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Impacts of Ownership Changes on Emissions and Industrial Production: Evidence From Europe

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Impacts of ownership changes on emissions and industrial production: Evidence from Europe*

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Abstract

Firm ownership is a major determinant for the economic performance of firms, and emissions of pollutants are often by-products of industrial production. We investigate the impact of ownership on pollutant emissions of firms and their industrial facilities in Europe jointly with their output, productivity, and other key economic outcomes. To disentangle the influence of ownership from other firm characteristics, we analyse the effects of ownership changes in an event-study approach. We find that facilities and firms do not change their emissions and emissions intensity if they remain in operation after a change in ownership. Firms that shut down after acquisition strongly reduce their emissions via reductions in output. The reductions cannot be attributed to the ownership change as they already start before acquisition. There is no evidence for transfers in pollution abatement technologies between target and acquiring parent company. Overall, we do not find environmental benefits from ownership changes.

Keywords: Ownership changes, pollution, productivity, event study
JEL Classification: D22, D23, Q53

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1 Introduction

Corporate ownership affects the economic performance of firms, such as productivity (e.g., Commander and Svejnar, 2011; Li, 2013) and innovation activity (e.g., Aghion et al., 2013; Clo et al., 2020). Ownership can affect knowledge transfer and management practices within firms (e.g., Burstein and Monge-Naranjo, 2009; Alcacer and Zhao, 2012; Bloom et al., 2013) as well as internal goal setting (e.g., Shleifer, 1998). Ownership changes, e.g., through mergers and acquisitions (M&A), often influence production and investment decisions. Furthermore, these changes reallocate funds across firms, thereby impacting even aggregate economic outcomes (David, 2021). However, against the background of climate change and pollution as two major societal challenges, it is unclear how these changes in firms' economic performance and overall economic outcomes translate to environmental impacts of firms, such as the emission of pollutants.

In this paper, we analyze the impact of ownership changes on emissions of industrial facilities and firms in Europe jointly with their output, productivity and other key economic outcomes.[1] In 2019, the industrial sectors had a share of about 16 percent of Europe's total employment (Eurostat, 2022a) and about 18 percent in its gross domestic product (GDP) (Eurostat, 2022b), but were also responsible for a substantial share in Europe's pollution: about 48 percent of total greenhouse gas emissions (EEA, 2022), 28 percent of nitrogen oxide emissions, and 81 percent of sulphur oxide emissions (EEA, 2021). These numbers underline the importance of the industrial sectors for economic but also environmental outcomes in Europe. Also in 2019, around 17 500 M&A deals (Thomson Reuters, 2019a) with a volume of € 991 billion were made in the European economy (Thomson Reuters, 2019b).

To shed light on the impact of ownership changes on emissions and economic performance, we use ZEW's ME-FINE dataset, which combines emission information of industrial facilities from the European Pollutant Release and Transfer Register (E-PRTR) and financial indicators of firms from Bureau van Dijk's Orbis database. Our

[1] Industrial refers to facilities and firms active in the manufacturing and energy supply sectors.

sample includes about 6,000 industrial facilities[2] associated to 4,600 firms[3] in the EU15[4] plus Hungary and Norway from 2007 to 2016.[5]

Since ownership changes and firm decisions, such as input and output choices, are likely endogenous, we use an event study design, exploiting variation in the timing of ownership changes among all units that experience a change in ownership during our observation period. In our sample, 47 percent of facilities and 43 percent of firms experience at least one ownership change between 2007 and 2016. Since ownership changes occur at different years across units, we address treatment effect heterogeneity by applying the estimator proposed by Sun and Abraham (2021) in addition to conventional two-way fixed effects models. We use only the within-variation in facilities' and firms' emissions and ownership status by including individual and a variety of year fixed effects.

In the context of large polluting industrial facilities in the European Union (EU), we investigate the effect of ownership changes on firms' and their industrial facilities' total emissions. On average, emissions decrease both in the lead up to and following an ownership change. The decrease after acquisition is at about 46 percent at the facility and at about 55 percent at the firm level. We differentiate between firms and facilities that remain in operation and those that close down in the years after an ownership change. Firms and facilities that remain in operation have insignificant pre-trends and neither change their emissions nor their emissions intensity of output after changing owners. Firms and facilities that close down after acquisition strongly reduce their emissions via output reductions. However, the falling trend in emissions and output starts already before the ownership change, so that we cannot causally attribute the emissions reductions to the acquisition.

[2]Facility is the reporting unit in EPER/E-PRTR and describes "one or more installations on the same site that are operated by the same natural or legal person" (Regulation (EC) No 166/2006).

[3]A firm is the observational unit in Orbis defined by the Bureau van Dijk identifier. In our sample, the mean and median number of facilities per firm are 1.4 and 1, respectively.

[4]Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

[5]2007 is the first year of the emissions reporting in E-PRTR. ZEW's ME-FINE dataset also includes emissions data for 2001 and 2004 from the E-PRTR's predecessor, the European Pollutant Emissions Registry (EPER). We restrict the sample to the time period from 2007 to 2016 for a more comprehensive coverage and consistent definitions of pollutant emissions in those countries over time.

Aggregate emissions in the acquiring parent company increase after the target joins but emissions intensity remains constant. The acquisition of the new facilities does not affect either emissions or emissions intensity of other facilities in the acquiring firm. This indicates that no transfer in pollution abatement technologies takes place between the target and the acquiring parent company. However, the acquisition appears to provide positive spillovers in terms of increases in productivity, operating profits and intangible fixed assets to other facilities in the acquiring parent company. In sum, acquisitions seem to be a zero-sum game that neither harms nor benefits the environment.

Our paper contributes to the large literature on the importance of corporate structure and ownership for firm performance and to the smaller literature on the effects of ownership on environmental performance. In a study closely related to ours, Jacqz (2021) finds that newly acquired facilities in the United States reduce their (toxic) emissions to the air, mainly driven by operational changes. Similar to our study, she uses an event study design. Two further US studies provide evidence that the ownership structure of facilities seems to matter for their emissions level: Grant and Jones (2003) compare emissions by subsidiaries and non-subsidiaries in the US and find that the former facilities pollute significantly more. Akey and Appel (2021) study how the degree of parent company liability affects pollution by subsidiaries in the US; they find that stronger liability protection for parents leads to increases in toxic pollutants emitted by subsidiaries. Several studies look at outcomes other than facility-level emissions related to pollution: Aden et al. (1999) study pollution abatement expenditures of foreign- and domestically-owned manufacturing plants in Korea. They find that domestically-owned plants spend more on abatement equipment than plants with some level of foreign ownership. Conversely, Albornoz et al. (2009) find that foreign direct investment (FDI) has a positive effect on the implementation of environmental management systems by Argentinean manufacturing firms. Ning and Wang (2018) find that FDI reduces local pollution intensity via spillovers at the prefectural city level in China.

The effect of mergers and acquisitions, specifically FDI, on other outcomes of firm performance has been studied more extensively. Most studies find a positive effect of foreign ownership on firm productivity (Javorcik, 2004; Haskel et al., 2007; Arnold and Javorcik, 2009; Newman et al., 2015). However, Aitken and Harrison (1999) find negative productivity spillovers on domestically-owned firms so that the net productivity increase from FDI is small. Harris and Robinson (2002) find that foreign-owned companies purchase the most productive facilities but productivity declines after the acquisition. Wang and Wang (2015) find no additional gains from FDI; both foreign and domestic acquisitions increase productivity of the target facilities equally.

The effect of acquisitions on output and employment depends on the context. Siegel and Simons (2010) find that Swedish firms in the manufacturing sector reduce output and employment after acquisition, while Wang and Wang (2015) find that foreign, but not domestic, acquisitions increase the output and employment of Chinese target firms. Also Arnold and Javorcik (2009) find a positive effect of foreign acquisitions on employment in Indonesian manufacturing firms. Conversely, Li (2013) finds that employment drops in US facilities after acquisition. Chen (2011) compares the effect of foreign and domestic acquisitions on target firms' profits and finds FDI to increase profits more compared to domestic acquisitions.

We contribute to the literature being the first to provide evidence on the role of ownership changes for emissions of firms in Europe, jointly with the impact of ownership changes on a wide range of firms' economic performance indicators. We use a novel data set combining information from Orbis and the E-PRTR. This enables us, as compared to single-country studies, to extend our analysis to a major economic region with a wide range of countries, allowing us to draw broader conclusions less dependent on country-specific peculiarities. Our findings differ from Jacqz (2021) who finds evidence for operational changes in newly acquired facilities in the US that reduce toxic emissions. Both studies cover a similar time period and the context of large facilities reporting to the Toxic Release Inventory is similar to our setting where large facilities report to the E-PRTR. The institutional context provides the most ap-

parent difference between the settings studied. However, more evidence needs to be generated to provide a clear picture of the differences in the EU and US context and which factors contribute to the different result. Contrary to findings by Aden et al. (1999), Albornoz et al. (2009), and Ning and Wang (2018) that foreign ownership (in the form of FDI) impacts pollution abatement expenditures in Korea, the implementation of environmental management systems in Argentina and local pollution intensity in China respectively, we do not find that foreign acquisitions differ from domestic acquisitions in their impact on pollutant emissions and emissions intensity. However, in this comparison, countries, time periods and institutional settings vary widely so that it is unclear which factors drive the difference in results. Furthermore, observing outcomes at different aggregation levels, such as at the facility, firm and parent company level, we can distinguish between those three levels of aggregation and shed light on potential reallocation effects emissions and production indicators across facilities and firms within the parent company, and assess the impact on productivity and profits. Our paper is the first to provide evidence on reallocation effects of emissions after acquisitions which provides evidence on environmental technology transfers also from target to acquiring parent company, in addition to transfers from acquiring firm to target. In that, we go beyond the analysis by Jacqz (2021) who limits her analysis to the facility and firm level and does not consider the impact of acquisition on the parent companies.

The remainder of this paper is structured as follows: The data is described in Section 2. Our empirical strategy for the analysis of ownership changes is outlined in Section 3. Section 4 presents our results and Section 5 concludes.

2 Data

Our main data source is ZEW's ME-FINE data set which combines emissions data from the EPER/E-PRTR and financial information from Orbis (Germeshausen et al.,

2022).[6] ME-FINE includes firms in the manufacturing and energy supply sectors (NACE Rev. 2: 10 - 35) in the EU-15 plus Norway and Hungary and covers about 70 percent of observations reported in EPER/E-PRTR in those sectors and countries. We use observations from the period 2007-2016[7], covering 6,097 facilities and 4,669 firms. For this period, ME-FINE covers about 87 percent of total E-PRTR observations in these sectors and countries. Furthermore, we add ownership links between firms and their parent company as reported in Orbis.

We divide the data set into three levels: facilities, firms and parent companies. At the facility level, facility-year observations contain information on reported emissions, on the associated firm and the parent company as well as the sector code (NACE Rev. 2). At the firm level, firm-year observations contain information on reported emissions (aggregated over all their E-PRTR facilities), financial indicators, the parent company, and the sector code. At the parent company level, parent company year observations contain information on reported emissions aggregated over all their E-PRTR facilities and financial indicators aggregated over all their firms with E-PRTR facilities. Reported emissions during our observation period stem from E-PRTR. Reporting emissions is mandatory for facilities in specific economic sectors that exceed capacity and pollutant-specific thresholds. These thresholds are set such that about 90 percent of the emissions of each of the 91 pollutants in E-PRTR is covered.This means that our aggregation at the firm and parent company level also only contains facility-level observations that release pollutant amounts beyond the threshold. Further information on the reporting procedures and data quality is provided in Appendix A.

Table 1 provides summary statistics on the outcome variables in our estimation sample at the facility, firm and parent company level. This sample includes only facilities and firms with one ownership change from 2007 to 2016. Total emissions is an aggregated measure which sums physical emission quantities over all pollutants

[6]The documentation of the dataset also includes an index decomposition at the sector level for the period 2007-2016 that separates scale, composition and technique effects on the evolution of total emissions.

[7]From 2007 on, the E-PRTR reports information on pollutant emissions annually. The EPER is the predecessor which reports pollutant emissions for the years 2001 and 2004.

reported to E-PRTR, whereby the quantity of each pollutant is divided by its pollutant-specific reporting threshold. Emissions intensity at the firm level scales total emissions by operating revenues in thousand euro (EUR). Operating revenues are deflated by two-digit sectoral (NACE Rev. 2) producer price indices from Eurostat. To obtain firm- and time-specific values for total factor productivity, we estimate a value added production function using firm investment as a proxy variable following Wooldridge (2009).[8]

Table 1: Summary statistics for final sample, 2007 - 2016

	N	Mean	St. Dev.	Min	P25	P75	Max
Variables at the facility level							
Total emissions	11,819	118.6	1,247.8	0.0	1.3	19.3	39,926.4
Variables at the firm level							
Total emissions	6,979	83.5	1,137.9	0.00	1.0	16.7	64,302.0
Operating revenues ('000 EUR)	6,210	838,806	9,204,588	0	20,411	227230	261,279,167
Emissions intensity	5,783	0.069	1.101	0.000	0.000	0.016	70.162
Total factor productivity	3,286	9.3	0.7	5.4	9.0	9.7	14.9
Number of employees	5,939	1,139	8,456	0	49	508	195,826
Tangible fixed assets ('000 EUR)	6,167	299,240	3,931,596	0	4,261	73,112	163,911,425
Labor expenditures ('000 EUR)	5,671	71,417	596,300	0	2,306	28,962	14,189,731
R&D expenditures ('000 EUR)	305	51,623	147,706	0	0	10,625	978,666
Intangible fixed assets ('000 EUR)	5,520	72,931	701,664	0	6	2,316	15,685,382
Variables at the parent company level							
Total emissions	2,612	202.7	1,408.2	0.0	2.9	59.7	35,201.3
Operating revenues ('000 EUR)	2,584	965,397	3,289,382	0	23,731	628,181	54,484,828
Emissions intensity	2,136	0.080	0.767	0.0	0.001	0.026	21.390
Total factor productivity	1,514	7.3	0.7	2.0	7.0	7.6	10.2
Number of employees	2,584	2,175	9,671	0	49	1,132	198,980
Tangible fixed assets ('000 EUR)	2,584	38,6025	1,561,469	0	5,225	220,251	25,848,393
Labor expenditures ('000 EUR)	2,583	125,575	658,641	0	1,704	56,949	12,188,843
R&D expenditures ('000 EUR)	2,584	13,818	170,347	0	0	0	453,9012
Intangible fixed assets ('000 EUR)	2,584	117,280	1,138,166	0	0	6,606	33,422,925

Notes: Total emissions is the sum over the quantities of all pollutants each divided by its reporting threshold. Emissions intensity refers to total emissions divided by deflated operating revenues at the firm level, and to total emissions divided by deflated operating revenues multiplied by 100,000 at the parent company level.

[8]Total factor productivity estimates are highly correlated to estimates obtained by applying the methods by Olley and Pakes (1996) and Ackerberg et al. (2015). However, in the case of Ackerberg et al. (2015) the coefficient of capital input is negative. Therefore, we use the estimates obtained from following Wooldridge (2009) as reference.

We define a change in ownership for both firms and facilities as a change in their parent company from one year to the next.[9] In total, we observe 2,621 changes of firm ownership in the sample. This corresponds to 1.3% of all M&A events recorded in the Zephyr Database for the EU15 plus Hungary and Norway for the period 2008-2016 (Zephyr Database, 2023). 978 firms experience one change, while in total 655 firms experience multiple ownership changes. 2,697 facilities experience at least one change in ownership, of which 1,525 change only once.[10] In our analysis, we only consider firms and facilities with one ownership change event.

There is considerable heterogeneity in the distribution of ownership change events over sectors and countries. In absolute terms, we observe most ownership changes in German, French and Spanish firms. Scaling the number of observed changes by the absolute number of observations for each country in our sample, heterogeneity is much less pronounced and, in relative terms, we observe most changes in Greek, Portuguese, German and Luxembourgian firms (see Figure B1 in the Appendix). The absolute number of ownership changes is highest in NACE sectors 20 (Manufacture of chemicals and chemical products), 23 (Manufacture of other non-metallic mineral products) and 24 (Manufacture of basic metals). In relative terms, the share of ownership changes is highest in sectors 27 (Manufacture of electrical equipment) and 33 (Repair and installation of machinery and equipment; see Figure B2 in the Appendix). The distribution of ownership change events over the years is more uniform. Both the absolute number and the percentage of changes is higher in 2008, but remains almost stable thereafter (see Figure B3 in the Appendix).

Total emission reports are unbalanced in our sample. We define facilities as active in years in which they report a positive amount of emissions. In years for which facilities do not report any emissions, facilities could either have closed down or they could

[9] That means that we do not observe ownership changes according to our definition that happened in 2007, the first year in our sample, since we do not observe ownership in 2006.

[10] For facilities, we count changes in the global ultimate owner as indicated by Orbis. If the global ultimate owner is unknown, we assign the associated firm as the global ultimate owner.

have emitted pollutants below the reporting thresholds.[11] We consider facilities with missing emission reports for a facility-year observation as active as long as the facilities report again in a later year in the sample. If facilities do not report again until the last year in our sample we assume they have closed down. To proxy their exit in the data, inactive facilities remain as zero-values in the sample for up to four years (at the latest until 2016) after their last reporting year, similar to the approach used by Jacqz (2021).[12] At the firm level, we apply the same procedure. Since firms' emissions are aggregated over all their facilities, we consider a firm to have exited only if none of its facilities reports again in a later year during the sample period. The largest share of facilities reports from 2007 on, only a small share of facilities enters the sample in later years. Later entries are relatively evenly distributed across years. The largest share of facilities reports until 2016, and similarly earlier exits are rather uniformly distributed.[13] At the firm level, most entries are recorded in the first two years and least entries in the later years. The majority of firms in our sample survive until the end of our observation period. The number of firm exits varies over time.[14]

Our sample consists of the overlap of E-PRTR and Orbis. Given the emissions reporting threshold in E-PRTR, we observe emission reports from rather large firms. With respect to Orbis, its coverage differs across the globe due to different national reporting requirements and firm structures. Bajgar et al. (2020) find that firms in Orbis are rather large, old and productive. While these characteristics of E-PRTR and Orbis facilitate the assignment of E-PRTR facilities to Orbis firms in the ME-FINE data set, it has to be considered in the interpretation of our results. Our final estimation sample is not necessarily representative of the overall economy but focuses on rather large industrial facilities and firms.

[11] Since reporting positive emission amounts is censored below the threshold (there are no reported emissions below the pollutant-specific threshold), we investigate the impact of this censoring by considering two different imputation strategies, i.e., either imputing missing values by zero or by the threshold value, as robustness checks.

[12] Results are qualitatively similar if we replace zero-values with the pollutant-specific threshold at the facility level since facilities could still emit up to this amount without reporting obligation. Using both approaches provides us with an upper and lower bound of emissions.

[13] See Figure B4 in the Appendix.

[14] See Figure B5 in the Appendix.

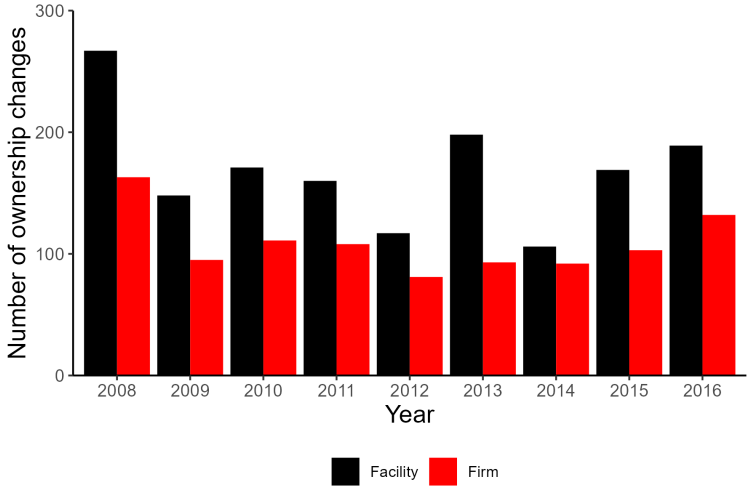
3 Empirical Strategy

We aim to identify the effect of a change in ownership (parent company change) on pollutant emissions and economic outcomes of firms and their facilities. In our sample, we observe 978 firms and 1,525 facilities whose parent company changes once during the period 2007-2016. Our empirical strategy relies on fixed unit characteristics at the facility and firm level which allows us to use only within-unit variation to identify the effect of ownership changes. The events are distributed over 9 years so that treatment adoption – change in ownership in our case – is "staggered". Our method is closely related to Jacqz (2021) who investigates a similar question in the US context.[15]

For our event study of ownership changes, we use the Sun and Abraham interaction-weighted estimator that is robust to treatment effects heterogeneity (Sun and Abraham, 2021). The estimator interacts treatment group and relative time dummies which are then aggregated to obtain the average treatment effect for the treated for each period. In our setting, we have nine treated groups of units (firms and facilities) whose parent company changed in the respective year 2008 to 2016. Figure 1 shows how the ownership change events are distributed over the sample period for facilities and firms. Each treatment group has observations in up to 10 periods relative to the treatment period.

[15] Jacqz (2021) uses plant-level data from the EPA's Toxic Release Inventory for the period 2001-2019 to investigate the effect of corporate acquisition on facility-level air pollution and its firm level distribution.

Figure 1: Distribution of ownership changes over time at facility and firm level



Notes: This figure shows number of ownership changes at the facility and firm level in each year for facilities and firms with only one ownership change during our observation period.

Based on Sun and Abraham (2021) the regression for our event study is:

$$Y_{it} = \alpha_i + \lambda_{ct} + \mu_{st} + \sum_{e \notin C} \sum_{l \neq -1} \delta_{el}(1\{E_i = e\} * D_{it}^l) + \varepsilon_{it},$$

where the outcome Y_{it} is aggregated emissions or economic outcomes of unit i in year t. D_{it}^l indicates the relative period of the observation, unit i being l periods away from year of treatment E in year t, and $1\{E_i = e\}$ indicates the treatment group that unit i belongs to. The specification interacts these indicators, but omits interactions with the last group of units with ownership change in 2016 because these units do not have a not-yet-treated control group, and with the reference period $l = -1$ to avoid issues of multicollinearity. δ_{el} represents the group-specific average treatment effect on the treated. α_i, λ_{ct}, and μ_{st} capture unit-specific, country-year and sector-year fixed effects, respectively.

To form the interaction-weighted estimator, δ_{el} is weighted with sample shares of each group in each period $Pr\{E_i = e|E_i \in [-l, T-l]$. The resulting weighted average estimate normalized for the number of periods after treatment g is then:

$$\hat{v}_g = \frac{1}{|g|} \sum_{l \in g} \sum_{e} \delta_{el} \hat{Pr}\{E_i = e|E_i \in [-l, T-l].$$

We employ the Sun and Abraham estimator to identify the effect of an ownership change event on total emissions, emissions intensity and economic outcomes of firms and on total emissions of facilities. We apply the inverse hyperbole sine transformation to the outcome so that we can interpret the effects in percentage changes.[16] Our preferred specification estimates the ownership change effect using 4 leads and lags around the treatment year.[17] We include only treated firms or facilities so that the later treated units act as controls for the earlier treated units. Firms or facilities with more than one ownership change event during the period 2007-2016 are excluded. We cluster the standard errors at the respective unit level.

The main identifying assumptions for the event study estimation to produce an unbiased effect of ownership changes on facility and firm indicators are, first, for the control group to have parallel trends in the outcomes of interest in the absence of treatment, and, second, that treatment timing is random, i.e., it is not associated with firm characteristics that also affect outcomes of interest. The first assumption of parallel trends connects to the empirical challenge of finding a valid counterfactual for facilities and firms that are acquired. Firms and facilities with an ownership change event may systematically differ from firms and facilities that keep their parent company over the entire period. Moreover, firms and facilities with more than one event may also be systematically different. We check empirically whether the groups of firms differ systematically in observable characteristics. We find small differences in capital, long-term debt, total emissions, employment and intangible fixed assets (see Figure

[16] We use the hyperbole sine transformation instead of the natural logarithm to deal with zero values when facilities do not report emissions or economic indicator values are equal to zero.

[17] We bin the first and the last lag following Schmidheiny and Siegloch (2020). Hence, we assume that effects remain constant before and after these years, respectively.

B6 in the Appendix). We deal with this issue by omitting firms and facilities with no ownership change and those with multiple ownership changes over the sample period. We inspect the pre-treatment coefficients in the event study to check if pre-trends are parallel.

The second assumption of treatment timing being unrelated to facility and firm characteristics cannot be tested empirically. We argue that the assumption is reasonable in our context:[18] M&A processes usually take a significant amount of time and it is ex-ante not predictable whether ownership will change within the same year or with considerable delay in the negotiations. Moreover, in our sample a significant share of the acquisitions happens in bundles where several facilities or firms change from one parent company to another jointly in the same year. Acquisition decisions taken at an aggregate level tend to be more independent of the performance of individual firms and even more so of facilities.[19] In addition, we provide suggestive evidence that the assumption appears to hold in our context by testing whether observed firm characteristics provide any predictive power for the timing of ownership changes. Except for intangible fixed assets, we do not find any observed firm characteristics to significantly predict treatment timing (see Table B1 in the Appendix).

