function of the divisional managers arise when emission allowances are (expected to be) constrained. As discussed above, when allowances are scarce, then the divisions will be incentivized to undertake costly abatement activity by employing a fraction of capital K. For the single–division firm, the profit function could be written as:

$$\Pi_c = (1-\alpha) \times K \times z - c(r) \times \alpha \times K + (a_1 + r - e) \times \lambda \times P \tag{5}$$

In the equation 5, a_1 is the free allowances of emissions allocated to the division. Since, the division is incurring the abatement cost $c(r)$, it can produce excess allowances, i.e., $a_1 + r - e > 0$. The total abatement cost is $c(r) \times \alpha K$ since αK of capital is invested in abatement. The parameter $\lambda > 1$ highlights that the division can bank the allowance and sell it at a favorable price that will be λ times more than the current carbon price P.[9] The division will only investment in abatement if $c(r)\alpha K \leq r\lambda P$.

For the ICO_2M–division, the divisional manager would compensate the dis-utility arising from giving up any excess allowance to the HQ for internal reallocation by allocating less capital for abatement. This results in lower reduction of emissions, r'. For simplicity, I assume that $r' = h{\times}r$, where, $0 < h < 1$. The profit function for this division can be written as:

$$\Pi_{ICO_2M,c} = (1{-}\alpha){\times}K{\times}z \, - \, c(r'){\times}\alpha{\times}K \, + \, (a_1{+}r'{-}e){\times}P \tag{6}$$

where, the divisional manager employs the same amount of capital for abatement but puts less effort in finding the most efficient abatement technology, thereby, only abating $r'(= h{\times}r < r)$ emissions. Hence, the selling division receives a dis-utility from providing the allowances at the current market price, P.

The difference in profitability between a ICO_2M–division and the single-division firm, when allowances are constrained compared with the scenario when allowances are not constraining can be expressed as:

$$\Delta U = (\Pi_c{-}\Pi_{nc}) \, - \, (\Pi_{ICO_2M,c}{-}\Pi_{nc}) = \Pi_{ICO_2M,c} \, - \, \Pi_c \tag{7}$$

Putting the values of Π_c and $\Pi_{ICO_2M,c}$ from equations (5) and (6), and additionally assuming a abatement cost function of $c(r) = \frac{\eta}{2}r^2$,[10] would yield that $\alpha = \frac{\eta \times r}{2K\lambda P}$. We can then rewrite equation (7), as:

$$\Delta U = c(\frac{r'}{\alpha K})\alpha \; K{-} \; c(\frac{r}{\alpha K})\alpha K \, + \, (e{-}a_1)(\lambda \, - \, 1)P \, - \, (\lambda \, - \, h)rP \tag{8}$$

Differentiating equation (8) with respect to r, we get $\Delta U'$ as:

[9] One can think of P in pure monetary terms but it can also include non-monetary benefits such as managerial autonomy.

[10] I use the functional form of the abatement costs motivated by Matvos and Seru (2014)

$$\Delta U' = \lambda P[h^2 K - 1] + hP \tag{9}$$

Since $h^2 << K$ and $K >> 1$[11], $h^2 K > 1$ and $\Delta U'$ is positive. This implies that a division in an ICO_2M derives less utility if they abate more emissions compared to a standalone firm when allowances get scarce.

[11] By definition h is positive and below 1 and, K being assets of a firm is always very large compared to h. Alternatively, one can easily show that for a very small value of $h \geq \frac{1}{\sqrt{K}}$, $\Delta U'$ is positive.

Table A1 – Internal Carbon Markets and Monitoring Difficulty – PSM
This table investigates whether the baseline results are driven by ICO_2Ms that are more difficult monitor on a propensity scored matched sample. The dependent variable is total emissions scaled by revenue of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The standard errors are clustered at the GUO level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Dep. Variable:		($Total\ Emissions/Revenue$)		
$ICO_2M_{nondivind}$ × POST	0.119**			
	(2.262)			
ICO_2M_{divind} × POST	0.145***			
	(2.739)			
$ICO_2M_{nondivgeo}$ × POST		0.043		
		(0.740)		
ICO_2M_{divgeo} × POST		0.182***		
		(3.660)		
ICO_2M_{sf} × POST			0.064	
			(0.858)	
ICO_2M_{mf} × POST			0.057	
			(1.422)	
ICO_2M_{Loc} × POST				0.114**
				(2.322)
ICO_2M_{NonLoc} × POST				0.193***
				(3.163)
Observations	30,624	30,624	24,216	30,624
Controls	Yes	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table A2 – Agency Issues based Explanation in Carbon Allowance Usage – PSM
This table investigates whether results are consistent with agency conflicts based explanation for resource allocation on a propensity score matched sample. The dependent variable is $(Emissions-Allocation)/Allocation$ of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. $POST$ takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1 and are same as defined in previous tables. The standard errors are clustered at the parent firm level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. t-statistics are displayed in parenthesis.

Dep. Variable:	$(Emissions-Allocation)/Allocation$			
$ICO_2M_{nondivind}$ × POST	-0.043			
	(-0.953)			
ICO_2M_{divind} × POST	0.054			
	(1.178)			
$ICO_2M_{nondivgeo}$ × POST		-0.175***		
		(-3.381)		
ICO_2M_{divgeo} × POST		0.100**		
		(2.357)		
ICO_2M_{sf} × POST			-0.197***	
			(-3.224)	
ICO_2M_{mf} × POST			0.049	
			(1.190)	
ICO_2M_{Loc} × POST				-0.074*
				(-1.750)
ICO_2M_{NonLoc} × POST				0.257***
				(5.036)
Observations	24,279	24,279	24,279	24,279
Controls	Yes	Yes	Yes	Yes
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table A3 – Effect of Internal Carbon Markets: PSM using Emissions Scaled by Assets
This table presents the baseline results showing the effects of internal carbon markets on the carbon emissions of firms. The dependent variable is total emissions scaled by total assets of a firm (or a subsidiary if the subsidiary belongs to a GUO) in a given year. *POST* takes the value of 1 for the years 2013-2019 and zero for the years 2008-2012. Other variables are defined in Table 1. The standard errors are clustered at the GUO level. ***, ** and * represents significance at the 1%, 5% and 10% level, respectively. *t*-statistics are displayed in parenthesis.

Dep. Variable:	(*Total Emissions/Total Assets*)			
ICO_2M	0.053	0.029	0.029	-0.023
	(1.237)	(0.756)	(0.756)	(-0.395)
ICO_2M × POST	0.125***	0.126***	0.126***	0.086**
	(3.491)	(3.856)	(3.853)	(2.294)
ROA		0.613***	0.613***	0.564***
		(12.466)	(12.458)	(9.712)
Log of Assets		-0.214***	-0.214***	-0.301***
		(-4.385)	(-4.382)	(-4.183)
CHE		-0.266*	-0.266*	-0.218
		(-1.822)	(-1.820)	(-1.469)
Constant	0.929***	2.695***	2.695***	3.834***
	(44.629)	(4.806)	(4.803)	(4.581)
Observations	37,682	33,152	33,152	30,736
Sub-FE	Yes	Yes	Yes	Yes
Parent Firm FE	No	No	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes