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Indirect cost compensation under the EU ETS: A firm-level analysis☆

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ABSTRACT

Decarbonisation implies conversion to electrification with a subsequent increase in electricity consumption. The EU Emission Trading System (EU ETS) compensates firms for the higher electricity costs. We exploit sectoral and country differences in regulation and a unique dataset on beneficiaries to evaluate the impact of EU ETS indirect cost compensation on the performance of aided firms. Receiving compensation for indirect costs does not have a statistically significant impact on labour productivity. Conversely, there is evidence of a negative performance in terms of turnover, value of total assets and employment of beneficiaries. Results suggest that the amounts transferred to firms might not fully compensate for the higher cost of energy in aided countries. However, the negative effects fade in sectors more exposed to carbon leakage risk. As far as aid intensity is concerned, estimates imply that higher compensation amounts improve performance.

1. Introduction

The European Commission (EC) has set to achieve ambitious environmental goals by 2050 through a package of measures, known as the European Green Deal, ranging from cutting-edge Research & Innovation to environmental policies, including severe emissions cuts European Commission (COM(2019) 640 final). Indeed, in her first State of the European Union address in September 2020, President Ursula von der Leyen announced a proposal to further reduce EU greenhouse gas emissions by at least 55% by 2030. The aim is to put the European Union (EU) on a path of more sustainable growth, thereby improving citizens' health and well-being and limiting environment-related risks. This initiative falls within a broader set of actions undertaken worldwide with the 2015 Paris Agreement on Climate Change (UNFCCC, 2015) to threaten global warming and reduce Greenhouse Gas (GHG) emissions.

Actions in preserving environmental quality in Europe are not recent. One of the primary tools of the EU policy to contrast climate change and reduce GHG emissions is the Emission Trading System (ETS). In place since 2005 and with the aim of meeting the goals of the Kyoto Protocol, the ETS is the largest trading system of emission allowances worldwide (Bocklet et al., 2019).

The ETS operates so as to create a carbon price signal that induces firms and businesses to reduce their emissions in two ways. On the one hand, businesses must buy CO_2 certificates equivalent to their industrial emissions (direct costs).[1] On the other hand, firms incur in an additional cost for the electricity they consume (indirect costs) because also their energy suppliers (power generators) are subject to direct costs. Therefore, firms regulated by the EU ETS can either decide to undertake (costly) emissions abatement or to buy emissions allowances, both yielding profit loss. Indeed, decarbonisation implies conversion to electrification, a transition which is still expensive and politically controversial, as electricity prices are above their marginal cost to act as a good incentive (Heal, 2020).

Another important potential drawback of the ETS and the costs associated to its application is that EU companies might be in a competitive disadvantage compared to businesses operating outside of

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[1] The ETS is based on a "cap and trade" mechanism, which sets a threshold for the total GHG emission volumes produced by energy-intensive installations and aircraft operators. Participants to the ETS receive a certain number of allowances (i.e. rights to produce GHG emissions, measured as tonnes of CO_2 equivalent) for free, which can then be exchanged in an auction-based market. The limited supply of allowances in the market fosters an efficient allocations of the emission rights where there is either a higher demand or a lower capacity to switch towards less pollutant productive system.

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the EU, with a subsequent drop in market shares. Therefore, CO_2-intensive industries might decide to relocate their production in countries with less strict provisions in terms of GHG emissions cut. This phenomenon, which is commonly known as “carbon leakage”, is detrimental for two reasons. First, firms moving to countries that have less stringent regulation would continue to contribute to high levels of worldwide emissions. Second, their relocation could translate into closing or downsizing of businesses operating in the EU, with a subsequent loss of jobs. Furthermore, in the medium and long run carbon leakage might discourage firms’ investment in new production facilities or reinvestment in those that are at the end of their lifetime (Matthes, 2008). In contrast, oversubsidizing firms to avoid leakage could determine potential market distortions, as it might provide financial support also to otherwise not profitable firms (Matthes and Monjon, 2008).

Power generators exhibit a more limited exposure to these competitiveness effects, as the market segmentation and the transmission network structure contain extra-EU competition, allowing to make up for the additional costs by increasing the electricity prices (Martin et al., 2016). Emission allowances represent, indeed, a production input for regulated companies that factor these additional costs in their production function (Coase, 1960). The pass-through of emission costs in the prices of carbon-related products, without incurring in a market share loss, might generate expectations of higher profits, i.e. “windfall profits”, depending on several factors.

The theoretical literature has showed that the degree of cost pass-through is influenced by market structure, supply and demand elasticities, exposure to international competition and information asymmetries.[2] Sijm et al. (2006) empirically show that the level of market concentration and the shape of demand and supply curves determine the degree of pass-through. In their study on Germany and the Netherlands, they outline that the pass-through rate is higher when demand is more inelastic and the market is less concentrated. Furthermore, Demailly and Quirion (2006) show that higher pass-through is expected when the allocation of allowances does not depend from current production. Most of the empirical research concentrates on cost pass-through in the electricity market, whereas only a few contributions consider industrial products (Cludius et al., 2020; Neuhoff and Ritz, 2019), finding significant cost pass-through especially within the cement, iron and steel, and refineries sectors. Nonetheless, cost pass-through can affect the price of goods sold and firm revenue, other than input costs and might be beneficial for unregulated or less-regulated firms operating in regulated industries (Bushnell et al., 2013).

To face these competition challenges, the ETS Directive European Commission (2003/87/EC) identifies the sectors exposed to a significant risk of carbon leakage and establishes some mitigating measures for the higher costs of electricity due to the ETS. While compensation of direct costs is mandated via the granting of free allowances by Member States directly under the ETS Directive, indirect costs can be compensated to electricity-intensive undertakings by Member States under approved State Aid measures. Compensation of indirect costs, however, is optional for Member States and, as such, it might give rise to distortions within the internal market.[3]

In this paper, we exploit country differences in the ETS regulation to causally evaluate the impact of the indirect costs compensation under State Aid measures in terms of competition distortion and carbon leakage risk, using firm-level data. To do so, we consider a unique dataset containing information on beneficiaries of indirect cost compensation. We link this data to Orbis, a Bureau Van Dijk database, which contains balance sheet information of firms. Our analysis covers the period 2009–2017 and comprises firms operating across different sectors in 12 European countries, 6 of which provide funding for indirect cost compensation. We follow a Difference-in-differences approach and compare the average change in performance for a group of firms receiving compensation with the one of a similar group of firms that operate in the absence of aid.

We assess the potential existence of competition distortions by resorting to per employee measures. As for the impact on carbon leakage risk in the short run, we consider changes in operating revenues (turnover) and number of employees. We complement the analysis by looking at the impact on the value of the firms’ total assets, which might be representative of the investment decisions and therefore signal the existence of leakage in the medium and long term, in so far as higher carbon costs may bring about the closure of the undertakings or redirect new investments to non-regulated areas.

Our results indicate that the indirect cost compensation supplied by EU Member States with an approved State Aid scheme had little or negligible impact on the measures of competitiveness considered, namely turnover per worker and value of total assets per employee. However, when outcomes are considered in absolute terms (i.e. turnover, total assets and number of employees), beneficiaries seem to perform worse than non-aided firms. We provide evidence suggesting that this could be due to the concurrent decrease in energy prices in countries that do not provide compensation compared to those that foresee this type of aid. Moreover, these negative effects fade away when sectors more exposed to carbon leakage are considered.

Results from the analysis on the intensive margin point out that firms receiving a higher subsidy tend to experience a better performance in terms of turnover, investments and job retention in comparison to firms receiving subsidy of lower amounts. Here, the focus is only on the beneficiaries of indirect compensation for which it was possible to retrieve aid intensity data, thus implying a more homogeneous sample of firms that have comparable characteristics in all, but for the treatment intensity.

The effectiveness of a cap-and-trade system relies on its ability to keep emissions below the cap. In 2005, the EU ETS was initially characterised by a generous allocation of free permits based on past CO_2 emissions that led to low costs abatement and a too generous cap. The non-optimal allocation produced an average annual cap that was 3% higher than the verified emissions in the first phase of the ETS (Abrell et al., 2011). This, in turn, determined an excess of allowances supply and a subsequent price drop that fell below 1 EUR per allowance. Bushnell et al. (2013) examine the impact of this price drop on share prices of affected firms. They find that the EU ETS was beneficial for several industrial sectors and especially for those more carbon-intensive, as the CO_2 price reduction implied a sharper decline in equity prices.

In the next phase, from 2007 to 2008, the number of allowances was reduced, the price per unit increased and emissions declined. The economic and financial crisis in 2009, however, induced a contraction in the demand that determined again a price drop. Indeed, overcompensating carbon-intensive industries, while shrinking general public spending, might counteract emissions trading, as showed by Martin, Muûls, De Preux and Wagner (2014b), who also discuss how the criteria adopted by the EC gave rise to inefficient allocations. Moreover, Smale et al. (2006) demonstrate that free permit allocation can lead to overcompensation by offsetting negative profit impacts, even though they acknowledge the adverse effects of rising electricity costs on profits for more exposed industries.

In 2009, the EC discontinued the free permits allocation (also in contrast with the initial plan of phasing in auctioning of permits in 2013). These were now foreseen only for industries experiencing higher risks of carbon leakage on the basis of their trade exposure and carbon intensity (Cludius et al., 2020; Martin et al., 2014b). A surplus of emission allowances was created, largely due to the economic crisis and

[2] See Cludius, de Bruyn, Schumacher and Vergeer (2020) for a detailed review.

[3] The value of the compensations, as well as the sectors eligible and the definition of electricity-intensive are specified in the State Aid decision of the Member State, in compliance with the ETS Guidelines European Commission (2012/C 158/04). The carbon leakage list of sectors is updated every five years and sectors remain in the list until renewal.

to the high imports of international credits. In turn, this reduced carbon prices and generated weak incentives to limit emissions, hampering the ability to effectively meet the emission targets in the long run. To overcome these issues, the EC introduced a back-load of allowances in the short-term and a market stability reserve, operating since 2019, as a long-term solution.

The empirical economic literature examines the effects of decarbonisation along different strands of research both at a macro and micro level of analysis, striving to define an appropriate combination of costs and incentives to ease the achievement of the fixed environmental targets. As discussed above, one of the most debated aspects is carbon pricing, which is crucial to have a proportionate emissions reduction. The potential price paths available to achieve the agreed Paris goals are examined in Stern and Stiglitz (2017). Recently, Parry (2020) develops a flexible model to quantify the expected economic gains of different pricing options.

A sizeable part of the existing studies focuses on the impact of carbon taxes on emissions at a macro level. Metcalf (2019) summarizes the studies for the United States and assesses the impact of the British Columbia Carbon Tax on GDP, finding no adverse effect on a panel of Canadian provinces. Turning to the EU case, the macroeconomic impact of the EU ETS on GDP and total employment growth rates at country level is investigated by Metcalf and Stock (2020). The authors reach inconclusive results, as the effect on GDP growth rate is positive but never statistically significant.

A detailed review of the studies on the first ten years of the ETS guidelines is illustrated by Martin et al. (2016), who focus especially on contributions seeking to establish a causal link and providing quantitative evidence. Although in the empirical literature there is widespread consensus in recognising the effectiveness of the ETS provisions in terms of emissions abatement, findings on firms' economic performance are not unambiguous, suggesting that the desired effects on emissions and innovation are costly, but still not confirming the existence of a marked detrimental effect. A number of studies looks at firms' economic performance, measured mainly by profits, revenues, output and employment, in the context of the EU ETS. Among them, Abrell et al. (2011) and Wagner et al. (2013) also observe a negative impact on employment. In contrast, Klemetsen et al. (2020) find a positive link on value added and labour productivity at plant level in Norway, while Chan, Li and Zhang (2013) identify a positive effect on turnover. Other studies using firm-level data find non-statistically significant effects on turnover (Abrell et al., 2011), employment (Flues and Lutz, 2015), total factor productivity and investment (Commins et al., 2011).

Our findings are also partially in line with some existing works that investigate on the effects of other energy-related interventions in Finland (Laukkanen et al., 2019) and in the United Kingdom (Martin, De Preux and Wagner, 2014a). The former finds a negative effect on revenues and gross output, the latter observes evidence pointing to the absence of an effect of the energy tax on productivity, production and employment.

Our work adds to the body of literature analysing the impact of the EU ETS on firms economic performance and competitiveness. In line with other papers (Abrell et al., 2011; Anger and Oberndorfer, 2008), we gather firm-level data from the Orbis database. We provide fresh evidence both for the period under analysis and for its main goals. Indeed, the vast majority of the literature looks at the impact of the ETS direct cost compensation, while we focus on the indirect one. Moreover, only a few papers cover the period after 2013, while none of them exploits the subsidy intensity, which we are able to look into.

The remainder of the paper is organised as follows. Section 2 illustrates and describes the data and the sampling procedure. Section 3 outlines the methodology used to evaluate the effects of the indirect cost compensation on firm financial outcomes and section 4 presents the results. Finally, section 5 concludes.

2. Data

In this section we describe the data used in the analysis. Then, we outline the procedure used to match data from the two sources. Finally, we describe the resulting sample.

2.1. Sources and matching

Compensation for the indirect costs generated by the ETS is voluntarily applied by each EU Member State following a standard State Aid procedure. Over the 28 EU Members, only 11 have decided to introduce compensation for indirect costs (Table A.1). We accessed official records for six countries (Belgium, Finland, Germany, the Netherlands, Spain and the United Kingdom), containing information on company name, 4-digit NACE and aid amount.[4]

Financial data on firms are extracted from the Orbis Bureau Van Dijk database, which provides balance sheet information at firm level. The panel is constructed following the methodology proposed by Kalemli-Ozcan et al. (2015) and all values are harmonised according to the Eurostat Consumer Price Index (HCPI). We include all firms operating in one of the sectors covered by the ETS (Table A.2). We consider businesses operating in one of the six EU Member States for which we have access to data on beneficiaries and those operating in six control countries (Czech Republic, Hungary, Italy, Poland, Portugal and Sweden).[5]

We then match the two databases using a probabilistic matching on company names by country.[6] In total, 398 out of 753 exact matches were found between the entries in Orbis and those in the beneficiaries records. The remaining ones were checked manually. Eventually, 603 beneficiaries were correctly matched to the Orbis database, i.e. 80% of the original pool of beneficiaries. Firms' sector of activity is identified via the NACE code.

Indirect cost compensation is sector-specific and is applied to all firms operating in eligible sectors in aiding countries. Hence, we exclude from our sample firms that do operate in eligible sectors in countries that have adopted indirect cost compensation schemes but do not appear in the records of beneficiaries transmitted by Member States, as they might receive compensation under the "de minimis" rule.[7] Furthermore, to ensure comparability between beneficiaries and non-beneficiaries and retain only firms that have similar size and economic potential, the sample is trimmed at a threshold that corresponds to the average turnover of the first percentile of the distribution of the beneficiaries (see

[4] Records for France, Greece, Luxembourg and Slovakia are not available. Lithuania also has an approved State Aid but it is not considered because only one beneficiary has been compensated over the years.

[5] Also Bulgaria, Ireland, Latvia, Malta and Romania do not provide indirect cost compensation. However, Bulgaria and Romania entered the EU only in 2007, hence, firms in these countries might be on a different growth path compared to those operating in other Member States. Ireland, Latvia and Malta are not considered due to their small sample size.

[6] Except for firms registered in Spain, which were matched on the basis of the VAT number. The probabilistic matching consists in an algorithm that assigns a score to each entry on the basis of how well it matches to any of the records existing in the data. The score goes from zero (no match) to one (perfect match) and considers the position of each letter in a given name.

[7] The "de minimis" rule provides that subsidies of less than 200,000 EUR granted to an undertaking over a period of 3 years do not constitute State Aid within the meaning of the EC Treaty's ban on aid liable to distort competition European Commission (Regulation (EU) No 1407/2013). Therefore, firms receiving this aid do not have any reporting obligation and do not appear in the list of beneficiaries. The absence of such information constitutes a major challenge when selecting a proper comparison group. The adopted sample selection aims at minimising arbitrariness.

Figure A.1).[8] Finally, we further refine the sample by removing businesses that do not appear in the Orbis database continuously over the period 2013–2017 to avoid potential distortions arising from different survival rates.

2.2. Descriptive statistics

The final sample consists of a panel of 3706 firms covering the period 2009–2017, for a total of 23,277 observations. Figure A.2 shows the total number of firms in the sample, by country and by year (left) and by sector of activity (right). The plots at the top refer to the beneficiaries of indirect cost compensation, those at the bottom to the comparison group (non-funded firms). The sample of the beneficiaries amounts to around 300 firms per year, while non-funded firms are about 2500 every year. The two samples are not homogeneous in the type of activity carried out. Funded firms are represented in many sectors, with the manufacture of paper and paperboard (NACE 17.12) being the largest group. In the case of firms that operate in countries that do not provide ETS indirect cost compensation, 45% of them belong to NACE 46.75 ("Wholesale of chemical products").[9]

Fig. 1 displays the distribution of the subsidies granted to beneficiaries, which appears to be quite heterogeneous across sectors. Table A.3 reports the main descriptive statistics of the amounts by country and year. Germany and Finland are the most generous countries with aid amounts above 100,000 EUR on average, while Spain grants the smallest amounts (6573 EUR on average).

Firms regulated by the ETS might indirectly pay for emissions reductions via lower profits due to costly abatement or permits purchase. Moreover, competition with rival companies not affected by the ETS could yield to lower market share. All these elements might discourage firms' new investments or even facilitate their relocation in unregulated areas. Balance sheet data included in the Orbis dataset allows assessing the potential competition distortion and carbon leakage risk at the firm level, by considering some standard indicators of economic performance. In particular, we assess the effect on competitiveness by looking at per employee measures, namely, labour productivity (turnover/employees) and assets per employee (total assets/employees). Both indicators offer a relative measure of firm performance, in terms of output value or investments scaled over firms size.

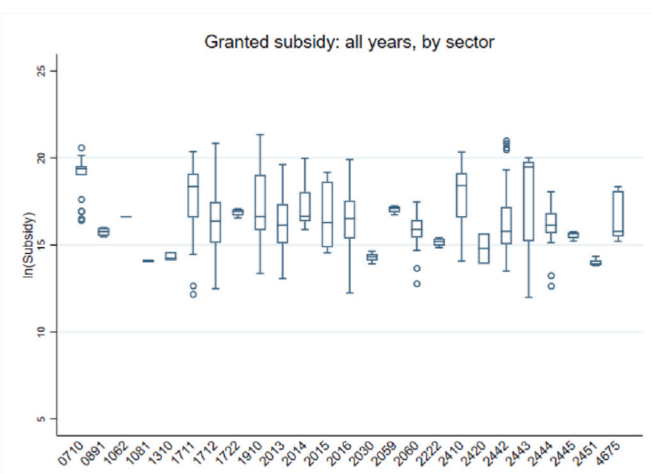

Fig. 1. Distribution of the subsidy transferred to beneficiaries by sector.

To provide a more complete picture of the effects that might occur in the short term, we also consider changes in operating revenues (turnover) and number of employees, which should mirror production choices directly. Turnover is a standard indicator of firm performance expressed as the value of the services and goods sold. It is widely considered as one of the main factors to assess the economic growth of a company, i.e. firm's profitability. Furthermore, while a pure measure of profit might suffer from potential profit shifting practices, turnover is unlikely to be affected by these operations. The number of employees accounts for firm size and helps identifying the potential risk of carbon leakage in terms of jobs loss. In the same vein, we consider the value of the firm's total assets as a proxy for changes in investment decisions, which allows us detecting expansions or shrinkages of the firms' assets endowments that are likely to happen in the medium-long term.

Figure A.3 shows the distribution of the firm performance indicators in the sample. The information provided by the two plots at the top clearly shows a difference in size, measured both as the value of the total assets and the number of employees, between beneficiaries and non-beneficiaries. However, this difference fades when performance is standardized on the basis of the workforce employed (plots at the bottom).

3. Methodology

The aim of the analysis is to assess whether the EU ETS compensation for indirect costs has contributed to reducing the risk of carbon leakage for firms operating in the exposed sectors, whilst not generating competition distortions within the internal market.

The intervention concerns firms operating in selected sectors in a given group of countries (Belgium, Germany, Spain, Finland, the Netherlands and the United Kingdom). For most countries the treatment starts in 2013, while in Finland it starts in 2016 and in Belgium-Wallonia in 2017. The control group is composed of firms that operate in the same sectors as those in the treatment group but in countries that do not provide indirect cost compensation (Czech Republic, Hungary, Italy, Poland, Portugal and Sweden). Data is available for the period 2009–2017, which includes the outset of the indirect compensation schemes in the countries considered.

We estimate the effect of receiving indirect cost compensation on firms' performance by adopting a Difference-in-differences approach:

$$Y_{isct} = \beta T_{sct} + \gamma_i + \delta_t + \sigma X_{ct} + \theta_{st} + \varepsilon_{isct} \tag{1}$$

where Y_{isct} is the outcome for firm i, operating in sector s in country c in year t. We consider five performance measures: turnover per employee, total assets per employee, turnover, total assets and number of employees. These are all expressed in logarithm to ease the interpretation of the results.

The variable T_{sct} takes two forms. In one case, it is an indicator that takes value one if the firm is deemed to receive indirect cost compensation, because it operates in a country where the sector is eligible to funding in that year, and value zero otherwise (i.e. either it operates in an aiding country in a period prior to the enactment of the State Aid scheme or it operates in a country where indirect cost compensation is not contemplated). Here, the indicator is referred to as 'Aid' and is used in the analysis described in section 4.1. Thus, the estimation of the coefficient β allows answering to the following question: by what percentage does the firm's performance change when it receives compensation, regardless of the amount of the aid?

In the second case, which applies to the results presented in section 4.2, T_{sct} is (the logarithm of) the amount of the subsidy received by each firm ('Subsidy'). Here, β expresses an elasticity, thus it addresses the question: by what percentage does the firm's performance change for

8 Thus, we exclude all firms with a turnover lower than 16,762 EUR, namely 15 beneficiaries and 11,554 non-funded firms. To some extent, this procedure also allows us to account for undetected "de minimis" recipients in non-aided countries.

9 We account for these differences in the analysis by using NACE fixed effects and by providing a robustness test where we exclude sectors one at a time.

every one per cent increase in the amount of the aid?

The model allows for several fixed effects, which are meant to capture differences that might exist across firms (γ_i) and years (δ_t), or shocks that might occur in specific time periods in given sectors (θ_{st}), including changes in regulations or market competition and all EU-wide sector-specific changes to the ETS and to other directives such as the Industrial Emission Directive (IED). These sets of fixed effects are vital to eliminate or attenuate any potential confounding factor that might arise, especially given the lack of observable characteristics to use as controls. As the treatment varies at the level of country and year, we also consider a set of time-varying country-specific control variables drawn from Eurostat (X_{ct}), which contains GDP per capita, the debit-to-GDP ratio, the average gross electricity price for the consumption band 70k-150k MWh and the yearly amount of greenhouse gases emitted. This captures fluctuations at the country-level, including the potentially disruptive impact of the 2008 recession, both directly (via GDP per capita and debit-to-GDP ratio) and indirectly (via greenhouse gas emissions, which, in turn, can affect the price of allowances and the cost of electricity). Finally, ε_{isct} represents the error and standard errors are clustered at the NACE-by-country level.

4. Results

In this section we present the effect of receiving EU ETS indirect cost compensation on the extensive margin (that is, whether funding is received or not) and on the intensive margin (namely, the effect of each EUR of aid received).

4.1. EU-ETS indirect cost compensation on the extensive margin

Table 1 shows the effect of receiving compensation for ETS indirect costs on a proxy of labour productivity, namely turnover per employee (columns 1–3) and on the average value of total assets per worker (columns 4–6). These are meant to account for the effect of the aid on competitiveness, thus giving insights on the existence of potential competition distortions.

A first simple estimation of the effect of receiving compensation on turnover per employee includes firm and year fixed effects, which account for all differences across firms that do not vary over time and for common shocks that occur across all firms in a given time period (column 1). In columns 2 and 3 we account, respectively, for those unobserved factors which are specific for each sector in a certain year (i.e. NACE–year fixed effects) and country characteristics that may vary over time. In all cases, the coefficient is not statistically different from zero. Columns 4 to 6 of Table 1 reproduce the same estimates when total assets per employee is considered and yield identical findings.

This first set of results suggests that the EU ETS indirect cost compensation on average did not have an impact on per worker measures, thus pointing to the absence of market distortions due to the compensation. Considering measures of profitability in absolute terms would capture changes in the production levels that firms overtake in the short run (turnover and employment) and in the medium run (total assets), hence approximating for the risk of carbon leakage, together with firm size (number of employees).

Table 2 shows the estimated effect of the compensation on turnover (column 1), total assets (column 2) and employment (column 3). These measures represent the economic profitability and the size of the firm in absolute terms. The estimated coefficients are always negative and statistically significant and suggest that receiving compensation yields lower levels of turnover by 5.6%, of total assets by 6.3% and reduces employment by 4.4.%.

While this paper is the first to empirically address the specific impact of the ETS indirect cost compensation, our results are partially in line with existing evidence on similar interventions. For instance, the compensation of the direct cost generated by the ETS is found to yield non-statistically significant effects on firms' value added and profit margins (Abrell et al., 2011), and on total factor productivity (Commins et al., 2011). Similarly, while Commins et al. (2011) estimate a null impact on investments and employment, evidence of a negative effect of the direct cost compensation on employment is also reported by Wagner et al. (2013) on manufacturing firms in France and by Demailly and Quirion (2006) on the iron and steel industry in Germany. By considering energy tax exemption in Sweden, Laukkanen et al. (2019) do not detect any significant effect on revenues, wages per employee, energy use and employees. Moreover, no evidence of carbon leakage is also found in a variety of studies covering Europe (Dechezleprêtre et al., 2019; Verde et al., 2019; Panhans et al., 2017) or specific countries (Anger and Oberndorfer, 2008; Klemetsen et al., 2020; Martin et al., 2014a, 2016), even if in different empirical settings.

In order to assess the validity of our empirical approach and test whether there has been any anticipation effect, we carry out an event-study analysis in the spirit of Autor (2003).[10] This is plotted in Fig. 2 and shows that the behaviour of firms before the approval of the ETS indirect cost compensation was following a similar trend with respect to firms operating in countries without aid. Fig. 2 also provides some insights on the dynamics of the effects, showing how the impact changes over time. When considering the years after the implementation, the results presented in Tables 1 and 2 are confirmed. In fact, the evidence points to a non statistically significant impact of the indirect cost compensation on per worker outcomes both in the short (at $t+1$) and in the medium run ($t+2$ to $t+5$). Notwithstanding, a negative effect is found on turnover, total assets and employment, especially four and five years after the compensation being in place.

These results are robust to the inclusion of country-specific linear and quadratic trends (Table A.4, panels A and B), that capture any residual sectoral difference which might evolve linearly or non-linearly over time, to restricting the sample to the post-recession period (Panel C) and to restraining the treatment group to units operating in countries that adopted the compensation since 2012 (panel D).[11]

To ensure that the results discussed above are not driven by a single group of observations, we re-run all estimates excluding each country or sector, one at a time. These are presented in Figures A.4 and A.5, respectively. The flat patterns confirm that results are not driven by a single country or sector, as their exclusion does not affect the overall estimates. This evidence is reassuring, also in view of the country differences in relative size and the sectoral heterogeneity across treated and control firms revealed by the descriptive statistics in Figure A.2.

We also assess whether being part of a group of companies could allow firms exploiting some comparative advantages with respect to other firms facing market challenges alone. To this end, we define the variable 'Firm in group' which takes value one if the firm belongs to a group counting at least two firms and is equal to zero otherwise. In the sample, around 10% of businesses belongs to a group. Estimates presented in Table A.5 show that, in general, there is no heterogeneous effect of the ETS compensation for indirect costs for businesses belonging to a group of at least two firms, as the p-values always exceed the conventional 5% level of significance.[12]

Previous studies (Abrell et al., 2011; Martin et al., 2016) have shown

[10] We consider three years before the implementation and five years after. The choice is driven by the fact that the bulk of the treated firms in the sample started receiving compensation in 2013. For this group of firms, the selected range allows for t-3 being the year 2009 and t+5 being the year 2017, which are the first and the last year observed in the data.

[11] Additionally, we test that the main estimated effects are largely driven (namely, by 77%) by the comparison between never-treated and "timing" units, i.e., those units that switch from being untreated to treated during the period of observation, by computing the decomposition proposed by Goodman-Bacon (2021).

[12] Results are identical if we consider an indicator for international groups, i.e. equal to one if the firm belongs to a group operating in at least two different countries and zero otherwise.

Table 1
Effect of receiving aid on turnover per employee and total assets per employee.

Dependent variable	(1) Turnover per employee	(2) Turnover per employee	(3) Turnover per employee	(4) Total assets per employee	(5) Total assets per employee	(6) Total assets per employee
Aid	0.020	−0.013	−0.012	0.004	−0.008	−0.020
	(0.024)	(0.023)	(0.023)	(0.027)	(0.028)	(0.028)
Observations	23,277	23,277	23,277	23,277	23,277	23,277
R-squared	0.922	0.924	0.924	0.917	0.918	0.919
Firm FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
NACE-Year FE		✓	✓		✓	✓
Country-specific controls			✓			✓

***p < 0.01, **p < 0.05, *p < 0.10. Country-specific controls include GDP per capita, debit-to-GDP ratio, gross electricity price for the consumption band 70k-150k MWh and emissions of greenhouse gases (in CO2 equivalent). Full sample.

Table 2
Effect of receiving aid on turnover, total assets and employment.

Dependent variable	(1) Turnover	(2) Total assets	(3) Employees
Aid	−0.056**	−0.063**	−0.044**
	(0.026)	(0.027)	(0.019)
Observations	23,277	23,277	23,277
R-squared	0.975	0.981	0.974

***p < 0.01, **p < 0.05, *p < 0.10. All regressions include firm, year and NACE-year fixed effects and country-specific controls (GDP per capita, debit-to-GDP ratio, gross electricity price for the consumption band 70k-150k MWh and emissions of greenhouse gases in CO2 equivalent). Full sample.

sample, we perform an heterogeneity analysis in a similar vein. To this end, we consider the possibility that sectors that are the most exposed to the risk of carbon leakage may react differently to the receipt of indirect cost compensation. We refer to the 2009 EC Carbon Leakage Assessment and identify the sectors that have above-median values of both estimated production costs, calculated as a proportion of the gross value added, and trade intensity with non-EU countries, which are the two indicators used to determine eligibility in the context of the ETS.[13] We then interact our main variable of interest ('Aid') with a dummy variable that takes value one if a firm operates in one of these sectors.

The estimated coefficients reported in Table A.6 suggest that the negative effect of the compensation on firm performance is attenuated in the case of businesses at high risk of carbon leakage. Among the reasons

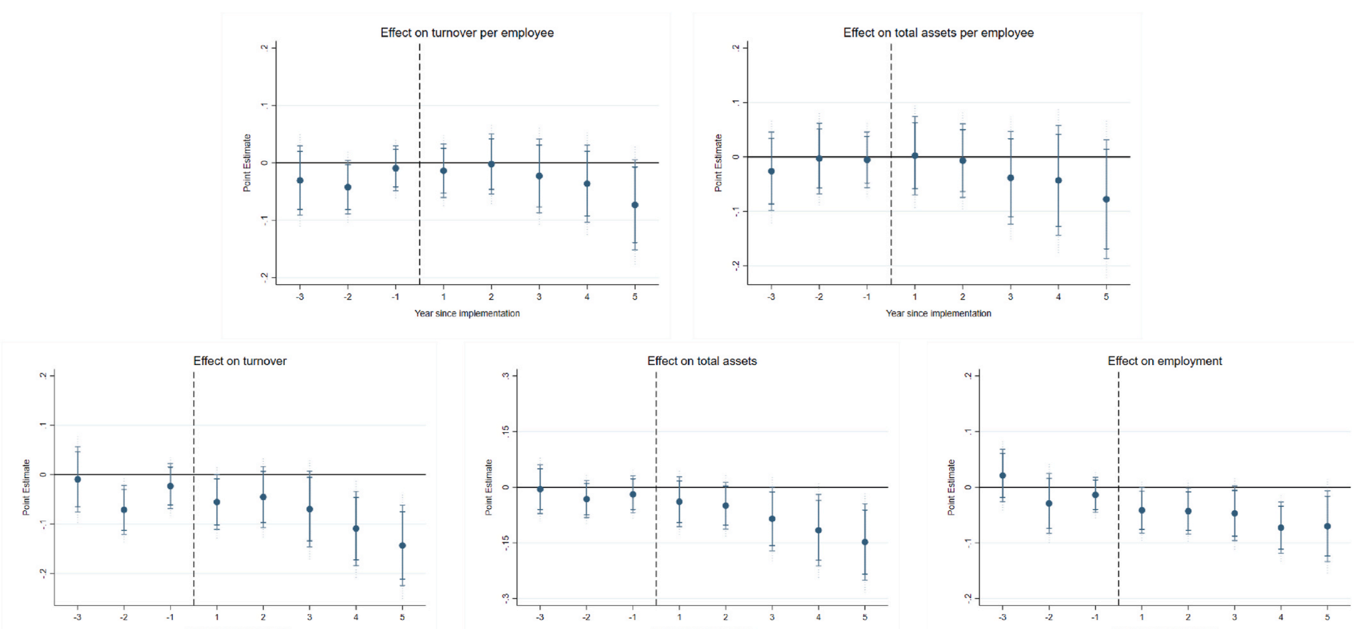

Fig. 2. Event studies: effect of receiving aid on firm performance. The vertical dashed line identifies the year of implementation (2012, 2015 or 2016, depending on the country considered). Blue dots are the point estimates of the effect of the aid in each year; vertical lines represent the respective 90%, 95% and 99% confidence intervals. Regressions include fixed effects and controls as from Equation (1). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

that sectoral differences are likely to exist among sectors regulated by the ETS. In particular, Abrell et al. (2011) conduct a sectoral analysis on under-versus over-allocated firms and show that the decrease in employment is driven by the non-metallic minerals sector. They also find sectoral differences in emission reduction. Even though their setting differs from ours both in terms of scope (type of compensation) and

[13] These are: Mining of chemical and fertiliser minerals; Manufacture of coke oven products; Manufacture of other organic basic chemicals; Aluminium production; Copper production; Other non-ferrous metal production. See https://ec.europa.eu/clima/system/files/2016-11/carbon_leakage_comparison_en.pdf.

that may explain such differences is the fact that, on average, these firms receive substantially larger subsidies in comparison to other businesses (EUR 115,661 vs. EUR 74,950). In addition, some of these firms may have a better ability of cost-pass through or may be negotiating special agreements with power generators, thus facing lower electricity prices.[14] Verifying whether this mechanism is driving our results, however, is not currently feasible due to data availability.

The above results might appear as counter-intuitive, as they suggests that firms receiving compensation experience a worse performance compared to firms in the control group who do not receive funding. According to the analysis, this occurs in particular in terms of absolute values of turnover, total assets and employment levels. There are different potential reasons behind these estimated effects.

A partial explanation may come from the differences in size of treated and control firms highlighted in Figure A.3. Considering normalised outcomes as in Table 1 attenuates potential systematic differences in market structure between the two groups. In addition, there exist some elements that enter the production function of firms which are not observed in their balance sheet data, such as the cost of the inputs. In the examined case, which focuses on firms that operate in energy-intensive sectors, the cost of energy is a non-negligible part of production costs. It is widely accepted in the literature that climate policies in support of renewable energy imply an increase of the electricity cost and this, in turn, induces firms to optimize their production function by using a different combination of inputs. Thus, as energy becomes more expensive it is substituted to labour (Cox et al., 2014; Marin and Vona, 2017). This interrelation between electricity prices and labour is deeply investigated in Cox et al. (2014) who focus on German manufacturing.[15] Yet, in principle, such mechanisms alone might only affect the number of employees and not necessarily imply a negative impact of indirect compensation on the performance of aided companies in comparison to those that do not receive any funding, unless the cost of energy for beneficiaries, net of the subsidy, was higher than that for firms in the comparison group.

A way to understand whether differentials in energy costs could represent a decisive determinant of this result is to look at the trends of energy prices in countries that compensate indirect costs and countries that do not. Fig. 3 depicts the average gross energy prices for non-household consumers in the consumption bands 20k–70k MWh and 70k-150k MWh and the average share of energy produced from renewable sources, split by group, i.e. compensating versus non compensating countries.[16]

The trends in the average energy prices suggest that energy costs are relatively similar in the period up until 2013 but substantially diverge in the following years. Specifically, in countries belonging to the control group the average prices fall steeply, while in the countries that provide compensation for indirect costs they start declining only after a few years. Moreover, Fig. 3 shows that non-aided countries are characterised by a higher share of energy production coming from renewable sources throughout the whole period considered.[17] This is coherent with energy having a lower price on average in countries that belong to the control group, and the more so given that in these areas firms could access extra benefits reserved to the use of renewable sources.

We further investigate this hypothesis by testing the effect of providing for indirect cost compensation on the average electricity prices and on the average share of renewable energy production at the country level. Estimates presented in Table 3 suggest the absence of anticipatory effects for each of the outcomes considered (columns 1, 4 and 7). At the same time, they imply that the adoption of compensation schemes is associated with a concurrent increase in the price of electricity in treated countries (columns 2 and 5), which persists in the following period (columns 3 and 6). This evidence, albeit suggestive, would be consistent with the co-existence of a premium in energy costs for firms receiving compensation compared to non-funded businesses, which could possibly offset the effects of the compensation.[18] Indeed, the existence of a positive and substantial pass-through rate in the context of the ETS has been highlighted in the recent literature (see, e.g., Sijm et al., 2006; Fabra and Reguant, 2014).

For what concerns the share of energy coming from renewable sources, the adjustment seems to have some delay (columns 8–9), but definitely points to rising levels of cleaner energy in aided countries. While innovation-related effects have been marginally assessed by the empirical literature, this result is coherent with (Martin et al., 2016) who also find evidence of an increase in clean innovation partially attributable to the ETS in its phase II.

4.2. *EU-ETS indirect cost compensation on the intensive margin*

The above findings present the effect of the ETS indirect compensation intended as a binary treatment. However, compensation is funded across beneficiaries with different intensities, as shown in Fig. 1. In this subsection, we analyse the impact of the aid on the performance of firms receiving a subsidy, in order to account for the intensity of the transfer. Thus, here the sample is reduced to firms operating in aided countries only and for which information on the subsidy is available. This implies that this part of the analysis contemplates a more homogeneous sample and is exempt from the potential systematic differences across treated and control countries discussed in the previous subsection.

Results are presented in Table 4. They highlight the absence of any significant impact on per worker productivity (columns 1 and 2), while turnover, total assets and the number of employees rise the larger the amount of aid received by firms. This suggests that among the aided countries only, for each 1% increase in the amount of subsidy received (i.e. around 1000 EUR), firms expand their turnover and their assets value by 0.01%, and their workforce by 0.07%.

Thus, within the group of subsidised firms, an increase in the amount granted is associated to a better performance, which would reduce the risk of carbon leakage. In other words, the existence of a positive effect suggests that firms receiving a higher subsidy tend to experience a marginal increase in terms of turnover and job retention in comparison to firms receiving grants of lower amounts.

5. Conclusions and policy implications

We assess the impact of the EU ETS compensation for indirect costs on firm outcomes. We do so by exploiting a unique panel dataset at firm level, containing detailed information on individual beneficiaries of the ETS indirect cost compensation gathered by the EC Directorate General for Competition (DG COMP) and balance sheet financial variables of

[14] As a matter of fact, turnover, amount of assets and workforce of the firms classified as highly exposed to carbon leakage risk with this approach are on average substantially larger in comparison to the other firms in the sample, hence they might be more likely to have stronger bargaining power when negotiating agreements on electricity costs.

[15] In this study, as in the analysis illustrated here, more accurate estimates would benefit of firm-level data on electricity prices, which is still largely unavailable.

[16] In the sample, the median amount of energy consumed by firms over the years 2005–2017, as reported in the beneficiaries records, is typically around 65k MWh.

[17] Here, no data is available for Finland and Hungary.

[18] The data on energy prices do not account for different taxation and deduction rates applied by the single MS to various price subcomponents. Thus, this reasoning might be less powerful if countries in the treated group applied systematically lower taxation and/or higher deduction rates in the post-2013 period with respect to MS in the control group. Furthermore, firms' energy costs might derive from bilateral negotiations with power generators which are not identified in balance sheet data.

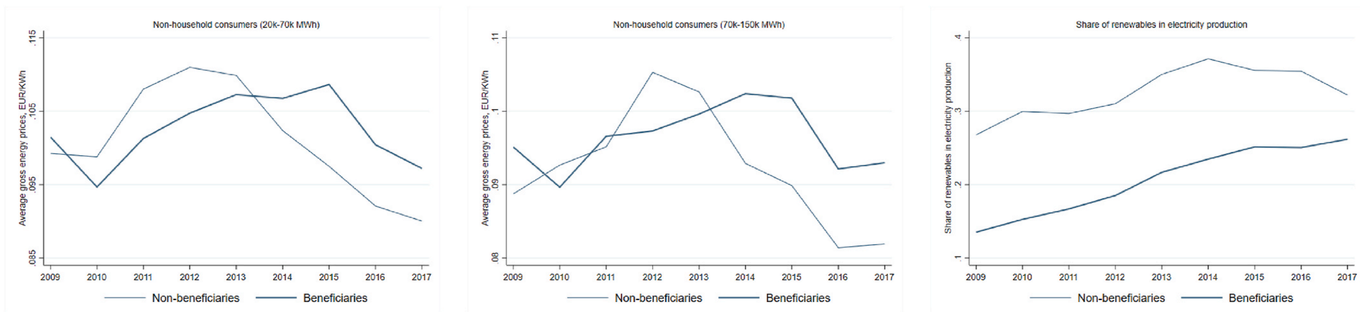

Fig. 3. Average gross energy prices and share of renewables in electricity production. The thick and thin solid lines represent the average values for the aiding and non-aiding countries, respectively. Sources: Eurostat (gross electricity prices) and Enerdata (share of renewables).

Table 3
Effect of receiving aid on electricity prices and share of renewables.

Dep. Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	20k-70k MWh			70k-150k MWh			Sh Renewables		
Country funded$_{t+1}$	0.056			0.029			0.026		
	(0.048)			(0.051)			(0.016)		
Country funded$_t$		0.089**			0.083*			0.026	
		(0.043)			(0.045)			(0.016)	
Country funded$_{t-1}$			0.109**			0.119**			0.032*
			(0.043)			(0.045)			(0.017)
Observations	108	108	108	108	108	108	90	90	90
R-squared	0.824	0.821	0.815	0.803	0.795	0.789	0.959	0.958	0.958

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Robust standard errors in parentheses. ‘Country funded’ is equal to one if the ETS indirect cost compensation is in place and equal to zero otherwise. The dependent variable is expressed in logarithm.

Table 4
Effect of the subsidy on the intensive margin.

Dependent variable	(1)	(2)	(3)	(4)	(5)
	Turnover per employee	Total assets per employee	Turnover	Total assets	Employees
Subsidy	0.025	0.026	0.098*	0.098*	0.073*
	(0.052)	(0.056)	(0.048)	(0.052)	(0.041)
Observations	617	617	617	617	617
R-squared	0.959	0.957	0.989	0.985	0.990

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. All regressions include firm, year and NACE-year fixed effects and country-specific controls (GDP per capita, debit-to-GDP ratio, gross electricity price for the consumption band 70k-150k MWh and emissions of greenhouse gases in CO2 equivalent). Sample of beneficiaries of indirect cost compensation only.

firms extracted from the Orbis database.

This is the first study evaluating the impact of the ETS indirect cost compensation at firm level and with an EU-wide coverage in a quasi-experimental setting. The analysis suggests that the aid has not had a significant effect on average relative competitiveness, measured in terms of turnover per worker and the value of total assets per employees. However, there is evidence of beneficiaries performing worse than firms operating in non-funded countries when turnover, value of total assets and number of employees are considered as outcomes.

This implies a downturn in the economic performance of aided firms, which might then be subject to a higher risk of carbon leakage. This could be due to systematic differences across countries that provide funding and those that do not, which might originate, for instance, from different patterns in the evolution of electricity prices. The suggestive evidence provided by differences in gross energy prices across the two groups of countries seems to support this hypothesis.

The analysis also suggests that the negative effects on firms operating in sectors that may be especially exposed to the risk of carbon leakage (namely, because of both their above-average trade exposure and their above-average predicted production costs increase) are attenuated. The reasons behind this finding might be manifold, including the fact that these firms are granted a substantially higher amount of aid, and that they might be less susceptible to changes in electricity prices thanks to stronger bargaining power when negotiating the cost of electricity with energy providers or to their ability to pass-through the cost of energy.

While more robust evidence would necessarily require information on the actual price of electricity faced by each firm, the analysis provided in this paper documents the co-existence of the compensation with systematically different patterns in average electricity prices across countries. Thus, it is possible that the provision of this type of aid could benefit from adjustments of the incentive mechanisms to account for such differences.

When focusing only on the beneficiaries for which the value of the subsidy is available, we identify a positive marginal impact of the compensation. In other words, firms receiving a higher subsidy experience a positive and significant impact on the measures of performance considered, in comparison to businesses that receive lower aid amounts. Estimates imply an increment in firm turnover and total assets value by 0.01% and in the number of employees by 0.07% for every 1% increase in the amount of subsidy received (i.e. around 1000 EUR).

These latter results rely on the comparison of firms operating in aided countries only, thus facing a more homogeneous evolution of the energy market. The existence of a positive impact of the compensation on the intensive margin calls attention on the beneficial effects of the compensation *per se* and on its potential to improve firm performance, hence reducing incentives to relocate elsewhere.