Firms and facilities with an earlier change in ownership could also differ from firms with later changes if the reasons for ownership changes differ over time, e.g., via the financial crisis which had its strongest impact at the beginning of the sample period. Similarly, merger waves could be sector-specific and their timing could differ across industries. Environmental policy regulation that came into force during the study

[18]Other studies that investigate the effect of M&A on firm-level outcomes and use variation in timing of ownership changes in event study settings are Jacqz (2021) and Blonigen and Pierce (2016).

[19]Of all firms that change their owner once during the study period, at least 26% are acquired in bundles of two or more firms. We can only provide this lower bound share from our data as we do not observe firms not included in the E-PRTR which are potentially also part of bundle deals but whose pollutant emissions are below the E-PRTR reporting thresholds.

period could additionally introduce a trend in emissions and emissions intensity over time.[20] We address these issues by including sector-year and country-year fixed effects.

Anticipation effects are another threat to identification if the prospect of a change in ownership affects reported emissions and economic outcomes of firms or facilities before an acquisition. If the effect of a change in ownership manifests through a change in management practice or a technology transfer, the effect is implausible to affect emissions before an acquisition. It could however be advantageous for firms in a merger process to play down their emissions in the negotiations and report lower emissions. On the other hand, firms could ramp up production and increase output to appear more profitable for potential investors. Such anticipation effects would be visible in the pre-treatment coefficients close to treatment. We do not find evidence for an anticipation effect. We find however significant pre-treatment coefficients for some of the outcomes at the firm level three to two years before an ownership change event. In these cases, we must be cautious to interpret the coefficient as an isolated effect of the ownership change since the coefficient may reflect also other differential trends.

Shocks that affect both emissions and the propensity for an ownership event of firms and facilities can also bias the estimate. If a positive demand shock leads parent companies to buy up promising firms that will expand in the coming years, the estimate of emission reductions will be biased downward. If a negative demand shock leads parent companies to sell low-performing firms which would otherwise have closed down, the change in ownership delays the closure so that the estimate will be biased upward. Arnold (2019) and Jacqz (2021) counter this source of bias by focusing on ownership changes of larger firms which are less affected by local demand shocks. Our sample mainly consists of large firms as well.

[20] Relevant environmental regulation that affects pollutants included in the E-PRTR is, first, the Large Combustion Plant EU Directive (European Parliament and European Council, 2001) that specified emission limits for SO_2, NO_x and dust from 2008 on. The regulation was binding mainly for plants in Southern and Eastern European economies that still operated on older technologies (European Environmental Agency, 2019). Second, the EU ETS (European Parliament and European Council, 2003) regulated CO2 emissions via a cap-and-trade system. However, the price per ton of CO2 was very low over the entire study period and the timing and strictness of the regulation was uniform across countries in the sample.

4 Results

We first present results on the effect of ownership changes on our main outcomes of interest, emissions and emissions intensity (see Section 4.1). Second, we show how ownership changes affect output and production inputs (see Section 4.2). Third, we investigate spillovers of the ownership changes on total factor productivity, operating profits and intangible fixed assets (see Section 4.3). For each set of outcomes, we move from the more granular levels of observation, the facility and firm, to the aggregated level, the parent company. In section 4.4, we discuss implications of our results.

4.1 Emissions and emissions intensity

Total emissions of facilities decrease steadily after an ownership change. In the third year after a change, their emissions decrease by about 50 percent (see Figure 2). The point estimate of the average effect of an ownership change on total emissions at the facility level is at negative 37 percent (see Table 2).[21] The estimates using the Sun and Abraham (2021) approach that we report here are larger in absolute terms as compared to the two-way fixed effects estimates.[22] Results are similar when we impute missing emission values at the facility level with either zero or the pollutant-specific thresholds (see Table B2 in the Appendix).

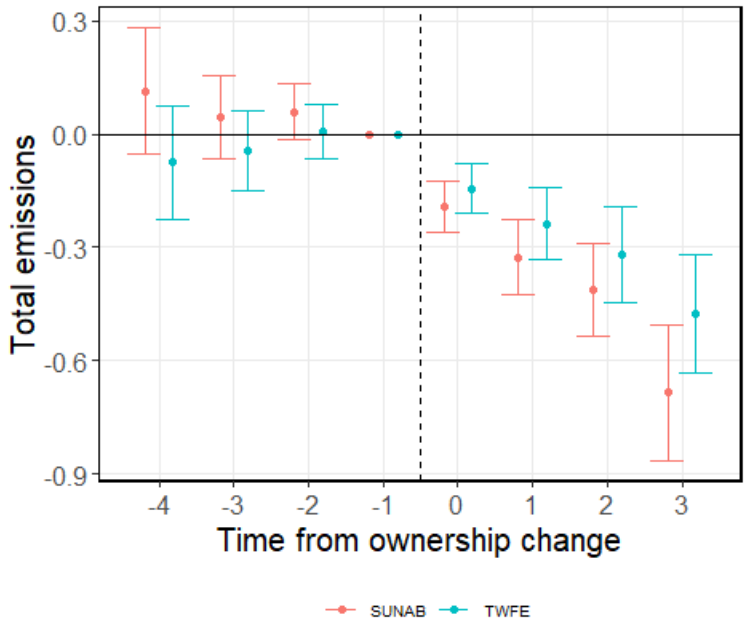
A falling trend in emissions is visible already in the pre-treatment period before the ownership change, but the slope is less steep than in post treatment and none of the coefficients is significant. We still conduct a sensitivity test using the Rambachan and Roth (2023) approach. The test shows that the reduction in emissions after changing ownership adjusted for the pattern in pre-trends is significant as long as the deviation from parallel trends in the post-treatment period is of similar size or smaller than the

[21] For interpretation of the coefficients x from the log/ihs-linear specifications, we use the formula $(e^x - 1) * 100$ to retrieve the percentage change estimate.

[22] The Sun Abraham estimator is larger in magnitude for total emissions. For some other outcomes it is the other way around. A deviation of the results of the Sun Abraham estimator from those of the naïve two-way fixed effects estimator indicates that treatment effects vary across units and cohort effects over the years are not constant. Consequently, the results for the two-way fixed effects estimator will be biased. In this section, we focus on reporting and discussing results from the Sun Abraham estimator but show results for the plain two-way fixed effects estimates in the event study plots for comparison.

maximum violation observed in the pre-treatment period.[23] Since the E-PRTR data does not provide information on output and other industrial indicators of industrial facilities, we cannot investigate the impact of ownership changes on production at the facility level.

Figure 2: Effect on total emissions at the facility level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions. The inverse hyperbolic sine transformation is applied to the independent variable.

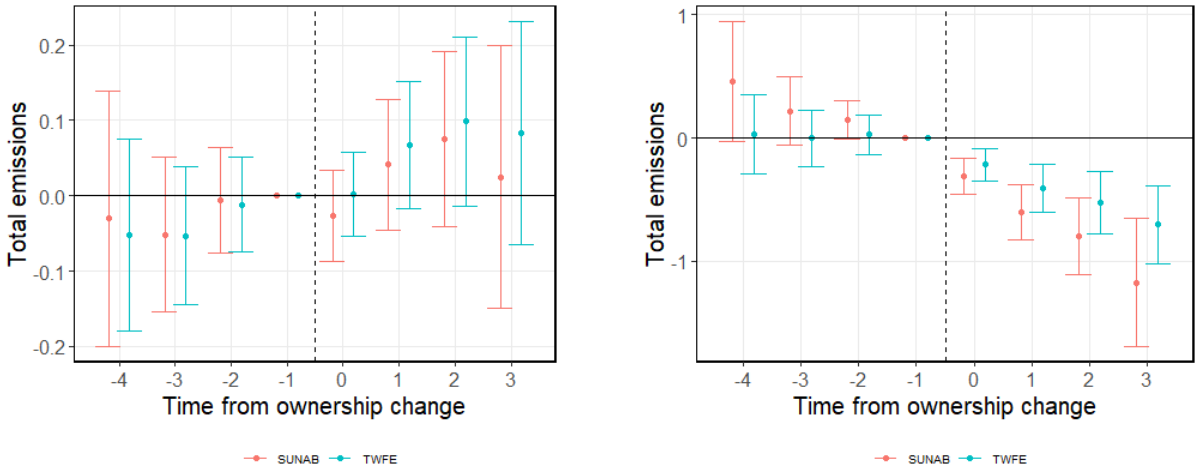
We separate the sample into facilities that remain in operation and facilities that are shut down after changing ownership to see how much of the reduction in emissions is due to shutdowns.[24] Figure 3 shows that emissions in facilities that remain in operation after changing owners do not change significantly while facilities that are shut down reduce their emissions strongly. The average reduction in exiting facilities is significant negative at 54 percent (see Table 2). A part of the facilities is only closed down after more than three years so that we do not see a reduction in the range of 100 percent. The reduction in emissions appears to be at least partially driven by a falling trend

[23] See Appendix C for a short introduction to the method and Figure C1 for the results of the sensitivity check.

[24] As explained in Section 2, we identify shutdowns of facilities and firms as those that stop reporting emissions in the observation period.

that already starts in the pre-treatment period so that the drop in emissions in exiting facilities may not be attributable to the ownership change. In a sensitivity check, we find that the effect is only significant if the deviation from parallel trends post treatment is half or less of the maximum violation observed in the pre-treatment period.[25]

Figure 3: Effect on total emissions at the facility level by subsample



(a) Remaining facilities **(b) Exiting facilities**

Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions. The inverse hyperbolic sine transformation is applied to the independent variable.

Table 2: Aggregate effects on facilities

	Full sample			Remaining facilities			Exiting facilities		
Dependent variables	**ATT**	**SE**	**N**	**ATT**	**SE**	**N**	**ATT**	**SE**	**N**
Total emissions	-0.455***	(0.058)	10,624	0.025	(0.055)	6,416	-0.785***	(0.157)	4,208

Notes: The first column denotes the dependent variable with an inverse hyperbolic sine transformation. The table shows three separate event study regressions on the full sample of firms, on remaining firms as well as on exiting firms. For each regression, we report the point estimate of the aggregated effect of the event study following Sun and Abraham (2021) (ATT), the standard error (SE) and the number of observations (N). Standard errors clustered at the facility level are in parenthesis. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

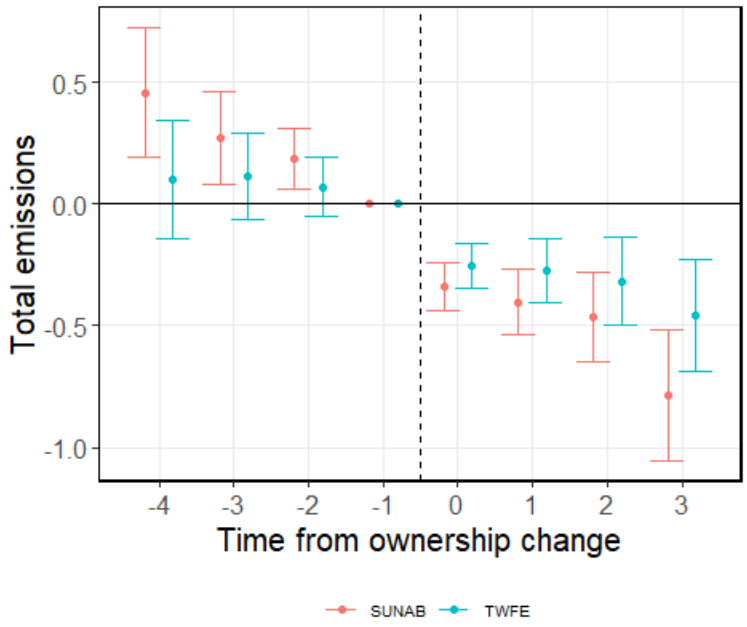
Up to this point, we assume that every ownership change has a similar impact, neglecting differences across types of ownership changes and across new owner characteristics. There is a large literature highlighting the role of foreign direct investments for firm performance. With respect to domestic and foreign ownership changes, we find similar effects to the average effects in the full sample of facilities presented above

[25]See Figure C2 in the Appendix for the results of the sensitivity check.

and confidence intervals overlap for all ownership type groups. These results suggest no large differences across different owner types (see Figure B7 and the more detailed explanation in the Appendix). Furthermore, we only find limited effect heterogeneity across sectors, with the exception of the sector manufacture of motor vehicles which experiences a larger reduction in total emissions compared to other sectors (see Figure B8 in the Appendix).

Facilities that reduce their emissions after a change in ownership are often part of a larger firm which potentially owns many industrial facilities. Investigating these firms for whom we have data on output and an abundance of financial and economic performance indicators allows us to also capture the effect of ownership changes on emissions intensity, production and spillovers, while this data is not available at the facility level.

Figure 4: Effect on total emissions at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions. The inverse hyperbolic sine transformation is applied to the independent variable.

Firms reduce their total emissions on average by 42 percent which is in the range of the effect at the facility level (see Figure 4 and Table 3).[26] After the third year, emissions decrease by about 54 percent.[27] The decline in emissions that is observed after the ownership change, starts already in the years before the acquisition event. This may point to additional underlying trends not driven by the ownership change. We run a sensitivity check and find that the effect is only significant if the deviation from parallel trends post treatment is half or less of the maximum violation observed in the pre-treatment period.[28]

When investigating the samples of firms remaining in operation versus firms that are closed down, the results look similar to the facility results (see Figure 5 and Table 3). Firms that remain in operation do not change their emissions. The falling trend observed both before and after changing ownership appears to be solely driven by the firms that shut down subsequently. The sensitivity check shows that the effect for exiting firms is only significant if the coefficient is adjusted with a deviation from parallel trends that is less than half of the maximum violation observed in the pre-treatment period.[29]

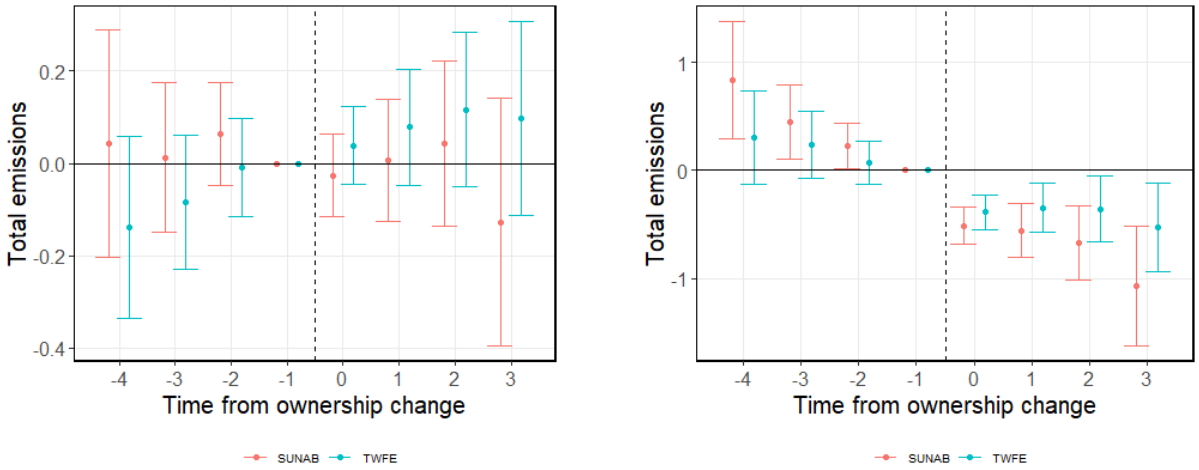
[26] As the firm level emissions are an aggregation of facility level emissions, firm results are a reweighing of facility results.

[27] The effect is robust to imputation of missing values with both zero-values and threshold-values (see Table B3).

[28] See Figure C3 in the Appendix for the results of the sensitivity check.

[29] See Figure C4 in the Appendix for the results of the sensitivity check.

Figure 5: Effect on total emissions at the firm level by subsample



(a) Remaining firms **(b) Exiting firms**

Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions. The inverse hyperbolic sine transformation is applied to the independent variable.

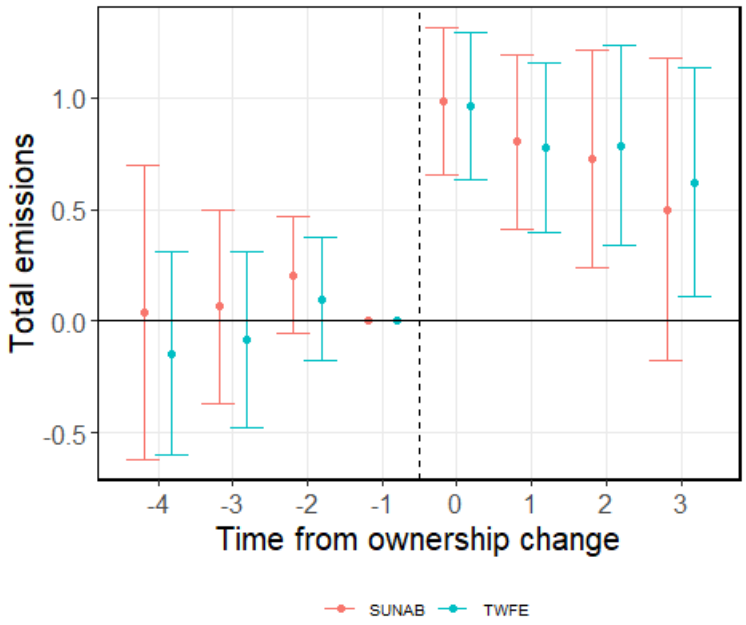
As in the case of facilities, we do not find differential effects based on the type of ownership change, i.e., from domestic to domestic, domestic to foreign, foreign to domestic or foreign to foreign owner, or across sectors (see Figure B9 and Figure B10 in the Appendix).[30]

After a change in ownership, facilities and firms appear to reduce their emissions through shutdowns of firms and their facilities that were already reducing emissions before acquisition, while facilities and firms that remain in operation do not change emissions. But how does their integration in the new parent company affect aggregate environmental performance at the parent company level and other industrial facilities within the new parent company? To shed light on this question, we aggregate all industrial facilities reporting to the E-PRTR at the parent company level for each year. Then, we re-run the event studies for the subset of parent companies that have already owned industrial plants before they acquired a new one and acquired new

[30]Furthermore, we explore whether effects differ for firms with one vs. many facilities and with above vs. below median parent company emissions. We do not observe any differential effects for these groups. Results are available upon request from the authors.

industrial facilities only once.[31] On average, total emissions of parent companies increase significantly and strongly after acquiring a new industrial facility (see Table 4). Furthermore, there is a downward trend over time after the change in ownership (see Figure 6), mirroring the results at the facility and the firm level. For parent companies that do not shut down their target after acquisition, the results are very similar (see Figure B11 in the Appendix).[32]

Figure 6: Effect on total emissions at the parent company level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

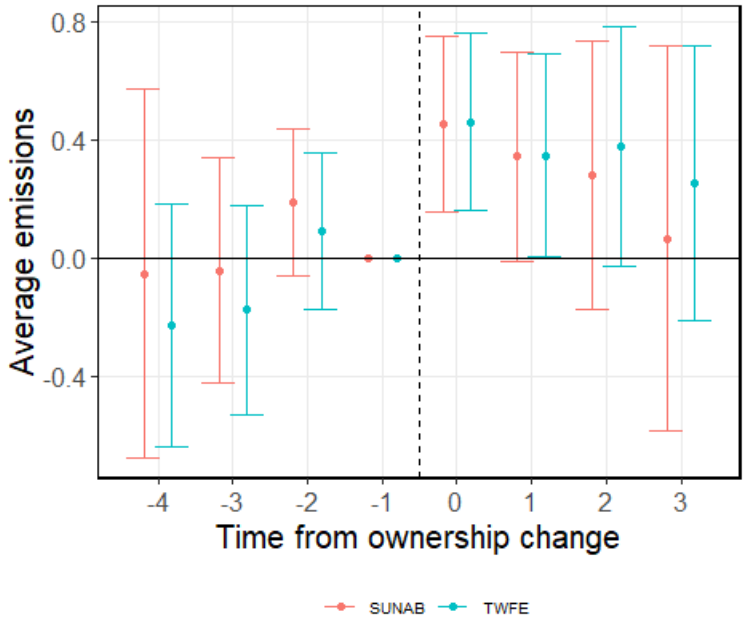
We also estimate the effect on average emissions at the facility level over all facilities in the parent company to see whether the newly acquired facility differs from the other facilities. The effect on average emissions per facility is positive, albeit insignificant after the first year, with a falling trend (see Figure 7). This indicates that emissions of the newly acquired facilities are not significantly above average. For the subsample of

[31] The ownership change event starts in the year in which the parent company acquires a new facility. In the event studies on the parent company level, we only include parent company and year fixed effects since we cannot unambiguously assign countries and sectors to the parent company.

[32] For parent companies that acquire more than one facility in the same year, we consider them in this sample if they do not shut down any of their targets. We do not run a separate regression for parent companies that close down at least one of their targets as the sample gets too small and estimation too imprecise.

parent companies that do not shut down their target after acquisition, the increase after the ownership change is smaller and also insignificant except for the year in which the ownership change happens (see Figure B12 in the Appendix). To trace out whether any reallocation in emissions happens across new and old facilities within a parent company after acquisition, we also look at the effect of ownership changes on the other facilities that were part of the acquiring parent company before the acquisition. For these facilities, emissions do not change after acquisition (see Figure 8 and Table 5).[33]

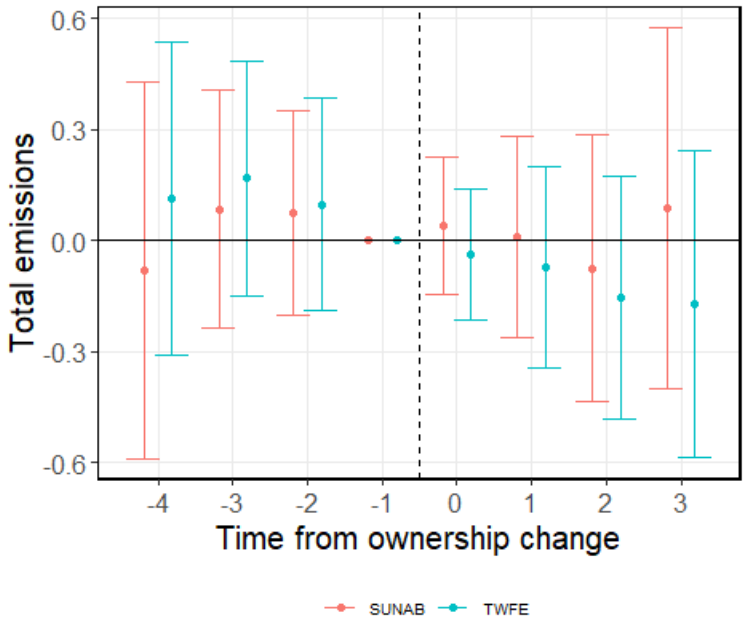
Figure 7: Effect on total emissions per industrial facility at the parent company level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

[33]We do not run separate regressions for the sample of other facilities in parent companies that do not close down their acquisitions versus parent companies that shut down acquisitions as the sample size gets too small.

Figure 8: Effect on total emissions in other industrial facilities of the acquiring parent company



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

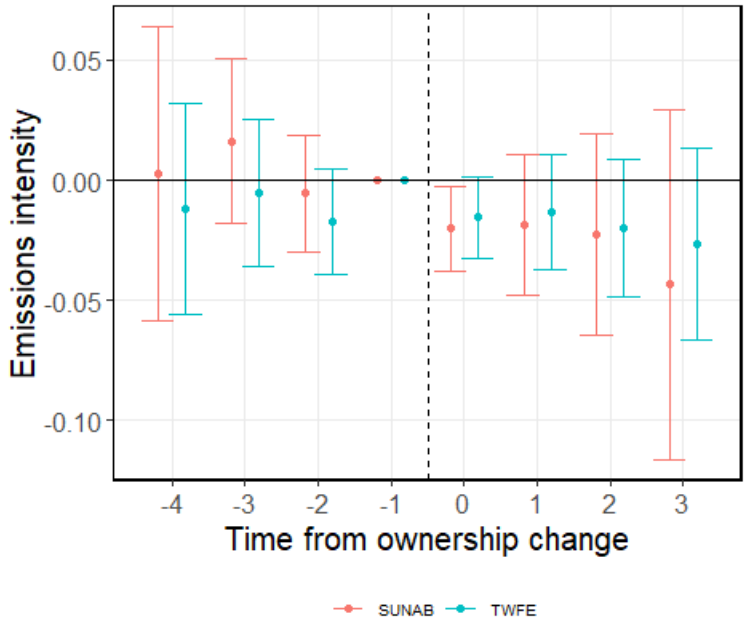
At the firm level, we have data available to estimate the effect of ownership changes on emissions intensity (emissions over operating revenues). Firms' emissions intensity seems relatively unaffected. A falling trend is observed in the post-treatment period but the magnitude of reduction is negligible. Only the effect in the year of ownership change is significant while all other years and the aggregate effect are insignificant. The small decrease appears to be solely driven by exiting firms. For firms that remain in operation, emissions intensity remains virtually constant (see Figure B13 in the Appendix).[34]

Also for the acquiring parent company both at the aggregated level and per facility, emissions intensity does not change as the new facility joins the parent company and

[34] Additionally, we calculate how emissions in firms with an ownership change had evolved if emissions intensity had remained constant and only output had changed (scale effect) and how emissions would have evolved if output had remained constant and only emissions intensity had changed (technique effect) comparing output and emissions two years before an ownership change versus two years after. Total emissions increased by 13 percent. Via the isolated effect of output expansion (scale), emissions would have increased by 65 percent and, via a reduction in the emissions intensity, emissions would have decreased by 32 percent.

the results do not differ considerably for the sample of only parent companies that do not shut down their targets after acquisition (see Figures B14 to B17 and Table 4). That means that the newly acquired facilities' emissions intensity is not significantly above average. Finally, for other facilities in the acquiring parent company emissions intensity remains unchanged as well after the new facility joins the group (see Figure B18 in the Appendix). Consequently, we do not find evidence for a technology transfer between the acquired facility and other facilities in the parent company that would affect environmental performance.

Figure 9: Effect on emissions intensity at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

In summary, we find that emission reductions observed for the full sample are driven by exiting facilities and firms that decrease emissions already before ownership changes. For facilities and firms that do not shut down, emissions remain constant before and after acquisition. Emissions intensity does not change significantly, neither for exiting firms nor for those remaining in operation. At the parent company level, aggregate emissions increase significantly. However, average emissions per facility do not change. Emissions intensity remains constant, both at the aggregate level and per

facility. These findings indicate that newly acquired facilities are of similar size and they produce at similar emissions intensity as facilities already in possession of the parent company. Moreover, there is no evidence for spillovers of the acquisition on the latter facilities as their emissions and emissions intensity remains constant as well.

Table 3: Aggregate effects on firms

	Full sample			Remaining firms			Exiting firms		
Dependent variables	**ATT**	**SE**	**N**	**ATT**	**SE**	**N**	**ATT**	**SE**	**N**
Total emissions	-0.549***	(0.085)	6,272	-0.053	(0.085)	3,097	-0.748***	(0.166)	3,175
Output	-1.484***	(0.300)	5,547	-0.952**	(0.365)	2,791	-1.494***	(0.523)	2,756
Emissions intensity	-0.030	(0.022)	5,175	-0.005	(0.017)	2,457	-0.058	(0.052)	2,718
Total factor productivity	0.004	(0.005)	2,945	0.001	(0.006)	1,598	0.005	(0.009)	1,347
Operating profits	-0.751*	(0.386)	4,191	-0.533*	(0.341)	2,168	-1.172	(0.732)	2,023
Labor input	-0.474***	(0.099)	5,264	-0.297**	(0.111)	2,609	-0.516**	(0.191)	2,655
Capital input	-1.217***	(0.292)	5,500	-0.701*	(0.352)	2,761	-1.446**	(0.515)	2,739
Labor expenditures	-1.152***	(0.301)	5,057	-0.663*	(0.288)	2,480	-1.176*	(0.529)	2,577
Intangible fixed assets	-0.148	(0.392)	5,004	-0.029	(0.482)	2,671	0.040	(0.709)	2,333

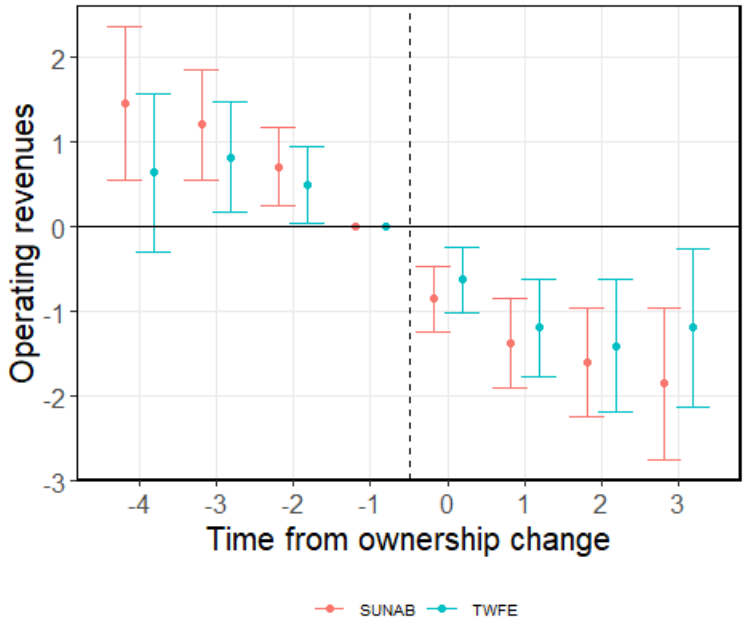
Notes: The first column denotes the respective dependent variables each with an inverse hyperbolic sine transformation. Each line represents three separate event study regressions on the full sample of firms, on remaining firms as well as on exiting firms. For each regression, we report the point estimate of the aggregated effect of the event study following Sun and Abraham (2021) (ATT), the standard error (SE) and the number of observations (N). Standard errors clustered at the firm level are in parenthesis. Output refers to deflated operating revenues, emissions intensity to total emissions divided by output, labor input to number of employees, capital input to deflated tangible fixed assets, respectively. As a robustness check, Table B5 in the Appendix reports the same estimations on the 50 percent largest firms. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

4.2 Output and production inputs

We also take a look at output and production inputs after ownership changes which are potential drivers of the emission reductions that we observe. At the firm level, output as proxied by operating revenues shows a relatively steep falling pre-trend before the change in ownership that continues after (see Figure 10). The average decrease after treatment is at 77 percent. Similar to the results for emissions, the falling pre-trend appears to be predominantly driven by the firms that are closed down in the years after the ownership change (see Figure B20 in the Appendix). For those firms, pre-trends fall steeply and the estimated reduction after the ownership change is at 78 percent. For firms that remain in operation, the coefficient in the year before treatment is marginally significant, but no clear pre-trend is visible. The reduction in output after the change in ownership is smaller, but still sizable at 61 percent. We run sensitivity checks for

all three samples that adjust the treatment effects for violation in parallel trends before treatment. We find for each of the effects in all firms, exiting firms and remaining firms, respectively, that coefficients are only significant when they are adjusted by less than half of the maximum violation of parallel trends in the pre-treatment period.[35] This indicates the observed reductions in output were rather not causally driven by the ownership changes but would – at least partially – have happened without acquisition as well.

Figure 10: Effect on output at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

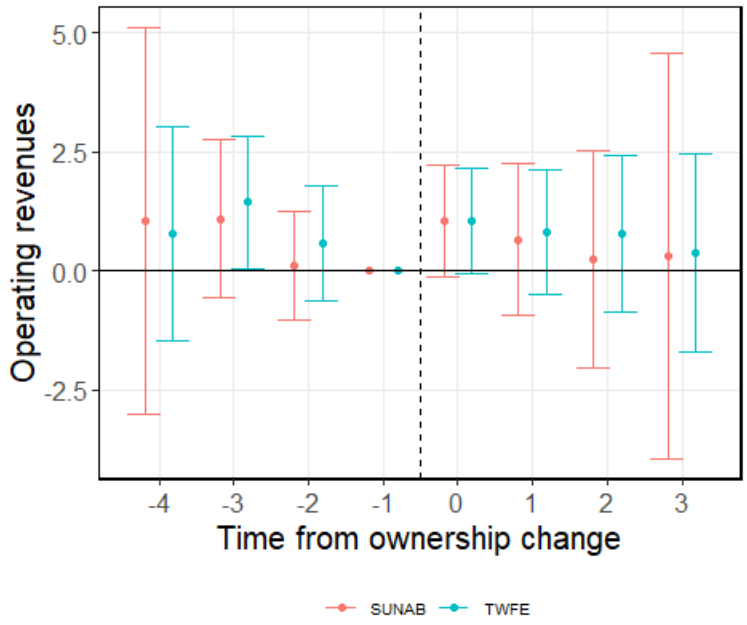
In the Orbis data, we also observe labour and capital production inputs as well as labour expenses. The results for these outcomes mirror the ones for the output: a steep falling trend before the change in ownership that continues after (see Figures B21 to B23 in the Appendix). A sensitivity test that adjusts post-treatment coefficients for violations in parallel trends before changing ownership finds that effects turn insignificant at adjustments of less than half of the maximum violation observed before

[35] See Figures C5 to C7 in the Appendix.

treatment for either of the three outcomes.[36] When separating the sample into firms that remain in operation versus those that close down, also for these outcomes the reductions are stronger for exiting firms. However, reductions are still sizable for firms remaining in operation (see Table 3).

At the level of acquiring parent companies, the effect of an ownership change on output is not significant. However, the estimation is rather imprecise as standard errors are very large and the same goes for the estimation on the subsample of parent companies that do not shut down their acquisition (see Figure 11 and Table 4). Labour and capital input as well as labour expenses increase significantly after acquisition, but the increases are smaller in the sample focusing on acquisitions that are not closed down - and the increase in labor expenses is not significant for the latter (see Figures B24 to B26 and Table 4).

Figure 11: Effect on output at the parent company level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Per industrial facility of the acquiring parent company, output does not change significantly, but again standard errors are quite large for this estimation. Capital

[36] See Figures C8 to C10 in the Appendix.

input and labor expenditures significantly increase and the increases are smaller in the sample focusing on acquisitions that are not closed down. This indicates that newly acquired facilities employ above average amounts of capital input and labor expenditures, and this effect is stronger for facilities that are closed down subsequent to the ownership change. Labor input relative to the number of facilities does not significantly change after the acquisition in neither of the samples (see Figures B28 to B30 in the Appendix and Table 4). For other facilities in the parent company, the acquisition of the new facility neither affects output nor production inputs (see Figures B31 to B34 in the Appendix and Table 5).

Table 4: Aggregate effects on acquiring parent companies

	Full sample			Remaining firms		
Dependent variables	**ATT**	**SE**	**N**	**ATT**	**SE**	**N**
Total emissions	0.742***	(0.217)	2,274	0.673*	(0.261)	1,444
Output	0.592	(1.186)	2,248	0.048	(1.440)	1,433
Emissions intensity	0.020	(0.028)	1,858	0.037	(0.033)	1,163
Total factor productivity	-0.007	(0.017)	1,305	-0.002	(0.020)	816
Operating profits	0.888	(2.124)	2,248	1.693	(1.785)	1,433
Labor input	0.834***	(0.286)	2,248	0.567	(0.346)	1,433
Capital input	2.701***	(0.774)	2,248	2.094*	(0.972)	1,433
Labor expenditures	2.270***	(0.670)	2,248	1.761*	(0.847)	1,433
Intangible fixed assets	1.477**	(0.601)	2,248	0.880	(0.709)	1,433
Total emissions per industrial facility	0.273	(0.204)	2,274	0.302	(0.240)	1,444
Output per industrial facility	0.256	(1.119)	2,248	-0.200	(1.363)	1,433
Emissions intensity per industrial facility	0.016	(0.021)	1,858	0.027	(0.026)	1,163
Total factor productivity per industrial facility	-0.435***	(0.076)	1,305	-0.277***	(0.067)	816
Operating profits per industrial facility	0.547	(2.036)	2,248	1.384	(1.713)	1,433
Labor input per industrial facility	0.426	(0.260)	2,248	0.253	(0.313)	1,433
Capital input per industrial facility	2.252**	(0.750)	2,248	1.741*	(0.940)	1,433
Labor expenditures per industrial facility	1.864**	(0.643)	2,248	1.430*	(0.814)	1,433
Intangible fixed assets per industrial facility	1.112*	(0.578)	2,248	0.615	(0.686)	1,433

Notes: The first column denotes the respective dependent variables each with an inverse hyperbolic sine transformation. Each line represents two separate event study regressions on the full sample of acquiring parent companies as well as on acquiring parent companies that do not close down their target. For each regression, we report the point estimate of the aggregated effect of the event study following Sun and Abraham (2021) (ATT), the standard error (SE) and the number of observations (N). Standard errors clustered at the firm level are in parenthesis. Output refers to deflated operating revenues, emissions intensity to total emissions divided by output, labor input to number of employees, capital input to deflated tangible fixed assets, respectively. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

In summary, the trends in output and production inputs mirror emissions at the firm level: these outcomes already decrease before acquisition and continue falling afterwards. These trends are stronger for firms that are shut down after they change owners, confirming that emissions reductions are indeed driven by output reductions.

For firms that remain in operation, the falling trends before and after acquisition are less pronounced. At the level of the acquiring parent company, production inputs increase. The increase is smaller for firms purchased by parent companies that keep their targets in operation, again mirroring the pattern of emissions. On average at the facility level, capital input and labor expenses increase, but the increase is less if acquired facilities remain in operation. Other facilities' inputs and output within the same parent company is not affected which suggests that production is not reallocated across facilities within a parent company after acquisition.

4.3 Total factor productivity, operating profits and intangible fixed assets

The finding that emissions of facilities and firms that remain in operation after acquisition do not change suggests that no technology is transferred to the acquisition that would affect its environmental performance. We also do not find emissions of other facilities in the acquiring company to change which indicates that no environmental technology is transferred to them from the acquisition either. In this section, we check whether the ownership change induces any other types of spillovers. To this end, we look at total factor productivity, operating profits and intangible fixed assets.

At the firm level, productivity remains virtually constant after ownership changes and the result remains the same when separating firms that remain in operation from firms that exit (see Figures B35 and B36 in the Appendix and Table 3).[37] Operating profits drop significantly by 52 percent - however, the falling trend starts already in the pre-treatment period so that the reduction can be at most partially attributed to the ownership change (see Figure B37 in the Appendix). A sensitivity check shows that the effect in the third year after ownership change turns even less significant when adjusting for violations in parallel trends before treatment.[38] The decrease appears to be driven by firms that remain in operation: for those, the reduction is significant and

[37] We use our estimated TFP values as an outcome variable in the event study regressions. We run the regression with the sample of firms for which capital input is available.

[38] See Figure C11 in the Appendix.

pre-trends are insignificant. For firms that shut down, the falling trend before treatment is even more pronounced and seems to continue after the change in ownership, but the average effect is not significant (see Figure B38 in the Appendix and Table 3). As for total factor productivity, the results on intangible fixed assets including, e.g., patents, copyrights, trademarks and goodwill, are all insignificant: both for the full sample and the split samples, the effect is close to zero (see Figures B39 and B40 in the Appendix and Table 3).

At the level of acquiring parent companies, the effect of an ownership change aggregated over all facilities on total factor productivity and operating profits is insignificant, and the same goes for the subsample of only parent companies that do not shut down their acquisition (see Figures B41 and B42 and Table 4). However, intangible fixed assets increase strongly and permanently after the acquisition (see Figure B43 in the Appendix). This results seems to be driven by parent companies that shut down their targets after acquisition as the effect is not significant for the sample where targets remain in operation (see Table 4).

Per industrial facility in the acquiring parent company, total factor productivity drops by 35 percent which means that the newly acquired facilities are on average less productive than the rest of facilities. The drop in the sample of parent companies that do not shut down their acquisitions is at 24 percent a bit smaller – acquired firms that are shut down tend to be less productive than the ones that remain in operation (see Figure B44 and Table 4). Operating profits per facility are not affected by the acquisition of the parent company, not either for the sample of parent companies that let their acquisitions continue operation (see Figure B45 and Table 4). Intangible fixed assets significantly and strongly increase per facility, meaning that acquired facilities hold above average intangibles, but this is only the case for the full sample. In the sample of only parent companies that do not shut down their acquisition, the effect is insignificant (see Figure B46 and Table 4). That indicates that parent companies tend to shut down facilities that hold above average intangible fixed assets.

For other facilities within the acquiring parent company, there appear to materialize spillovers from the acquisition: both operating profits and intangibles increase strongly and significantly (see Figures B48 and B49 in the Appendix and Table 5). The effect on total factor productivity shows a minor increase but the years before treatment indicate an increasing trend as well so that the increase is unlikely driven by the ownership change (see Figure B47 in the Appendix and Table 5).

Table 5: Aggregate effects on other industrial firms of acquiring parent companies

Dependent variables	ATT estimate	Std. Error	N
Total emissions	0.032	(0.153)	1,864
Output	−0.088	(0.715)	1,691
Emissions intensity	0.006	(0.019)	1,474
Total factor productivity	0.014*	(0.007)	972
Operating profits	3.625**	(1.479)	1,665
Labor input	−0.275	(0.184)	1,578
Capital input	−0.109	(0.639)	1,658
Labor expenditures	−0.101	(0.575)	1,534
Intangible fixed assets	0.995*	(0.522)	1,551

Notes: The first column denotes the respective dependent variables each with an inverse hyperbolic sine transformation. Each line represents a separate event study regression. Output refers to deflated operating revenues, emissions intensity to total emissions divided by output multiplied to 100,000, labor input to number of employees, capital input to tangible fixed assets, respectively. The second and third columns show the point estimates and standard errors of the aggregated effect of the event study following Sun and Abraham (2021). The fourth column contains the number of observations. Standard errors clustered at the firm level are in parenthesis. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

In summary, the results suggest that parent companies close down targets with below-average productivity and above-average intangible fixed assets. These intangibles subsequently appear to be transferred to other facilities owned by the acquiring parent company, potentially driving the increases in productivity and operating profits observed in these facilities.

4.4 Discussion

We observe two different patterns in facilities and firms after an ownership change. On the one hand, a significant share of them reduces their emissions strongly alongside a strong decrease in production and production inputs via shutdowns. Emissions

intensity, total factor productivity, operating profits and intangible fixed assets in these firms do not change significantly before the shutdown. These facilities and firms appear to have been on a downward trajectory already before acquisition so that we cannot attribute the reduction in emissions to the change in ownership. On the other hand, emissions and emissions intensity of facilities and firms that remain in operation after acquisition do not change significantly and reductions in output and inputs are smaller. Productivity and intangibles are not affected either, but profits decrease significantly.

At the parent company level, the dichotomy between parents that close down at least one of their targets versus parents that continue operation in all of their tragets after acquisition is visible as well. In the former group without shutdowns, the increase in production after acquisition both in the aggregate and per facility is smaller then for the full sample. Moreover, the drop in production is smaller per industrial facility and intangibles do not change significantly while they increase in the full sample. For other facilities in the acquiring parent company we are not able to investigate the dichotomy due to sample restrictions. Here, we observe that the acquisition significantly increases productivity, profits and intangibles in other facilities in the parent company. Emissions intensity is not affected at any level in any of the samples.

We conclude from these results that neither total emissions nor emissions intensity are affected by ownership changes. Even emissions reductions via shutdowns of facilities and firms after acquisition do not seem to be caused by ownership changes as emissions already start falling several years before an acquisition. The transfer of technologies between the acquiring and the acquired firm is often discussed as rationale for mergers and acquisitions in the literature. Our results do not provide evidence for a transfer of environmental technologies between acquiring and acquired firm in either direction as emissions intensity remains constant at all entity levels. Likewise, we do not find strong evidence for non-environmental technology transfers. Productivity in the other facilities of acquiring parent companies increases, but average productivity of targets is lower than in these other facilities. Our results for European industrial firms and facilities differ from the findings by Jacqz (2021) that US-American facilities that

continue operation after an M&A event reduce emissions of toxic chemicals, hinting at operational changes and technology transfers as reason for the observed reductions.

The significant share of close-downs in the years after acquisition seems to follow a rationale other than technology transfers. One explanation in the literature is that acquiring mother firms want to reduce output in sectors where there are oligopoly rents to harvest. Previous empirical work in various settings finds a tendency of acquiring firms to shut down a significant proportion of their targets after acquisition. Several studies report that the probability of shutdown after acquisition is higher if target and acquiring firm are not active in the same sector. Blonigen and Pierce (2016) find that the exit probability of acquired US plants is higher than for plants in the control group and that the shutdowns are predominantly in constellation where the acquiring firm does not operate in the same sector as the target. Kaplan and Weisbach (1992) study shutdowns of targets over a longer time horizon of up to 18 years after acquisition and find that 44 percent of acquired firms close down over this period. Diversifying acquisitions that are active in another industry than the acquirer are close to four times more likely to shut down. Maksimovic et al. (2011) find that in acquisitions of US targets, 19 percent are closed down after the third year. The likelihood of shutdown is lower for targets in the same industry as the acquirer, larger targets and larger acquirers. These findings point to objectives other than market power prevalent in these settings studied. Cunningham et al. (2021) document objectives of market power to matter in shutdown decisions finding that 5 to 7 percent of acquisitions in the pharmaceutical sector are killer acquisitions that are supposed to discontinue the targets' innovations and kill future competition. Davis et al. (2014) find productivity gains to be the rationale of shutdowns after private-equity buyouts, where less productive targets are closed down after acquisition.

To explore whether market power is a rationale for shutdowns in our sample, we conduct two empirical tests. First, we check whether we observe exits after acquisition predominantly in specific sectors. In Section 4.2, we find that the output reduction is relatively uniform over sectors (see Figure B19 in the Appendix). Moreover, we

compare whether the share of firms that change ownership in each NACE2 sector is in the same range as the share of firms that shuts down after acquisition in the same sector. Doing this, we hope to uncover whether there are specific sectors that most of the shutdowns observed in our sample can be attributed to. We do not see strong differences in shares of firms and shutdowns for any sector, but nevertheless we conduct a two-sided proportion test to test for statistically significant differences in the shares. We find a few sectors in which the share out of all exiting firms is significantly higher than the share out of all firms with ownership change. But neither of the differences in sector shares is economically significant.[39]

As a second empirical check, we investigate whether a higher share of acquisitions that happen within the same sector is shut down subsequently as compared to acquisitions where the target and the acquiring company are predominantly active in different sectors. If the rationale for shutdowns is market power, we would mainly observe them by parent companies that are active in the same sector. We define an acquisition within the same sector as the target being predominantly active in the same sector as the majority of firms owned by the acquiring parent company according to their NACE2 classification. We find that the largest share, 91.4 percent of acquisitions, are within-sector. We conduct a t-test (p value = 0.5744) and do not find a significant difference in the share of within-sector acquisitions between the firms being shut down and the firms remaining in operation. The shares of within-sector acquisitions are 90.4 percent for exiting firms and 91.6 percent for firms remaining in operation. Our empirical checks do not provide evidence for that a significant share of firms in our sample is shut down strategically after acquisition to gain market power.

An alternative explanation for the rationale of closing down targets after acquisition is the transfer of intangible fixed assets from the acquired to the acquiring firm. Intangible fixed assets are assets of non-physical nature, such as intellectual property, licenses, trademarks or patents. While the stock of intangibles does not significantly

[39]The sectors for which the difference in shares is statistically significant are manufacture of electrical equipment, manufacture of printed goods, beverage production, food and animal feed, and collection, treatment and disposal of waste, recycling. Detailed results on the sector shares and the proportion tests are available upon request from the authors.

change in acquired firms that shut down subsequently, the increase in the aggregate stock of intangibles in the parent company seems to be driven by this subset of firms. Meanwhile, intangibles do not change in parent companies that do not shut down any of their targets. The stock of intangibles increases in other facilities of acquiring parent companies, probably via transfers of intangibles from the acquired firm that is about to shut down to these other facilities. Literature suggests that the transfer of intangibles is often an objective of mergers and acquisitions as it is expected to create value for the acquiring company, either directly or via exploiting differences in tax rates which would not necessarily affect production (Juranek et al., 2018a,b; Mamun et al., 2021; Filipovic and Wagner, 2023). We look at profits before taxes so that a potential effect on taxes paid is not observable. We see positive spillovers on operating profits and productivity which may be driven by a transfer of intangibles. Evidence on the effect of acquisitions on intangibles in other settings is not conclusive.[40]

The acquired facilities and firms do not all exit in the year of their acquisition. As can be deduced for the step-wise reduction in output and emissions over the four years since the ownership change, a substantial share of acquired firms and their facilities only exit after two or three years. Potential reasons for the grace period that the parent companies grant their newly acquired firms could be rigid labour markets in the form of strong labour protection laws in some of the sample countries that do not allow for a quicker shutdown of large entities as they are present in our sample. Previous literature finds that the likelihood of shutdown after acquisition is smaller for larger entities.[41] Along the same lines, in our sample the propensity to be shut down after acquisition is smaller for the largest facilities and firms. However, reductions in total

[40] Lerner et al. (2011) study the effect of leveraged buyouts on innovation activities measured by patenting activity and find a positive impact. Amess et al. (2016) look at the effect of private equity-backed leveraged buyouts on the patent stock and find it to increase as a result of the acquisition. Conversely, Cumming et al. (2020) find a negative effect of public-to-private buyouts on patents and patent citations. Haucap et al. (2019) find a negative effect of horizontal mergers in the pharmaceutical market in Europe on patenting of the merged entity.

[41] McGuckin and Nguyen (1995) observe for acquisitions in the US food manufacturing sector that larger facilities are more likely to be purchased than closed when they are performing poorly. Maksimovic et al. (2011) find that the likelihood of shutdown in acquisitions of US targets is lower for larger targets and larger acquirers.

emissions, output and production inputs as well as profits already start in the years before the ownership change. The mechanisms driving these patterns are unclear.

5 Conclusion

We estimate the impact of ownership changes on pollutant emissions and economic performance indicators of industrial firms in Europe. We find a robust decrease in total emissions of newly acquired facilities and firms, which is exclusively driven by facilities and firms closing down in the years after acquisition rather than changes in abatement technology. Acquired firms that remain in operation do not change their total emissions and emissions intensity and neither do other firms in the acquiring parent company. From an environmental perspective, these acquisitions are a zero-sum game that neither harms nor benefits the environment. The shutdowns would benefit the environment if the firms had continued operation in the absence of the ownership change. However, the observed reductions in emissions and output that start prior to the change in ownership indicate that the acquisition may not have been the cause for the shutdowns.

Even though we use a comprehensive data set and cover a major industrial continent with different countries, more research is needed to investigate these effects in other settings. Similarly, future research should try to disentangle even more deeply the mechanisms of the effects on emissions and economic performance indicators and assess their consequences on the firm distribution.

Finally, our research highlights that – absent comprehensive pollution regulation – environmental components could deserve more attention when discussing the costs and benefits of ownership changes as well as potentially play a more prominent role in M&A regulation.

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Appendix A. Background on the E-PRTR

Reporting procedures to the E-PRTR are set in the E-PRTR Regulation (European Parliament and European Council, 2006). Facilities located within the EU that undertake any of the activities specified for reporting must report the amounts of all pollutants that are higher than the capacity and pollutant-specific thresholds to its competent authority, i.e., the national authorities. The national authorities report them to the European Commission.

The stakes of reporting accuracy may vary spatially, as strict enforcement of accuracy, completeness, consistency and credibility of the reported data is the responsibility of national authorities. However, national authorities are liable to the European Commission in following its enforcement rules and can be penalized by the Commission in the case of infringement. Non-compliance of facilities in reporting to the national authorities is penalized via the national justice systems. There are no incentives for purposefully inaccurate and incorrect reporting as no direct consequences follow from pollutant reports, the European Commission collects the data for informational purpose. Since pollutant reports are made at the facility level, it is unlikely that a change in ownership would directly affect reporting behavior.

Appendix B. Results

Additional tables

Table B1: Predictive power of firm characteristics for treatment timing

	(1)	(2)
Total emissions	0.0001	0.0001
	(0.0001)	(0.0001)
Emissions intensity	0.0213	0.0102
	(0.0383)	(0.0283)
Output	0.0598	-1.94e-12
	(1.25e-11)	(1.32e-11)
Capital input	5.54e-11	4.06e-11
	(4.59e-11)	(3.73e-11)
Labor expenditures	-5.15e-8	1.32e-5
	(2.12e-5)	(1.95e-5)
Labor input	-1.56e-10	-2.67e-10
	(3.58e-10)	(3.28e-10)
Operating profits	2.2e-11	1.7e-11
	(3.53e-11)	(5.76e-11)
Intangible fixed assets	2.15e-10*	-4.18e-10***
	(1.27e-10)	(9.25e-11)
Adjusted R^2	0.00748	0.19498
Observations	3,946	3,946
Country-Year fixed effects		✓
Sector-Year fixed effects		✓

Notes: The outcome variable in both columns is the year of ownership change of firms as continuous variable. Standard errors clustered at the firm level are in parentheses. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

Table B2: Event study estimates for total emissions at the facility level

	Main	Imp (0)	Imp (threshold)
	(1)	(2)	(3)
time_to_treat = -4	0.1143	0.1510	0.1260
	(0.0851)	(0.0931)	(0.0817)
time_to_treat = -3	0.0469	0.0149	0.0225
	(0.0563)	(0.0635)	(0.0546)
time_to_treat = -2	0.0598	0.0209	0.0197
	(0.0371)	(0.0414)	(0.0358)
time_to_treat = 0	-0.1927***	-0.1705***	-0.1937***
	(0.0350)	(0.0395)	(0.0341)
time_to_treat = 1	-0.3256***	-0.2831***	-0.3244***
	(0.0507)	(0.0549)	(0.0496)
time_to_treat = 2	-0.4134***	-0.3793***	-0.4107***
	(0.0632)	(0.0671)	(0.0610)
time_to_treat = 3	-0.6856***	-0.6322***	-0.6775***
	(0.0916)	(0.0954)	(0.0880)
Adjusted R^2	0.77745	0.74034	0.76831
Observations	10,624	11,479	11,479
Country-Year fixed effects	✓	✓	✓
Sector-Year fixed effects	✓	✓	✓
FacilityID fixed effects	✓	✓	✓

Notes: The first column shows the point estimates and standard errors of the main specification. The second and third column present the results using the data set in which gaps in emission reports are imputed with zero and the pollutant specific threshold, respectively. The fourth column shows results on total emissions scaled by CO2 emissions for the data set without imputation. All results refer to the Sun and Abraham (2021) specification. Standard errors clustered at the facility level are in parentheses. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

Table B3: Event study estimates for total emissions at the firm level

	Main (1)	Imp (0) (2)	Imp (threshold) (3)	Intensity (4)
time_to_treat = -4	0.4570***	0.4282***	0.4475***	0.0026
	(0.1360)	(0.1357)	(0.1294)	(0.0312)
time_to_treat = -3	0.2696***	0.1841*	0.2318***	0.0162
	(0.0970)	(0.0961)	(0.0897)	(0.0175)
time_to_treat = -2	0.1863***	0.1254*	0.1505**	-0.0054
	(0.0642)	(0.0652)	(0.0599)	(0.0124)
time_to_treat = 0	-0.3389***	-0.3683***	-0.3518***	-0.0201**
	(0.0509)	(0.0530)	(0.0484)	(0.0090)
time_to_treat = 1	-0.4028***	-0.4244***	-0.4373***	-0.0186
	(0.0690)	(0.0697)	(0.0661)	(0.0148)
time_to_treat = 2	-0.4638***	-0.4282***	-0.4504***	-0.0226
	(0.0924)	(0.0919)	(0.0881)	(0.0215)
time_to_treat = 3	-0.7854***	-0.7389***	-0.7700***	-0.0435
	(0.1373)	(0.1317)	(0.1306)	(0.0372)
Adjusted R^2	0.71605	0.69154	0.71246	0.41212
Observations	6,272	6,737	6,737	5,175
Country-Year fixed effects	✓	✓	✓	✓
Sector-Year fixed effects	✓	✓	✓	✓
BVDID fixed effects	✓	✓	✓	✓

Notes: The first column shows the point estimates and standard errors of the main specification. The second and third column present the results using the data set in which gaps in emission reports are imputed with zero and the pollutant specific threshold, respectively. All results refer to the Sun and Abraham (2021) specification. Standard errors clustered at the firm level are in parentheses. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

Table B4: Event study estimates for total emissions at the parent company level

	Main (1)	Imp (0) (2)	Imp (threshold) (3)	Intensity (4)
time_to_treat = -4	0.0396	0.0396	0.0753	0.0214
	(0.3364)	(0.3364)	(0.3312)	(0.0335)
time_to_treat = -3	0.0649	0.0649	0.0859	-0.0028
	(0.2217)	(0.2217)	(0.2212)	(0.0172)
time_to_treat = -2	0.2039	0.2039	0.1870	0.0155
	(0.1334)	(0.1334)	(0.1305)	(0.0153)
time_to_treat = 0	0.9832***	0.9832***	0.9847***	0.0398
	(0.1670)	(0.1670)	(0.1629)	(0.0372)
time_to_treat = 1	0.8008***	0.8008***	0.8426***	0.0368
	(0.1989)	(0.1989)	(0.1944)	(0.0399)
time_to_treat = 2	0.7257***	0.7257***	0.7548***	0.0335
	(0.2499)	(0.2499)	(0.2432)	(0.0405)
time_to_treat = 3	0.4986	0.4986	0.5113	-0.0128
	(0.3463)	(0.3463)	(0.3362)	(0.0196)
Adjusted R^2	0.74651	0.74651	0.75650	0.45075
Observations	2,274	2,274	2,274	1,858
Year fixed effects	✓	✓	✓	✓
ParentCompany fixed effects	✓	✓	✓	✓

Notes: The first column shows the point estimates and standard errors of the main specification. The second and third column present the results using the data set in which gaps in emission reports are imputed with zero and the pollutant specific threshold, respectively. Note that the first and second columns are the same since gaps in individual facilities or firms do not contribute to overall emissions of the parent company as in the case in which gaps are imputed by zero. All results refer to the Sun and Abraham (2021) specification. Standard errors clustered at the firm level are in parentheses. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

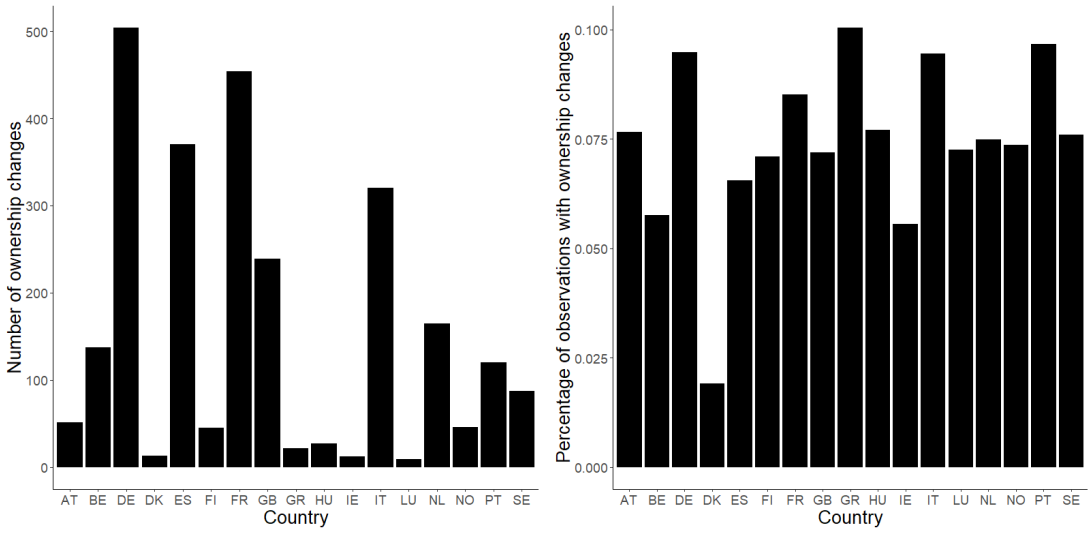
Table B5: Aggregate effects on firms: 50% largest firms

Dependent variables	ATT	SE	N
Total emissions	-0.284	(0.182)	1,654
Output	-1.754**	(0.618)	1,656
Emissions intensity	-0.010	(0.020)	1,542
Total factor productivity	0.015*	(0.009)	990
Operating profits	-0.394	(0.713)	1,312
Labor input	-0.627**	(0.236)	1,555
Capital input	-1.450*	(0.610)	1,646
Labor expenditures	-0.853	(0.583)	1,532
Intangible fixed assets	0.097	(0.094)	1,562

Notes: The first column denotes the respective dependent variables each with an inverse hyperbolic sine transformation. Each line represents a separate event study regression on the sample of 50 percent largest firms according to operating revenues in 2007. For each regression, we report the point estimate of the aggregated effect of the event study following Sun and Abraham (2021) (ATT), the standard error (SE) and the number of observations (N). Standard errors clustered at the firm level are in parentheses. Output refers to deflated operating revenues, emissions intensity to total emissions divided by output, labor input to number of employees, capital input to deflated tangible fixed assets, respectively. $^{***}p < 1\%$, $^{**}p < 5\%$, $^{*}p < 10\%$.

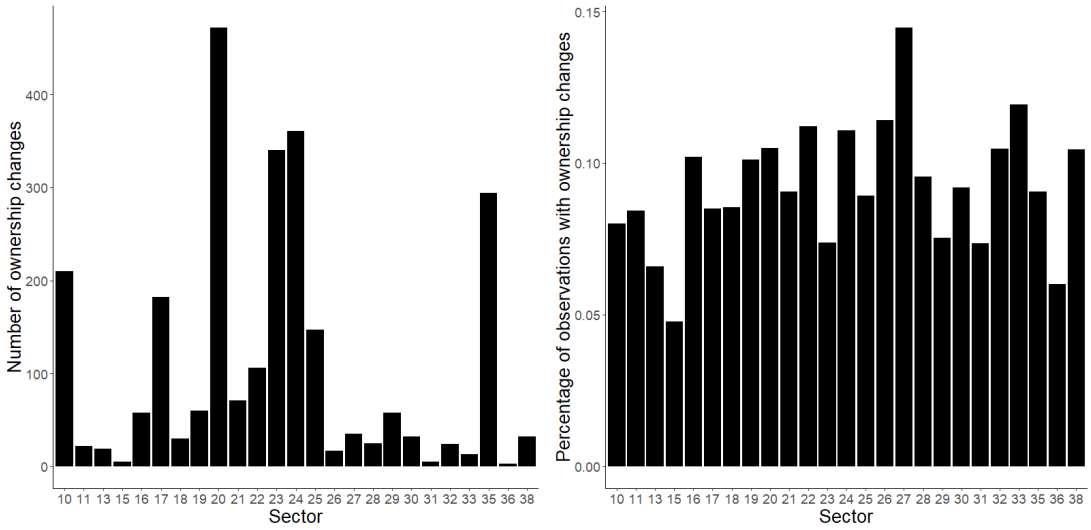
Additional figures

Figure B1: Distribution of ownership changes over countries



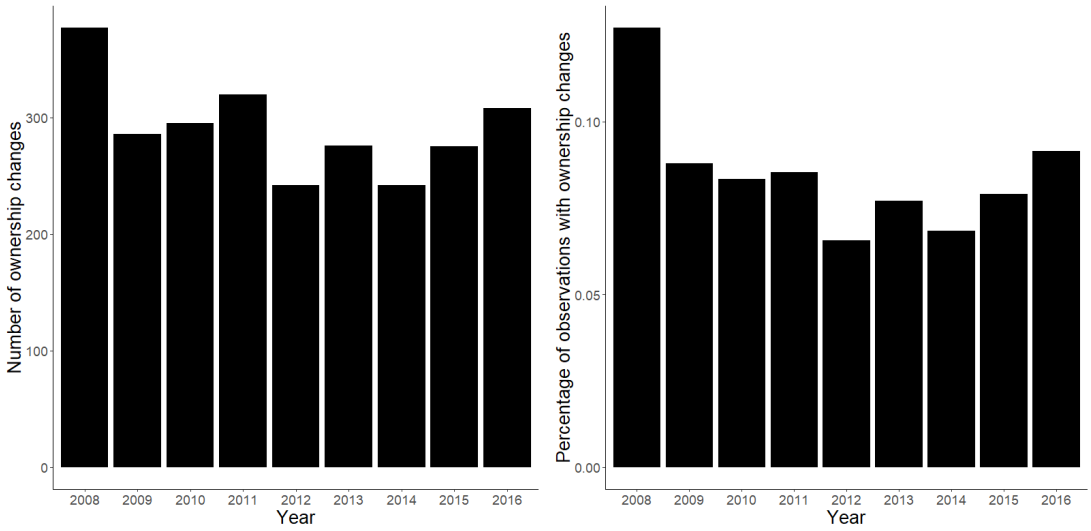
Notes: This figure shows the distribution of ownership changes over countries. The left panel shows the absolute number of changes and the right panel shows the relative share of changes out of all observations for the respective country.

Figure B2: Distribution of ownership changes over sectors



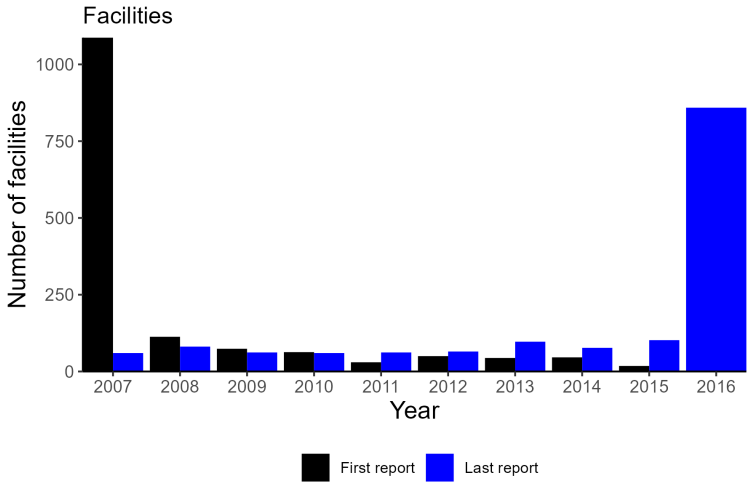
Notes: This figure shows the distribution of ownership changes over the sectors. The left panel shows the absolute number of changes and the right panel shows the relative share of changes out of all observations for the respective sector.

Figure B3: Distribution of ownership changes over years



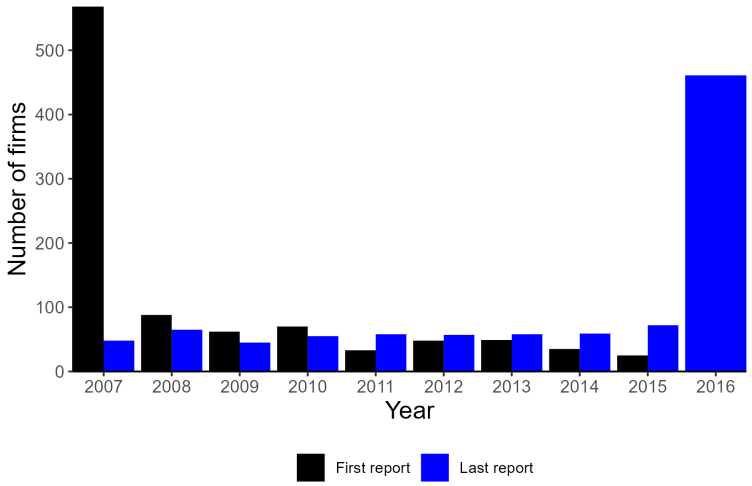
Notes: This figure shows the distribution of ownership changes over the years. The left panel shows the absolute number of changes and the right panel shows the relative share of changes out of all observations for the respective year.

Figure B4: First and last reporting year of facilities



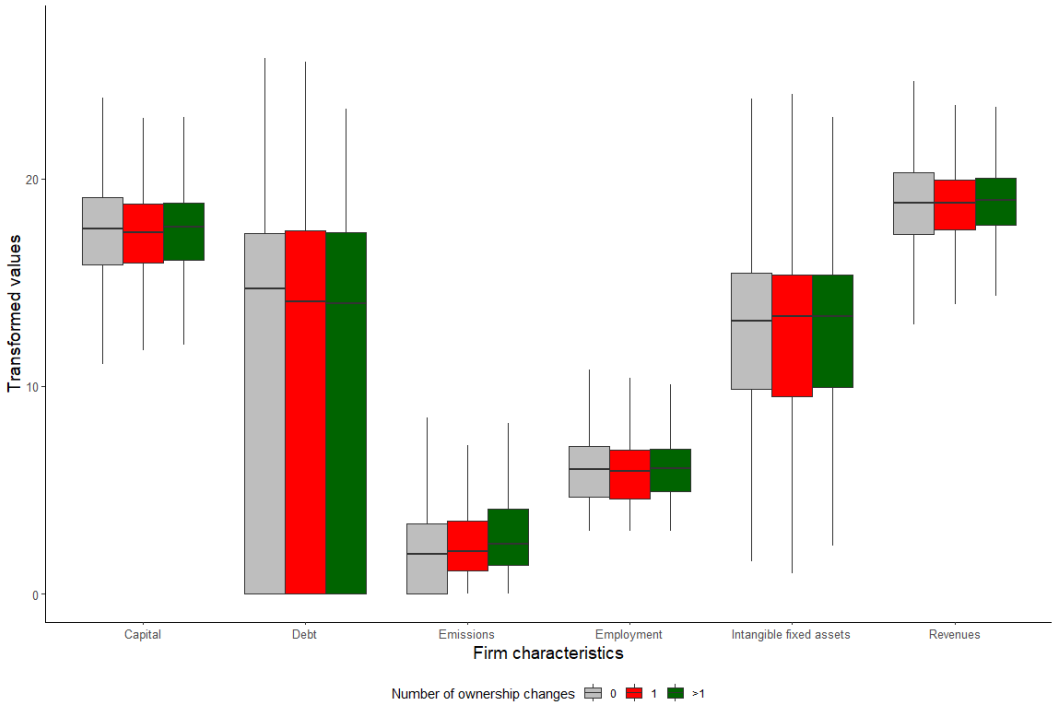
Notes: This figure shows the number of facilities that have their first reporting year and last reporting year, respectively, in the particular year. The sample is restricted to facilities that experience only one change in ownership.

Figure B5: First and last reporting year of firms



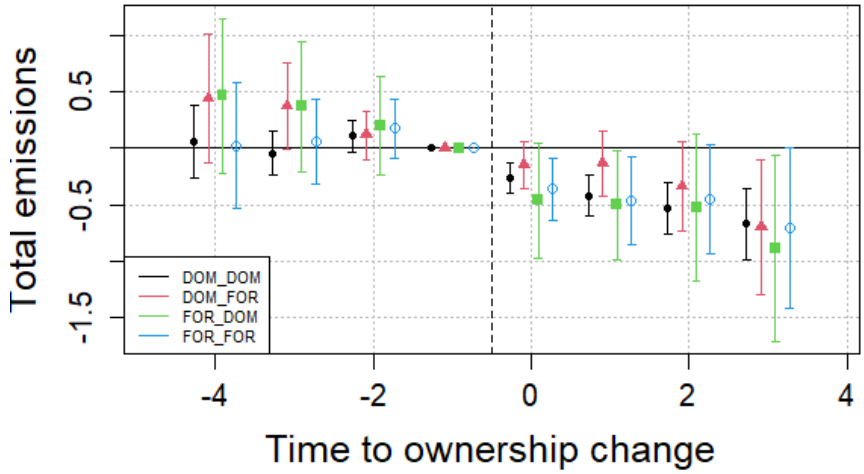
Notes: This figure shows the number of firms that have their first reporting year and last reporting year, respectively, in the particular year. The sample is restricted to firms that experience only one change in ownership.

Figure B6: Differences in firm characteristics for firms with and without ownership change



Notes: This figure shows a comparison of several firm characteristics for groups of firms with no, one and more than one ownership change event during our sample period. The values for capital, long-term debt, total emissions, employment, intangible fixed assets and operating revenues are inverse hyperbolic sine transformed to facilitate the comparison.

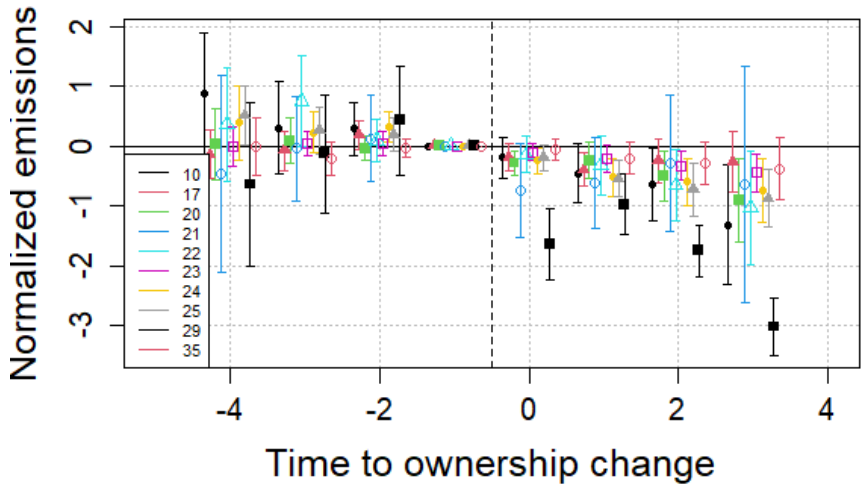
Figure B7: Effect on total emissions by type of ownership change at the facility level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions for different subsamples of ownership change types for the Sun and Abraham (2021) estimator. The inverse hyperbolic sine transformation is applied to the independent variable. "DOM_DOM", "DOM_FOR", "FOR_DOM", and "FOR_FOR" are the changes from a domestic to a domestic owner, from a domestic to a foreign owner, from a foreign to a domestic owner, and from a foreign to a foreign owner, respectively.

