Environmental-Unfriendly Tax Avoidance *

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Abstract

This paper examines how firms use carbon allowances to reduce corporate tax burdens by routing allowance transactions through internal trading hubs in low-tax jurisdictions and by exploiting fluctuations in carbon prices. Using a dataset that captures the universe of carbon-allowance transactions in the European Union Emissions Trading System (EU ETS) from 2014 to 2020, we document that roughly 35% of corporate groups operate internal hubs that collect and redistribute allowances across affiliated entities required to surrender them. Many of these hubs are located in jurisdictions with low statutory tax rates or in recognized tax havens, resulting in significantly lower effective tax rates for hubs relative to other entities within the same multinational group. With such internal reallocations of allowances, firms can generate substantial tax savings. We further document that such tax-motivated internal trading and profit shifting is associated with lower investment in decarbonization and higher volumes of allowance surrenders. Taken together, it appears that tax avoidance alleviates the financial pressure to reduce emissions.

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1 Introduction

Over the past several years, few topics have dominated political, media and academic debate more than carbon emissions and corporate tax avoidance. Despite the importance of each individual issue, policymakers as well as academics frequently examine the two in isolation.[1] In this paper, we combine these two topics by exploring whether and to what extent firms avoid corporate taxes with carbon allowances — a key feature of increasingly popular market-based approaches to reduce carbon emissions (e.g., International Carbon Action Partnership, 2024) — and how this tax avoidance is associated with decarbonization investment and carbon emissions.

Carbon allowances (or emission rights) are central to cap-and-trade systems: Regulators impose an aggregate emissions cap, and firms must trade and ultimately surrender allowances to meet their compliance obligations. These cap-and-trade systems are implemented not only in the European Union but also across other major economies, including Australia, Canada, China, Japan, South Korea, and the United Kingdom. At the same time, since their inception, cap-and-trade systems such as the European Union (EU) Emission Trading System (ETS) have faced challenges, including issues such as "carbon leakage" (see, e.g., Naegele and Zaklan, 2019; Borghesi et al., 2020; Dechezleprêtre et al., 2022; Känzig et al., 2024; Colmer et al., 2025).[2] We argue that tax avoidance is an important and, to date, overlooked issue in cap-and-trade systems.[3] In this paper, we therefore describe how firms avoid taxes using carbon allowances and how this form of tax avoidance is associated with decarbonization investment and, ultimately, carbon emissions.

In the absence of specific tax-planning strategies, the tax treatment of carbon allowances is relatively straightforward. A common distinction is drawn between allowances that are allocated

[1] For example, when setting environmental policy, taxes enter the debate through emission taxes. Corporate tax avoidance does not play a role when setting environmental policy. Likewise, when setting tax policy against corporate tax avoidance, environmental issues do not enter the tax policy debate.

[2] While policymakers responded to carbon leakage by implementing the carbon-border adjustment mechanism, or CBAM (see, e.g., Alonso et al., 2024), other problems such as earnings management-induced trading of carbon allowances still prevails (N'Gatta et al., 2025).

[3] The concurrent working papers by Kundu (2025) and Schultz (2024) also mention such tax motives. However, Schultz (2024) only states the hypothesis that internal carbon trading may facilitate profit shifting but she does not provide any systematic empirical evidence for this prediction or the tax motive. Importantly, Kundu (2025) ultimately rules out profit shifting with carbon allowances.

free of charge by regulators and those that are purchased. In many tax systems, the free allocation of allowances to a firm does not lead to immediate taxable income. Consequently, their surrender to satisfy compliance obligations does not result in a tax-deductible expense. By contrast, purchased allowances are treated as assets for tax purposes — often as intangible assets or, depending on the circumstances, as inventory. When these allowances are surrendered to cover emissions, taxpayers are entitled to deduct their acquisition cost as expenses, irrespective of the market price. For example, if an allowance was bought for EUR 50, a deduction of EUR 50 is recorded upon surrender even if the market price has risen to EUR 70.

Firms can avoid taxes with carbon allowances by i) establishing internal carbon allowance trading hubs in a low-tax country and ii) internally trading carbon allowances through this hub. Building on the previous example, assume a firm purchases one allowance for EUR 50. At the time the two allowances are surrendered, the market price is EUR 70. The firm acquires the purchased allowance through its trading hub located in a low-tax country (e.g., a country with a tax rate of 10%). When the allowance is transferred internally to the plant on the surrender date, the transfer price must correspond to the observable market price of EUR 70.[4] This approach increases the plant's tax-deductible expense to EUR 70, while the trading hub recognizes a taxable profit of EUR 20, taxed at the lower rate. A similar mechanism applies to free allowances. By routing the free allowance through the low-tax trading hub, the firm can generate an additional tax-deductible expense of EUR 20 at the plant while recognizing the corresponding EUR 20 profit in the low-tax jurisdiction.[5] Using a tax rate of 30% for the plant's country (e.g., Germany) and 10% for the trading-hub jurisdiction, this structure yields total tax savings of EUR 4, equivalent to 8% of the initial EUR 50 allowance price. Since trading hubs can be located flexibly in tax havens such as Switzerland or Jersey, whereas production facilities are often situated in high-tax economies such as France or Germany, these strategies can generate substantial tax savings.

[4] Because there is an observable market price for ETS-traded allowances, firms are required to use the comparable uncontrolled price (CUP) method for transfer pricing.

[5] The transaction proceeds as follows: The plant in the high-tax country receives the free allowance and transfers it to the low-tax trading hub when the market price is EUR 50, realizing a taxable gain of EUR 50. When the hub transfers the allowance back to the plant at EUR 70, it realizes a profit of EUR 20. The plant now records net expenses of EUR 20 (= EUR 50 gain from the initial transfer minus EUR 70 expense upon surrender).

A key challenge in examining the use of carbon allowances as a tax savings tool as well as its consequences on decarbonization investments and carbon emissions is the need for highly granular data. Researchers need information not only on the allocation, acquisition, surrender, and sale of carbon allowances, but also on the locations of the buyers, sellers, and users of these allowances (also called EU General Allowances, EUA) to observe tax avoidance behavior. Moreover, one needs data on the ownership structure of these entities to identify within-company transactions.

We address these challenges by assembling a dataset that integrates several complementary sources. First, we use account-level EUA allocation, transaction, and surrender data from the European Union Transaction Log (EUTL), which is the official registry of the EU ETS. The EUTL provides the names, countries, and account types of all participating entities, together with the quantities of allowances allocated, traded, or surrendered. These details allow us to classify each entity as either a manufacturing or energy installation covered by the ETS (denoted "operator") or as a trading hub. Second, we incorporate firm-level accounting information from Bureau van Dijk's (BvD) Orbis database. Third, to link individual entities to their respective groups, we combine ownership information from Orbis with an additional layer of ownership identification based on large language models (LLMs), followed by systematic manual inspection and verification. Because Orbis does not allow us to match many entities to their groups, the integration of LLM-generated links and manual validation substantially improves the data coverage. Combining these steps allows us to match firm-level accounting data and group-level ownership structures to the entities observed in the EUTL. Our final dataset contains roughly 15,000 within-group cross-border carbon-allowance transactions conducted by more than 1,000 entities (or subsidiaries) affiliated with 326 corporate groups (or parent companies).

We find strong evidence that the use of internal, cross-border carbon-trading hubs by multinational enterprises (MNEs) is, to a substantial extent, tax-motivated.[6] In our sample, 35% of

[6] Beyond our aggregate statistics and regression evidence, we examine two detailed case studies—Dow Chemicals and INEOS—to illustrate how firms structure internal carbon allowance transactions. For example, Dow Chemicals operates a central trading hub in Switzerland alongside numerous operating entities. Between 2014 and 2020, approximately 9.7 million allowances (valued at EUR 111.79 million) were transferred internally to the Swiss hub, and 29 million allowances (valued at EUR 328.37 million) were transferred back to operating entities. We estimate that these transactions reduced Dow's global tax expense by 1.9 to 2.7% in 2019. Similarly, INEOS

multinational groups used a trading hub at least once during the sample period, and 39% of group-years feature at least one hub. While operating entities — those required to surrender allowances for compliance — are concentrated in Germany, the United Kingdom, France, Spain, Belgium, and Italy, trading hubs are disproportionately located in jurisdictions with preferential tax regimes. Switzerland hosts the largest number of international hubs, with additional hubs located in Ireland, Jersey, and the Netherlands. Over the period 2014–2020, hubs sold 1.17 billion carbon allowances to operating entities, with an estimated value of USD 15.8 billion, and 1.29 billion allowances to other hubs, valued at approximately USD 13.4 billion. These figures highlight the central role hubs play in intra-group allowance flows.

In addition to documenting where trading hubs are located, we also explore how firms use these hubs to shift profits through cross-border carbon allowance transactions. Firms deploy hubs for heterogeneous purposes, and many hubs are clearly structured to facilitate tax avoidance. Consistent with this interpretation, the effective tax rates (ETRs) of international trading hubs are, on average, at least 7 percentage points lower than ETRs of operating entities within the same multinational group. Focusing on hubs that are not established for operational purposes — defined as hubs where intra-group purchases and sales are approximately balanced — we find that tax avoidance is concentrated in these "balance hubs." When a hub serves as both an international hub and a balance hub, its ETR is, on average, 14.8 percentage points lower than that of other entities within the group, implying that profits realized in these hubs generate substantial tax savings.

Another key advantage of our data and approach is that they allow us to directly observe profit-shifting activities through trading hubs located in tax havens or preferential tax jurisdictions such as Jersey, Switzerland, or Ireland. Profit shifting through trading hubs often occurs in contexts where standard databases, such as Orbis, do not report financial information for most firms. As a result, prior studies typically have to drop these observations when estimating profit shifting (see, e.g., the discussion in De Vito et al., 2025). In contrast, our data provide broader coverage of profit-shifting activities in these countries, as we observe all cross-border allowance trades and the

operates one trading hub in Switzerland and another in Jersey, where the statutory corporate tax rate is 0%. We estimate that INEOS lowered its global tax expense by 2.39% through internal allowance transactions in 2019.

jurisdictions in which they are booked, allowing us to capture profit-shifting behavior even when hub-level financial accounts are unavailable. Empirically, we show that hubs without publicly available financial information account for a disproportionate share of profit shifting, with profits routed through these hubs being approximately twice as large as those routed through hubs with available financial data.

Taken together, these findings indicate that profit shifting with carbon allowances reflects both firms' choice of hub location and, more fundamentally, their strategic use of particular hubs within the group. In additional group-level analyses, we document that tax-induced, within-group trading of allowances is associated with economically meaningful tax savings at the group level. Specifically, a one–standard-deviation increase in tax-induced within-group carbon allowance trading (scaled by total assets; corresponding to 0.6 overall standard deviations) decreases the three-year cash effective tax rate by 7 percentage points.

In the final step, we explore how tax avoidance with carbon allowances is associated with investment in decarbonization technologies. The prediction is ex-ante ambiguous. On the one hand, tax avoidance may increase decarbonization investments. Because decarbonization technologies are capital intensive, lowering tax burdens can relax financial constraints and free up internal resources that can be redirected toward abatement (e.g., Law and Mills, 2015; Edwards et al., 2016; Campbell et al., 2021).[7] By lowering tax burdens, tax avoidance with carbon allowances may free up financial resources that can then be allocated to green investments, thereby facilitating the decarbonization process. On the other hand, tax avoidance may reduce investment in abatement if it effectively lowers the net price firms face for carbon allowances, thereby weakening incentives to decarbonize. To test this potential association, we use data on decarbonization investments (i.e., abatement) from CDP disclosure following Fuchs et al. (2024). Across different specifications, we find a negative association between current tax-induced carbon allowance trading and future decarbonization investments. A one–standard-deviation increase in the profit of tax-induced carbon allowance trading within a group is associated with a reduction in decarbonization investments over

[7] Consistent with this idea, we find that less profitable firms are more likely to sell carbon allowances to cross-border affiliates within the same corporate group.

the subsequent three years equivalent to 1.8-1.9% of lagged total assets. Moreover, we find empirical evidence that profit shifting with carbon allowances is associated with an increase in verified carbon emissions under the EU ETS over the subsequent three years. Hence, tax avoiding groups appear to have greater carbon emissions within the EU. These two results suggest that tax avoidance with carbon allowances may have adverse environmental effects and that the disciplining function of carbon pricing might be partly undermined by tax avoidance.

Our paper contributes to two streams of the literature. First, our paper adds to the literature on cap-and-trade systems such as the EU ETS. These systems have been implemented to reduce carbon emissions and to incentivize the transition towards greener investments. However, the EU ETS continues to face challenges. For example, there is evidence of earnings management-induced trading of carbon allowances (N'Gatta et al., 2025) and of "carbon leakage" (e.g., Naegele and Zaklan, 2019; Borghesi et al., 2020; Dechezleprêtre et al., 2022; Känzig et al., 2024; Colmer et al., 2025). Our paper shows that the EU ETS faces an additional issue: Multinational firms use carbon allowances for tax avoidance purposes. By internally trading carbon allowances across borders through hubs in low-tax countries, multinationals achieve substantial tax savings, which in turn reduce firms' incentives to innovate and invest in abatement technologies and to cut emissions.

With these findings, we also contribute to the literature on tax avoidance in two ways (see, e.g., the reviews by Hanlon and Heitzman, 2010; Wilde and Wilson, 2018). First, we contribute to the literature on firms' profit shifting strategies with intangible assets and R&D, with the strategic location of assets such as trademarks and patents, or with the physical flow of goods (e.g., Grubert, 2003; Dischinger and Riedel, 2011; De Simone et al., 2014; De Simone and Sansing, 2019; De Simone et al., 2020; Ciaramella, 2023; Chow et al., 2025). We provide — to the best of our knowledge — the first comprehensive evidence on how firms utilize internal cross-border carbon allowance transactions via hubs in tax havens to avoid taxes. This offers new insights into how firms shift profits (Lester and Olbert, 2025).[8] We find that cross-border trading of carbon allowances

8 A small literature studies internal carbon markets within business groups, largely focusing on operational, informational, or organizational aspects rather than tax incentives (e.g., Chen, 2024; Lehmann and Schleich, 2025). Moreover, Compagnie et al. (2023) study tax avoidance as an unintended consequence of environmental regulation in the EU ETS, without analyzing internal carbon trading and how it facilitates profit shifting.

within a multinational substantially reduces corporate tax burdens.[9] Second, we complement prior literature that focused mostly on the determinants, but less on the consequences of tax avoidance (Wilde and Wilson, 2018; Jacob, 2022). Our paper suggests that there are adverse environmental consequences of tax avoidance. We show that greater tax avoidance using carbon allowances is associated with lower investment in decarbonization technologies and higher emissions.

Hence, our findings also have policy implications. Although internal cross-border trading of carbon allowances through tax-haven entities is legally permitted, it unlikely reflects the intentions of the policymakers who designed the ETS. Because this form of tax avoidance appears to undermine environmental objectives — while simultaneously eroding tax revenues — our results suggest that policymakers should better align environmental and tax policy to support not only fiscal goals but also the achievement of climate targets. However, we acknowledge that our results are subject to several limitations and caveats. For example, our approach does not allow for a causal interpretation of the association between tax avoidance and investments. The nature of our results and approach is descriptive. Moreover, despite our best efforts, there might be internal transactions which we cannot isolate due to a lack of a complete ownership structure database. Hence, our estimates might represent a lower-bound estimate of the extent of profit shifting with carbon allowances.

2 Institutional Background

This section summarizes the institutional features of the EU ETS relevant for our analysis and motivates the sample period. We focus on the design and operation of the carbon market, emphasizing features that shape firms' allowance trading and tax incentives. For completeness, we discuss the financial accounting treatment of emission allowances in Section A of the Online Appendix.

2.1 The European carbon market

Launched in 2005, the EU ETS is the world's first and largest multinational cap-and-trade program and remains the central instrument of EU climate policy. The system operates across all EU Member

[9] Our findings potentially generalize to other commodities. Internal trading in oil, steel, and traded agricultural products may also facilitate profit shifting across jurisdictions.

States as well as Iceland, Liechtenstein, and Norway, and covers emissions from more than 16,000 stationary installations and aircraft operators in power generation, energy-intensive manufacturing, and intra-European aviation. Maritime transport was added to the system beginning in 2024. Taken together, regulated sectors account for approximately 40% of total greenhouse gas emissions in the European Economic Area.

The EU ETS has evolved through four regulatory phases. Phase 1 (2005–2007) served as a pilot period, with decentralized national allocation plans and limited intertemporal flexibility, as banking of allowances was generally prohibited. Phase 2 (2008–2012), which coincided with the first Kyoto commitment period, expanded sectoral coverage and permitted limited use of Kyoto-mechanism credits, while free allocation remained the dominant distribution method. Phase 3 (2013–2020) marked a structural break in the design of the system, introducing a single EU-wide emissions cap, harmonized allocation rules, expanded auctioning, and the market stability reserve (MSR) to address allowance surpluses. Phase 4 (2021–2030), the current phase, further tightens the cap, updates benchmarks for free allocation, and strengthens the link between allocation and decarbonization incentives. Emission allowances are distributed to regulated entities through three channels: free allocation, auctioning, and the use of international credits.

Free allocation. During phases 1 and 2, the vast majority of allowances were allocated for free, reflecting concerns about competitiveness and carbon leakage in the early stages of the program. Beginning in Phase 3, free allocation transitioned to a harmonized, benchmark-based system targeted at installations in sectors deemed at risk of carbon leakage. Sector-specific benchmarks are defined by the emissions intensity of the most efficient producers, and free allowances are allocated proportionally to verified activity levels. Electricity generators generally ceased receiving free allowances from 2013 onward, although certain lower-income EU countries retained a temporary option to allocate free permits to support power-sector modernization under strict conditions. Free allocation continues in Phase 4 but is gradually scaled back and increasingly conditioned on decarbonization performance. Consistent with the EU's broader climate policy, free allocation phases out for some sectors (e.g., aviation by 2026) and is expected to decline further for non–leakage-exposed sectors in conjunction with the Carbon Border Adjustment Mechanism (CBAM).

Auctioning. Since Phase 3, auctioning has been the default allocation mechanism and accounts for the majority of general allowances. Auctions are conducted by EU Member States under a harmonized regulatory framework and implement the "polluter pays" principle. Auction revenues are economically significant and are largely earmarked for climate-related expenditures. Primary auctions are typically conducted on the European Energy Exchange (EEX), while secondary trading takes place on regulated spot and derivatives markets.

International credits. During Phase 3, firms were permitted to surrender a limited quantity of Certified Emission Reductions and Emission Reduction Units toward compliance, subject to both quantitative caps and qualitative restrictions. The eligibility of international credits ended with the transition to Phase 4, and such units are no longer accepted for EU ETS compliance after 2020.

Our empirical analysis focuses on the period 2014–2020 for four reasons. First, Phase 3 introduced a unified and fully fungible allowance architecture, substantially reducing cross-country heterogeneity in allocation rules and registry infrastructure and thereby improving comparability across firms and jurisdictions. Second, earlier phases imposed binding constraints on intertemporal flexibility — most notably, restrictions on banking — that generated compliance and trading behavior fundamentally different from the regime in place after 2013. Third, we exclude 2013 because it was a transitional year in which key elements of Phase 3, including the centralized Union Registry, harmonized auctioning, and benchmark-based free allocation, were not yet fully operational. Fourth, data for Phase 4 remain incomplete due to reporting lags in the European Union Transaction Log (EUTL). Although the statutory disclosure lag is three years, as of November 2025 complete transaction records for 2021 had not yet been released. We therefore restrict the main sample to 2014–2020, the longest period with a stable institutional environment and comprehensive transaction-level data. Figure 1 plots the spot price of European Union Allowance (EUA) over time.

2.2 Tax Treatment of Carbon Allowances

European Commission (2019) provides an overview of the tax treatment of carbon allowances in the EU. Several general principles apply to the tax treatment of carbon allowances across EU Member States. First, income generated from the sale of carbon allowances is generally subject to the corporate income tax. Purchased allowances are typically recorded in the financial statement at acquisition cost (but may also be recorded at fair value). However, tax implications only arise upon sale or upon surrender. In these cases, the gain or loss is calculated based on the difference between the sales price and the recorded historical acquisition cost. For example, if a firm acquired an allowance for EUR 50 and sells it later at a market price of EUR 70, it realizes a profit of EUR 20 subject to corporate income tax. When surrendering acquired allowances, the acquisition costs for purchased allowances are tax deductible as expenses, thereby reducing corporate income tax payments. For example, if the firm surrenders an allowance acquired for a value of EUR 50, the tax deductible expense is EUR 50 irrespective of the current market price at the time of surrendering the allowance.

Second, when firms receive free allowances, EU member states generally defer taxation until the allowances are sold or surrendered. For example, if a firm receives a free allowance and later sells it for EUR 70, it realizes taxable income of EUR 70. In contrast, surrendering a free allowance has no tax consequences: No tax is due when the allowance is received, and there is no tax deductible expense when it is surrendered. This practice aligns the tax impact with actual income realization. For instance, in Belgium and Germany, free allowances are exempt from immediate taxation upon receipt, only triggering tax when utilized or sold, thus ensuring that taxable income aligns with the point of economic benefit realization.

2.3 Tax Planning and Transfer Pricing with Carbon Allowances

Significant transfer pricing considerations arise when emission allowances are traded within multinational groups, particularly as regulatory regimes such as the EU Emissions Trading System (EU ETS) require firms to manage emissions and allocate allowances across plants and facilities. Internal trading is especially common in energy-intensive industries, where allowances are crucial for meeting compliance obligations. For transfer pricing purposes, emission allowances transferred within a group must adhere to the arm's length principle. This means that inter-company transactions should reflect prices as if they were between independent parties. Adhering to this standard mitigates the risk of tax adjustments, penalties, or double taxation. Because carbon allowances trade in a liquid and transparent market with observable daily prices, the appropriate transfer pricing method is the comparable uncontrolled price (CUP) method.

Firms can reduce their overall tax burden by exploiting fluctuations in the market price of carbon allowances together with differences in statutory tax rates across countries. To do so, they must operate establishments in multiple jurisdictions. For illustrative purposes, consider a simple structure with one plant that must surrender an allowance and one trading hub, as shown in Figure 2. The plant is located in a high-tax country with a statutory tax rate of 30%, while the trading hub is located in a 10% tax-rate jurisdiction.[10] Suppose the trading hub purchases one allowance for EUR 50 (Step 1 in Figure 2). When the plant later needs to surrender the allowance, assume that the market price has increased to EUR 70. Because the internal transfer price must equal the contemporaneous market price according to the CUP method, the allowance is transferred from the hub to the plant at a transfer price of EUR 70 (Step 2). The hub therefore realizes a profit of EUR 20. Upon surrender, the plant records an expense of EUR 70 (Step 3). In the absence of tax planning, the plant would record an expense of only EUR 50. Thus, the intragroup transaction creates a tax advantage of EUR 4, equal to 8% of the initial allowance price. This gain arises from the difference between the tax saving with planning — EUR 19 (= 70 × 30% – 20 × 10%) — and the tax saving without planning — EUR 15 (= 50 × 30%).[11]

This also works with free allowances. In this case, the firm can create an additional tax-

[10] A natural question is whether the parent company could apply Controlled Foreign Company (CFC) rules to attribute the trading hub's profit back to the high-tax jurisdiction. However, as long as the trading hub has sufficient substance, its trading activity can be classified as active income, in which case CFC rules do not apply. In our example, the MNEs employs staff in the trading hub to oversee carbon allowance trading, thereby meeting the substance requirement.

[11] Firms can also exploit temporary price fluctuations. Suppose the price first falls from EUR 50 to EUR 30 and later returns to EUR 50. If the plant sells the allowance to the hub at EUR 30, the plant realizes a tax-deductible loss of EUR 20. When the hub sells the allowance back at EUR 50, it earns a EUR 20 profit, and the plant records a EUR 50 expense upon surrender. In total, the plant recognizes EUR 70 of deductible expenses or losses and the hub earns EUR 20 of taxable profit, again yielding net tax savings of EUR 4. Figure C.3 shows that, on average, balance hubs in our sample time their transactions effectively, as the volume-weighted average buy price is lower than the corresponding sell price from 2015 to 2020.

deductible expense of EUR 20 in the high-tax country while recognizing the corresponding EUR 20 of taxable income in the low-tax country. This works as follows: First, the plant in the high-tax country receives the free allowance and transfers it to the trading hub at the prevailing market price of EUR 50. This generates a taxable profit of EUR 50 in the plant. Second, when the allowance is later transferred back to the plant at a market price of EUR 70, the trading hub realizes a profit of EUR 20 (i.e., the difference between the transfer price of EUR 70 and the cost of acquisition of EUR 50). Upon surrender of the allowance, the plant records a EUR 70 expense. Netting the initial EUR 50 gain from the first transfer against the EUR 70 expense from the second transfer leaves the plant with a net deductible loss of EUR 20. With a 30% tax rate in the plant's jurisdiction and a 10% tax rate in the hub's jurisdiction, the transaction again yields total tax savings of EUR 4, equal to 8% of the initial market price of the allowance.

Arguably, this strategy relies on the volatility of allowance prices rather than on predictable or monotonic price increases. Firms can neither perfectly forecast future allowance prices nor optimally time internal transactions. Instead, transfers occur at prevailing market prices and are guided by expectations, internal pricing rules, and compliance constraints. The examples above are stylized illustrations of potential outcomes, and companies may also incur losses when prices move unfavorably. While emission allowances can be banked, they are not purely financial assets, as regulated entities must ultimately surrender allowances to cover verified emissions. These compliance obligations constrain firms' ability to delay transactions until favorable prices materialize and may force transfers even when prices are temporarily low. Realizing losses in the low-tax trading hub is thus part of the economic risk that firms must bear to substantiate the hub's activity beyond merely employing staff. If the hub did not bear such risks, tax authorities — especially in the high-tax country where the headquarters is located — might question the hub's economic substance and seek to apply CFC rules.[12] Despite this uncertainty and the presence of both gains and losses, our empirical evidence shows that MNEs subject to the EU ETS, on average,

12 In a discussion with an industry expert in transfer pricing, this importance of also realizing losses in a low-tax country was highlighted. Our discussion partner noted that the occasional realization of losses helps justify the economic substance of such entities.

realized profits from internal transactions of the kind illustrated in Figure 2.

3 Data

We compile a comprehensive, multi-source dataset covering the period 2014–2020. Our EU ETS data are from the European Union Transaction Log (EUTL) and include account-level allocation, transaction, and surrender records[13]. We link these to subsidiary-level accounting data from Bureau van Dijk Orbis, ownership-structure information constructed via our three-step framework detailed below, and consolidated group-level financial statements from Worldscope. Decarbonization investments and verified emissions under the EU ETS are drawn from CDP, and spot prices for EUAs come from Refinitiv. To ensure accurate tax-jurisdiction assignment, including for non-sovereign jurisdictions such as Jersey (Murphy and Vernon, 2025), we code each registry account's location using the two-digit country code of its registered address. Statutory corporate tax rates are obtained from the panel compiled by Jacob et al. (2019, 2025), and we follow their procedure to fill missing years and jurisdictions in our sample.

3.1 Subsidiary-level transaction, compliance, and accounting data

The European Union Transaction Log (EUTL) serves as the central registry platform of the EU ETS. It enables the European Commission to monitor and publicly disclose compliance information of regulated entities, participants in the program, and all transactions between them. The database records account-level activities related to the verification, allocation, surrender, retirement, and transfer of EUAs. While the raw EUTL data are publicly available, we rely on the structured and cleaned version dataset by EUETS.INFO (Abrell, 2024).

The EUETS.INFO dataset is composed of three key modules. The *account block* contains account names, identifiers, account-holder names, and associated Orbis identifiers (`bvdID`). The mapping from EUTL accounts to Orbis firm identifiers builds on Letout (2021) and is refined by

[13] The European Union Transaction Log (EUTL) monitors, records and authorises all transfers of allowances and eligible internationally-issued credits (such as Certified Emission Reductions (CERs) and Emission Reduction Units (ERUs)) that are valid for compliance under the EU ETS.

Abrell (2024) using location data from the Google Maps API. For entities included in our sample, we further verify these ID–`bvdID` matches to ensure that the `bvdID` corresponds to the firm-level entity (rather than a branch) for accurate accounting-data matching. The *compliance block* reports annual and cumulative EUA allocations and surrenders at the installation level. The *transaction block* traces all EUA transfers between accounts, including the date, volume and transaction type (e.g., issuance, cancellation).

We begin with the full transaction-owner dataset over the period 2014–2020 and apply a sequence of filters to define our transaction sample. First, we exclude any records from trading systems that include the term `ESD` in their identifier.[14] Next, we restrict the sample to transactions whose main type is 10 (Internal). We drop those transactions for which the supplementary type belongs to the 2 (Allowance surrender), 82 (Reversal of surrender), 36 (Allocation of general allowances), 86 (Reverse of Excess Allocation), 136 (Allocation of general allowances), 72 (Exchanged), 172 (Reversal of Transfer of Exchanged), or 90 (Deletion of allowance). We then further restrict the sample to transactions in which both the buyer and the seller hold account types in the list 100-7 (Operator Holding Account), 100-9 (Aircraft Operator Account), 120-0 (Former Operator Holding Account), 100-8 (Person Holding Account), 100-12 (Trading Account), or 121-0 (Person Account in National Registry). We eliminate all transactions where the buyer's holder identifier equals the seller's holder identifier or where the buyer's holder name equals the seller's holder name, as such transactions reflect intra-entity transfers across accounts rather than intra-group transfers across firms.[15] In addition, we remove transactions in which the buyer or seller is one of a set of clearinghouse entities (i.e., names matching "European Commodity Clearing AG", "Stichting Emissiebeurs Clearing", "ICE Clear Europe Limited", "ICE Clear Europe Ltd").

This sample selection procedure ensures that our final transaction sample focuses on bona-fide inter-firm allowance transfers (rather than internal, regulatory, or clearing-house transactions), between distinct entities with the relevant account types. This inter-firm transaction sample has

[14] Effort Sharing Decision (ESD) is a set of national, binding targets for member states to reduce emissions in sectors outside the ETS, such as buildings, transport, and agriculture.

[15] Firms may have multiple accounts in the system, for example, both an operator account and a holding account.

177,710 observations.

The subsidiary-level financial accounting data are obtained from Orbis. We retain only unconsolidated financial statements as identified by Orbis' consolidation codes "U1" or "U2". Fiscal years with fewer than 12 months of data are excluded. When multiple unconsolidated financial statements are available for a given subsidiary-year, we prioritize and retain the version based on local registry filings.

3.2 Three-Step Verification Framework for Group Affiliation

Our primary objective is to detect transactions that occur within one corporate group. Orbis data provide information on the global ultimate owner (GUO), but its coverage is incomplete. Subsidiaries and operational hubs often share branding and business structures without being formally linked in Orbis, especially in jurisdictions with weak reporting standards (see Online Appendix Part B). Relying solely on Orbis would therefore understate intra-group relationships and bias our analyses of corporate networks and internal capital flows. To address this, we implement a conservative three-step framework that combines heuristic screening, evidence-based verification, and targeted manual review in the following way.

3.2.1 Step 1: Heuristic Screening via Large Language Models

In the first stage, we query two large language models (GPT-4.1 and DeepSeek), configured to act as corporate structure analysts. Each model assesses whether a given company pair is likely part of the same business group, using general corporate knowledge, brand consistency, naming conventions, and common organizational patterns such as parent–subsidiary or affiliate relationships. The output is a binary classification of "Yes" or "No," without explanation. When the affiliation is unclear, the models are explicitly instructed to default to "No." This ensures that only the most plausible matches advance to the next stage.

3.2.2 Step 2: Evidence-Based Verification

Pairs classified as affiliated to the same corporate group in Step 1 by either model are subjected to a second, more stringent check. In this stage, a separate LLM prompt frames the task as a search for public, verifiable evidence of shared ownership or affiliation. The model must confirm affiliation using authoritative sources such as corporate registries, press releases, or reputable news articles. When evidence is found, the model returns:

- The time period of affiliation (start and end dates, or indication of ongoing status),
- The simplified name of the parent or umbrella business group (e.g., "Samsung" rather than "Samsung Electronics Co. Ltd."), and
- A source URL that substantiates the claim.

If no such evidence is available or if the model cannot verify the relationship with high confidence, it returns a structured "No" response, indicating that no affiliation can be confirmed. This procedure is used solely to reduce potential hallucinations from the large language model. When a buyer-seller pair is identified as being affiliated to multiple corporate groups, we manually check the start date and end date of each affiliation. Note that account names in the EU ETS registry are often retrospectively updated (i.e., backfilled) to reflect current ownership, while historical names are not preserved. To address this issue, when we detect transactions involving entities that appear under backfilled names, we attribute them to the group that actually owned the business at the time, thereby reconstructing intra-group relationships as accurately as possible.[16]

[16] For example, our sample includes the entity *LAT Nitrogen France*, which is currently affiliated with the *AGROFERT* group. However, *AGROFERT* only acquired *Borealis*' nitrogen business in 2023, and *LAT Nitrogen France* was established as part of that transaction. In other words, *LAT Nitrogen France* did not formally exist before 2023, which indicates that the account holder name in our dataset has been backfilled. Notably, we observe frequent transactions recorded between *Borealis* and *LAT Nitrogen France* dating back to 2014. This pattern suggests that the account may in fact correspond to *Borealis*' nitrogen division prior to the sale. Accordingly, we classify these transactions as intra-group trades within *Borealis* rather than as external transactions with *LAT Nitrogen France*.

3.2.3 Step 3: Manual Verification

Finally, we conduct manual verification to assess the accuracy of our identification procedure. Three research assistants independently review targeted subsamples designed to capture observations with a higher likelihood of error: (i) *all* cases in which a single entity is associated with multiple global ultimate owners; (ii) *all* cases in which GPT and DeepSeek yield conflicting classifications; and (iii) a 10% random sample of the remaining observations — that is, those not included in subsamples (i) or (ii).

The manual review indicates that most errors arise either from disagreements between GPT and DeepSeek or from situations in which multiple ultimate owners legitimately coexist due to mergers, spin-offs, or complex ownership structures. Manual verification of subsample (i) reveals a false positive rate of 5.1%, while subsample (ii) exhibits a substantially higher false positive rate of 17.2%. All false positives identified in these subsamples are corrected based on the manual review. Finally, subsample (iii) — which consists of pairs classified as correct by both GPT and DeepSeek and not previously reviewed — serves as a benchmark for the residual error rate. In this subsample, we find a false positive rate of only 1.6%.

We repeat the verification process across several rounds to refine accuracy. In addition, we utilize the GPT web search API to identify potential false negatives within the subset of counterparties that have traded with entities involved in intra-group transactions. We also use the API to flag potential false positives from our manually verified linking table. For any cases where GPT's assessment diverges from human judgment, we conduct a final round of human verification to establish the most reliable classification.

3.2.4 Performance Benchmark and Final Sample Selection

Our LLM-based approach, combined with targeted human verification, substantially improves coverage of intra-group transactions compared to relying solely on Orbis. Relative to the initial sample using only Orbis, we have obtained a much larger and more reliable sample given the additional verification steps. In our final sample of intra-group cross-border transactions, at least

35% of unique buyer–seller pairs cannot be identified by Orbis. For this reason, we adopt a hybrid classification: buyer–seller pairs are treated as belonging to the same corporate group if either Orbis indicates that they share the same global ultimate owner (GUO) or the LLMs identify them as part of the same group. In the rare cases where Orbis suggests a link but the LLMs do not, we exclude the pair to maintain a conservative definition of intra-group transactions. All LLM-based matches are further subjected to manual verification on targeted subsamples, ensuring the accuracy and reliability of the final dataset. This strategy combines the reliability of structured ownership data, the broad coverage enabled by contextual inference, and the rigor of human oversight.

The contribution of LLMs is particularly evident given the structure of the sample, where a substantial share of buyer–seller pairs either involve firms with missing GUO identifiers in Orbis or include cases of conflicting identifiers among entities of the same corporate group. For example, Carmeuse Holding SRL and Carmeuse S.A. are recorded by Orbis as having different global ultimate owners (Netherlands versus Luxembourg), yet LLMs correctly associate them with the Carmeuse group. Similarly, Arjowiggins Scotland Limited and Arjowiggins Papiers Couches both lack GUO identifiers, and incomplete Orbis data obscure their affiliation with the Arjowiggins group. Together, these examples demonstrate that Orbis and LLMs are complementary tools: Orbis supplies reliable ownership data, while LLMs help identify intra-group links not captured in the database. Without this combined approach, a large share of intra-group transactions would be overlooked, distorting our understanding of corporate networks and trade flows.

After applying this methodology to our data, we are able to identify 3,218 individual entities in the EUTL, which we can link to 679 groups. As we explain in more detail below, these entities serve various purposes. Many of these entities are operating plants (denoted ”operators”) that also surrender allowances. Others are hubs that are used for internal and external trading of carbon allowances. We then further restrict our sample to cross-border intra-group transactions by requiring that the two parties' country codes differ. We also exclude financial groups such as Deutsche Bank and Société Générale. In addition, we exclude groups whose principal business is providing environmental services as many of them are carbon offset project developers and carbon credit suppliers in the voluntary carbon market (see Chen, 2024) as well as those in the aviation industry. The rationale is that intra-group transactions undertaken by carbon-credit suppliers may reflect cross-market arbitrage[17] rather than the profit-shifting activities we seek to study. In the case of aviation firms, emissions accounting is inherently cross-border — for instance, the EU ETS covers flights within, into, and departing from the European Economic Area (EEA), which complicates assignment of individual country codes. The final dataset comprises 14,933 transactions across 326 corporate groups. Our sample selection procedure is detailed in Table 1. Table 2 reports the descriptive statistics for the sample.

3.3 Group-level information

Group-level financial information is obtained from Worldscope. Data on decarbonization investments are sourced from CDP (formerly the Carbon Disclosure Project). CDP is a non-profit organization that conducts the world's largest survey on corporate climate actions. In each year, respondents are asked to "*provide details on the [emissions reduction] initiatives implemented in the reporting year in the table below.*" This information is reported under sub-question CC3.3b in the 2015–2017 questionnaires and C4.3b in the 2018–2023 versions.

As described in Fuchs et al. (2024), this annual questionnaire collects firm-level disclosures on implemented emission-reduction initiatives, reporting the activity type, targeted emission scope, investment amount in local currency, and a brief project description. Firms specify whether each project reduces direct emissions from firm-controlled sources (scope 1), indirect emissions from purchased energy (scope 2), or other indirect emissions along the value chain (scope 3). Some projects may span multiple scopes. These data provide granular, project-level insights into firms' realized decarbonization efforts.

For each year, we aggregate firms' investment amounts in decarbonization initiatives and convert these values into euros (EUR) using annual exchange rates from the OECD exchange rate database. Currency conversion is based on the currency specified by each firm (CDP sub-question C.04) and

[17] During the Phase 3 of the EU ETS, certain international credits still could be exchanged for EUAs.

the exchange rate corresponding to the year preceding the survey publication year, which typically marks the end of the reporting period for most respondents. Based on the reported emission scopes, we construct two measures: *Scope 1 Abatement*, which includes all initiatives targeting Scope 1 emissions, and *Scope 1–3 Abatement*, which includes all reported initiatives.

From CDP, we also collect firms' disclosed verified emissions under the EU ETS. In each survey year, respondents are asked whether they participate in any emissions trading schemes. If so, they are required to indicate the scheme name, report the corresponding verified emissions, and provide related details. This information is reported under sub-question CC13.1a in the 2015–2017 questionnaires and C11.1b in the 2018–2023 versions.

4 Empirical Results

Our empirical approach is primarily descriptive and unfolds in three steps. First, before engaging in a broader analysis of group structures in a more systematic framework, we present two case studies of large MNEs to illustrate how internal carbon allowance trading is organized in practice. Second, we analyze the full dataset to provide a broader overview of how trading hubs are used for tax-motivated purposes. Finally, we examine whether tax avoidance is associated with abatement investments and verified carbon emissions at the group level.

4.1 Evidence from Case Studies

We start our analysis by examining two specific companies, their group structures, and their internal transactions of carbon allowances. The objective of these case studies is to illustrate how firms organize the internal trading and allocation of carbon allowances through designated hubs, and how the location of these hubs and the associated trading activity can be tax-motivated. In our sample, each subsidiary is classified as either an operator or a trading hub. A subsidiary is identified as a trading hub if it neither receives free allocations nor has surrender obligations, whereas an operator is any entity that either receives free allowances or surrenders allowances.

4.1.1 The Case of Dow Chemical Company

As our first case, we use the example of The Dow Chemical Company, or Dow Inc. (henceforth ”Dow”). Dow was founded in 1897 in Midland, Michigan, United States. Today, Dow is a multinational enterprise operating at the intersection of materials science and chemical manufacturing. Historically, Dow has maintained a diversified portfolio encompassing plastics, industrial chemicals, performance materials, and agricultural sciences, while more recently emphasizing specialty chemicals and advanced materials. Dow has significant operations in North America, Europe, and Asia. We are interested in the operations in Europe because, despite Dow being an American multinational, its European operations are covered by the EU ETS. That is, for its European manufacturing operations, Dow receives free carbon allowances, and to the extent that these do not cover total emissions, the company must purchase additional allowances on the market.

Figure 3 illustrates the structure of Dow’s European operations as identified in our data.[18] The rectangles describe the operating entities. That is, these are entities that surrender carbon allowances, which is a signal that this entity engages in production leading to carbon emissions. Dow has three such entities in Germany, two in Belgium, two in the United Kingdom, and one each in the Netherlands, Portugal, Spain, and France.[19] Importantly, we observe one trading hub (as indicated by the circle), the *Dow Europe GmbH*, located in Switzerland.[20] As shown in Figure 3, all but two of the operating entities transfer allowances to the hub, and most of them receive allowances from it. Over the period 2014–2020, Dow transferred over 9.7 million allowances with a value around EUR 111.79 million to the Swiss hub. Over the same period, the Swiss hub transferred 29

[18] In our analysis, we classify joint ventures as subsidiaries of both partner firms. For instance, when *BASF Dow HPPO Production* engages in transactions with other Dow subsidiaries, we treat these as intra-group transactions. This approach is consistent with prior literature (e.g., Luo et al., 2025), which documents that firms can engage in profit shifting through not-wholly-owned subsidiaries.

[19] Dow holds an Aircraft Operator Holding Account (AOHA, accountType id = 109) which is registered under the country code ‘US’. Under the EU ETS, the designation of ‘aircraft operator’ is set out in Article 3(o) of Directive 2003/87/EC, defining the ‘aircraft operator’ as the natural or legal person who operates an aircraft at the time it performs an aviation activity listed in Annex I to that Directive. Accordingly, the country of registration of the operator may lie outside the EU, yet the operator remains subject to the EU ETS when it conducts flights to or from, or within, an aerodrome in the territory of the EU (or EEA-EFTA states under the scheme).

[20] *Dow Europe GmbH* is the European headquarter. Hence, it appears natural that this entity also takes over the function of a trading hub. This also helps documenting economic substance. We note that *Dow Europe GmbH* is also listed in Dow’s Exhibit 21 list of subsidiaries.

million allowances with a value of around EUR 328.37 million to these operating entities. Most of these allowances are transferred to Germany (approx. 17 million allowances), the Netherlands (approx. 9 million allowances), and Spain (approx. 3 million allowances).

The location of the hub vis-à-vis the operating entities is consistent with our predictions. While the hub in located in Switzerland with a tax rate of about 14%, Dow's operating entities are located in countries with tax rates between 25% (Spain and the Netherlands) and 30% (Germany).[21] Over the period 2014–2020, we estimate that Dow realized profits in its Swiss hub only from the internal transfer of carbon allowances of EUR 217 million. In 2019 (2020) alone, the hub's profit from the internal transfer of carbon allowances amounted to EUR 73 million (EUR 62 million), after yielding profits from internal transactions in Switzerland of EUR 38 million and EUR 34 million in 2017 and 2018, respectively. Given that profits are taxed in Switzerland at a rate of about 14% and that these profits lead to tax deductions in the operating entities located in countries with tax rates between 25% and 30%, this results in tax savings between EUR 24 to 35 million over the 2014–2020 period. For 2019 alone, we estimate Dow's tax savings due to these transactions to be between EUR 8.0 million to 11.6 million. This is a sizable reduction in the tax expense given Dow's worldwide income tax expense of USD 470 million (or about EUR 420 million) in 2019.[22] Put differently, taking our values at face value, Dow reduced its tax expense by 1.9% to 2.7% in 2019 only with the help of the Swiss trading hub for internal transfers of carbon allowances.

4.1.2 The Case of Ineos Group Limited

As our second example, we use Ineos Group Limited (henceforth "Ineos"). Ineos was established in 1998 and is headquartered in London, United Kingdom. Ineos is a multinational chemical company that produces not only a large variety of products relating to the oil & gas industry, chemicals and polymers, but also consumer products. Today, Ineos is one of the world's largest chemical producers. Given that its headquarters is in the United Kingdom, Ineos has considerable

21 Although the Netherlands is frequently perceived as a tax haven or low-tax country—especially regarding royalty payments linked to patents, trademarks, and licenses—the statutory corporate tax rate for manufacturing and other business activities stands at 25%.

22 The tax expense is taken from Dow's 2019 financial statement.

operations in Europe that are subject to the EU ETS.

Figure 4 illustrates the structure of Ineos' European operations as identified in our data. While the structure of Ineos is more complex than Dow, we again find tax-induced within-company trading. There are many operating entities in countries such as Belgium, Germany, Denmark, Spain, or France. Moreover, there are three internal hubs: i) *Ineos Europe AG* in Switzerland, ii) *Petroineos Treading Ltd.* on Jersey, and iii) *Ineos Fluor Ltd.* in the United Kingdom. The vast majority of within-company transactions are related to the Swiss hub and the hub on Jersey, both of which are low-tax jurisdictions. We observe that except for one entity, all operating entities receive carbon allowances from the hubs in tax havens. Most operating entities transfer allowances to the hubs. Over the period 2014–2020, Ineos transferred over 31.6 million allowances with a value of around EUR 438.73 million to its trading hubs. Over the same period, the three hub transferred over 44.2 million allowances worth around EUR 622.18 million to these operating entities. Most allowances are transferred to Germany (approx. 20 million allowances), the United Kingdom (approx. 12 million allowances), and France (approx. 4 million allowances).

Similar to Dow, Ineos was able to use this structure to shift profits to low-tax jurisdictions. Over the period 2014–2020, we estimate that Ineos made profits in its three allowance tradings hubs of EUR 183 million. In the Swiss trading hub and in the trading hub in Jersey, Ineos made a profit of approximately EUR 30 million each year between 2017 and 2019. More specifically, in 2019, Ineos generated a profit of EUR 7.67 million in Jersey and of EUR 25.5 million in Switzerland. When calculating the tax savings, one has to take into account that the tax rate in Jersey is 0% and that Ineos transferred allowances to several countries. To approximate the tax rate at which the additional expenses are deductible, we calculate a weighted average tax rate using the number of allowances transferred from the hub to the operator in each country as weights. This gives us a tax rate of 26.32% at the operating countries. Using this input, we estimate the tax savings in 2019 to be EUR 5.16m (= $7.67 \times 26.32\% + 25.5 \times (26.32\%-14\%)$). These are sizeable tax savings relative to Ineos' global tax expense in 2019: Ineos states a global tax charge of EUR 216m in its financial statement, which implies that through its trading hubs for and through internal transactions with carbon allowances, Ineos reduced its tax expense by 2.39% in 2019.[23]

While the tax savings for Dow as well as for Ineos in 2019 are already sizable, we note that these tax savings are likely higher in the coming years. This is because the carbon price has increased substantially since 2020. Hence, potential profits from within-group transfers of carbon allowances are more likely to increase.

4.2 Aggregate Statistics on Profit Shifting and Hubs

In the second step of our empirical analyses, we analyze the trends and natures of the transactions using aggregate statistics based on the subsidiary-level data. We begin by presenting descriptive evidence on the aggregate use of hubs and the extent of profit shifting in the sample derived from cross-border intra-group transactions. Figure 5(a) shows that most groups have two to three operating entities——that is, two to three subsidiaries with surrender obligations that engage in cross-border internal trading each year. Related to tax planning, Figure 5(b) shows that, at the group-year level, 61% of observations do not involve any hubs, 30% involve one hub, and 9% involve multiple hubs. In Figures 5(c) and 5(d), we distinguish between international and local hubs. A hub is classified as international if more than 50% of its total transaction volume (purchases and sales combined) is across borders. We find that 70% of group-year observations do not involve an international hub, 25% involve one, and 6% involve more than one. In contrast, 87% of group-year observations do not involve any local hubs, 11% involve one, and only 2% involve more than one. This shows that most hubs exist for cross-border transactions.

Next, we present evidence on the time trend of hub usage in cross-border intra-group transactions in Figure 6. Overall, the number of local hubs remains relatively stable over time, ranging from a low of 20 in 2016 to a high of 27 in 2019 and 2020. In contrast, the number of international hubs among our 326 sample firms involved in cross-border intra-group transactions is first stable between 2014 and 2018 and then increases in 2019 and 2020—from a low of 52 in 2017 to a high of 78 in 2020. Hence, it appears as if there is an increased used of international hubs over time.

[23] The tax charge is taken from Ineos' 2019 financial statement.

We plot the geographical distribution of countries for different types of entities involved in cross-border intra-group transactions in Figure 7. We find that the Switzerland hosts the largest total number of trading hubs. It is perhaps unsurprising that Germany, the United Kingdom, France, Spain, and Belgium are the top five countries in terms of operators. In contrast, among tax havens or countries with preferential tax regimes, international hubs dominate the composition of entities. This is the case, for example, in Switzerland, the Netherlands, or Jersey. A striking pattern is that, in our cross-border intra-group sample, no operators are located in Switzerland or Jersey. A similar pattern arises in Figure 8, which plots the verified surrender allowance amounts alongside the absolute value of net flows in intra-group transactions for all entities in our cross-border intra-group sample. Hence, firms do not just have trading hubs in low-tax countries, but they also appear to use them actively, as indicated by the significant trading volumes.

Finally, we present descriptive statistics on potential tax-induced trading with carbon allowances between 2014 and 2020 in Figure 9. The net volume of carbon allowances involved in cross-border intra-group transactions exceeds 0.4 billion tons of carbon dioxide (tCO_2) in 2014, rises to over 0.5 billion tCO_2 in 2015, declines to around 0.4 billion tCO_2 in 2017 and 2018, and shows a further downward trend in 2019 and 2020 (falling below 0.3 billion tCO_2). In terms of profits from trading—calculated as the sale of carbon allowances minus their purchase, multiplied by the spot price[24] on each transaction date—we find profits of around EUR 3 billion in 2014 that increase to EUR 4 billion in 2015 and that decline to about EUR 3 billion in the following two years. In the final sample years, the profits rise sharply to nearly EUR 6 billion in 2018, EUR 8 billion in 2019, and above EUR 7 billion in 2020. For our statistics, we also separate transactions likely driven by operational needs (i.e., cases where verified surrender exceeds free allocation so that the operating subsidiary needs internal transfers) from those more plausibly tax-motivated (i.e., all

[24] We acknowledge that some registry transfers may reflect the physical settlement of forward, futures, or other derivative contracts, for which the economic terms were determined prior to the recorded transfer date. While transaction prices for such contracts are unobserved, we use the contemporaneous EUA spot price as a transparent and institutionally relevant proxy for the economic value of the transfer. This choice is consistent with the arm's length valuation principle applied by tax authorities and with the tight arbitrage relationship between spot and futures markets in the EU ETS.

other transactions).[25] We find that operational transactions account for only a small share of total activity—below EUR 1 billion in all years except 2019. This implies that the majority of cross-border intra-group carbon allowance transactions—and hence the profit shifting involved—are tax-induced and economically large in magnitude.

4.3 Subsidiary-level Evidence

In the next step, we examine the sample of subsidiaries which we were able to link to the respective groups. The objective of these tests is to assess whether the trading hubs are utilized for tax planning. To this end, we restrict the sample to subsidiaries that engaged in at least one intra-group cross-border transaction during the year. Our analysis then proceeds in two stages. We first examine transactions through trading hubs, and then turn to the trades among operators.

4.3.1 Transactions via Trading Hubs

We classify trading hubs along three dimensions: (1) international versus local, (2) collect, balance, and supply functions, and (3) opacity versus transparency. The first classification is straightforward and follows the classification in Figures 5(c) and 5(d). The second classification partitions all hubs into three groups: *Collect*, *Balance*, and *Supply*. These categories are defined by intra-group trading patterns because some hubs mostly collect allowances (*Collect*), others collect and sell (*Balance*), and yet other hubs mostly sell during a year (*Supply*).[26] The final classification captures whether financial accounting information is available for the hub (*Transparent*) or not (*Opaque*).

For the first two classifications, we then examine how tax avoidance differs across different hub

[25] We acknowledge that, empirically, it is not feasible to cleanly identify intra-group transactions that are purely tax-driven. In practice, such transactions may reflect a combination of tax considerations, risk management, and centralized operational arrangements. Our classification therefore does not attempt to isolate "pure" tax motives. Instead, it adopts a deliberately narrow definition of operational necessity—based on verifiable shortfalls of free allocation relative to surrender—to identify cases where operational needs are most clearly established. Transactions outside this category are best interpreted as likely influenced by tax considerations, rather than exclusively tax-motivated. To the extent that some efficiency-driven or risk-management transfers are included in this group, this would bias our estimates toward understating, rather than overstating, the role of tax incentives.

[26] Table C.1 reports the determinants of hub existence and hub counts. We find that both the likelihood of having a hub and the number of hubs increase with firm size but decrease with ROA. We also document a negative association between leverage and the number of hubs.

types. Specifically, we estimate the following regression model:

$$ETR_{i,t} = \beta Hub\,Types_{i,t} + \gamma Controls_{i,t} + Fixed\,Effects + \epsilon_{i,t} \tag{1}$$

where the dependent variable *ETR* is the effective tax rate of subsidiary *i* in year *t* (Kohlhase and Pierk, 2020). As control variables, we follow prior literature and include the natural logarithm of total assets as measure of size (*Asset*), return on assets (*ROA*) as a measure of profitability, *Leverage*, and the ratio of tangible assets to total assets (*Tangible Ratio*) as control variables (e.g., Dyreng et al., 2008; Atwood et al., 2012). We also include the statutory corporate tax rate of the subsidiary's country (*Tax Rate*) as a control variable. We use two fixed-effects specifications: one with group- and year-fixed effects, and another with group-year fixed effects to exploit within-group variation.[27] With this approach, we can explore the extent to which the effective tax rates of the (strategically located) hubs differ from the operating entities of the same group. Because neither dependent nor control variables are available for opaque hubs, we use a separate approach to study these entities (see below).

International versus Local Hubs We begin by comparing effective tax rates between trading hubs and operators. We present the results in Table 3. Figure C.1(a) shows that more than half of the hubs in the full transaction log have no cross-border intra-group transactions and therefore do not appear in our main sample. We find that hubs, on average, face ETRs that are 6-7 percentage points lower than those of operators. When decomposing hubs into *International* and *Local* categories, we observe that the ETRs of local hubs do not differ significantly from those of operators within the same group–year. In contrast, international hubs exhibit substantially lower ETRs — approximately 7 percentage points — relative to operators. The results hold when using either group- and year-fixed effects or group–year fixed effects. The group–year fixed effects provide a stricter comparison by effectively contrasting international hubs with all other subsidiaries in the same group during the same year. Collectively, our findings indicate that international trading hubs, which primarily

[27] Our results are robust to clustering by group (untabulated).

facilitate cross-border intra-group carbon transactions, systematically bear lower tax burdens than their affiliated operators. This suggests that any transaction through international hubs can lead to substantial tax savings as the hub faces a much lower ETR than the operating entities in a group.

Collect, Balance, and Supply Hubs Next, we examine a distinct categorization of trading hubs. Specifically, we partition all hubs into three groups: *Collect*, *Balance*, and *Supply*. These categories are defined by intra-group trading patterns. We measure a hub's trading orientation using the *Sell Ratio*, defined as the volume of intra-group sales divided by the hub's total intra-group transaction volume. Hubs with a sell ratio below 0.4 are classified as *Collect Hubs*, which primarily acquire allowances from affiliates; hubs with a ratio above 0.6 are classified as *Supply Hubs*, which primarily distribute allowances to affiliates; and hubs with a ratio between 0.4 and 0.6 are classified as *Balance Hubs*, which maintain relatively even levels of intra-group purchases and sales. Figure C.2 presents the distribution of the *Sell Ratio* across hubs. Overall, 24% of hubs are classified as *Collect Hubs* and 13% as *Balance Hubs*, with the remaining majority identified as *Supply Hubs*. The distribution exhibits a noticeable spike at a *Sell Ratio* of 50%.

We present the results in Table 4. We find that *Balance Hubs* are the only category exhibiting a statistically significant difference in effective tax rates across all specifications, with effect sizes ranging from 10 to 14 percentage points. That is, *Balance Hubs* exhibit an up to 14 percentage points lower ETR than other operating entities in the same multinational group. *Collect* and *Supply* Hubs appear more operational in nature. *Collect Hubs* concentrate allowances from affiliates with surpluses, thereby serving as internal aggregators of carbon allowances, whereas *Supply Hubs* distribute allowances to affiliates with deficits, enabling compliance within the group. These roles suggest that both *Collect* and *Supply Hubs* primarily facilitate the internal reallocation of allowances in response to operational needs. In contrast, *Balance Hubs* engage in roughly equal levels of intra-group purchases and sales, without a clear role in either pooling or redistributing allowances. The absence of a strong operational rationale makes it more plausible that *Balance Hubs* are a strategic organizational choice, potentially designed to shift profits.

Overlap of International and Balance Hubs Next, we examine the interaction between the two hub classifications. Building on our earlier finding that both international hubs and balance hubs exhibit higher levels of tax avoidance than other categories, we examine whether a hub that combines these two characteristics shows the strongest tax avoidance. The results in Table 5 confirm this: Hubs that are simultaneously international and balance hubs display the highest levels of tax avoidance, with effective tax rates that are 12 to 14 percentage points lower than the effective tax rates of operators.

Among the other categories, *Balance* × *Local Hub* shows a negative coefficient in all specifications. *Supply* × *International Hub* shows a negative coefficient in the first two specifications. Importantly, in every specification, the coefficients for *Collect* × *International Hub* and *Supply* × *International Hub* are statistically different from those of *Balance* × *International Hub*.

Taken together, these results indicate that the tax avoidance effect is not uniformly driven by international hub status alone. Instead, it is the specific combination of cross-border intra-group activity and the strategic organizational positioning of balance hubs that generates the most pronounced tax avoidance. In other words, when hubs are integral to cross-border intra-group transactions and reflect a deliberate organizational design, they exhibit the strongest and most consistent levels of tax avoidance. In robustness check, we shift the cutoffs to 0.35 and 0.65 and find very similar results (see Tables C.2 and C.3 in the Online Appendix).

Opaque versus Transparent Hubs We finally examine the third classification of trading hubs that is based on their opacity. Specifically, we define a hub as transparent if unconsolidated financial statements are available in Orbis. In contrast, a hub is considered opaque under two conditions: (1) when no or only very limited financial information is available in Orbis, or (2) when only consolidated financial statements are reported. Because opaque hubs lack the necessary data on financials, direct comparisons of effective tax rates—or assessments of profit shifting—between opaque and transparent hubs are not feasible. This mirrors a key limitation in prior research, which often lacks granular data for low-tax jurisdictions such as Switzerland or Jersey. As a result, existing studies on profit shifting often have to exclude such entities from their estimates.

In contrast, our setting provides evidence on these subsidiaries through two profit-shifting–related dimensions. First, we examine whether opaque hubs are disproportionately located in countries with lower statutory corporate tax rates. For this analysis, we use the statutory tax rate in a hub's country as a dependent variable. Second, we examine whether opaque hubs attract more profit inflows from intra-group counterparties relative to other entities. To this end, we use the net gains from intra-group cross-border transactions as the dependent variable. Net gains are defined as revenues from intra-group cross-border sales minus costs from intra-group cross-border purchases. We then scale this measure by the median absolute value of net gains. Because the resulting variable can take zero or negative values and is highly skewed, we apply the inverse hyperbolic sine transformation and use the transformed variable — *Carbon Profit* — in the regressions. The distribution of *Carbon Profit* is shown in Figure C.1(b).

Table 6 shows the empirical results on opaque versus transparent hubs for our two dependent varaibles. First, opaque hubs are, on average, located in jurisdictions with statutory tax rates that are about 3.5 percentage points lower than those faced by operators and transparent hubs. Second, while both transparent and opaque hubs receive substantial intra-group profit inflows, the magnitude is considerably higher for opaque hubs. The estimated coefficients imply that opaque hubs have roughly twice the profits of transparent hubs. In other words, profit shifting through opaque hubs appears substantially larger than through transparent hubs. Note that the coefficients should be interpreted as relative magnitudes due to the inverse-hyperbolic-sine transformation of the dependent variable.

Taken together, these results show that opaque hubs are located in low-tax jurisdictions and exhibit disproportionately high levels of profit shifting. This implies that our earlier analyses—comparing international versus local hubs and distinguishing collect, balance, and supply hubs—likely understate the total tax benefits associated with internal carbon-allowance trading. Because opaque hubs facilitate a larger share of transactions in low-tax countries, the actual extent of tax advantages is likely greater than what can be captured using only transparent entities.

4.3.2 Transactions among Operators

Before turning to our analyses at the group level, we finally explore the transactions of entities that act as operators. Hence, we exclude trading hubs to focus on the factors that shape their intra-group, cross-country carbon-allowance transactions within operators. While tax considerations may influence how profits are allocated across affiliates, such transactions can also reflect broader financial constraints, performance incentives, or compliance needs. To capture the direction of intra-group flows, we construct the dependent variable *Inbound Profit Share*, defined as the share of net revenue from cross-border intra-group carbon-allowance transactions. Specifically, it is calculated as the revenue from selling allowances to foreign affiliates minus the cost of purchasing allowances from them, scaled by the subsidiary's total revenue. We then examine the determinants of this measure using the following regression model:

$$\begin{aligned} Inbound\ Profit\ Share_{i,t} = {} & \beta_1 Asset_{i,t} + \beta_2 ROA\ (Exclude\ Inbound\ Profit)_{i,t} \\ & + \beta_3 Leverage_{i,t} + \beta_4 Tangible\ Ratio_{i,t} + \beta_5 Tax\ Rate_{i,t} \\ & + \beta_6 Surrender - Allocation\ Gap_{i,t} + Fixed\ Effects + \epsilon_{i,t} \end{aligned} \tag{2}$$

The control variables are defined as above, but when calculating profitability (*ROA*), we exclude the profits from carbon allowance transactions. Results are reported in Table 7. We use several fixed-effects specifications to account for unobserved heterogeneity. Column (1) includes group- and year-fixed effects, controlling for time-invariant group characteristics and common time trends. Column (2) adds group and country-by-year fixed effects to capture country-specific shocks over time. Column (3) employs group-by-year fixed effects, absorbing all variation at the group-year level. Column (4) combines group-by-year and country-by-year fixed effects to account for both group-level and country-level time-varying factors. Finally, Column (5) introduces subsidiary fixed effects alongside country-by-year fixed effects, thereby controlling for persistent subsidiary-level heterogeneity and time-varying country effects. Across specifications, we find that the *Surrender–Allocation Gap* is negatively associated with *Inbound Profit Share* in all but the final model. This relationship is consistent with our intuition. Entities lacking sufficient free allocations to meet their surrender obligations are less likely to sell allowances externally.

We also observe that firms with lower return on assets (ROA)—measured excluding inbound profits—and lower leverage tend to exhibit higher inbound shifting shares. This pattern is consistent with incentives for earnings management and tax minimization. Inbound shifting can inflate reported profits (particularly attractive for low-performing firms) while simultaneously reducing tax burdens, especially for loss-making entities that are not tax-liable. Our results also indicate that financial structure further shapes firms' carbon allowance behavior. Highly leveraged firms are less likely to sell allowances because high debt levels heighten risk aversion and impose financial constraints. Such firms retain allowances as a buffer against future emissions or price uncertainty, avoiding potential buyback costs or non-compliance penalties. Moreover, as noted by Antoniou et al. (2024), carbon allowances can serve as collateral, helping firms mitigate financing costs. High-leverage entities may thus regard stored allowances as valuable, liquid assets that support financing flexibility and strengthen balance sheet positions.

In four of the five specifications, the *Tangible Ratio* is negatively associated with *Inbound Profit Share*. Firms with more tangible, emission-intensive assets are less likely to sell allowances because their fixed production structures make them value these permits as protection against future compliance risks. In contrast, we find no statistically significant relationship between *Tax Rate* and *Inbound Profit Share* for trades between operating entities (presumably because operators are more often located in high tax countries), while *Asset* shows only a weakly positive association in the first and third specifications.[28]

[28] As a robustness check, we re-run the analysis for operators whose groups had no cross-border intra-group transactions through a trading hub in the given year. The results, presented in Table C.4, remain largely consistent with our baseline findings. Specifically, *Asset* is positively associated with *Inbound Profit Share* in the first four specifications, while *Leverage* exhibits a negative association in all specifications. In addition, both *ROA (Exclude Carbon)* and *Tangible Ratio* show negative relationships with *Inbound Profit Share* across the first four specifications. The *Surrender–Allocation Gap* also displays significant negative coefficients in the first and third specifications. Overall, these results indicate that, irrespective of trading hub usage, transactions among operators follow broadly similar patterns: Firms with higher profitability (when excluding carbon-related effects), higher tangible intensity, or greater leverage are less likely to sell and profit from carbon-allowance transactions.

4.4 Group-level Evidence

4.4.1 Empirical Approach

In the third part of our empirical analysis, we examine whether intra-group profit shifting is associated with outcomes at the level of the corporate group as a whole. To do so, we aggregate the dataset at the group-year level. For each year, we compute the net amount of carbon allowances traded between each buyer–seller pair, excluding sales of allowances to subsidiaries whose verified surrender obligation is lower than the free allocation they receive. These sales are omitted because they primarily reflect compliance-related reallocations of surplus allowances rather than tax-motivated transfers. We then aggregate these net transactions within each group to obtain the group-year level of shifted profits. We then scale this amount by total assets to derive the shifted profit share (*Shifted Profit Share*). We use this measure as our main independent variable of interest and estimate the following equation:

$$\begin{aligned} Group - level\ Outcome_{g,t\sim t+2} &= \beta Shifted\ Profit\ Share_{g,t} + \gamma Controls_{g,t-1} \\ &\quad + Group\ Fixed\ Effects + Year\ Fixed\ Effects + \epsilon_{g,t} \end{aligned} \tag{3}$$

where we examine three different dependent variables, which we explain in the next subsections. All regressions include the group-level controls *Asset*, *ROA*, *Leverage*, and *Cash*, each measured in the preceding year. We also include group fixed effects and year fixed effects.

4.4.2 Aggregate Tax Avoidance Outcomes

First, we verify whether profit shifting through carbon allowances meaningfully reduces the group-level three-year cash effective tax rate (Cash ETR). This analysis complements the subsidiary-level evidence showing that profits are disproportionately shifted toward trading hubs with relatively low ETRs. While the subsidiary-level results identify *where* profits are relocated within the group, the group-level analysis assesses whether such shifting behavior ultimately affects the group's overall tax burden. To this end, we use the Cash ETR from t to $t + 2$ as the dependent variable. We present our results in Table 8 and find that, as expected, more profits via carbon allowance trading is associated with lower cash ETRs. We find that a one–standard-deviation increase in *Shifted Profit Share* within a group (equal to 0.6 overall SDs) decreases the three-year cash effective tax rate by seven percentage points. Moving from the first to the third quartile of *Shifted Profit Share* is associated with a 0.10–0.13-percentage-point reduction in the group's three-year cash ETR, equivalent to roughly 0.3–0.4% of the mean cash ETR (29%). This result is consistent with the subsidiary-level evidence, suggesting that profit-shifting through intra-group carbon allowance transactions can meaningfully reduce the group's effective tax burden, thereby highlighting its aggregate financial implications beyond the operational level.

4.4.3 Abatement Investments

Next, we consider how tax avoidance with carbon allowances is associated with firm's decarbonization efforts, which we measure through investments in abatement technologies. These data are sourced from CDP and have been used in prior literature such as Fuchs et al. (2024). Specifically, we distinguish between two categories of such investments: (1) investments aimed at reducing Scope 1 emissions, and (2) total investments targeting the reduction of all types of emissions. Each investment measure is calculated as the sum of investments over a three-year period (the current year and the following two years), scaled by lagged total assets. Arguably, this equation cannot establish a causal relation. However, we examine the association of *current* profit shifting with *future* investments, thereby reducing concerns about potential reverse causality of the estimated association.[29] The direction of this association is ex-ante unclear. On the one hand, tax avoidance can alleviate financial constraints, which may explain a positive association between tax avoidance and investment in abatement technologies (see, e.g., Li et al., 2021, and the case of innovation). On the other hand, tax avoidance may reduce the financial pressure to decarbonize. That is, carbon pricing provides firms with an incentive to invest in costly abatement technologies to reduce costly emissions. Tax avoidance lowers the net carbon price and therefore weakens the incentive to invest

[29] An alternative perspective on reverse causality is that multinationals may first determine an abatement investment target and subsequently engage in tax avoidance to support this target. In the absence of such tax avoidance opportunities, firms might have to revise their planned level of abatement investments.

in greener technologies, resulting in a negative association between profit shifting and investments in abatement technologies.[30]

Table 9 presents the results, which are consistent with a negative association between profit shifting and investments in abatement technologies. Economically, a one–standard-deviation increase in *Shifted Profit Share* within a group (equal to 0.66 overall SDs) is associated with a reduction in three-year cumulative abatement-related investments equal to 1.8-1.9% of lagged total assets. Moreover, in a supplemental test, we find that, instead of investing, firms appear to increase their cash holdings when shifting more profits (see Table C.5 in the Online Appendix). Collectively, these findings suggest that profit-shifting behavior weakens firms' incentives to invest in decarbonization, implying that tax avoidance through carbon allowances may hinder firms' progress toward emission reductions. Again, we highlight that this result does not reflect a causal relation.

4.4.4 Verified Emissions

Finally, we examine the association between profit shifting and carbon emissions. To this end, we use the verified emissions over the years t to $t + 2$. These are the emissions based on surredered allowances, i.e., emissions under the EU ETS that required the surrender of allowances. In Figure C.4, we show that corporate groups with an active international trading hub exhibit higher verified carbon emissions than when such a hub is absent.

In the next step, we use the three-year cumulative verified emissions as the dependent variable. The model now includes group-fixed effects as well as industry $\times$ year fixed effects to account for substantial cross-industry variation in emissions. We include industry $\times$ year fixed effects because industries differ markedly in their baseline emissions and in their decarbonization opportunities. The results, reported in Table 10, show a positive association between profit shifting and emissions. This association suggests that firms that engage in profit shifting with carbon allowances appear to exhibit higher verified carbon emissions. In economic terms, a one–standard-deviation increase

[30] Consider a simple example in which the cost of an abatement investment needed to eliminate emissions is EUR 65, while the market price of a carbon allowance is EUR 70. In this case, the firm would prefer to invest in the abatement technology. However, if profit shifting with carbon allowances reduces the net carbon price faced by the firm to below EUR 65, the firm would no longer invest and would instead find it cheaper to continue emitting.

in *Shifted Profit Share* within a group corresponds to a 9 to 12% increase in verified emissions in the EU over a three-year period. This evidence further supports the conclusion that tax avoidance through carbon-allowance transactions is associated with poorer environmental performance and that tax-induced profit shifting may undermine policy efforts to reduce carbon emissions.

5 Conclusion

This paper provides evidence on how multinationals use internal carbon-allowance trading to shift profits from high-tax to low-tax jurisdictions and thereby reduce their effective tax rates. Drawing on comprehensive transaction-level data from the EU Emissions Trading System linked with firm-level accounting and ownership information, we document that more than one-third of multinational groups in the EU ETS operate internal trading hubs—often located in tax havens or in countries with preferential tax regimes such as Switzerland, the Netherlands, or Jersey—that facilitate tax-motivated cross-border transfers of emission allowances. These transactions generate substantial tax savings at the group level by reallocating profits from operating entities in high-tax jurisdictions, including Germany, France, and the United Kingdom, to hubs in low-tax countries or tax havens.

Beyond uncovering this new channel of profit shifting, our findings suggest that there might be an unintended consequence of corporate tax avoidance. Taken at face value, our results imply that tax avoidance weakens the environmental incentives embedded in carbon-pricing systems. We document that greater tax-induced trading of emission allowances is associated with lower subsequent investments in decarbonization technologies and with greater verified emissions. One implication of this finding is that tax avoidance dampens the disciplining role of carbon pricing. More broadly, our results underscore that environmental and tax policies and, in particular, anti-tax avoidance rules cannot be designed in isolation; effective climate policy requires careful coordination with tax policy. Aligning the tax treatment of carbon allowances with the objectives of cap-and-trade systems is essential to prevent tax-induced profit shifting to low-tax jurisdictions, which can undermine both tax revenues and the effectiveness of climate policy.

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Figure 1: **The evolution of the price of European Union Allowance (EUA)**

This figure plots the spot price of European Union Allowance (EUA) from 2014 through the end of 2020. This sample period features a unified and fully fungible allowance design, centralized registry infrastructure, harmonized auctioning, and unrestricted banking.

Figure 2: **Illustrating tax avoidance with carbon allowances**

This figure illustrates a stylized example of how a multinational enterprise can reduce its overall tax burden by internally trading carbon allowances through a low-tax trading hub. The plant (located in a high-tax country) requires one carbon allowance to surrender, while the trading hub (located in a 10 %-tax jurisdiction) purchases one allowance at EUR 50 (Step 1). When the plant later needs to surrender the allowance at a market price of EUR 70, the hub transfers the allowance internally at this price (Step 2). The hub realizes a EUR 20 profit taxed at 10 %, while the plant recognizes a EUR 70 expense deductible at 30 % upon surrender (Step 3). Compared with a case without tax planning (expense = EUR 50), the group saves EUR 4 in taxes—equivalent to 8 % of the initial allowance price. The mechanism also applies when the allowance was received for free, as described in the text.

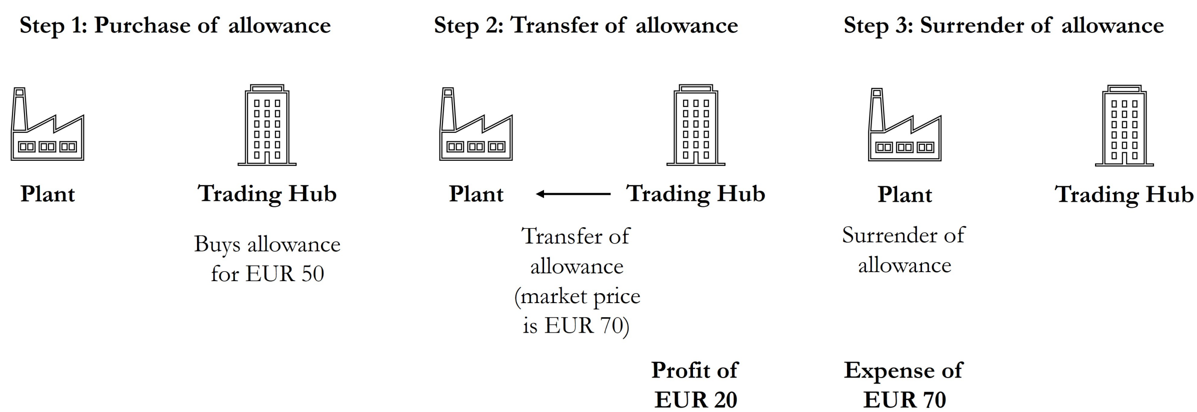


Figure 3: **Illustrating tax avoidance with carbon allowances: The case of Dow Inc.**

This figure maps Dow's European structure of operating entities and its internal carbon-allowance trading hub. Rectangles represent operating entities that produce emissions and surrender allowances; the circle denotes the group's central trading hub, Dow Europe GmbH, located in Switzerland. Arrows indicate within-group carbon-allowance transfers between the hub and operating entities in Germany, Belgium, the United Kingdom, the Netherlands, Portugal, Spain, and France. The Dow Chemical Company operates a U.S.-registered aircraft operator that, by virtue of operating flights arriving at or departing from EU aerodromes, must surrender allowances to cover the emissions of its European routes. Over 2014–2020, Dow transferred approximately 9.7 million allowances ($\approx$ EUR 111.79 million) to the Swiss hub and received 29 million allowances ($\approx$ EUR 328.37 million) from it. The hub's location in a 14 %-tax jurisdiction, contrasted with 25–30 % rates in the operating countries, implies substantial tax savings. The estimated profits from internal transfers reached EUR 217 million over the period, translating into tax reductions of roughly EUR 24–35 million and lowering Dow's 2019 global tax expense by about 2 %.

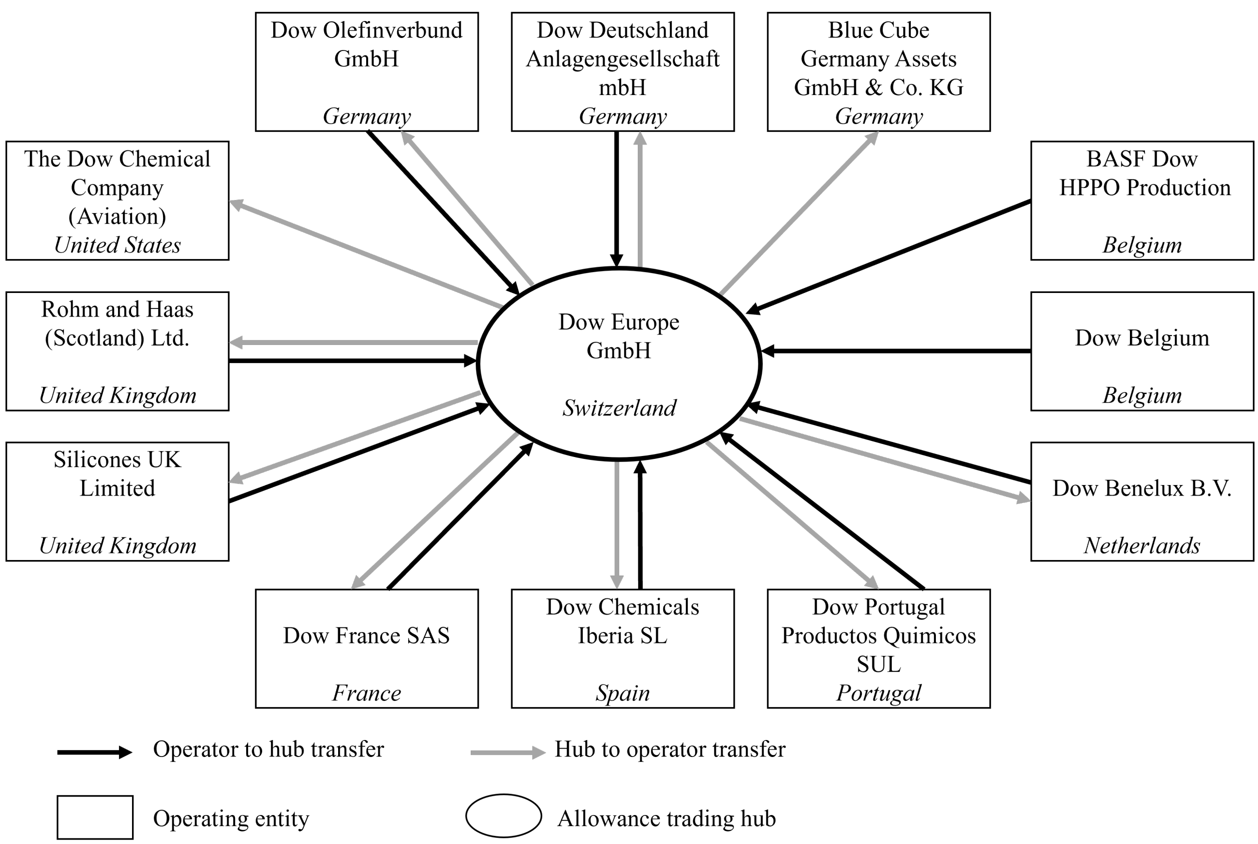


Figure 4: **Illustrating tax avoidance with carbon allowances: The case of Ineos Group Limited**

This figure depicts the structure of Ineos Group's European operations and the internal trading of carbon allowances across its multiple hubs. Rectangles represent operating entities with verified surrender obligations under the EU ETS; circles denote trading hubs located in low-tax jurisdictions, namely Ineos Europe AG (Switzerland), Petroineos Trading Ltd (Jersey), and Ineos Fluor Ltd (United Kingdom). Arrows indicate the direction of intra-group allowance flows between the hubs and operating entities in Belgium, Germany, Denmark, Spain, and France. Between 2014 and 2020, Ineos transferred about 31.6 million allowances (≈ EUR 438.73 million) to its hubs and received 44.2 million allowances (≈ EUR 622.18 million) in return, with most inflows directed to Germany, the UK, and France. The Swiss and Jersey hubs—taxed at 14 % and 0 %, respectively—generated combined profits of roughly EUR 33 million per year in 2017–2019, producing an estimated EUR 5.1 million in tax savings in 2019 (≈ 2.39 % of Ineos's tax expense).

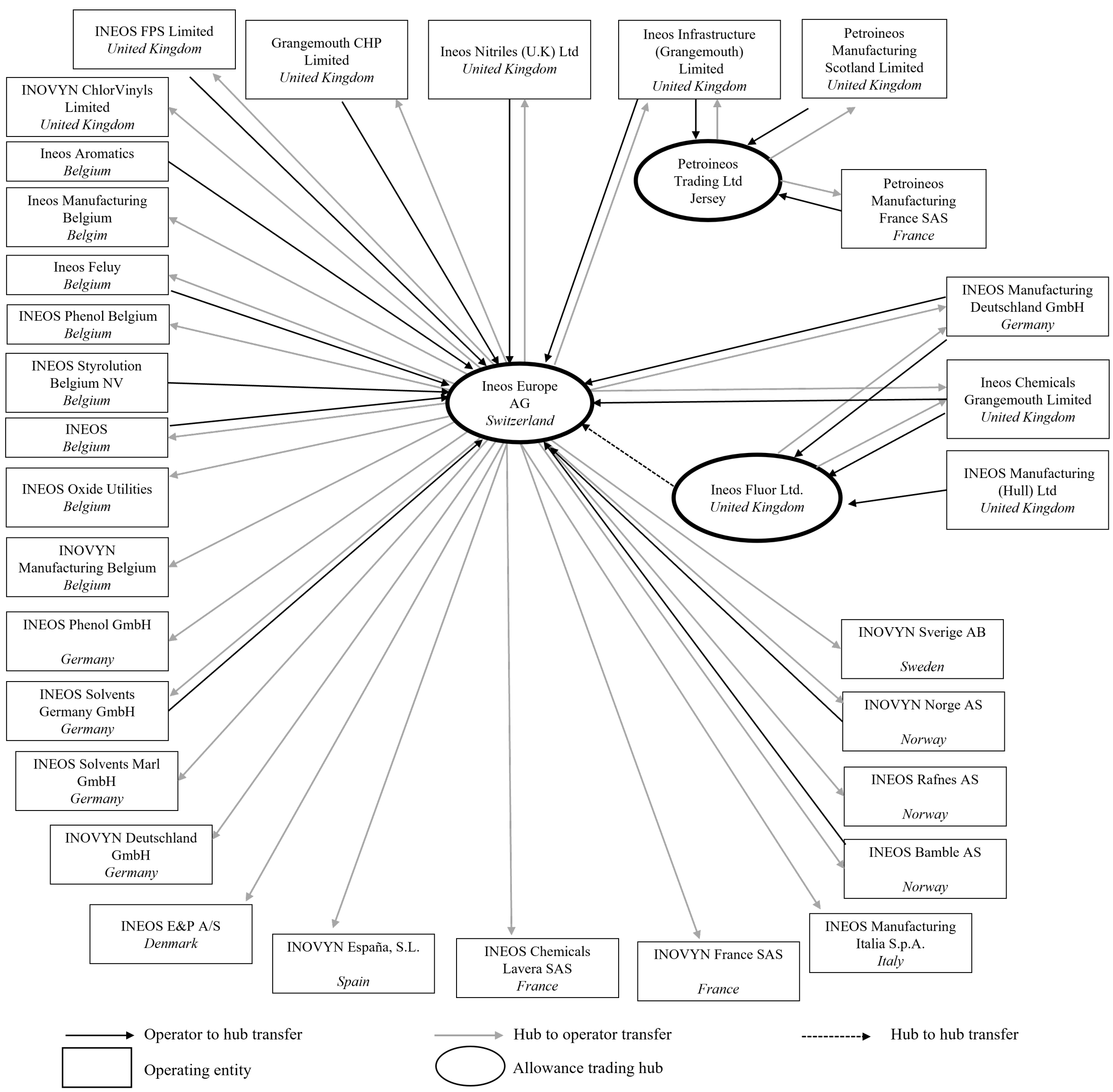


Figure 5: **Sample descriptives: Operators and non-operators**

This figure presents the distribution of entities across multinational groups involved in cross-border intra-group carbon-allowance transactions, distinguishing between operators (subsidiaries with verified surrender obligations) and trading hubs (subsidiaries without such obligations). Panel (a) shows the distribution of the number of operating entities. Panel (b) displays the number of hubs per group. Panels (c) and (d) separate hubs into international (where more than 50% of intra-group trading volume is cross-border) and local (within-country) hubs.

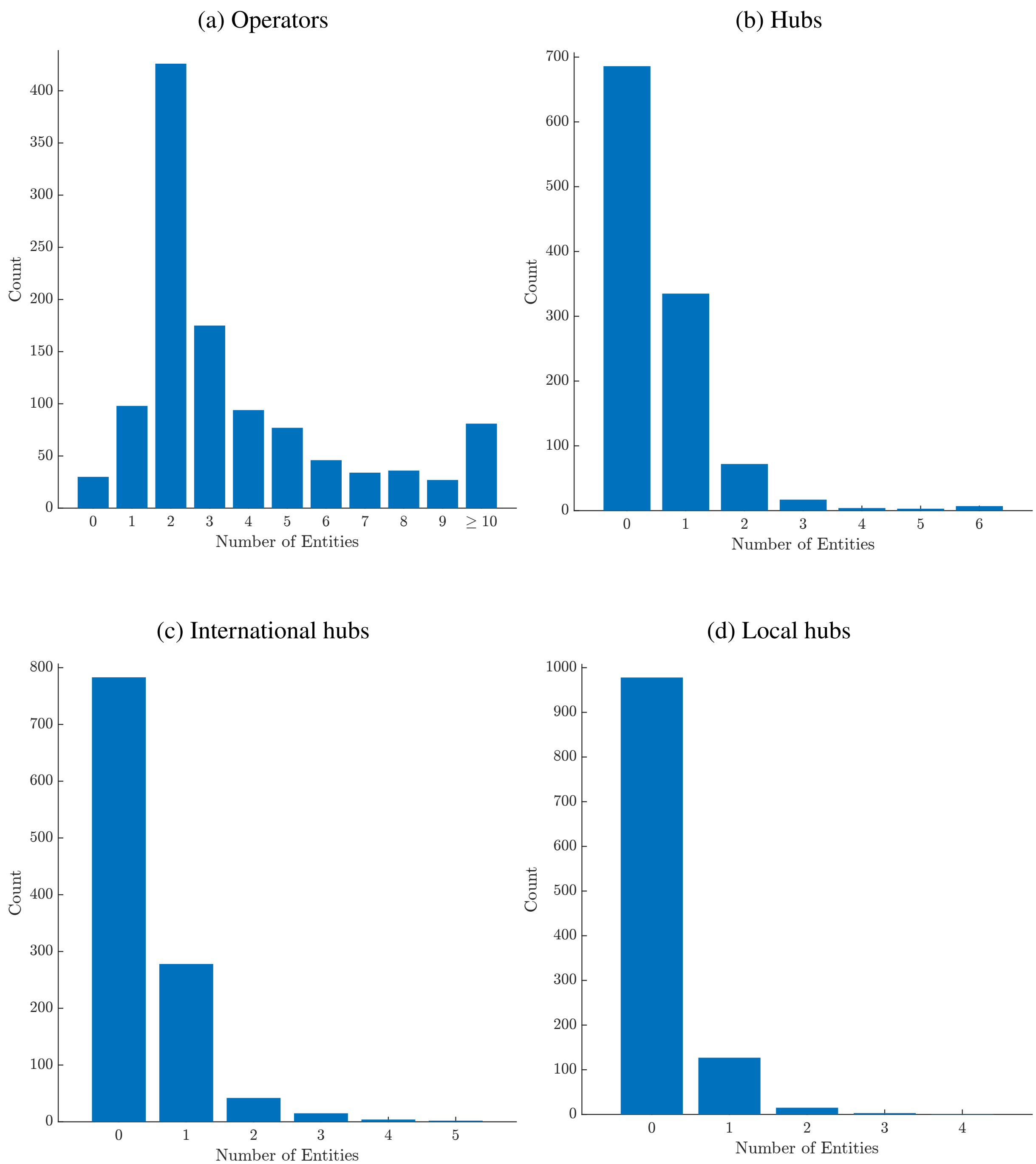


Figure 6: **Trends in local and international hubs, 2014–2020**

This figure shows the evolution of local and international trading hubs used in cross-border intra-group carbon-allowance transactions from 2014 to 2020. A hub is classified as international if more than 50 % of its total intra-group transaction volume is cross-border and as local otherwise. The number of local hubs remains relatively stable at around 20–27 throughout the period, whereas the number of international hubs increases markedly after 2018—from 52 in 2017 to 78 in 2020. This upward trend indicates a growing use of cross-border hubs for internal carbon-allowance trading, consistent with rising tax-motivated profit-shifting activity among multinational groups participating in the EU ETS.

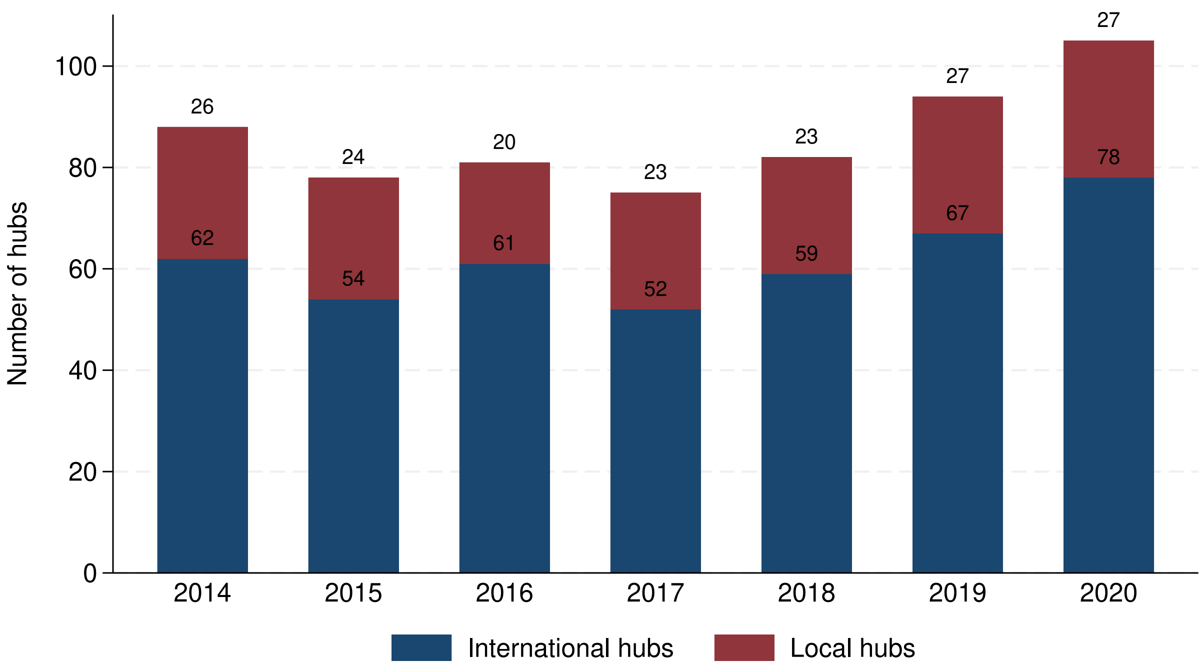


Figure 7: **Geographic distribution of hubs and operators**

This figure shows the geographical distribution of trading hubs and operators involved in cross-border intra-group carbon-allowance transactions under the EU ETS. Bars (left axis) report the number of hubs by country, where the blue segments represent international hubs—those for which more than 50% of total intra-group trading volume is cross-border—and the gray segments represent local hubs that mainly trade domestically. The black line (right axis) indicates the number of operators, i.e., subsidiaries with verified surrender obligations. Countries with blue-bordered bars denote preferential tax regimes, including Switzerland (CH) and the Netherlands (NL). Countries with red-bordered bars denote tax havens, including Singapore (SG), Ireland (IE), Jersey (JE), Luxembourg (LU), and Cyprus (CY). The figure shows that operators are concentrated in high-tax manufacturing economies such as Germany, the United Kingdom, France, Spain, Belgium, and Italy, whereas hubs—particularly international hubs—are clustered in preferential-tax and haven jurisdictions. Few operators are located in Switzerland, Jersey, Singapore, or Cyprus, underscoring the role of these low-tax countries as internal trading centers for profit shifting through carbon-allowance transactions.

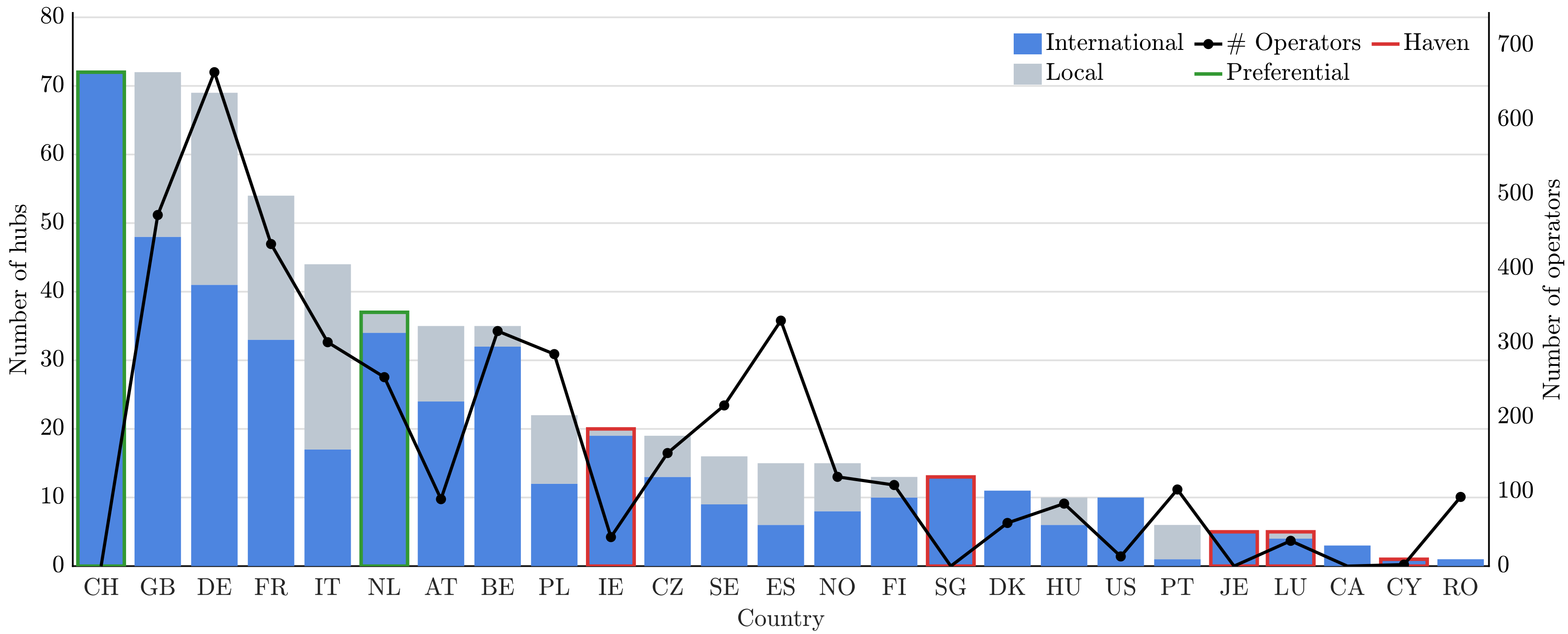


Figure 8: **Comparison of absolute flows and surrendered amounts across countries**

This figure compares, for each country in the cross-border intra-group sample, the absolute value of intra-group carbon-allowance flows (blue bars) with the verified amount of surrendered allowances (yellow bars).“Absolute flow” measures the absolute value of net intra-group cross-border transaction flows across all entities, capturing the total magnitude of intra-group financial activity irrespective of direction. “Surrendered” indicates the verified allowances submitted under the EU ETS. The figure shows that countries such as Germany, France, the United Kingdom, Spain, and Belgium dominate in verified surrender amounts, consistent with their large manufacturing bases. In contrast, Switzerland, Jersey, Luxembourg, and Singapore exhibit substantial intra-group trading volumes but almost no surrendered emissions, confirming that entities in these low-tax jurisdictions function primarily as trading hubs rather than as operating facilities. The stark divergence between high surrender activity in production economies and high transaction volumes in low-tax locations underscores the profit-shifting nature of internal carbon-allowance transfers.