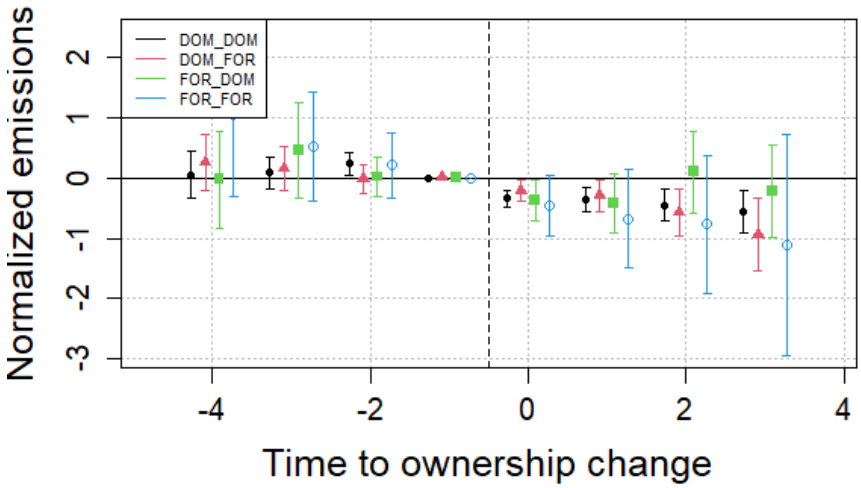
We investigate differences in the effects of ownership changes among foreign or domestic parent companies. We define a foreign (domestic) parent company when the global ultimate owner is based in a different (the same) country as facility or firm. Based on this definition, we distinguish four different cases of ownership changes: first, from a domestic to another domestic owner; second, from a domestic to a foreign owner; third, from a foreign to a domestic owner; fourth, from a foreign to a foreign owner. Dividing samples by these four different categories, we estimate the event study regression for each of the samples. The effects are similar to the overall sample and confidence intervals for all point estimates overlap for all groups, suggesting no large differences across different owner types.

Figure B8: Effect on total emissions by sector at the facility level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions for different subsamples based on the facility's main sector for the Sun and Abraham (2021) estimator. The inverse hyperbolic sine transformation is applied to the independent variable. We include only sectors with a minimum of 1,000 observations. Sector 10 refers to manufacture of food products, sector 17 to manufacture of paper and paper products, sector 20 to manufacture of chemicals and chemical products, sector 21 to manufacture of basic pharmaceutical products and pharmaceutical preparations, sector 22 to manufacture of rubber and plastic products, sector 23 to manufacture of other non-metallic mineral products, sector 24 to manufacture of basic metals, sector 25 to manufacture of fabricated metal products, except machinery and equipment, sector 29 to manufacture of motor vehicles, trailers and semi-trailers, and sector 35 to electricity, gas, steam and air conditioning supply.

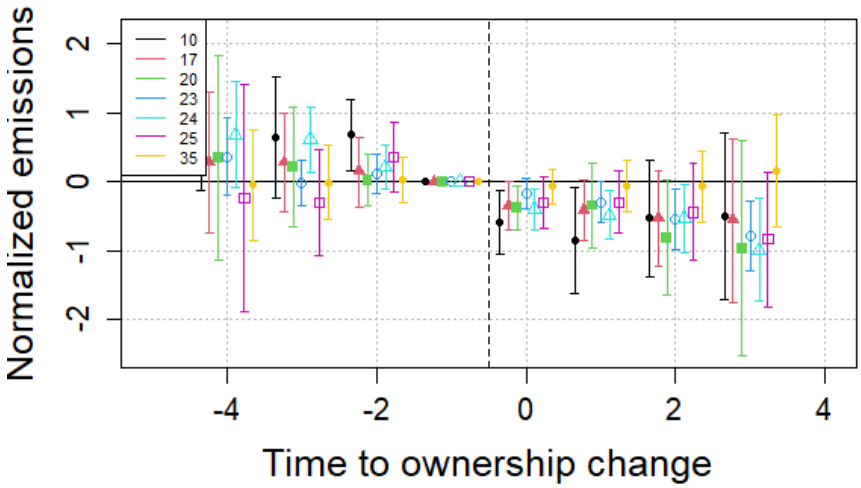
Figure B9: Effect on total emissions by type of ownership change at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions for different subsamples of ownership change types for the Sun and Abraham (2021) estimator. The inverse hyperbolic sine transformation is applied to the independent variable. "DOM_DOM", "DOM_FOR", "FOR_DOM", and "FOR_FOR" are the changes from a domestic to a domestic owner, from a domestic to a foreign owner, from a foreign to a domestic owner, and from a foreign to a foreign owner, respectively.

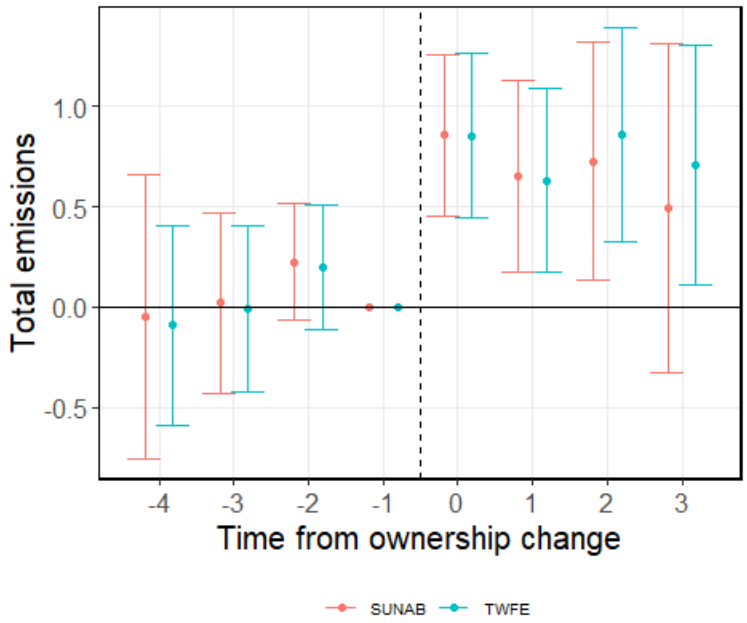
We investigate differences in the effects of ownership changes among foreign or domestic parent companies. We define a foreign (domestic) parent company when the global ultimate owner is based in a different (the same) country as facility or firm. Based on this definition, we distinguish four different cases of ownership changes: first, from a domestic to another domestic owner; second, from a domestic to a foreign owner; third, from a foreign to a domestic owner; fourth, from a foreign to a foreign owner. Dividing samples by these four different categories, we estimate the event study regression for each of the samples. The effects are similar to the overall sample and confidence intervals for all point estimates overlap for all groups, suggesting no large differences across different owner types.

Figure B10: Effect on total emissions by sector at the firm level



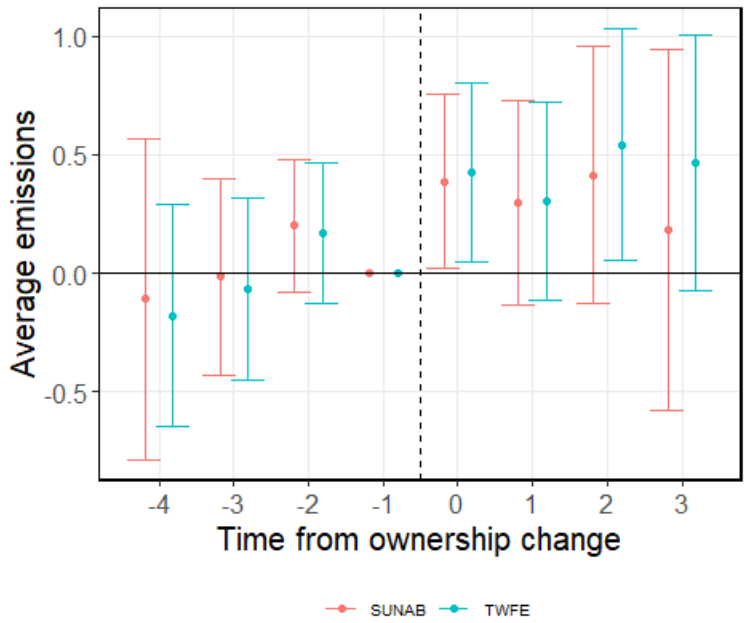
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions for different subsamples based on the firm's main sector for the Sun and Abraham (2021) estimator. The inverse hyperbolic sine transformation is applied to the independent variable. We include only sectors with a minimum of 1,000 observations. Sector 10 refers to manufacture of food products, sector 17 to manufacture of paper and paper products, sector 20 to manufacture of chemicals and chemical products, sector 23 to manufacture of other non-metallic mineral products, sector 24 to manufacture of basic metals, sector 25 to manufacture of fabricated metal products, except machinery and equipment, and sector 35 to electricity, gas, steam and air conditioning supply.

Figure B11: Effect on total emissions at the parent company level without shutdown of targets



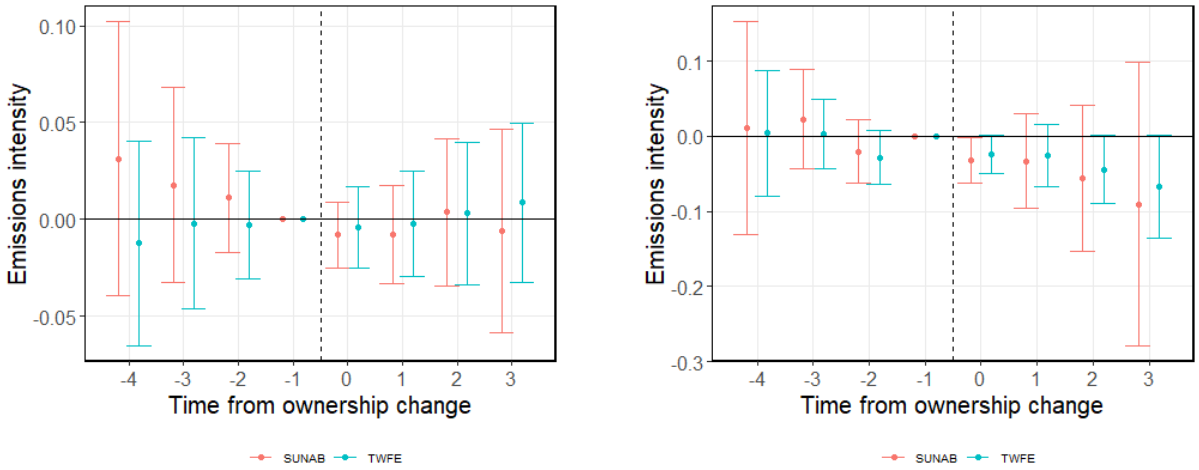
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B12: Effect on total emissions per industrial facility at the parent company level without shutdown of targets



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total emissions per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

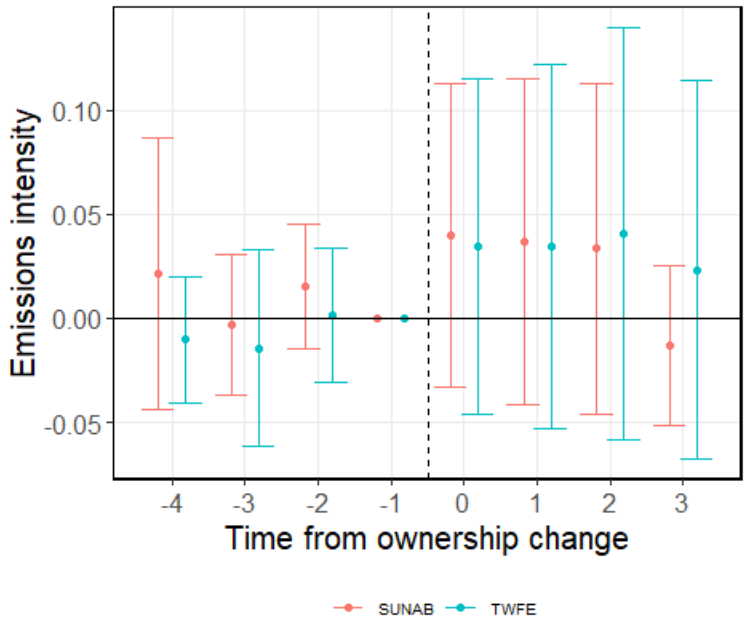
Figure B13: Effect on emissions intensity at the firm level by subsample



(a) Remaining firms **(b) Exiting firms**

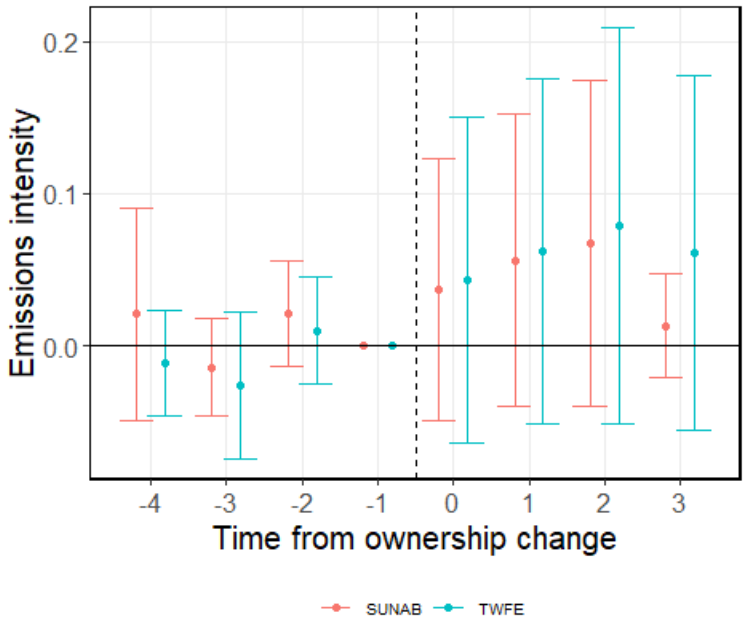
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B14: Effect on emissions intensity at the parent company level



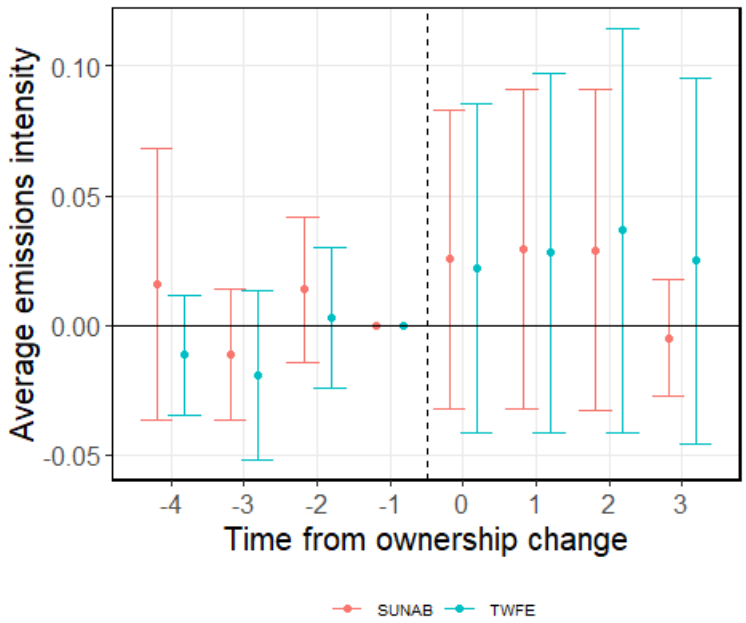
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B15: Effect on emissions intensity at the parent company level without shutdown of targets



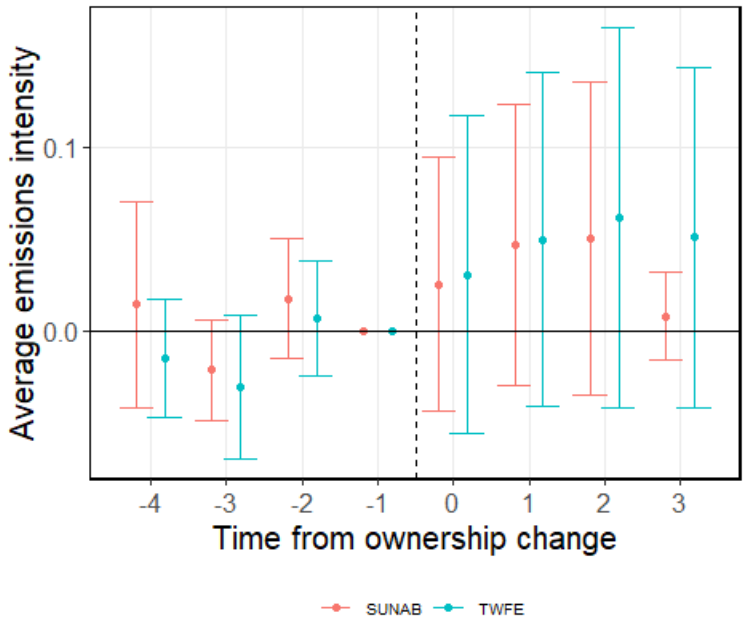
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B16: Effect on emissions intensity per industrial facility at the parent company level



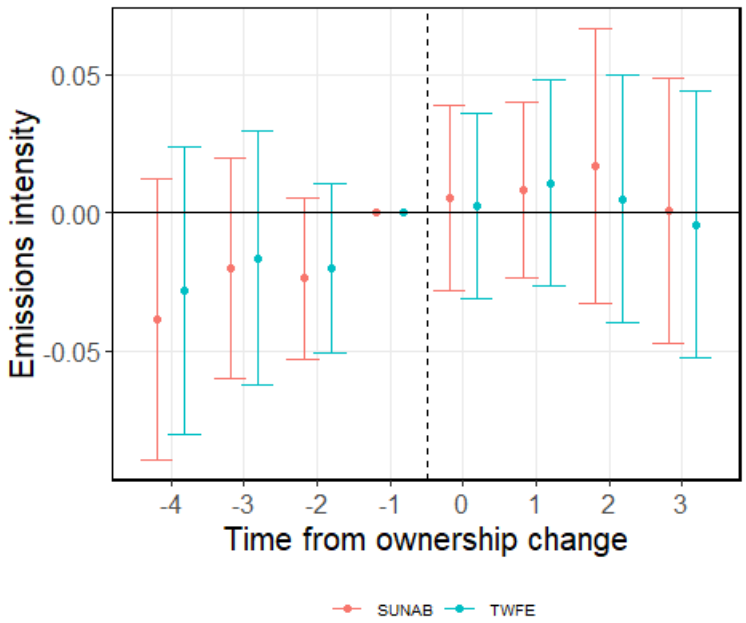
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B17: Effect on emissions intensity per industrial facility at the parent company level without shutdown of targets



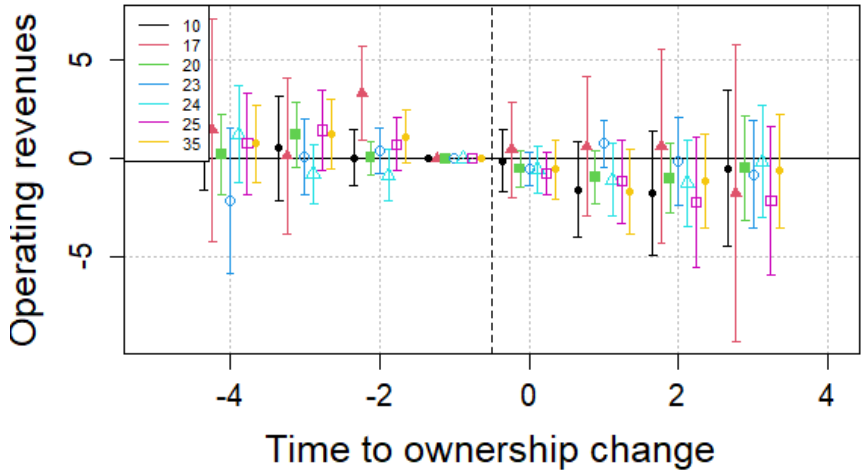
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B18: Effect on emissions intensity in other facilities of the acquiring parent company



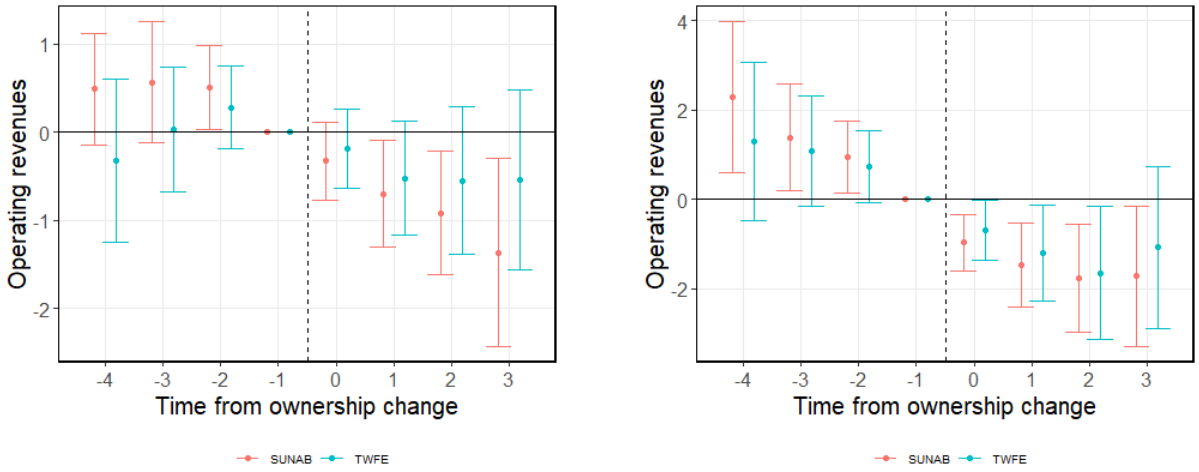
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on the emissions intensity, i.e., total emissions scaled by deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B19: Effect on output by sector at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on operating revenues for different subsamples based on the firm's main sector for the Sun and Abraham (2021) estimator. The inverse hyperbolic sine transformation is applied to the independent variable. We include only sectors with a minimum of 1,000 observations. Sector 10 refers to manufacture of food products, sector 17 to manufacture of paper and paper products, sector 20 to manufacture of chemicals and chemical products, sector 23 to manufacture of other non-metallic mineral products, sector 24 to manufacture of basic metals, sector 25 to manufacture of fabricated metal products, except machinery and equipment, and sector 35 to electricity, gas, steam and air conditioning supply.

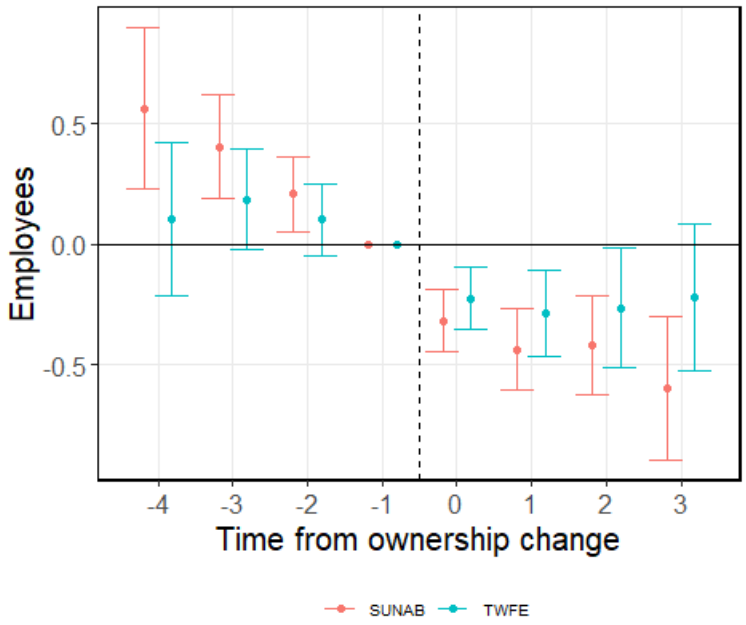
Figure B20: Effect on output at the firm level by subsample



(a) Remaining firms **(b) Exiting firms**

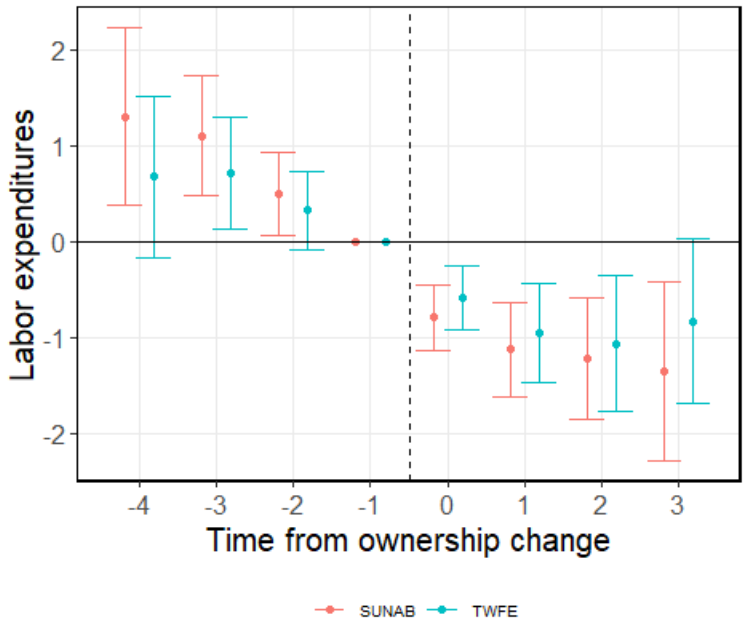
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B21: Effect on labour input at the firm level



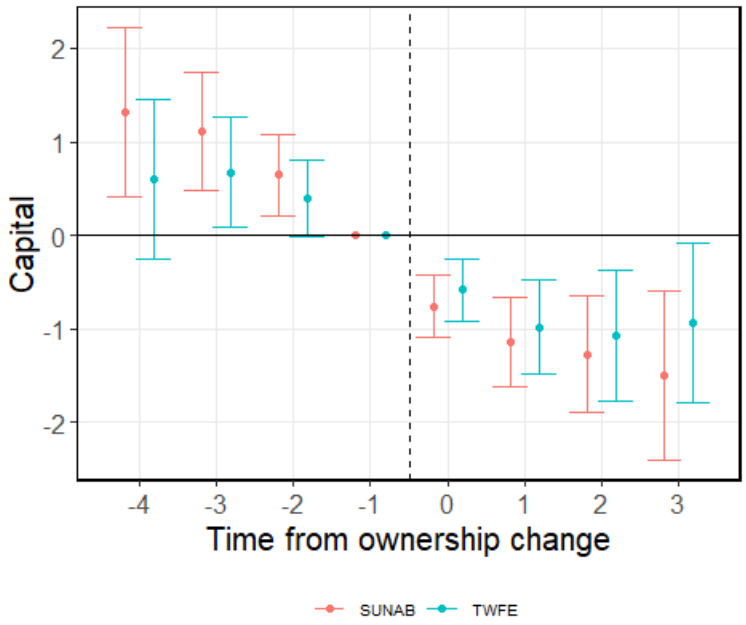
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labour input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B22: Effect on labour expenses at the firm level



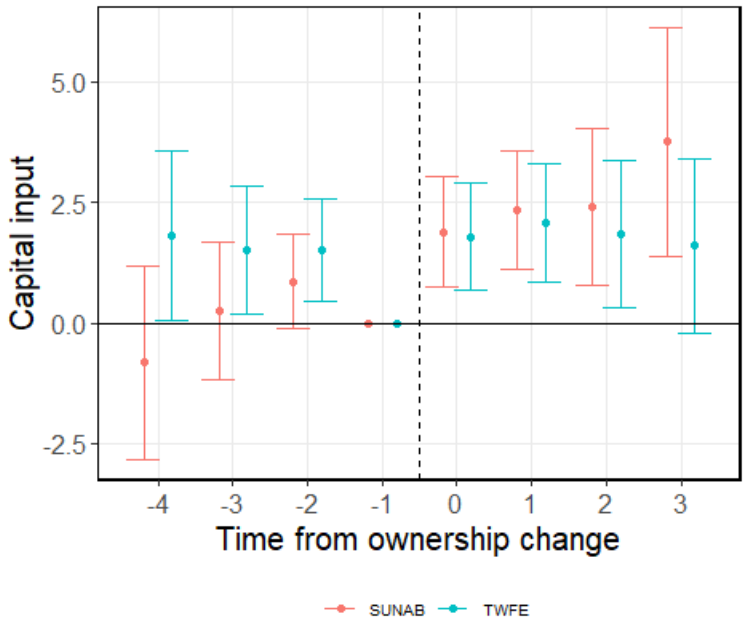
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labour expenses. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B23: Effect on capital input at the firm level



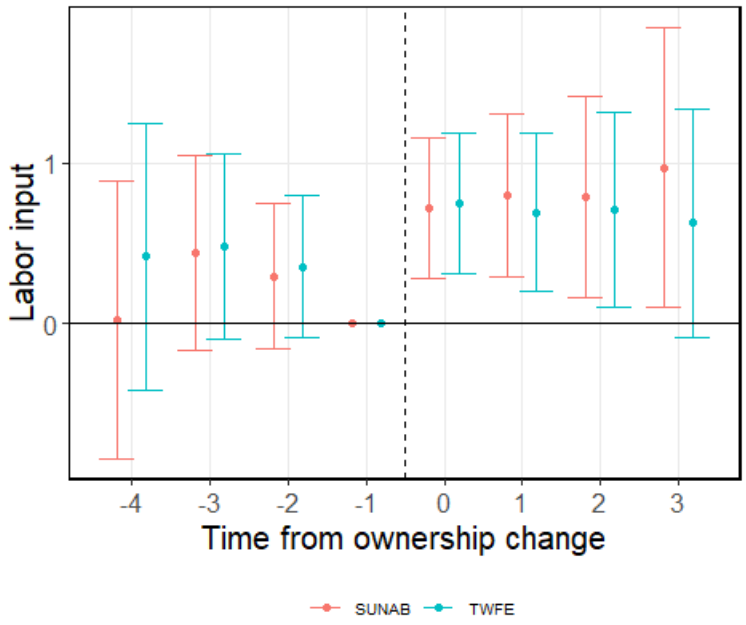
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on capital input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B24: Effect on capital input at the parent company level



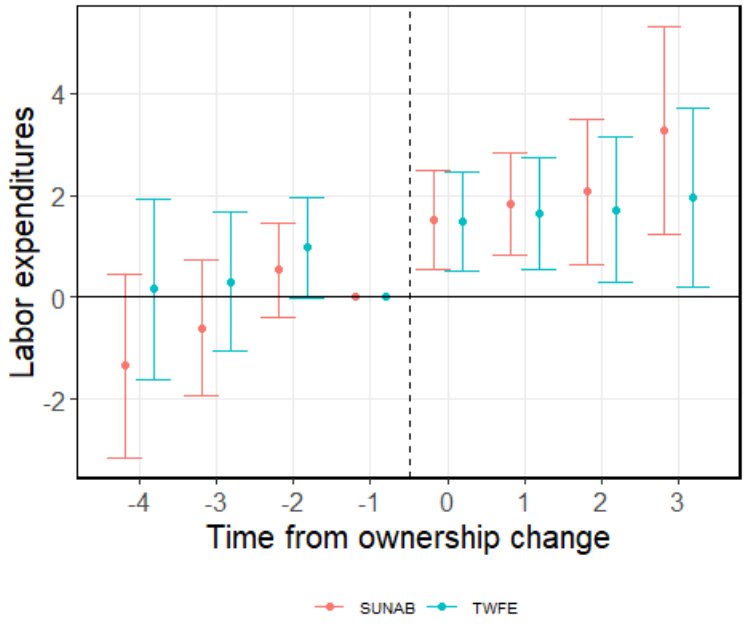
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on capital input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B25: Effect on labor input at the parent company level



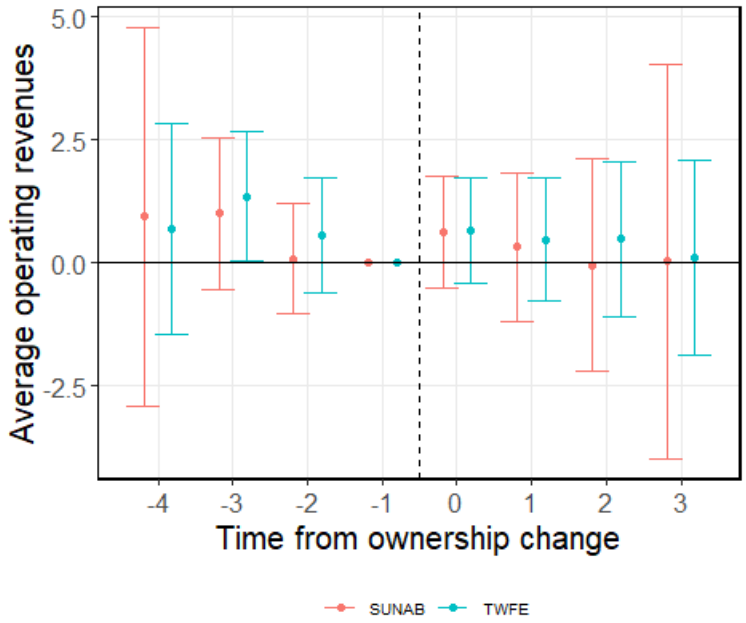
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B26: Effect on labor expenses at the parent company level



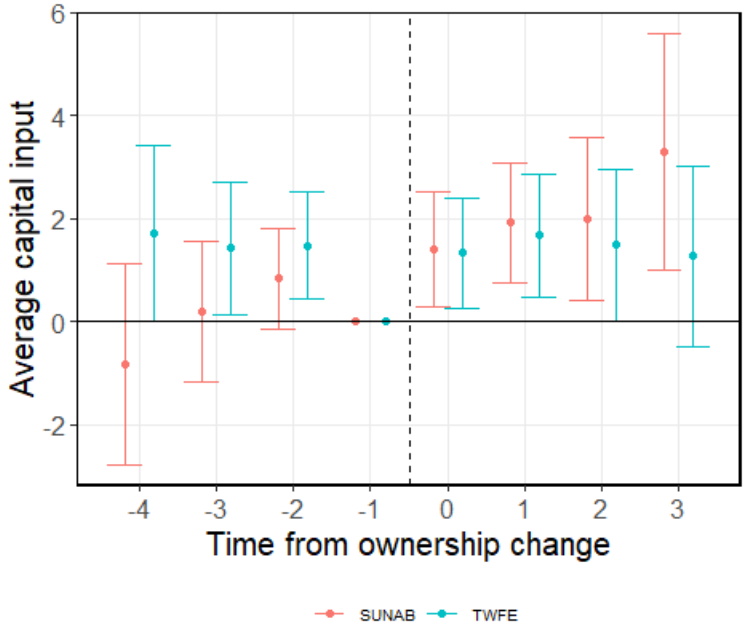
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor expenses. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B27: Effect on output per industrial facility at the parent company level



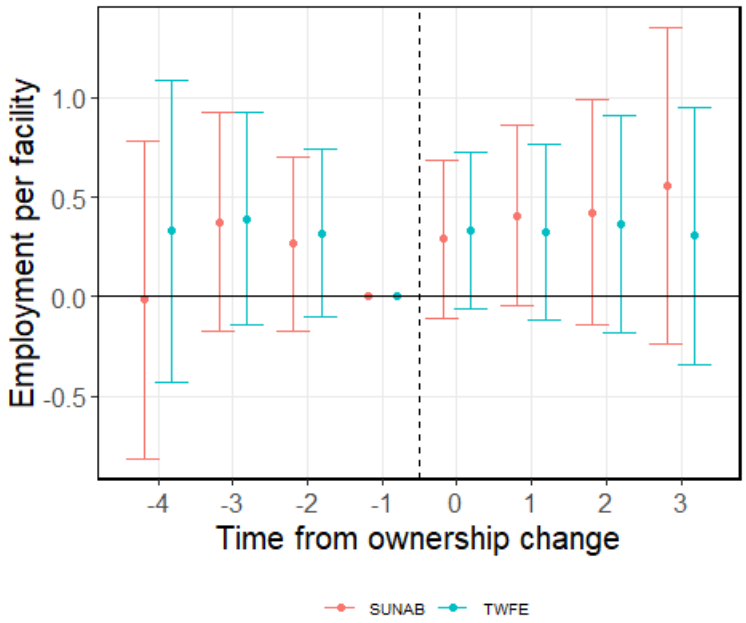
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B28: Effect on capital input per industrial facility at the parent company level



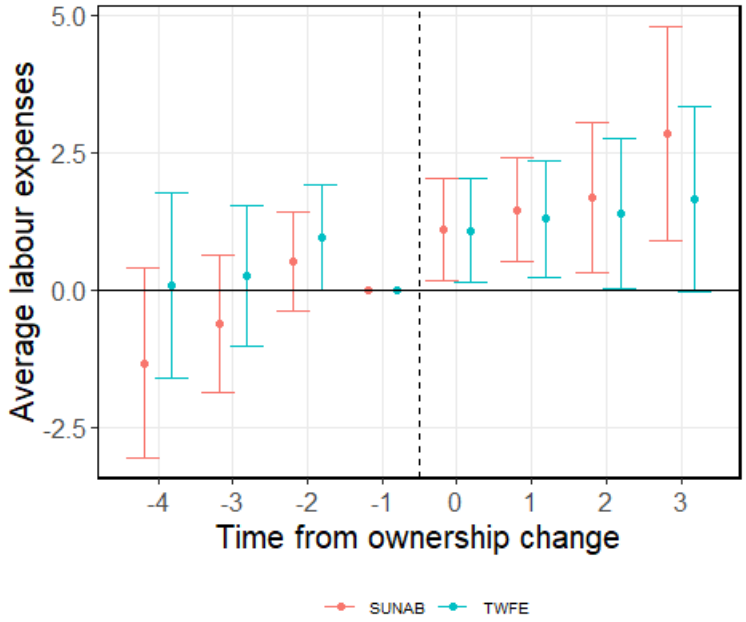
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on capital input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B29: Effect on labor input per industrial facility at the parent company level



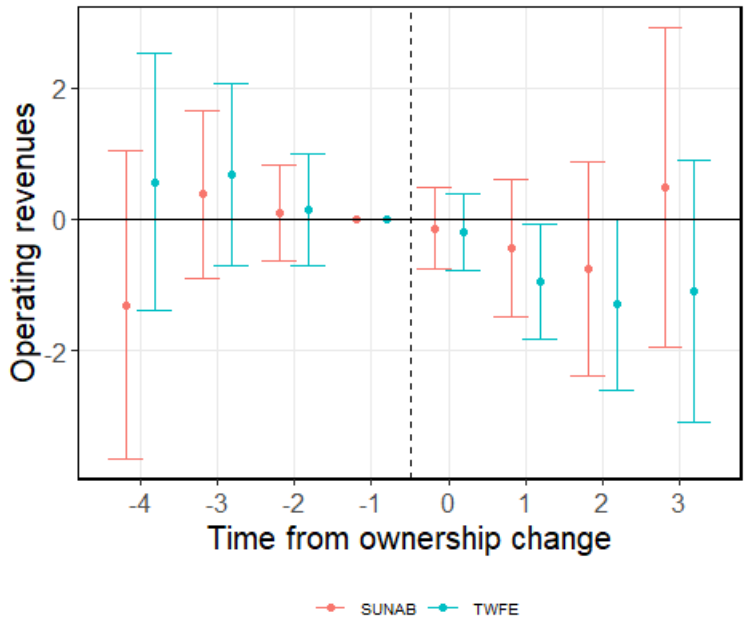
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B30: Effect on labor expenses per industrial facility at the parent company level



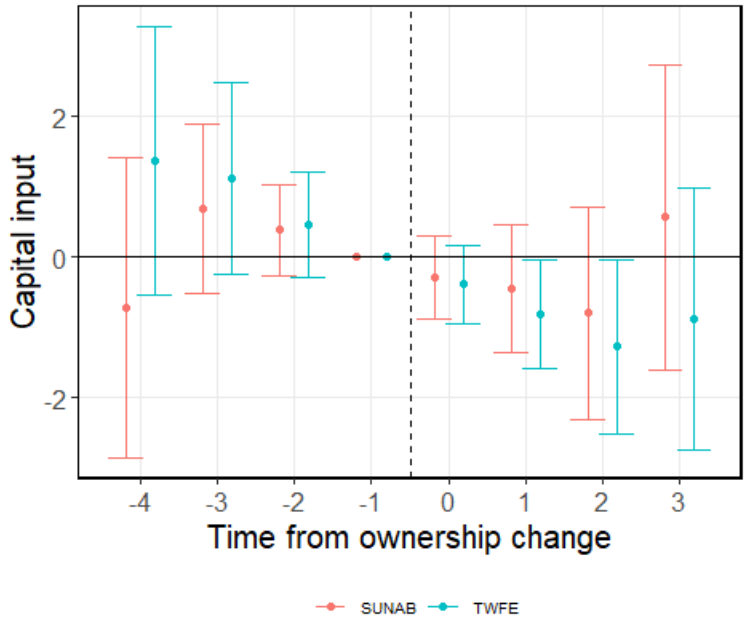
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor expenses. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B31: Effect on output of other facilities of the acquiring parent company



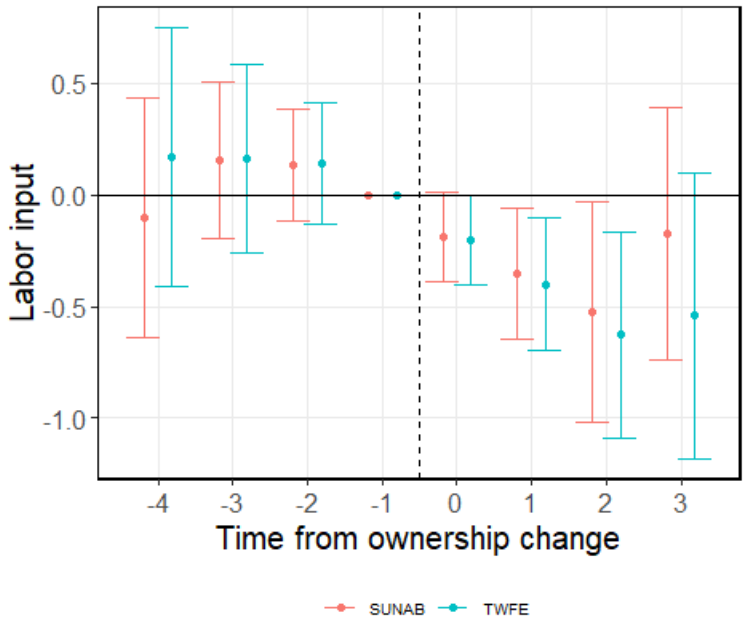
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated operating revenues. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B32: Effect on capital input of other facilities of the acquiring parent company



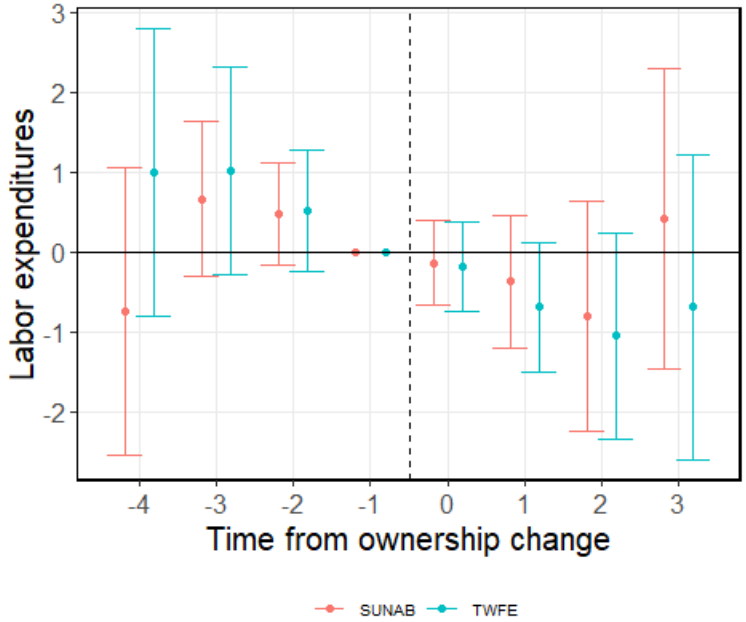
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on capital input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B33: Effect on labor input of other facilities of the acquiring parent company



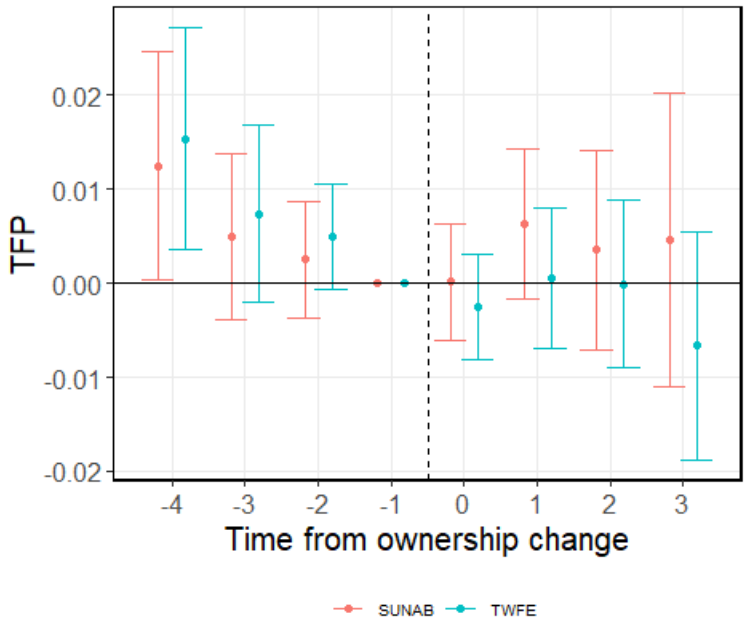
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor input. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B34: Effect on labor expenses of other facilities of the acquiring parent company



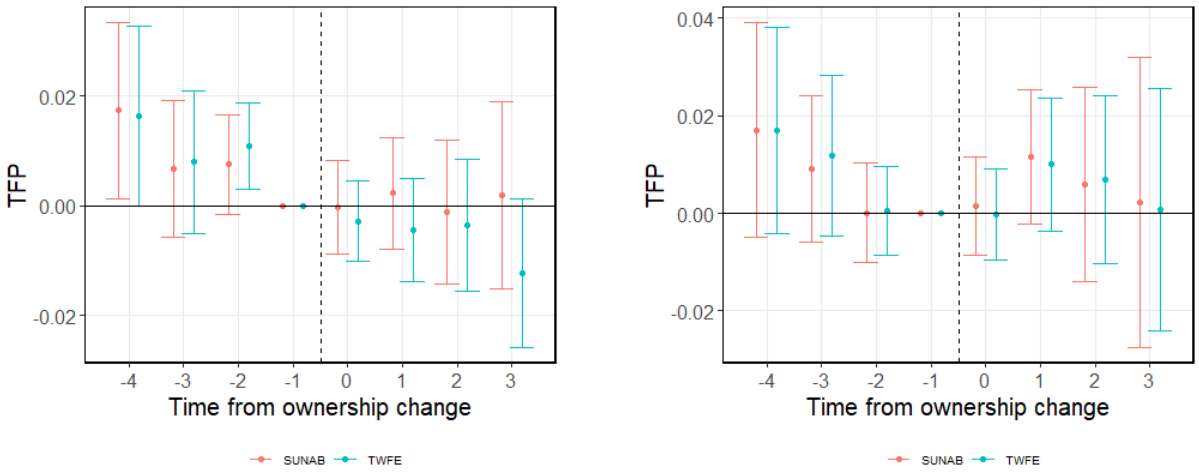
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor expenses. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B35: Effect on total factor productivity at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

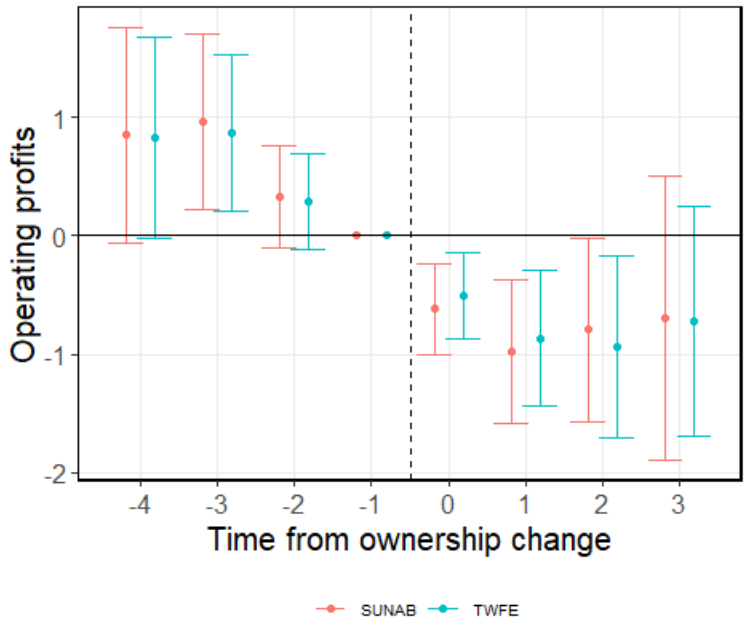
Figure B36: Effect on total factor productivity at the firm level by subsample



(a) Remaining firms **(b) Exiting firms**

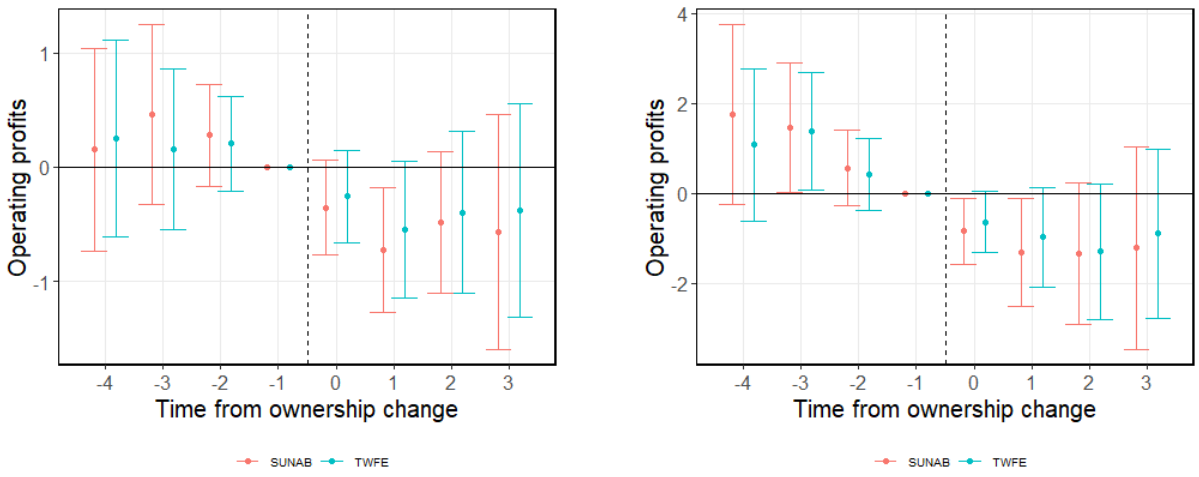
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B37: Effect on operating profits at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