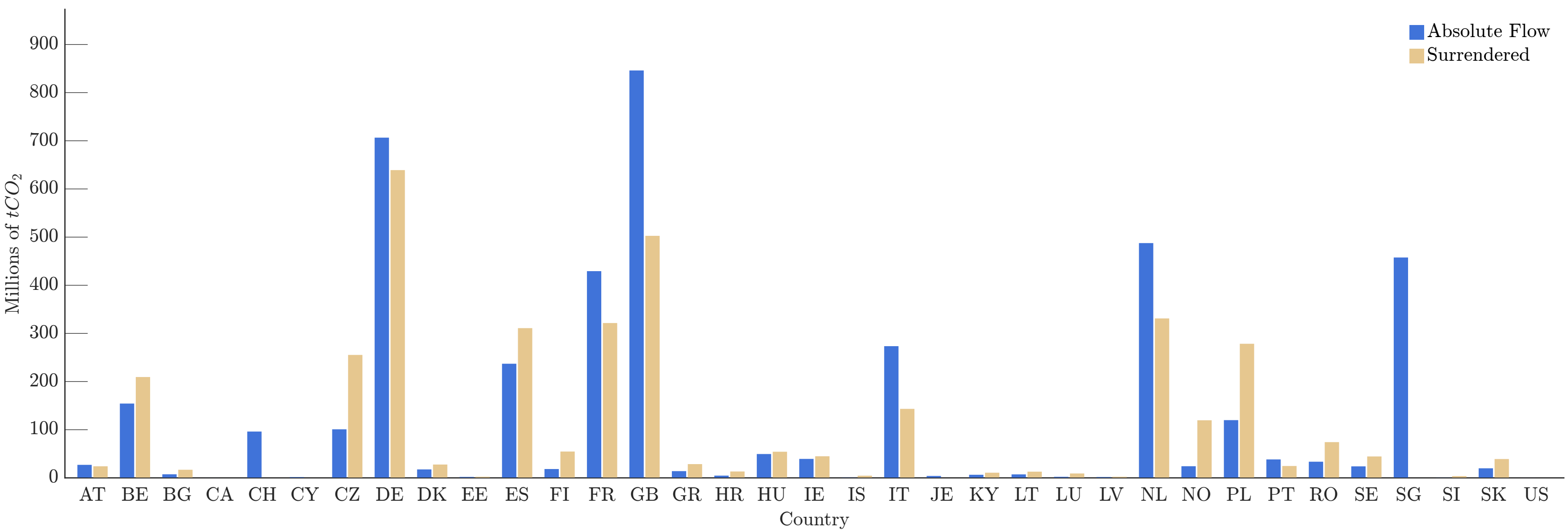
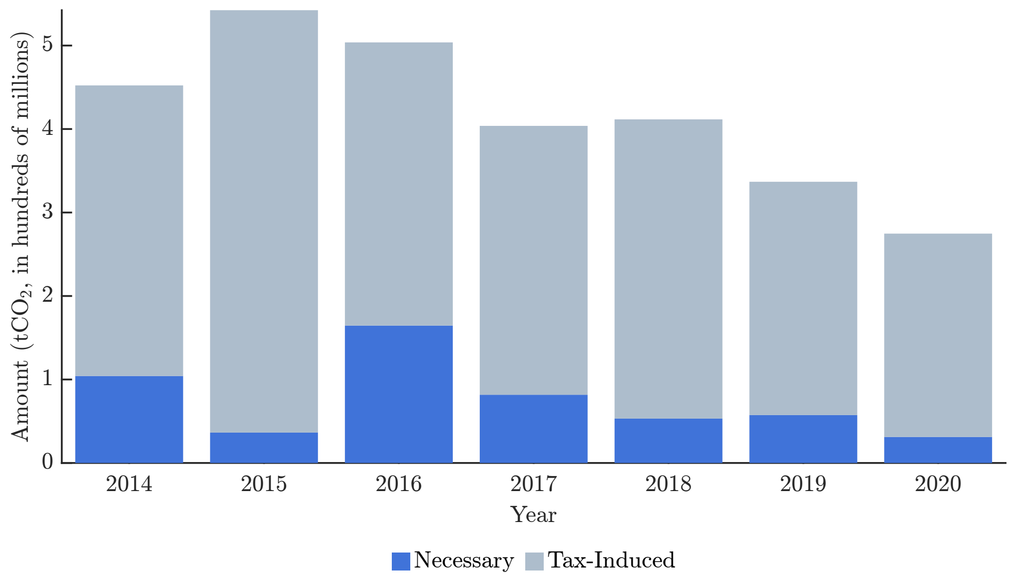


Figure 9: **Aggregate profit shifting from carbon allowance transactions by year**

This figure presents the evolution of cross-border intra-group carbon-allowance transactions between 2014 and 2020. Panel (a) shows the total amount of traded allowances (in hundreds of millions of tCO_2), distinguishing between transfers driven by operational necessity—that is, cases where subsidiaries' verified surrender obligations exceed free allocations—and those that are tax-induced, reflecting transactions not required for compliance. Panel (b) reports the corresponding monetary values (in EUR billions) based on contemporaneous EU ETS spot prices. Across both panels, the volume of tax-induced transactions exceeds operational ones throughout the sample period. Total transaction volumes peaked in 2015 and declined thereafter, while the traded values surged in 2018-2020 amid rising carbon prices. Together, the panels highlight that the majority of intra-group allowance transfers are economically large and primarily tax-motivated, rather than driven by production or compliance needs.

(a) Amount



(b) Amount in EUR

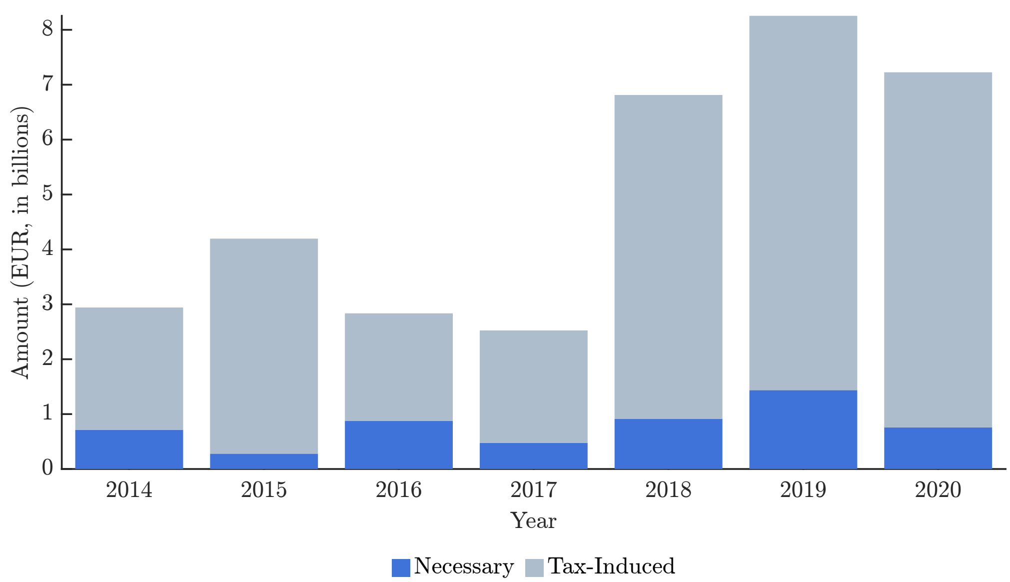


Table 1: **Sample selection**

This table presents details on the selection of the sample used in our main analyses. All variables are defined in the Appendix.

Selection Step	Observations	Entities	Groups
All transactions (2014–2020)	177,710		
Intra-group cross-border transactions (2014–2020, excluding financial companies)	14,933		326
Less: Groups primarily engaged in environmental services, climate initiatives, or capital solutions	-815		-13
Less: Groups in the aviation industry	-316		-25
Converted to entity–year level observations	5,117	1,481	288
Less: Entities do not have a full fiscal year in the sample	-14	-1	0
Less: Entities jointly held by multiple groups with intra-group transactions across groups	-28	-0	0
Operators	4,472		
Hubs	603		
Entities included in Tables 3–5	1,600	536	95
Entities included in Table 6	2,676	785	100
Operators included in Table 7	3,631	1,090	270

Table 2: **Descriptive statistics**

This table presents descriptive statistics for the variables employed in our analyses. Panels A, B, and C present descriptive statistics for the sample at the subsidiary-level. Panel D presents descriptive statistics for the sample at the group-level. All continuous variables in Panels A and D are winsorized at the 1% and 99% levels.

Variable	N	Mean	SD	p25	p50	p75
Panel A: Financial characteristics						
Inbound Profit Share	4037	-0.0051	0.0618	-0.0055	-0.0004	0.0010
Surrender–Allocation Gap	4465	0.7164	1.8485	-0.1323	0.3668	1.6262
Assets	4135	19.3998	1.7916	18.2498	19.2883	20.5008
Leverage	4125	0.5868	0.3306	0.3659	0.5588	0.7623
Tangible Ratio	4134	0.5388	0.2515	0.3663	0.5679	0.7456
ROA	4083	0.0441	0.1333	0.0013	0.0391	0.0976
ROA (Exclude Carbon)	4083	0.0464	0.1562	0.0008	0.0419	0.1036
Carbon Profit	5075	-0.2722	2.1371	-1.1965	-0.1008	0.4745
Panel B: Tax variables						
Effective Tax Rate	3006	0.2014	0.1937	0.0574	0.1902	0.2639
Panel C: Hub classifications						
International Hub	5075	0.0853	0.2794	0	0	0
Local Hub	5075	0.0335	0.1799	0	0	0
Collect Hub	5075	0.0309	0.1732	0	0	0
Balance Hub	5075	0.0215	0.1450	0	0	0
Supply Hub	5075	0.0664	0.2490	0	0	0
Opaque Hub	5075	0.0400	0.1960	0	0	0
Transparent Hub	5075	0.0788	0.2695	0	0	0
Panel D: Group-level variables						
3-year Scope 1 Abatement	957	0.0181	0.0709	0.0001	0.0007	0.0040
3-year Scope 1–3 Abatement	957	0.0232	0.0826	0.0003	0.0014	0.0067
Shifted Profit Share (unstandardized)	957	0.0286	0.1064	0	0	0.0042
3-year Cash ETR	812	0.2905	0.1873	0.1840	0.2570	0.3379
Verified Emissions	810	14.7857	2.3899	13.0776	14.7925	16.7187
Asset	957	23.9349	1.2651	23.0160	23.9669	24.8361
ROA	957	0.0517	0.0546	0.0264	0.0506	0.0750
Leverage	957	0.2348	0.1171	0.1600	0.2192	0.3036
Cash	957	0.0922	0.0637	0.0446	0.0815	0.1226

Table 3: **Hub status and effective tax rate**

This table reports the results of estimating equation (1) using the subsidiary-level sample. The dependent variable is *Effective Tax Rate*, defined as $\min\{1, \max(0, \texttt{taxa}/\texttt{plbt})\}$, where `taxa` denotes income tax expenses and `plbt` denotes profit before tax. Observations with negative `plbt` are set to missing. For the remaining observations, ETR values below 0 are truncated at 0 and values above 1 are truncated at 1; missing values are otherwise retained. The primary independent variable is *Hub*, an indicator equal to 1 if the entity is a hub in year t. In columns (3) and (4), the independent variables are *International Hub* and *Local Hub*, respectively. *International Hub* (*Local Hub*) equals 1 if the entity is a hub with a cross-border ratio > 0.5 ($\leqslant 0.5$), where *Cross-Border Ratio* is defined as the share of a hub's total allowance transactions that are cross-border intra-group. Control variables include *Asset*, *ROA*, *Leverage*, *Tangible Ratio*, and *Tax Rate*. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. All regressions include either group- and year-fixed effects or group-by-year fixed effects, as indicated. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Effective Tax Rate			
	(1)	(2)	(3)	(4)
Hub	-0.0696**	-0.0685**		
	(0.0277)	(0.0320)		
International Hub			-0.0746**	-0.0732**
			(0.0305)	(0.0360)
Local Hub			-0.0594	-0.0584
			(0.0364)	(0.0437)
Controls	Yes	Yes	Yes	Yes
Group FE	Yes		Yes	
Year FE	Yes		Yes	
Group $\times$ Year FE		Yes		Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary	Subsidiary
N	1593	1507	1593	1507
Adj. R^2	0.08	0.02	0.08	0.02

Table 4: **Hub function and effective tax rate**

This table reports the results of estimating equation (1) using the subsidiary-level sample. The dependent variable is *Effective Tax Rate*, defined as $\min\{1, \max(0, \texttt{taxa}/\texttt{plbt})\}$, where `taxa` denotes income tax expenses and `plbt` denotes profit before tax. Observations with negative `plbt` are set to missing. For the remaining observations, ETR values below 0 are truncated at 0 and values above 1 are truncated at 1; missing values are otherwise retained. The independent variables classify hubs according to their intra-group trading patterns. A *Collect Hub* (*Supply Hub*) is a hub with a sell ratio < 0.4 ($\geqslant 0.6$), while a *Balance Hub* has a sell ratio between 0.4 and 0.6. The sell ratio is defined as the volume of intra-group sales divided by total intra-group transaction volume (sales plus purchases). All hub indicators equal 1 if the entity is identified as a hub in year t based on EU ETS transaction data. Control variables include *Asset*, *ROA*, *Leverage*, *Tangible Ratio*, and *Tax Rate*. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Effective Tax Rate		
	(1)	(2)	(3)
Collect Hub	-0.0245	-0.0497	-0.0410
	(0.0388)	(0.0414)	(0.0507)
Balance Hub	-0.1055***	-0.1117***	-0.1406***
	(0.0280)	(0.0319)	(0.0327)
Supply Hub	-0.0518*	-0.0564*	-0.0425
	(0.0295)	(0.0311)	(0.0365)
Controls	Yes	Yes	Yes
Group FE		Yes	
Year FE	Yes	Yes	
Group×Year FE			Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary
N	1600	1593	1507
Adj. R^2	0.04	0.08	0.02

Table 5: **Interaction of hub function and cross-border classification and effective tax rates**

This table reports the results of estimating equation (1) using the subsidiary-level sample, where the independent variables capture the interaction between hub functions and cross-border classifications. The dependent variable is *Effective Tax Rate*, defined as $\min\{1, \max(0, \texttt{taxa}/\texttt{plbt})\}$, where `taxa` denotes income tax expenses and `plbt` denotes profit before tax. Observations with negative `plbt` are set to missing. For the remaining observations, ETR values below 0 are truncated at 0 and values above 1 are truncated at 1; missing values are otherwise retained. A *Collect Hub*, *Balance Hub*, or *Supply Hub* equals 1 if the entity is a hub with a sell ratio < 0.4, between 0.4 and 0.6, or $\geqslant 0.6$, respectively, where the sell ratio is defined as intra-group sales divided by total intra-group transaction volume (sales plus purchases). An *International Hub* (*Local Hub*) equals 1 if the entity is a hub with a cross-border ratio > 0.5 ($\leqslant 0.5$), where the cross-border ratio measures the share of a hub's total allowance transactions that are cross-border intra-group. The interaction terms combine these classifications to assess whether international balance hubs exhibit the strongest tax advantages relative to other hub types. Control variables include *Asset*, *ROA*, *Leverage*, *Tangible Ratio*, and *Tax Rate*. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Effective Tax Rate		
	(1)	(2)	(3)
Collect × International Hub	-0.0321	-0.0603	-0.0502
	(0.0401)	(0.0457)	(0.0555)
Collect × Local Hub	0.0077	-0.0071	0.0020
	(0.1043)	(0.0775)	(0.1058)
Balance × International Hub	-0.1161***	-0.1201***	-0.1447***
	(0.0256)	(0.0328)	(0.0391)
Balance × Local Hub	-0.0894*	-0.0984**	-0.1338***
	(0.0538)	(0.0488)	(0.0426)
Supply × International Hub	-0.0584*	-0.0589*	-0.0475
	(0.0311)	(0.0334)	(0.0393)
Supply × Local Hub	-0.0440	-0.0539	-0.0352
	(0.0464)	(0.0464)	(0.0576)
Controls	Yes	Yes	Yes
Group FE		Yes	
Year FE	Yes	Yes	
Group×Year FE			Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary
N	1600	1593	1507
Adj. R^2	0.03	0.08	0.02

Table 6: **Opaque versus transparent hubs**

This table reports the results of comparing opaque and transparent trading hubs using the subsidiary-level sample. The dependent variables are *Tax Rate* and *Carbon Profit*. *Tax Rate* is the statutory corporate income tax rate in the hub's country. *Carbon Profit* measures net gains from intra-group cross-border transactions, defined as revenues from cross-border intra-group sales minus costs from intra-group purchases, scaled by the median absolute net gains and transformed using the inverse hyperbolic sine. *Opaque Hub* equals 1 if the entity is identified as a hub but unconsolidated financial information is unavailable in Orbis, whereas *Transparent Hub* equals 1 if unconsolidated fundamentals are available. All regressions include either group- and year-fixed effects or group-by-year fixed effects, as indicated. Standard errors are clustered at the subsidiary level and reported in parentheses. The rows labeled p (Opaque Hub = Transparent Hub) and F (Opaque Hub = Transparent Hub) report, respectively, the p-values and F-statistics from a linear Wald test of the null hypothesis $H_0: \beta_{\text{Opaque}} - \beta_{\text{Transparent}} = 0$ in each specification. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Tax Rate		*Carbon Profit*	
	(1)	(2)	(3)	(4)
Opaque Hub	-0.0352***	-0.0358***	2.8065***	2.9599***
	(0.0111)	(0.0118)	(0.4988)	(0.5482)
Transparent Hub	0.0003	0.0004	1.4685***	1.4740***
	(0.0075)	(0.0081)	(0.3169)	(0.3513)
Group FE	Yes		Yes	
Year FE	Yes		Yes	
Group$\times$Year FE		Yes		Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary	Subsidiary
N	2675	2672	2675	2672
Adj. R^2	0.24	0.18	0.12	0.02
p (Opaque Hub = Transparent Hub)	0.004	0.007	0.017	0.018
F (Opaque Hub = Transparent Hub)	8.261	7.366	5.695	5.614

Table 7: **Flow of Carbon Allowances among Operators**

This table reports the results of estimating equation (2) using the sample of subsidiaries that act as operators, i.e., entities with verified surrender obligations under the EU ETS. The dependent variable is *Inbound Profit Share*, defined as the share of a subsidiary's net revenue attributable to cross-border intra-group carbon-allowance transactions, calculated as sales to foreign affiliates minus purchases from foreign affiliates, scaled by total revenue. The key explanatory variables include firm characteristics: *Asset* (natural logarithm of total assets), *ROA (Exclude Carbon)* (return on assets excluding gains or losses from carbon-allowance trading), *Leverage* (total liabilities divided by total assets), *Tangible Ratio* (fixed assets over total assets), *Tax Rate* (statutory corporate tax rate in the entity's country), and *Surrender–Allocation Gap*, which measures the difference between verified surrenders and free allocations, scaled by the median absolute value and transformed using the inverse hyperbolic sine. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. All regressions include combinations of group, year, country-by-year, group-by-year, and subsidiary fixed effects as indicated. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Inbound Profit Share				
	(1)	(2)	(3)	(4)	(5)
Asset	0.0037***	0.0036***	0.0040***	0.0037**	0.0050
	(0.0013)	(0.0013)	(0.0015)	(0.0015)	(0.0049)
ROA (Exclude Carbon)	-0.0689***	-0.0659***	-0.0694***	-0.0649***	-0.0504***
	(0.0198)	(0.0205)	(0.0203)	(0.0205)	(0.0142)
Leverage	-0.0173***	-0.0154**	-0.0151**	-0.0129*	-0.0331***
	(0.0062)	(0.0062)	(0.0067)	(0.0067)	(0.0109)
Tangible Ratio	-0.0193**	-0.0185**	-0.0218**	-0.0200**	-0.0047
	(0.0077)	(0.0077)	(0.0087)	(0.0088)	(0.0187)
Tax Rate	-0.0104	0.0295	-0.0152	-0.0613	-0.0741
	(0.0190)	(0.1555)	(0.0208)	(0.2184)	(0.0739)
Surrender–Allocation Gap	-0.0057***	-0.0048***	-0.0059***	-0.0049***	0.0017
	(0.0010)	(0.0010)	(0.0012)	(0.0012)	(0.0046)
Constant	-0.0483**	-0.0578	-0.0530*	-0.0389	-0.0639
	(0.0245)	(0.0480)	(0.0275)	(0.0660)	(0.1000)
Group FE	Yes	Yes			
Year FE	Yes				
Country×Year FE		Yes		Yes	
Group×Year FE			Yes	Yes	Yes
Subsidiary FE					Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary	Subsidiary	Subsidiary
N	3599	3583	3423	3399	3104
Adj. R^2	0.21	0.27	0.19	0.25	0.40