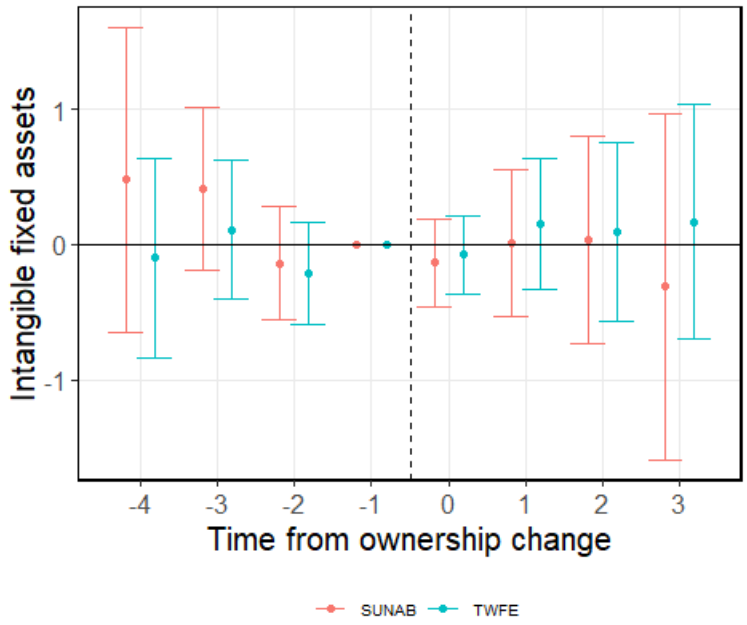
Figure B38: Effect on operating profits at the firm level by subsample



(a) Remaining firms **(b) Exiting firms**

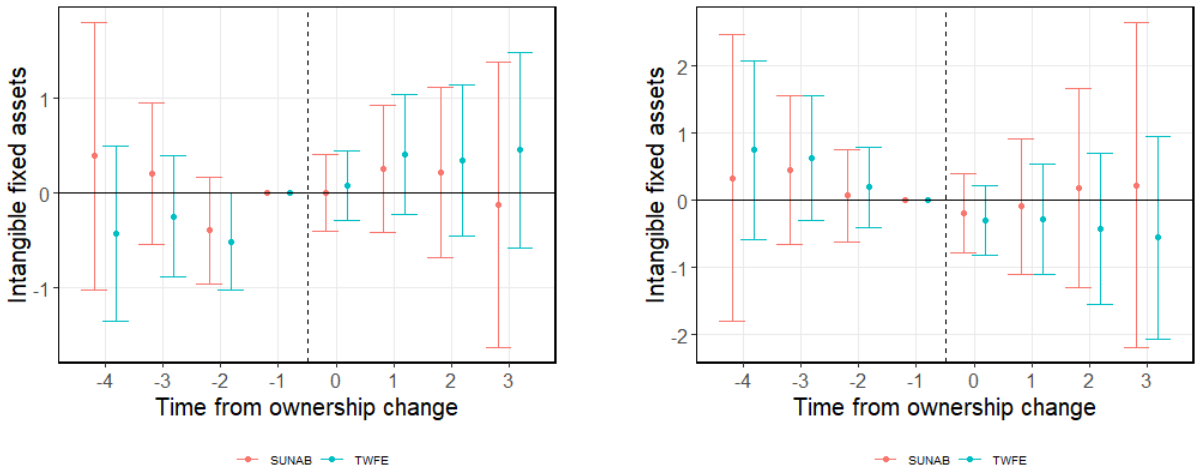
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B39: Effect on intangible fixed assets at the firm level



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on intangible fixed assets. The inverse hyperbolic sine transformation is applied to the independent variable.

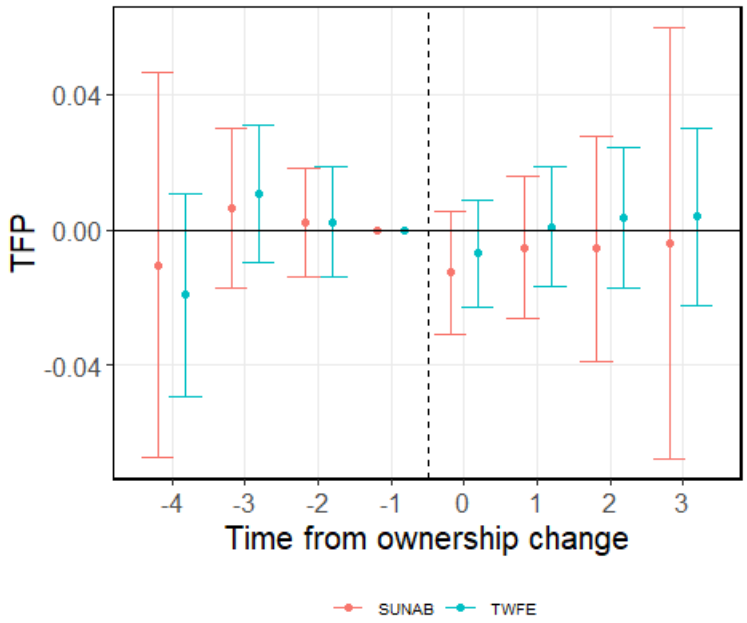
Figure B40: Effect on intangible fixed assets at the firm level by subsample



(a) Remaining firms **(b) Exiting firms**

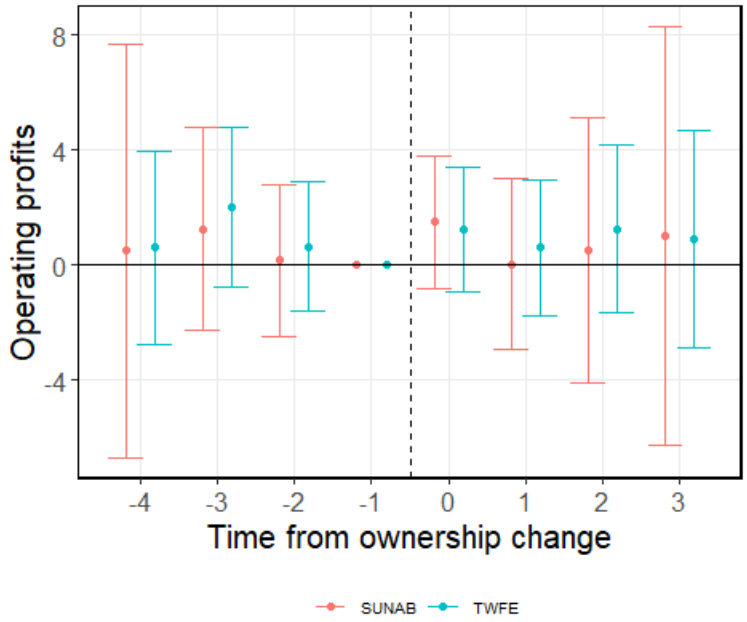
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on intangible fixed assets. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B41: Effect on total factor productivity at the parent company level



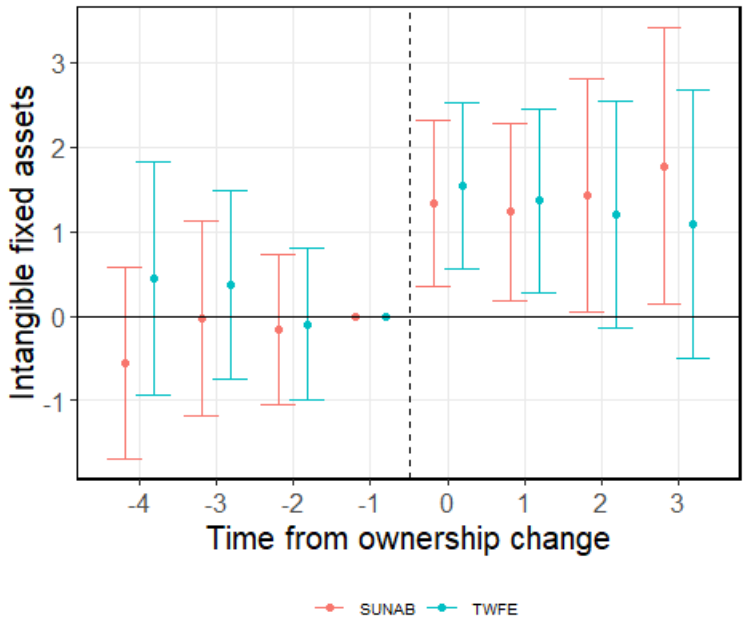
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B42: Effect on operating profits at the parent company level



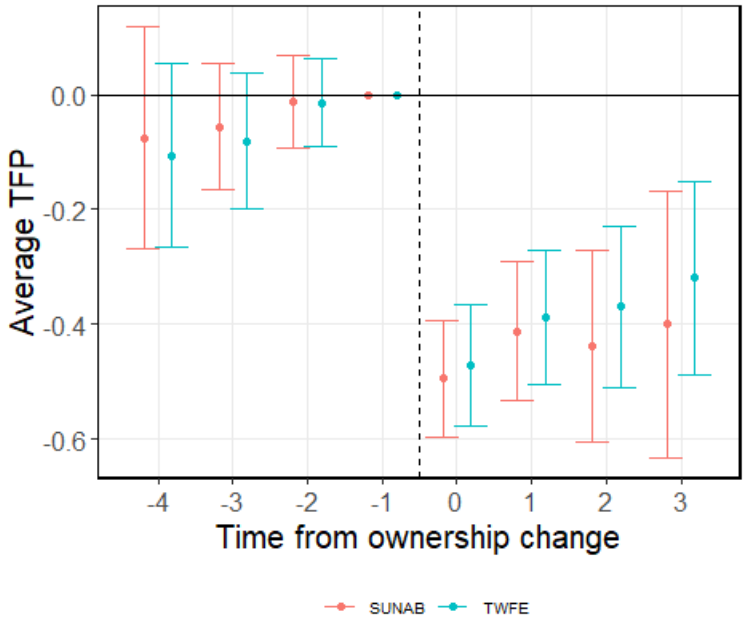
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on operating profits. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B43: Effect on intangible fixed assets at the parent company level



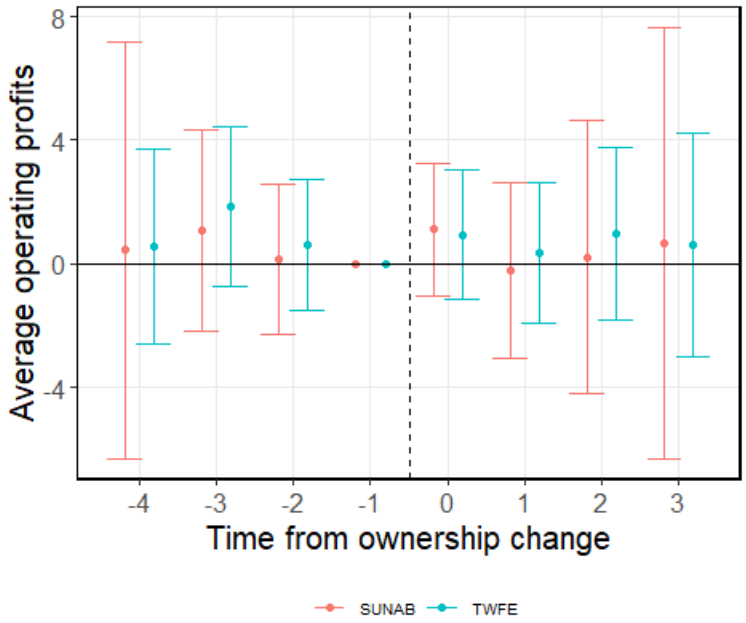
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on intangible fixed assets. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B44: Effect on total factor productivity per industrial facility in the parent company



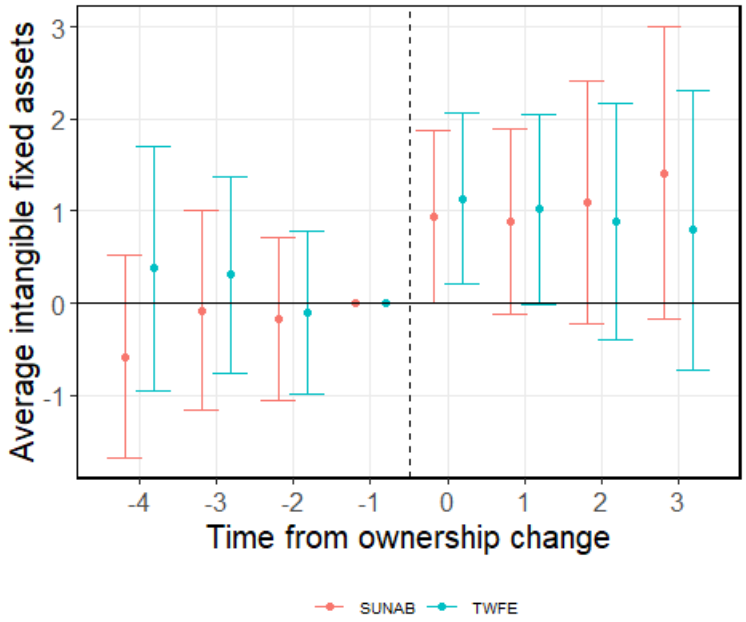
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B45: Effect on operating profits per industrial facility in the parent company



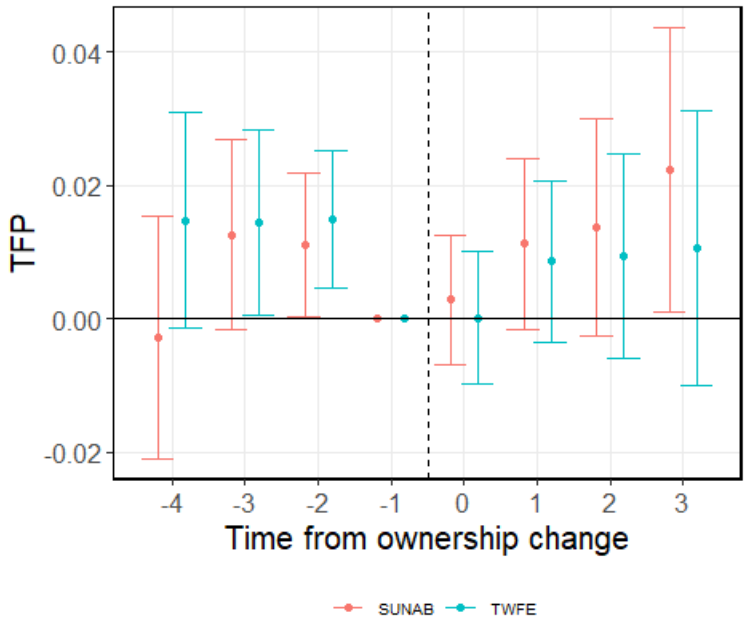
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on operating profits. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B46: Effect on intangible fixed assets per industrial facility in the parent company



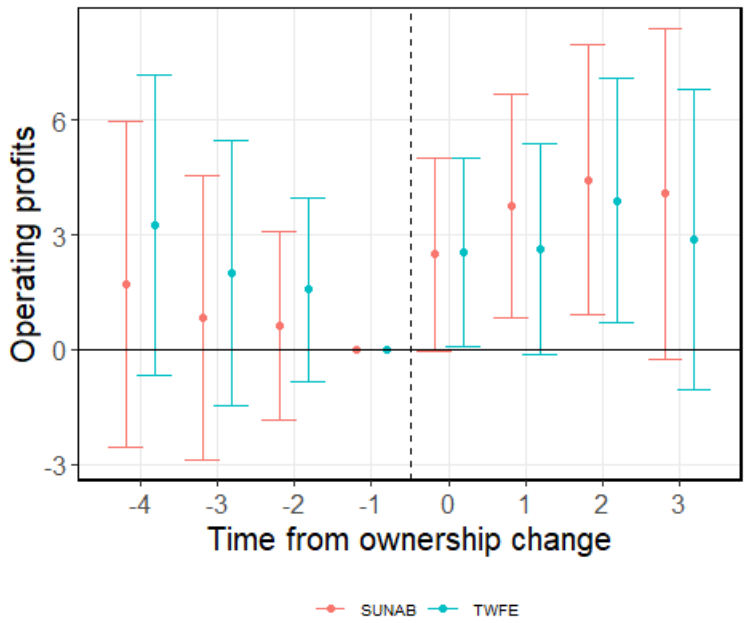
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on intangible fixed assets. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B47: Effect on total factor productivity in other industrial facilities of the acquiring parent company



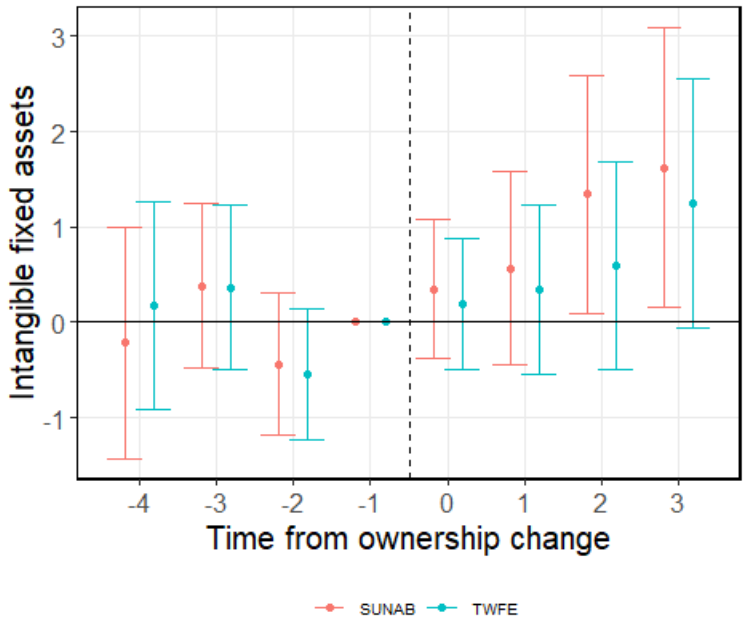
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B48: Effect on operating profits in other industrial facilities of the acquiring parent company



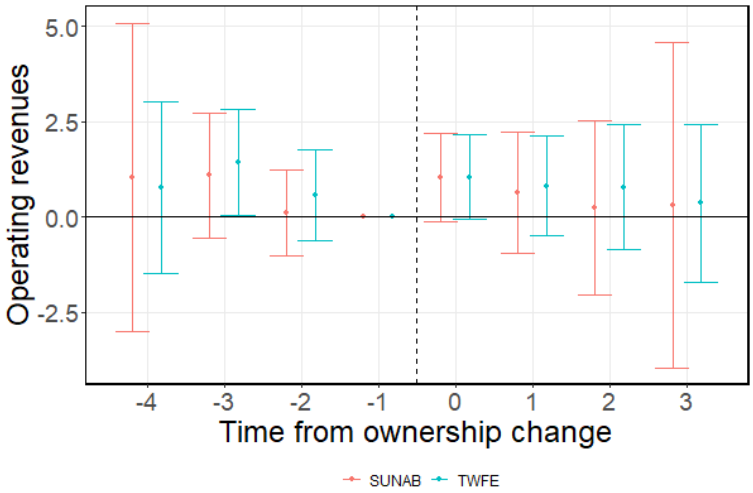
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on operating profits. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B49: Effect on intangible fixed assets in other industrial facilities of the acquiring parent company



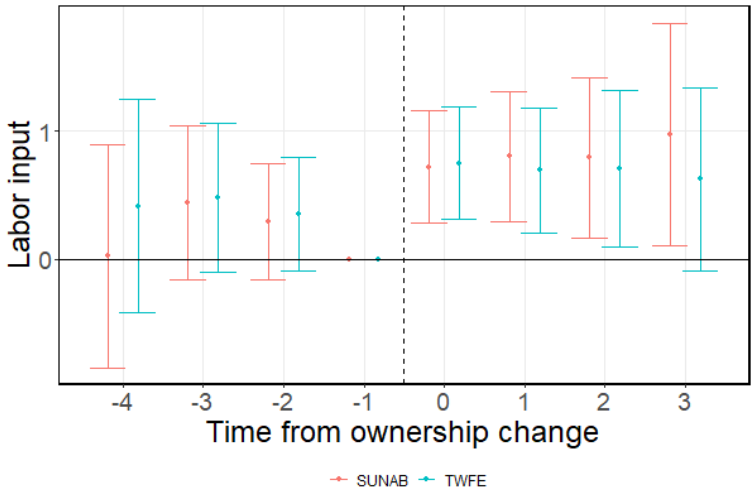
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on intangible fixed assets. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B50: Effect on output at the parent company level



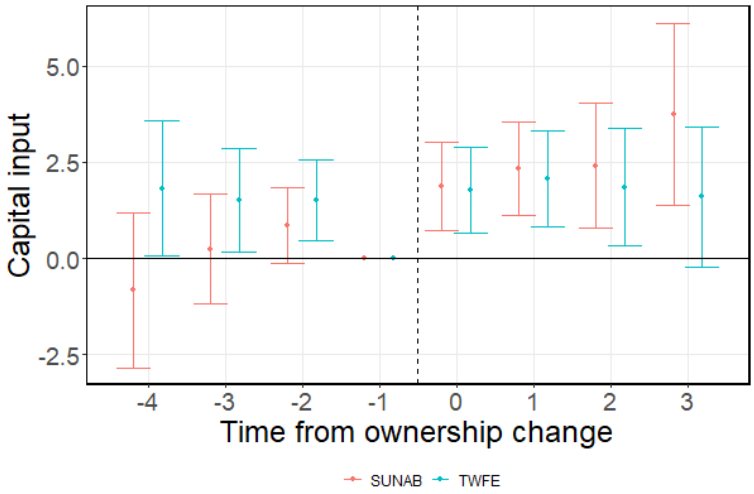
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated operating revenues at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B51: Effect on labor input at the parent company level



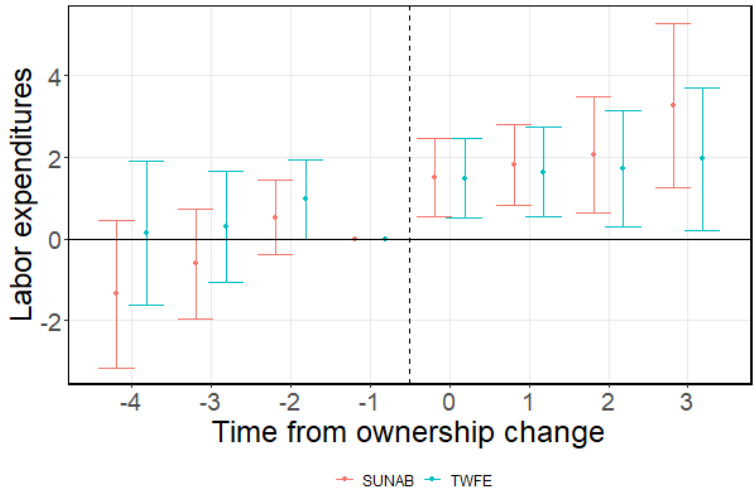
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on number of employees at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B52: Effect on capital input at the parent company level



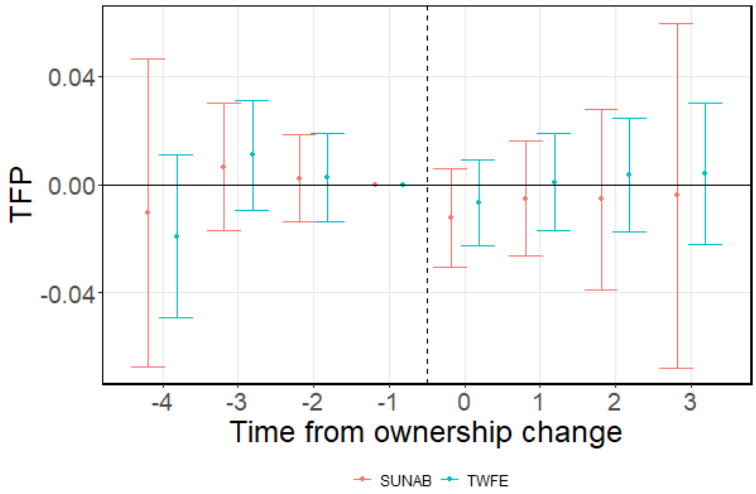
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated tangible fixed assets at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B53: Effect on labor expenditures at the parent company level