Table 8: **Future 3-year Cash ETR and profit shifting**

This table reports the results of estimating equation (3) using the group-level sample. The dependent variable is *3-year Cash ETR*, defined as the sum of cash taxes paid in years t to $t + 2$ divided by the sum of pretax income over the same period. The ratio is set to 0 if the numerator is negative, set to missing if the denominator is negative, and capped at 1 if the computed value exceeds 1 and is non-missing. The key independent variable is *Shifted Profit Share*, defined as the standardized value of tax-induced intra-group carbon-allowance trading profits (total shifted profit minus necessary shifted profit) scaled by total assets. All specifications control for group-level *Asset*, *ROA*, *Leverage*, and *Cash*. Samples are defined as follows: *All* includes all groups in the panel; *Ever* includes groups that ever engage in cross-border intra-group transactions at any time in the sample window; *CDP* restricts to groups with CDP coverage. All continuous variables are winsorized at the 1% and 99% levels. All regressions include group- and year-fixed effects. Standard errors are clustered at the group level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	3-year Cash ETR		
	(1)	(2)	(3)
Shifted Profit Share	-0.1149***	-0.1128***	-0.1481***
	(0.0414)	(0.0415)	(0.0466)
Sample	All	Ever	CDP
Controls	Yes	Yes	Yes
Group FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
S.E. clustered by	Group	Group	Group
N	1411	928	556
Adj. R^2	0.50	0.53	0.52

Table 9: **Decarbonization investments and profit shifting**

This table reports the results of estimating equation (3) using the group-level sample to examine the relationship between profit shifting and subsequent decarbonization investments. The dependent variables are three-year cumulative abatement intensities: *3-year Scope 1 Abatement* and *3-year Scope 1-3 Abatement*. *3-year Scope 1 Abatement* is defined as the three-year sum of investments in projects that reduce Scope 1 emissions (pure and mixed abatement types) divided by lagged total assets, while *3-year Scope 1-3 Abatement* extends the numerator to include all abatement projects covering Scopes 1, 2, and 3. The key independent variable is the standardized value of *Shifted Profit Share*, defined as tax-induced intra-group carbon-allowance trading profits (total shifted profit minus necessary shifted profit) scaled by total assets. Samples are defined as follows: *All* includes all groups in the panel; *Ever* includes groups that ever engage in cross-border intra-group transactions at any point in the sample period; and *Current* includes only groups that engage in cross-border intra-group transactions in year t. Control variables include *Asset*, *ROA*, *Leverage*, and *Cash*. All continuous variables are winsorized at the 1% and 99% levels. All regressions include group- and year-fixed effects. Standard errors are clustered at the group level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	3-year Scope 1 Abatement			*3-year Scope 1-3 Abatement*		
	(1)	(2)	(3)	(4)	(5)	(6)
Shifted Profit Share	-0.0269*	-0.0257**	-0.0242*	-0.0284*	-0.0278*	-0.0274*
	(0.0140)	(0.0129)	(0.0127)	(0.0155)	(0.0144)	(0.0144)
Sample	All	Ever	Current	All	Ever	Current
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
S.E. clustered by	Group	Group	Group	Group	Group	Group
N	933	650	424	933	650	424
Adj. R^2	0.49	0.47	0.44	0.53	0.53	0.51

Table 10: **Verified emissions and profit shifting**

This table reports the results of estimating equation (3) using the group-level sample. The dependent variable is *3-year Verified Emissions*), computed as the natural logarithm of the three-year cumulative verified emissions. The key independent variable is the standardized value of *Shifted Profit Share*, which measures the proportion of profits shifted through intra-group transactions relative to the total profits of the multinational group. Column (1) uses the full sample, column (2) restricts to groups that have ever engaged in cross-border intra-group transactions, and column (3) focuses on groups with current-year cross-border intra-group transactions. All specifications include controls for group characteristics (*Asset*, *ROA*, *Leverage*, and *Cash*), as well as group- and industry-by-year fixed effects. All continuous variables are winsorized at the 1% and 99% levels. Standard errors are clustered at the group level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	3-year Verified Emissions		
	(1)	(2)	(3)
Shifted Profit Share	0.1205	0.1431*	0.1810*
	(0.0854)	(0.0804)	(0.0993)
Sample	All	Ever	Current
Controls	Yes	Yes	Yes
Group FE	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes
S.E. clustered by	Group	Group	Group
N	720	518	353
Adj. R^2	0.90	0.97	0.96

Table A: **Variable definitions**

Variable name	Definition	Source
Subsidiary-level variables		
Inbound Profit Share	Share of a subsidiary's net revenue attributable to cross-border intra-group carbon allowance transactions. Calculated as sales to foreign affiliates minus purchases from foreign affiliates, scaled by total revenue. *Formula:* $\text{Inbound Shifting Share}_{i,t} = \frac{\text{Sales to foreign affiliates}_{i,t} - \text{Purchases from foreign affiliates}_{i,t}}{\text{Total revenue}_{i,t}}$	EU ETS
Surrender–Allocation Gap	The difference between verified surrenders and free allocations, scaled by the median of its absolute value, and transformed using the inverse hyperbolic sine (asinh) function.	EU ETS
Cross-Border Ratio	Share of a hub's total allowance transactions that are cross-border intra-group. Computed as cross-border purchases plus sales, divided by total purchases plus sales. *Formula:* $\text{Cross-border Ratio}_{i,t} = \frac{\text{Cross-border purchases}_{i,t} + \text{sales}_{i,t}}{\text{Total purchases}_{i,t} + \text{sales}_{i,t}}$	EU ETS
International Hub	Equals 1 if the entity is a hub (no free allocations or surrenders) and cross-border ratio > 0.5.	EU ETS
Local Hub	Equals 1 if the entity is a hub and cross-border ratio $\leqslant 0.5$.	EU ETS
Hub	Equals 1 if the entity is a hub in year t.	EU ETS
Sell Ratio	Share of a hub's intra-group transactions that are sales. Computed as sales divided by total intra-group volume (purchases + sales). *Formula:* $\text{Sell Ratio}_{h} = \frac{\text{Sales to intra-group counterparties}_{h,t}}{\text{Total intra-group volume}_{h,t}}$	EU ETS
Collect Hub	Equals 1 if entity is a hub and sell ratio < 0.4.	EU ETS
Balance Hub	Equals 1 if entity is a hub and $0.4 \leqslant$ sell ratio < 0.6.	EU ETS
Supply Hub	Equals 1 if entity is a hub and sell ratio $\geqslant 0.6$.	EU ETS
Opaque Hub	Equals 1 if entity is a hub but unconsolidated fundamentals are not available in Orbis.	EU ETS; Orbis
Transparent Hub	Equals 1 if entity is a hub with unconsolidated fundamentals available in Orbis.	EU ETS; Orbis

Continued on next page

Table A: **Variable definitions** (Continued)

Variable name	**Definition**	**Source**
Asset	Natural logarithm of total assets (Orbis item: `toas`).	Orbis
ROA	Profit or loss before tax (Orbis item: `plbt`) divided by total assets (Orbis item: `toas`).	Orbis
ROA (Exclude Carbon)	Return on assets adjusted to exclude gains/losses from carbon allowance trading in the numerator, and to incorporate allowance holdings adjustments in the denominator. *Formula:* $\text{ROA (Exclude Carbon)}_i = \frac{\text{Profit before tax}_i - \text{Gains from allowance sales}_i + \text{Losses from allowance purchases}_i}{\text{Total assets}_i}$	Orbis; EU ETS
Leverage	Total liabilities (current liabilities, Orbis item: `culi`, plus non-current liabilities, Orbis item: `ncli`) divided by total assets (Orbis item: `toas`).	Orbis
Tangible Ratio	Fixed assets (Orbis item: `fias`) divided by total assets (Orbis item: `toas`).	Orbis
Effective Tax Rate	$\min\{1, \max(0,\ \texttt{taxa}/\texttt{plbt})\}$; values < 0 set to 0, > 1 to 1; missing retained, set to missing if `plbt` is negative.	Orbis
Tax Rate	Statutory corporate income tax rate of the entity's country.	Paper
Carbon Profit	Net gains from intra-group cross-border transactions, calculated as revenues from intra-group cross-border sales minus costs from intra-group cross-border purchases, scaled by the median value of absolute net gains, and transformed using the inverse hyperbolic sine (asinh) function.	EU ETS
Group-level variables		
3-year Scope 1 Abatement	Sum of three-year Scope 1 abatement investments scaled by lagged assets (Worldscope item: `item2999`).	CDP; Worldscope
3-year Scope 1-3 Abatement	Sum of three-year abatement investments scaled by lagged assets (Worldscope item: `item2999`).	CDP; Worldscope
3-year Verified Emissions	Natural logarithm of the three-year cumulative verified emissions under EU ETS	CDP
Shifted Profit Share	100 × (Total shifted profit – necessary shifted profit) divided by total assets (Worldscope item: `item2999`), standardized.	EU ETS; Worldscope
3-year Cash ETR	The sum of cash taxes paid (Worldscope item: `item4150`) over years t, t + 1, and t + 2, scaled by the sum of pretax income (Worldscope item: `item1401`) over the same period. The ratio is set to 0 if the numerator is negative, set to missing if the denominator is negative, and capped at 1 if the computed value exceeds 1 and is non-missing.	Worldscope

Continued on next page

Table A: **Variable definitions** (Continued)

Variable name	**Definition**	**Source**
Asset	ln(Total Assets (Worldscope item: `item2999`)/The exchange rate of the euro against the local currency)	Worldscope
ROA	pre-tax income (Worldscope item: `item1401`)/ Total Assets (Worldscope item: `item2999`)	Worldscope
Leverage	long-term debt (Worldscope item: `item3251`)/ Total Assets (Worldscope item: `item2999`)	Worldscope
Cash	cash and short-term investments (Worldscope item: `item2001`)/ Total Assets (Worldscope item: `item2999`)	Worldscope

Online Appendix

Environmental-Unfriendly Tax Avoidance

February 26, 2026

Contents

A Accounting Treatment of Carbon Allowances

Under MiFID II, carbon allowances are classified as financial instruments, bringing them under the regulatory framework that governs trading practices to promote market transparency and stability. However, MiFID II does not prescribe the accounting treatment for these allowances; instead, their financial reporting is governed by national accounting standards and each member state's reporting practices.

Currently, there is no specific IFRS accounting standard dedicated to the recognition, measurement, and presentation of carbon allowances. In practice, companies typically classify carbon allowances as assets when they are acquired or granted. These allowances are most commonly categorized as either intangible assets or inventories (PricewaterhouseCoopers and International Emissions Trading Association, 2021), depending on their intended use and the company's accounting policies. European Securities and Markets Authority (2024) provides an overview of the observed practices on carbon allowances. The most commonly observed practice is to treat carbon allowances as inventory under IAS 2 when held for sale in the ordinary course of business or when used in the production process to fulfill contracts with customers, and to treat them as intangible assets under IAS 38 when carbon allowances are intended to settle obligations and are tradeable.[1]

Both the inventory approach and the intangible assets approach share common practices in initial recognition and subsequent measurement. Under both approaches, carbon allowances that are purchased are recorded at cost. Free allowances are generally recorded at a nominal amount (often zero). However, some firms choose to initially measure free allowances at fair value[2], with the difference between fair value and nominal cost recognized as deferred income under IAS 20, treating it as a government grant.

1 For different countries, the local accounting standards provide different guidance. In many Member States, such as Germany, Poland, Belgium, and France, carbon allowances are classified as intangible assets on the balance sheet, as allowances represent a right to emit CO_2 and provide economic benefit to the holder. In France, the accounting treatment differs based on the intended use of the allowances. Under the "production model," allowances are treated as inventory, recorded at purchase value (or zero if allocated for free), and removed from inventory when emissions occur. Under the "trading model" (e.g., for brokers), allowances are maintained at acquisition cost, with adjustments for impairment if the carrying value exceeds market value.

2 Belgium allows this.

For purchased allowances, both approaches rely on a cost basis for subsequent measurement. The inventory approach typically uses FIFO or weighted average cost, while intangible assets are generally carried at cost, minus any impairments, without amortization. When allowances are granted for free and initially recorded at fair value, deferred income is gradually recognized as an offset to expenses when the allowances are used for emissions. This practice applies across both approaches, aligning the release of deferred income with the allowance's consumption.

A provision may be recognized under both approaches if the issuer (1) uses free allowances recorded at market value for emissions, or (2) exceeds the allowable emissions threshold, thereby incurring a potential liability to purchase additional allowances or pay penalties. This provision reflects the future obligation to comply with emissions regulations and is measured at the best estimate of the expenditure required to settle it. Typically, this involves using current market prices for carbon allowances or the carrying value of allowances already held. This ensures that the provision accurately reflects the financial impact of the issuer's emissions obligations.

Under both approaches, gains or losses are recognized when allowances are sold. If allowances are held for trading purposes, such as by broker-traders seeking short-term profit, the inventory approach under IAS 2 allows for fair value measurement, with any changes in fair value recognized in profit or loss as they occur. This treatment captures the financial impact of price fluctuations in the carbon market, enabling broker-traders to reflect real-time market conditions in their financial statements. For allowances used in emissions, deferred income initially recognized at fair value is released as an offset against emission expenses. This approach aligns income recognition with the consumption of the allowances, ensuring that the financial statements accurately reflect the cost associated with emissions and the corresponding utilization of the allowances.

B Additional Details on Sample Construction

This section presents the full text of the two sets of prompts we use to instruct the LLMs in identifying corporate group affiliations. It also describes two cases in which Orbis fails to identify the common group affiliation.

B.1 First-round prompt

First-round prompt

You are a knowledgeable assistant specializing in analyzing corporate ownership and business group relationships between companies. I need your help determining whether the following two companies belong to the same corporate group:

- Company A
- Company B

Key Considerations:

1. The companies should belong to the same business group (e.g., parent-subsidiary, affiliate under same holding company, etc.).
2. Use your general business and corporate knowledge to identify brand consistency, naming conventions, and structural relationships.
3. If you cannot reasonably determine a connection, assume the companies do NOT belong to the same group.

Output: If they appear to belong to the same group, respond with "Yes." If not, respond "No." Only reply "Yes" or "No" — do not include any explanations.

B.2 Second-round prompt

Second-round prompt

You are a corporate ownership research assistant. Your task is to determine whether two companies are or were affiliated through common ownership, such as parent-subsidiary relationships, shared holding companies, or mergers & acquisitions.

Determine whether the following two companies belong to the same business group:

- Company A
- Company B

Instructions:

1. Only respond “Yes” if you can find **public, verifiable evidence** (e.g., corporate registry, news article, press release).
2. If the companies were ever part of the same group, state:
   - **When the affiliation began** (e.g., “from 2015”)
   - **Whether it is ongoing** (“to present”) or ended (“to 2021”)
   - **The name of the business group** they belonged to

     IMPORTANT:
     - Use the **most commonly recognized and simplified group name**. For example: “Samsung” instead of “Samsung Electronics” or “Samsung Group”; “Tata” instead of “Tata Sons Ltd.” or “Tata Group”.
     - Avoid suffixes like “Inc.”, “Ltd.”, “Group”, “Corp.” unless essential for clarity.
3. Include a **source URL** that directly supports the claim.
4. If there is **no clear evidence**, or you’re uncertain, respond **“No”**.

Format your response exactly like this:

- Group Affiliation: Yes, from [start year] to [end year or ‘present’].
- Group Name: [business group name]
- Source: [URL]

Do not speculate or guess. If you are unsure or cannot find a source, say:

- Group Affiliation: No, there is no evidence of shared group membership.
- Group Name: N/A
- Source: N/A

B.3 When Orbis Splits a Group: Understanding Parallel GUOs

We have identified cases where Orbis assigns different global ultimate owners (GUOs) to entities that large language models (LLMs) and manual verification suggest belong to the same corporate group. This raises an important question: Is Orbis making mistakes, or is this divergence the result of methodological differences?

To investigate, consider the case of Carmeuse Holding SRL and Carmeuse S.A. In Orbis, the Romanian entity (Carmeuse Holding SRL) is assigned the G.U.O. Carmeuse Nederland B.V. (NL*E00976438), while the Belgian parent (Carmeuse S.A.) is assigned the G.U.O. Carmeuse Holding S.A. (LULB114218).

Independent sources, however, suggest both ultimately belong to the same corporate group. For example, Belgian business press explicitly describes Carmeuse Holding (Luxembourg) as the société mère (parent company) of the Carmeuse group.[3] Meanwhile, Carmeuse's own EU contact page lists Carmeuse Nederland B.V. at the group's official address, confirming it as part of the Carmeuse network.[4]

So why does Orbis not consolidate them under a single G.U.O.? The answer lies in Orbis' methodology. According to documentation from the UK Office for National Statistics (ONS), Orbis defines an ultimate parent as follows:

- The ultimate parent of company X must hold at least a 25% total (direct or indirect) share in company X.

[3] See the reference here.
[4] See the reference here.

- The ultimate parent itself must not be majority-owned ($\geqslant$ 25%) by another company.
- At each ownership step, Orbis follows the path of largest total ownership, so the chain always represents the route of maximal control over the business.

In practice, Orbis therefore relies strictly on documented legal ownership chains from public filings and registries. When two holding companies exist in parallel — as in this case, a Dutch entity controlling some subsidiaries and a Luxembourg entity controlling others — Orbis treats them as separate G.U.O.s because their legal chains do not visibly converge.

This does not necessarily imply an error. Rather, it reflects limitations of available registry data. Carmeuse is a privately held group, and its family/shareholder structure is not disclosed in all jurisdictions. Both Luxembourg and the Netherlands allow intermediate holding companies whose shareholder registers are not fully public. As a result, Orbis cannot document the ownership chain from Carmeuse Nederland B.V. to Carmeuse Holding S.A., even if such a link exists in practice.

B.4 When Orbis Leaves the GUO Blank

Orbis occasionally classifies the Global Ultimate Owner (GUO) of an entity as missing. This occurs in several distinct situations.

First, entities ultimately owned by public authorities or sovereign states are not assigned a GUO. For instance, Gazprom Marketing & Trading Singapore Pte. Ltd. is ultimately owned by the Russian Federation through Gazprom PJSC, yet Orbis does not label its GUO. In our classification, we treat transactions within the Gazprom group as internal, but we do not consider transactions between Gazprom and other Russian state-owned enterprises as intra-group trades.

Second, Orbis does not assign a GUO when ownership is shared among multiple significant shareholders, even if each exceeds the 25% threshold. Orbis's rule requires that a single shareholder both surpass the 25% threshold and face no conflicting ownership claims. For example, Borealis AB was jointly owned by OMV Group and Mubadala, both holding significant stakes. Because no single ultimate controller could be identified, Orbis left the GUO blank. In contrast, for the purposes of our intra-group analysis, we treat Borealis as a standalone corporate group: transactions among Borealis subsidiaries are classified as internal trades of the Borealis group until 2020, when OMV acquired a controlling interest and Borealis was consolidated into the OMV group structure.

When the entity is a joint venture co-owned by multiple corporate groups, we apply a split classification. Transactions between the joint venture and subsidiaries of a given parent group are attributed to that group. For example, if a joint venture is co-owned by Group A and Group B, its transactions with subsidiaries of Group A are classified as internal to the A group, while its transactions with subsidiaries of Group B are classified as internal to the B group. This rule and ensures that intra-group linkages are consistently captured even when Orbis does not assign a GUO due to shared ownership.

Third, the completeness of Orbis ownership data varies substantially across jurisdictions. In countries where corporate registries lack coverage or transparency—particularly for unlisted firms not legally required to disclose shareholders—Bureau van Dijk (BvD) is unable to trace ownership structures fully upstream. As a result, the GUO field in Orbis may be left blank when verifiable ownership links cannot be established from available registry and filing sources (Bajgar et al., 2020).

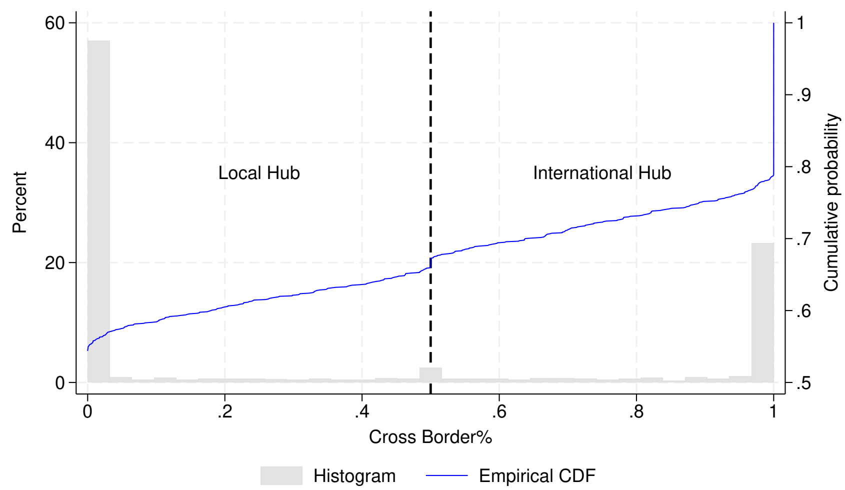
Finally, when ownership is held through trusts, private investment vehicles, or entities incorporated in secrecy jurisdictions lacking reliable documentation, Orbis cannot confirm the ultimate ownership chain and therefore does not assign a GUO.

C Additional Analyses

Figure C.1: **Distributions of Cross-Border Activity across Hubs**

This figure illustrates the distribution of cross-border activity across trading hubs identified in the EU ETS transaction data. The panel (a) plots the distribution of the *Cross-Border Ratio*. The panel (b) displays the distribution of the *Carbon Profit*. Each panel reports both the histogram (bars, left axis) and the empirical cumulative distribution function (line, right axis).

(a) Cross-Border Ratio



(b) Carbon Profit

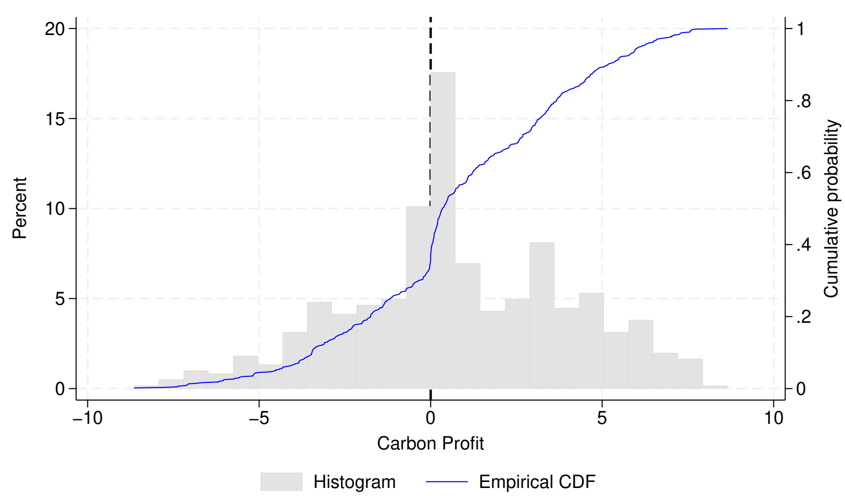


Figure C.2: **The Distribution of Sell Ratio across Hubs**

This figure presents the distribution of the *Sell Ratio*, defined as the share of intra-group transactions by a hub that are sales rather than purchases. The histogram (bars, left axis) and empirical cumulative distribution function (line, right axis) reveal three dominant hub types: Collect Hubs (*Sell Ratio* < 0.4), which mainly accumulate allowances from affiliates; Balance Hubs ($0.4 \leqslant$ *Sell Ratio* < 0.6), which engage in roughly equal intra-group buying and selling; and Supply Hubs (*Sell Ratio* $\geqslant 0.6$), which primarily distribute allowances to affiliates. These trading patterns underpin the classification used in the main text and demonstrate that balance hubs—those without a clear operational purpose—form a distinct subset potentially linked to profit-shifting motives.

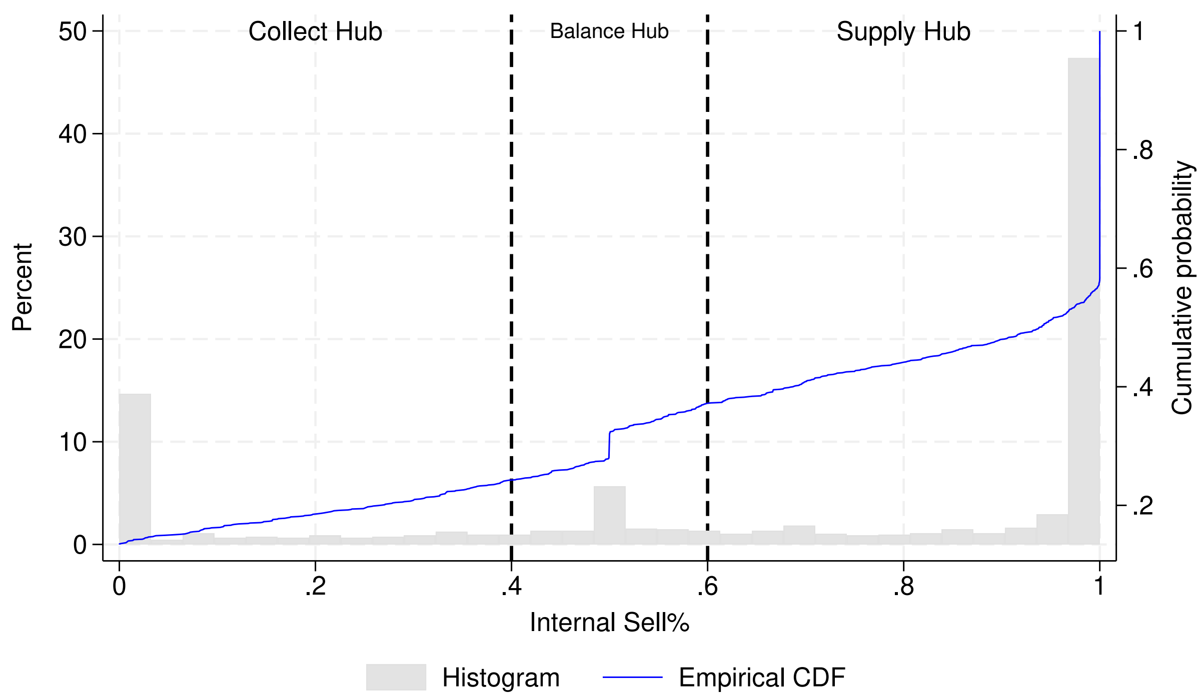


Figure C.3: **Average Buying and Selling Prices of Balance Hubs**

This figure plots the volume-weighted average buying and selling prices of European Union Allowances (EUAs) for balance hubs, based on within-group cross-border transactions. Transactions occurring between hubs are excluded from the calculation.

Figure C.4: **Predicted Effect of International Hub Existence**

This figure presents the estimated effect of international hub existence on groups' verified emissions under the EU ETS. We examine how the presence of an international trading hub relates to the natural logarithm of three-year cumulative verified emissions, with controls for Asset, ROA, Leverage, and Cash. Group and industry-by-year fixed effects are included, and standard errors are clustered at the group level. The bars display predicted log-emissions for groups with and without an international hub, with capped lines showing 95% confidence intervals.

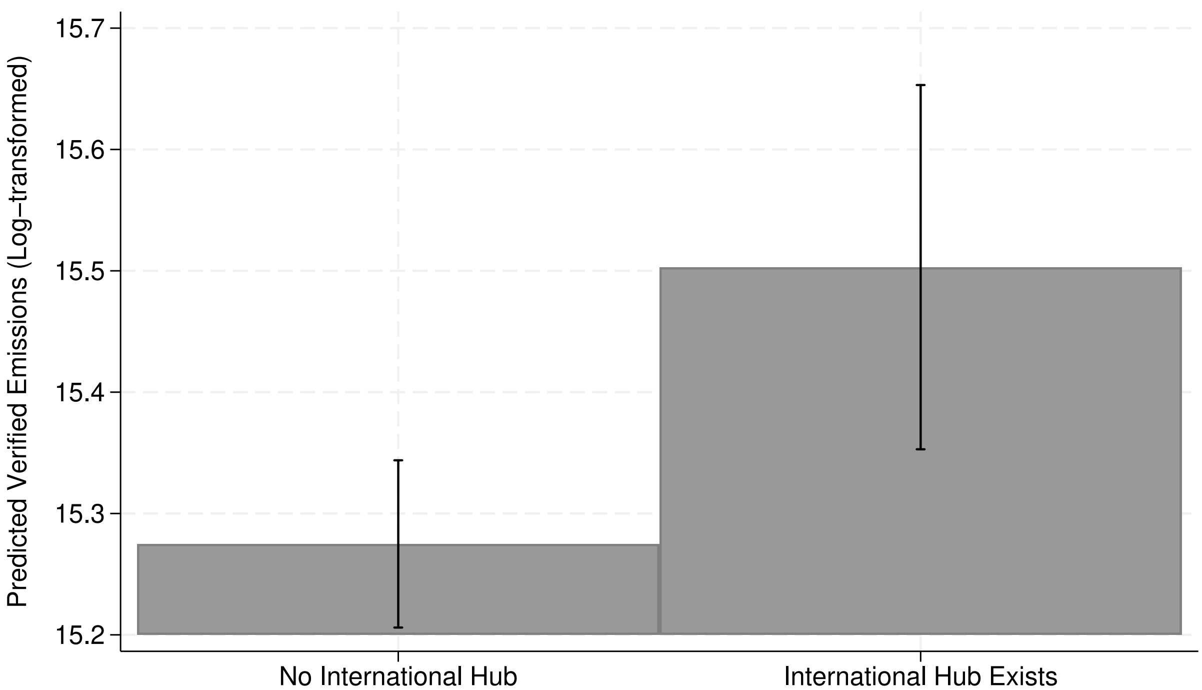


Table C.1: **Determinants of Hub Presence and Scale**

This table reports one-year predictive regressions examining group characteristics associated with the existence and scale of different types of hubs. The dependent variables in Columns (1)–(3) are indicator variables that equal 1 if a group establishes any hub (*Hub*), an *International Hub* (a hub with a cross-border ratio > 0.5), or a *Balance Hub* (a hub with a sell ratio between 0.4 and 0.6) in year t. Columns (4)–(6) use corresponding hub counts within each group-year as dependent variables. The *cross-border ratio* is defined as the share of a hub's total allowance transactions that are cross-border intra-group, calculated as the sum of cross-border purchases and sales divided by total intra-group purchases and sales. The *sell ratio* is the share of a hub's intra-group transactions that are sales, computed as intra-group sales divided by the total intra-group transaction volume (sales plus purchases). The key explanatory variables are group-level characteristics measured in the prior year: *Asset* (natural logarithm of total assets), *ROA* (return on assets), *Leverage* (total liabilities divided by total assets), and *Cash* (cash and short-term investments divided by total assets). All continuous variables are winsorized at the 1% and 99% levels. All regressions include country-by-Year fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Hub existence			*Hub counts*		
	Hub	International	Balance	Hub	International	Balance
	(1)	(2)	(3)	(4)	(5)	(6)
Asset	0.4428***	0.4216***	0.5527***	0.4388***	0.4396***	0.6706***
	(0.0478)	(0.0537)	(0.1021)	(0.0455)	(0.0484)	(0.0919)
ROA	-9.0956***	-8.7960***	-10.0942***	-7.4672***	-6.3454***	-9.7430***
	(1.3172)	(1.4819)	(2.5949)	(0.9282)	(1.1751)	(1.7331)
Leverage	-0.5424	0.5011	1.8332	-1.1046***	-0.7140*	-0.3983
	(0.6187)	(0.6869)	(1.2142)	(0.3631)	(0.4219)	(0.6665)
Cash	-1.2535	-1.3298	3.9427*	1.5261	0.9949	4.2079***
	(1.1898)	(1.3460)	(2.3565)	(0.9729)	(1.2710)	(1.6135)
Constant				-11.3217***	-11.7682***	-19.0589***
				(1.0554)	(1.1175)	(2.3020)
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1452	1271	855	1778	1778	1778
Pseudo R^2	0.14	0.12	0.15	0.13	0.11	0.16

Table C.2: **Hub Function and Effective Tax Rate (robustness)**

This table reports robustness regressions of *Effective Tax Rate* on alternative hub-type indicators using the subsidiary-level sample. The dependent variable is *Effective Tax Rate*, defined as $\min\{1, \max(0, \texttt{taxa}/\texttt{plbt})\}$, where `taxa` denotes taxes accrued and `plbt` denotes profit before tax. Observations with negative `plbt` are set to missing. For the remaining observations, ETR values below 0 are truncated at 0 and values above 1 are truncated at 1; missing values are otherwise retained. The independent variables classify hubs according to their intra-group trading patterns based on an alternative definition of the sell ratio thresholds. A *Collect Hub (alt)* (*Supply Hub (alt)*) is a hub with a sell ratio < 0.35 ($\geqslant 0.65$), while a *Balance Hub (alt)* has a sell ratio between 0.35 and 0.65. The sell ratio is defined as the volume of intra-group sales divided by total intra-group transaction volume (sales plus purchases). All hub indicators equal 1 if the entity is identified as a hub in year t based on EU ETS transaction data. Control variables include *Asset*, *ROA*, *Leverage*, *Tangible Ratio*, and *Tax Rate*. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Effective Tax Rate		
	(1)	(2)	(3)
Collect Hub (alt)	-0.0118	-0.0361	-0.0341
	(0.0402)	(0.0428)	(0.0517)
Balance Hub (alt)	-0.1121***	-0.1251***	-0.1411***
	(0.0233)	(0.0281)	(0.0324)
Supply Hub (alt)	-0.0489	-0.0504	-0.0401
	(0.0297)	(0.0311)	(0.0367)
Controls	Yes	Yes	Yes
Group FE		Yes	
Year FE	Yes	Yes	
Group×Year FE			Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary
N	1600	1593	1507
Adj. R^2	0.04	0.08	0.02

Table C.3: **Interaction of Hub Function and Cross-Border Classification on Effective Tax Rate (robustness)**

This table reports robustness regressions of *Effective Tax Rate* on interaction terms between alternative hub-type classifications and cross-border hub indicators, using the subsidiary-level sample. The dependent variable is *Effective Tax Rate*, defined as $\min\{1, \max(0, \texttt{taxa}/\texttt{plbt})\}$, where `taxa` denotes taxes accrued and `plbt` denotes profit before tax. Observations with negative `plbt` are set to missing. For the remaining observations, ETR values below 0 are truncated at 0 and values above 1 are truncated at 1; missing values are otherwise retained. A *Collect Hub (alt)*, *Balance Hub (alt)*, or *Supply Hub (alt)* equals 1 if the entity is a hub with a sell ratio < 0.35, between 0.35 and 0.65, or $\geqslant 0.65$, respectively, where the sell ratio is defined as the volume of intra-group sales divided by total intra-group transaction volume (sales plus purchases). An *International Hub* (*Local Hub*) equals 1 if the entity is a hub with a cross-border ratio > 0.5 ($\leqslant 0.5$), where the cross-border ratio measures the share of a hub's total allowance transactions that are cross-border intra-group. The interaction terms combine hub function and cross-border scope to examine whether international balance hubs continue to exhibit the lowest effective tax rates under the alternative sell ratio thresholds. Control variables include *Asset*, *ROA*, *Leverage*, *Tangible Ratio*, and *Tax Rate*. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Effective Tax Rate		
	(1)	(2)	(3)
Collect Hub (alt) × International Hub	-0.0229	-0.0468	-0.0394
	(0.0404)	(0.0460)	(0.0557)
Collect Hub (alt) × Local Hub	0.0441	0.0125	-0.0102
	(0.1193)	(0.0930)	(0.1201)
Balance Hub (alt) × International Hub	-0.1196***	-0.1316***	-0.1527***
	(0.0244)	(0.0330)	(0.0401)
Balance Hub (alt) × Local Hub	-0.1009**	-0.1138***	-0.1208***
	(0.0409)	(0.0334)	(0.0406)
Supply Hub (alt) × International Hub	-0.0565*	-0.0545	-0.0443
	(0.0313)	(0.0334)	(0.0393)
Supply Hub (alt) × Local Hub	-0.0394	-0.0448	-0.0350
	(0.0475)	(0.0473)	(0.0585)
Controls	Yes	Yes	Yes
Group FE		Yes	
Year FE	Yes	Yes	
Group×Year FE			Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary
N	1600	1593	1507
Adj. R^2	0.04	0.08	0.02

Table C.4: **Flow of carbon allowances in the absence of a trading hub**

This table reports the results of estimating equation (2) using the sample of EU ETS operators whose corporate groups had no cross-border intra-group transactions through a trading hub in the given year. The dependent variable is *Inbound Profit Share*, defined as the share of a subsidiary's net revenue attributable to cross-border intra-group carbon-allowance transactions, calculated as sales to foreign affiliates minus purchases from foreign affiliates, scaled by total revenue. The explanatory variables include firm characteristics: *Asset* (natural logarithm of total assets), *ROA (Exclude Carbon)* (return on assets excluding gains or losses from carbon-allowance trading), *Leverage* (total liabilities divided by total assets), *Tangible Ratio* (fixed assets divided by total assets), and *Tax Rate* (statutory corporate income tax rate in the entity's country). *Surrender–Allocation Gap* measures the difference between verified surrenders and free allocations, scaled by the median absolute value and transformed using the inverse hyperbolic sine. All continuous variables are winsorized at the 1% and 99% levels, except for variables that are naturally bounded, which are left unadjusted. All regressions include combinations of group, year, country-by-year, group-by-year, and subsidiary fixed effects as indicated. Standard errors are clustered at the subsidiary level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Inbound Profit Share				
	(1)	(2)	(3)	(4)	(5)
Asset	0.0038*	0.0045**	0.0044*	0.0051*	0.0010
	(0.0021)	(0.0023)	(0.0024)	(0.0027)	(0.0048)
ROA (Exclude Carbon)	-0.0841**	-0.0837*	-0.0922**	-0.0916**	-0.0301
	(0.0405)	(0.0430)	(0.0436)	(0.0458)	(0.0205)
Leverage	-0.0279***	-0.0269**	-0.0259**	-0.0255**	-0.0349**
	(0.0107)	(0.0110)	(0.0115)	(0.0127)	(0.0174)
Tangible Ratio	-0.0293**	-0.0308**	-0.0319**	-0.0328**	-0.0003
	(0.0131)	(0.0136)	(0.0146)	(0.0150)	(0.0172)
Tax Rate	0.0035	0.0985	0.0059	-0.0259	-0.1043
	(0.0211)	(0.2180)	(0.0248)	(0.3398)	(0.1154)
Surrender–Allocation Gap	-0.0034**	-0.0019	-0.0032*	-0.0015	0.0068
	(0.0016)	(0.0018)	(0.0018)	(0.0020)	(0.0073)
Constant	-0.0407	-0.0770	-0.0524	-0.0571	0.0199
	(0.0399)	(0.0776)	(0.0447)	(0.1099)	(0.0975)
Group FE	Yes	Yes			
Year FE	Yes				
Country$\times$Year FE		Yes		Yes	
Group$\times$Year FE			Yes	Yes	Yes
Subsidiary FE					Yes
S.E. clustered by	Subsidiary	Subsidiary	Subsidiary	Subsidiary	Subsidiary
N	1903	1873	1820	1779	1556
Adj. R^2	0.24	0.30	0.20	0.24	0.47

Table C.5: **Future 3-year Cash Holdings and Profit Shifting**

This table reports the results of estimating equation (3) using the group-level panel. The dependent variable is *3-year Cash Holdings*, defined as the sum of cash holdings from years t to $t+2$, scaled by total assets. The key independent variable is the standardized value of *Shifted Profit Share*, which measures the proportion of profits shifted through intra-group transactions relative to the total profits of the multinational group. All specifications control for group-level *Asset*, *ROA*, and *Leverage*. Samples are defined as follows: *All* includes all groups in the panel; *Ever* includes groups that ever engage in cross-border intra-group transactions at any time; *Current* restricts to groups engaged in such transactions in year t. All regressions include group fixed effects and year fixed effects. Standard errors are clustered at the group level and reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	3-year Cash Holdings		
	(1)	(2)	(3)
Shifted Profit Share	0.1353*	0.1100	0.1599*
	(0.0770)	(0.0698)	(0.0859)
Sample	All	Ever	Current
Controls	Yes	Yes	Yes
Group FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
S.E. clustered by	Group	Group	Group
N	1741	1105	653
Adj. R^2	0.67	0.62	0.53

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