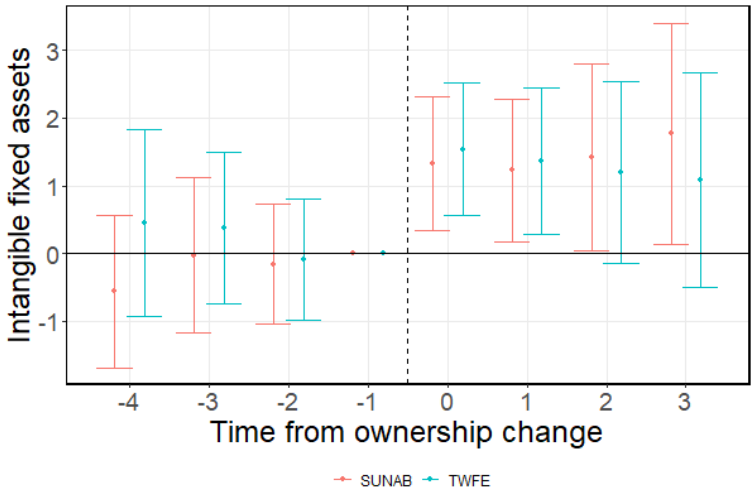
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated labor expenditures at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B54: Effect on total factor productivity (TFP) at the parent company level



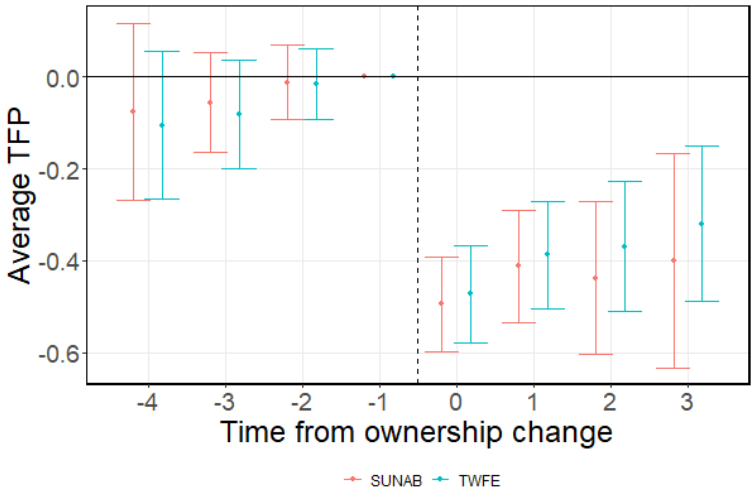
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B55: Effect on intangible fixed assets at the parent company level



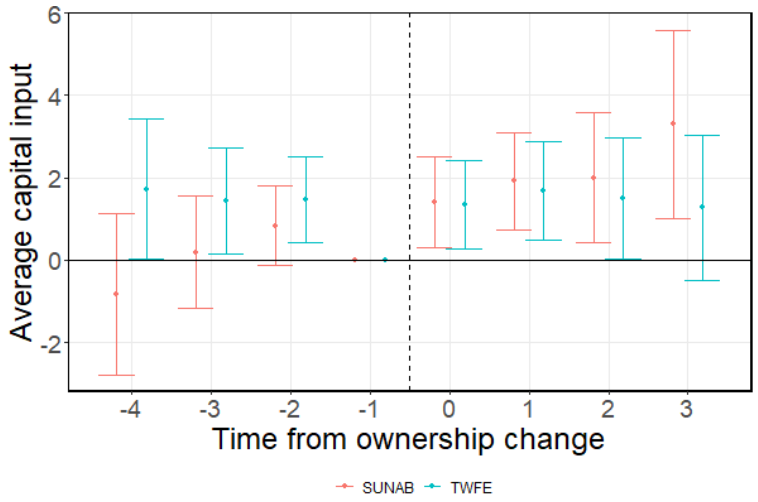
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated intangible fixed assets at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B56: Effect on average total factor productivity (TFP) per industrial facility at the parent company level



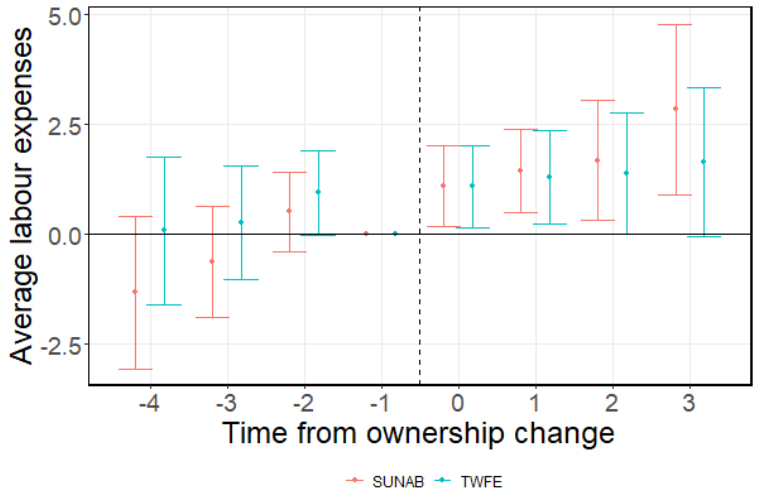
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B57: Effect on average capital input per industrial facility at the parent company level



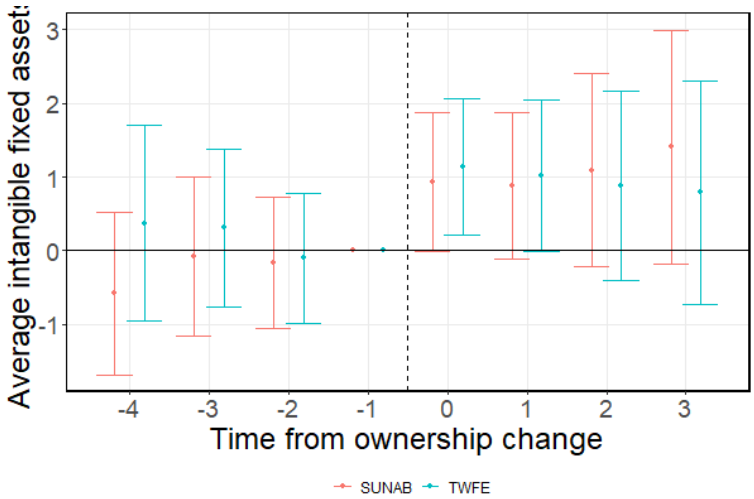
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated total fixed assets per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B58: Effect on average labour expenditures per industrial facility at the parent company level



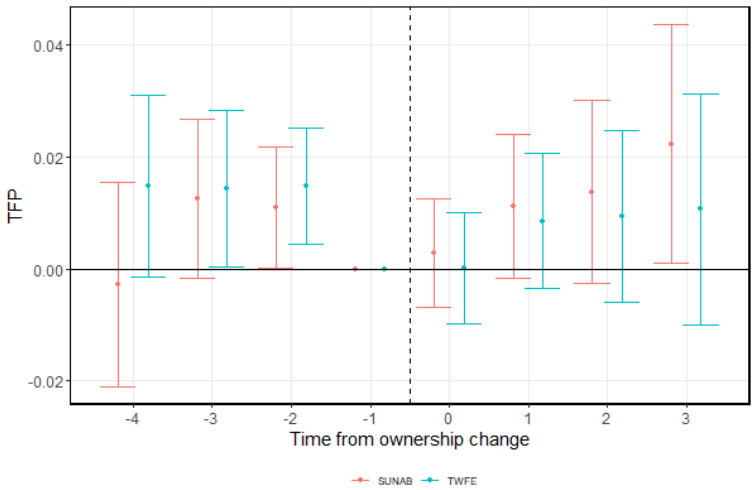
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on labor expenditures per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B59: Effect on average intangible fixed assets per industrial facility at the parent company level



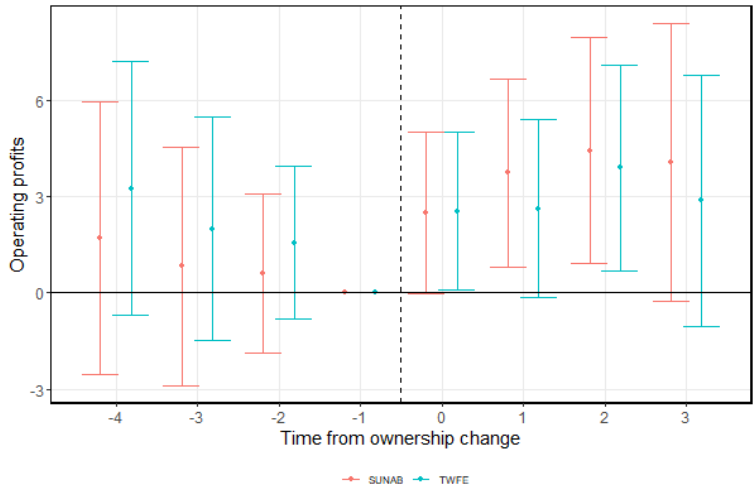
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on deflated intangible fixed assets per industrial facility at the parent company level. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B60: Effect on total factor productivity (TFP) for the other firms of the parent company acquiring a new facility



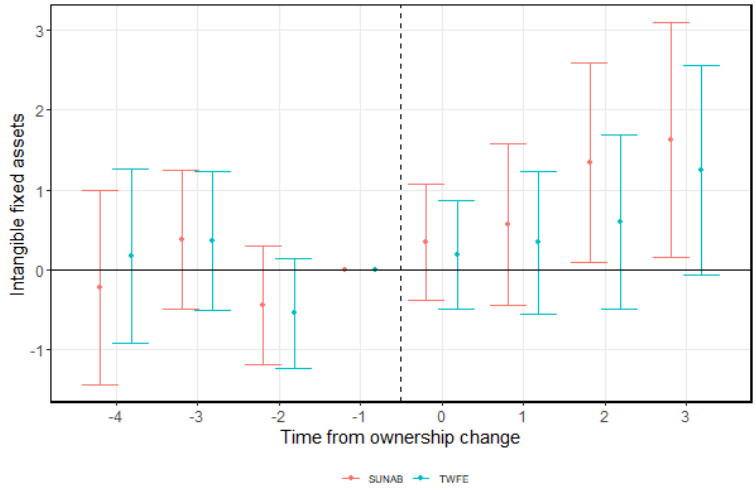
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on total factor productivity for the other firms of the parent company acquiring a new facility. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B61: Effect on operating profits for the other firms of the parent company acquiring a new facility



Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on operating profits for the other firms of the parent company acquiring a new facility. The inverse hyperbolic sine transformation is applied to the independent variable.

Figure B62: Effect on intangible fixed assets for the other firms of the parent company acquiring a new facility



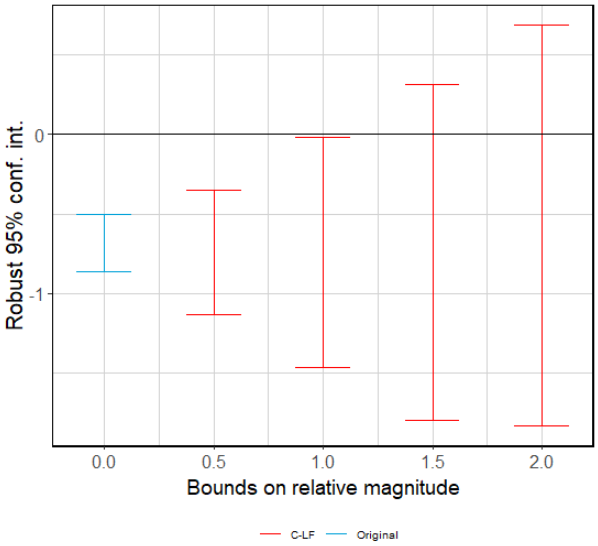
Notes: This figure shows the estimates and 95% confidence intervals for the event study coefficients for the effect of an ownership change on intangible fixed assets for the other firms of the parent company acquiring a new facility. The inverse hyperbolic sine transformation is applied to the independent variable.

Appendix C. Sensitivity analysis on pre-trends

Our identification in the event study rests on the parallel trends assumption that facilities and firms that experienced an ownership change would have developed the same way in absence of treatment as entities that do not (yet) experience an ownership change. A common check for this assumption is to look at pre-trends before treatment. In this setting, pre-treatment coefficients for some outcomes at the firm level are significantly different from zero and even show a falling trend in the years before acquisition. Therefore, we cannot readily interpret the estimated effect after treatment as causal impact of the ownership change. To get an idea about how significant pre-trends could have affected the robustness of our findings, we apply a method by Rambachan and Roth (2023). Their approach estimates the magnitude of the post-treatment violations of parallel trends, relative to the observed maximum pre-treatment violation, and provides the bounds of relative magnitude in post-treatment violation at which the estimated coefficient would turn insignificant. The assumption behind it is that the violation of parallel trends in the post-treatment period may be similar to that in the pre-treatment period. Bounds of relative magnitude equal to 1 would impose that the post-treatment violation is not stronger than the strongest pre-treatment violation between consecutive periods. The results from the test provide a check on how sensitive estimates are to violation of the parallel trends assumption.

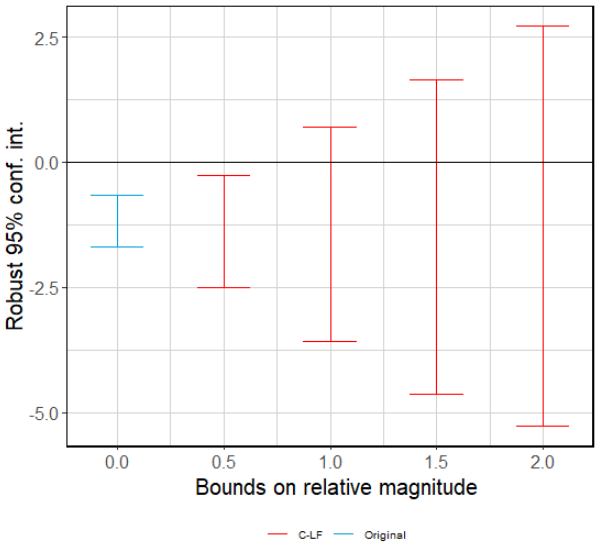
In our setting, we conduct the test on the bounds of relative magnitude for the fourth post-treatment coefficient (the third year after the ownership change). The standard approach is to test sensitivity for the first coefficient after treatment. However, most of our treatment effects increase over time and are largest at the end of the post-treatment period.

Figure C1: Test on the bounds of relative magnitude for the effect on emissions at the facility level



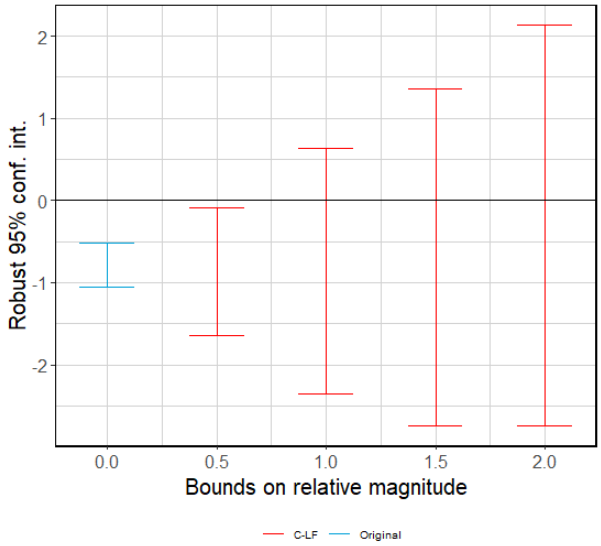
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is up to the maximum violation oberved in the pre-treatment period.

Figure C2: Test on the bounds of relative magnitude for the effect on emissions for exiting facilities



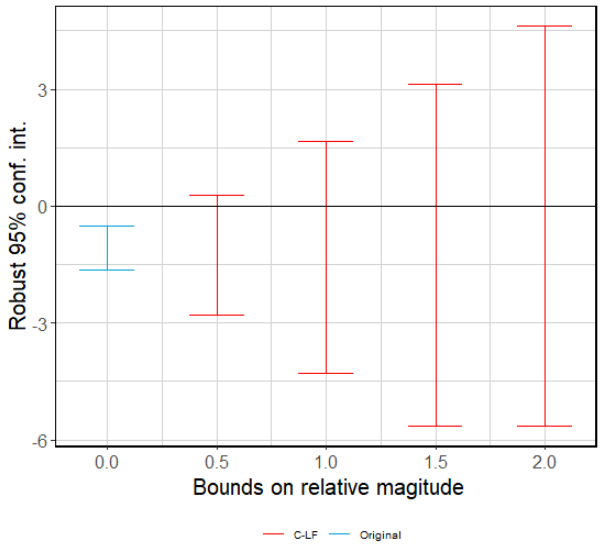
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is half or less of the maximum violation observed in the pre-treatment period.

Figure C3: Test on the bounds of relative magnitude for the effect on emissions at the firm level



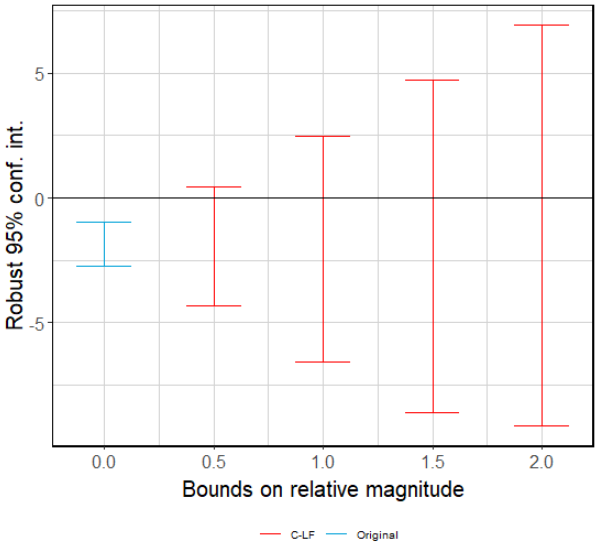
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is half or less of the maximum violation observed in the pre-treatment period.

Figure C4: Test on the bounds of relative magnitude for the effect on emissions for exiting firms



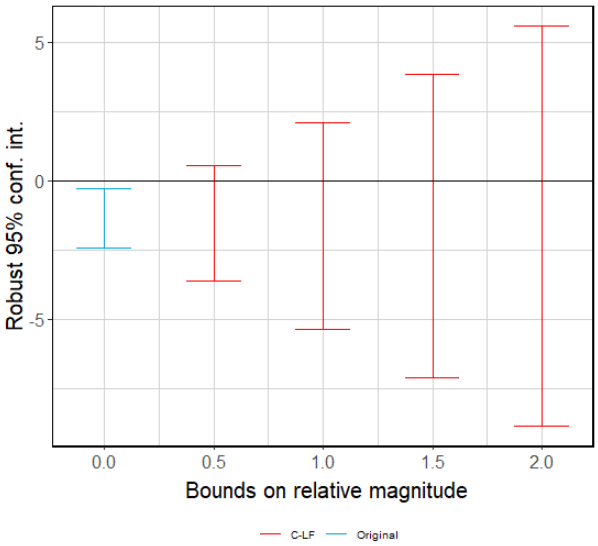
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C5: Test on the bounds of relative magnitude for the effect on output at the firm level



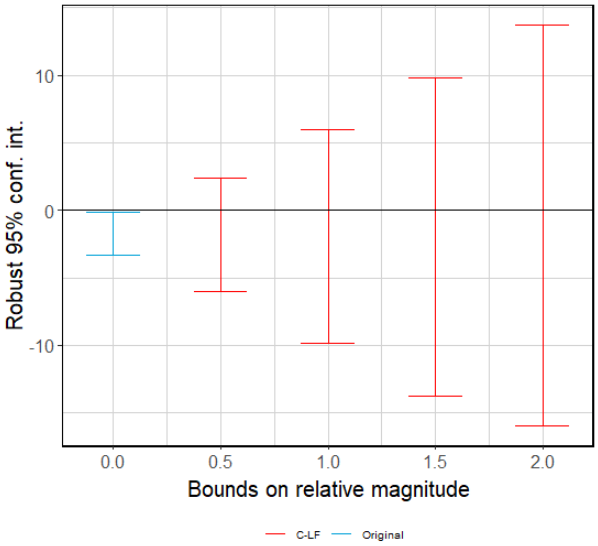
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C6: Test on the bounds of relative magnitude for the effect on output for firms remaining in operation



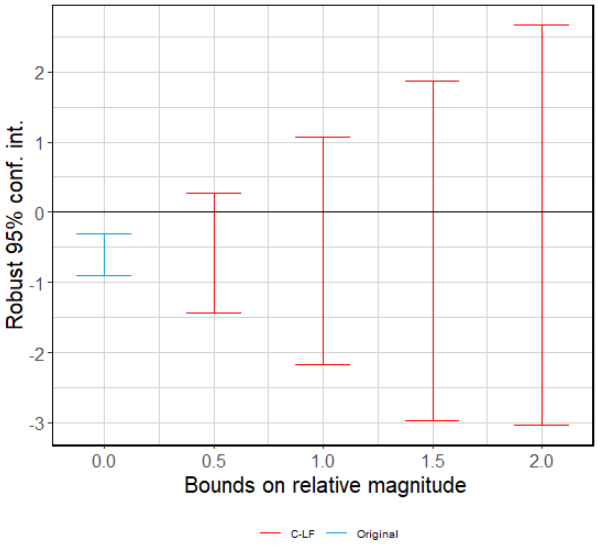
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C7: Test on the bounds of relative magnitude for the effect on output for exiting firms



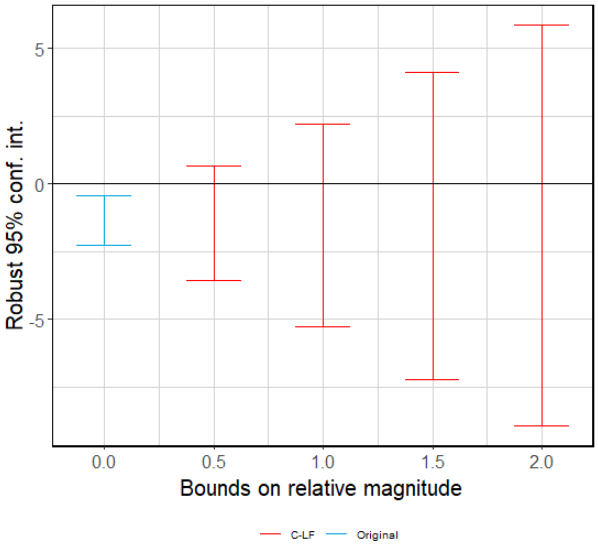
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C8: Test on the bounds of relative magnitude for the effect on labor input at the firm level



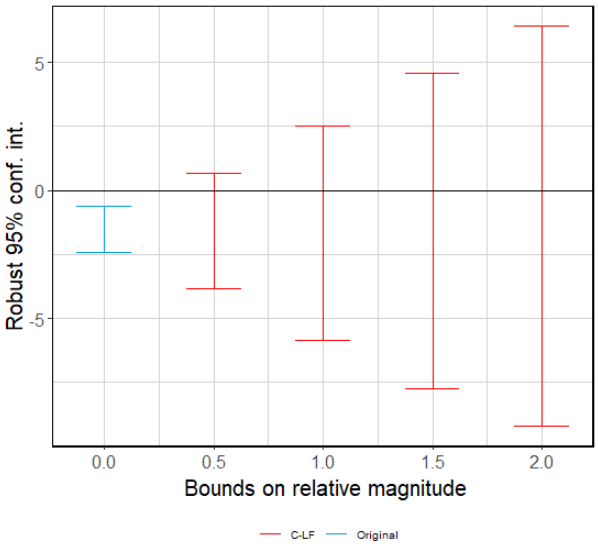
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C9: Test on the bounds of relative magnitude for the effect on labor expenses at the firm level



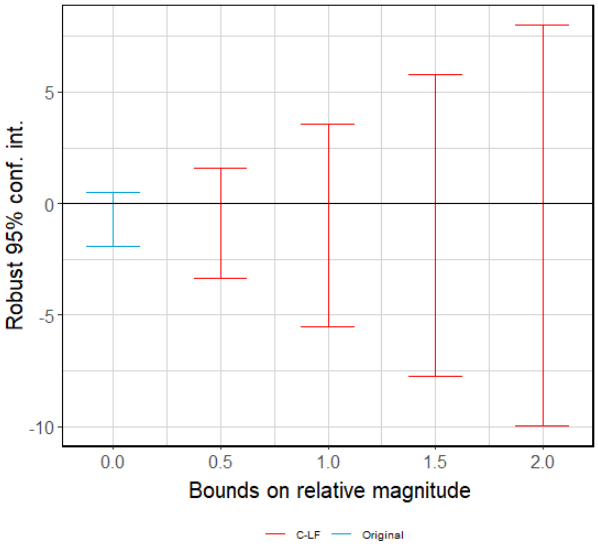
Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C10: Test on the bounds of relative magnitude for the effect on capital input at the firm level



Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The coefficient is significant as long as the deviation from parallel trends is less than half of the maximum violation observed in the pre-treatment period.

Figure C11: Test on the bounds of relative magnitude for the effect on profits at the firm level



Notes: This figure shows the event study coefficient with 95% confidence interval in the fourth year after the ownership change in blue and robust coefficients with 95% interval in red that adjust for different degrees of violation in parallel trends in the post-treatment period relative to violation in the pre-treatment period. The original coefficient is not significant in the fourth year after the ownership change. When adjusting for deviations from parallel trends, adjusted coefficients are even less significant.

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https://ideas.repec.org/s/zbw/zewdip.html

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