These results offer interesting insights in terms of how firms adapt production decisions to transfer “doses” and the extent to which heterogeneous treatment intensities might affect firms’ economic performance and, in turn, market competition and leakage. An adequate cost compensation should be sufficient to discourage firms to relocate, but overcompensation might also counteract emissions abatement or induce factors’ misallocation by financing *zombie firms*. Therefore, the policy objective to regulate negative externalities raised by more ambitious climate goals should be accompanied by an efficient allocation system of the compensation allowances that sets adequate criteria to identify firms more exposed to the leakage risk, their propensity to relocate and the extent to which they can pass their additional costs along the supply chain.

While contributing to the EU policy agenda in view of the revision of the ETS Guidelines European Commission (SWD(2020)190), these findings set the ground for future EU actions pursuing energy and environmental goals under the Recovery Plan umbrella and in view of the ambitious 2050 goals for emissions' abatement.

A question which is left unanswered, but that would be relevant to the objectives of the EU ETS as a whole, refers to the impact this policy has had on firms' behaviour in terms of electricity consumption, as some firms might decide to switch to energy generated from more sustainable sources. Energy transition to a low carbon economy is undoubtedly a longer-term objective of the ETS. Indeed, a *sine qua non* condition for the ETS dynamic efficiency is to trigger emissions' abatement in the short run and innovation in clean technologies in the medium and long run. Nonetheless, a more efficient adoption of clean technologies might require complementary actions that combine cost compensation with more targeted investment incentives. Unfortunately, our data do not allow setting a fully-fledged analysis on firms investment decisions, but the suggestive evidence offered in our study points to the existence of a positive association between indirect compensation and the share of energy coming from renewable sources, albeit relevant only at a later stage.

CRediT authorship contribution statement

Antonella Rita Ferrara: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Ludovica Giua:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A1
State Aid decisions on EU ETS indirect compensation

Country	Duration	Annual Budget
Belgium (Flanders)	2013–2020	EUR 7–113 mln†
Belgium (Wallonia)	2017–2020	EUR 17,5 mln
Finland	2016–2020	EUR 149 mln
France	2015–2020	EUR 364 mln‡
Germany	2013–2020	EUR 576 mln^
Greece	2013–2020	EUR 14–20 mln†
Lithuania	2014–2020	EUR 13,1 mln
Luxembourg	2017–2020	EUR 48–60 mln
Slovakia	2014–2020	EUR 250 mln
Spain	2013–2020	EUR 695 mln
The Netherlands	2013–2020	EUR 156 mln⋆
United Kingdom	2013–2020	GBP 113 mln^

Note: †annual budget based on CO_2 price. ‡refers to 2015–2018. ^refers to 2013–2015. ⋆refers to 2014–2015. Poland recently had a State Aid approved for the period 2019–2020 (SA.53850).

Table A2
List of aided sectors

NACE Rev. 2 code	Description
7.1	Mining of iron ores
8.91	Mining of chemical and fertiliser minerals
10.62	Manufacture of starches and starch products
10.81	Manufacture of sugar
10.91	Manufacture of prepared feeds for farm animals
13.1	Preparation and spinning of textile fibres
13.2	Weaving of textiles
13.93	Manufacture of carpets and rugs
14.11	Manufacture of leather clothes
17.11	Manufacture of pulp
17.12	Manufacture of paper and paperboard
17.22	Manufacture of household and sanitary goods and of toilet requisites
18.14	Binding and related services
19.1	Manufacture of coke oven products
19.2	Manufacture of refined petroleum products
20.11	Manufacture of industrial gases
20.12	Manufacture of dyes and pigments
20.13	Manufacture of other inorganic basic chemicals
20.14	Manufacture of other organic basic chemicals

(*continued on next page*)

Table A2 (*continued*)

NACE Rev. 2 code	Description
20.15	Manufacture of fertilisers and nitrogen compounds
20.16	Manufacture of plastics in primary forms
20.2	Manufacture of pesticides and other agrochemical products
20.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
20.59	Manufacture of other chemical products n.e.c.
20.6	Manufacture of man-made fibres
22.22	Manufacture of plastic packing goods
24.1	Manufacture of basic iron and steel and of ferro-alloys
24.2	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
24.42	Aluminium production
24.43	Lead, zinc and tin production
24.44	Copper production
24.45	Other non-ferrous metal production
24.51	Casting of iron
28.94	Manufacture of machinery for textile, apparel and leather production
46.12	Agents involved in the sale of fuels, ores, metals and industrial chemicals
46.75	Wholesale of chemical products

Note: The list of aided sectors is based on the Annex II, of the ETS Guidelines ((alias?)) and on the list of NACE codes derived from the beneficiaries records provided by Member States.

Table A3
Descriptive statistics on aid paid to beneficiaries, final sample

Country	Year	N	Mean	Std. Dev.	Min	Max
BE	2013	75	657.342	1313.425	5.261	6850.670
	2014	77	389.103	748.620	2.316	4097.465
	2015	77	511.476	985.072	1.132	5383.989
	2016	78	599.364	1156.559	1.150	6352.736
	2017	30	250.000	325.074	6.097	1170.421
DE	2013	324	1009.256	2580.008	6.845	25745.660
	2014	320	605.364	1582.049	5.746	15175.500
	2015	319	996.288	2613.815	0.000	25290.570
	2016	313	677.319	1736.169	7.020	16491.550
FI	2016	35	1083.028	1971.585	19.850	11204.670
ES	2016	101	59.279	118.824	0.483	823.666
NL	2014	68	786.110	1763.323	0.000	8735.586
	2015	66	474.730	1030.872	6.058	5155.428
	2016	73	732.559	1586.668	9.503	8086.945
	2017	76	485.566	1082.863	6.579	5598.655
UK	2013	52	609.754	1419.539	8.627	8888.148
	2014	54	362.304	872.818	0.000	5564.604
	2015	54	394.771	795.618	18.857	4031.508
	2016	57	295.580	579.005	5.068	3141.160
Total	2013	451	904.671	2306.084	5.261	25745.660
	2014	519	571.671	1456.005	0.000	15175.500
	2015	516	794.282	2151.311	0.000	25290.570
	2016	657	567.685	1472.570	0.483	16491.550
	2017	106	418.896	937.080	6.097	5598.655

Note: Aid is expressed in thousands of EUR. BE 2013–3016 refers to Flanders only; BE 2017 refers to Wallonia only.

Table A4
Robustness checks

Dependent variable	(1)	(2)	(3)	(4)	(5)
	Turnover per employee	Total assets per employee	Turnover	Total assets	Employees
Panel A: including NACE-specific linear trends					
Aid	−0.012	−0.020	−0.056**	−0.063**	−0.044**
	(0.023)	(0.028)	(0.026)	(0.027)	(0.019)
Observations	23,277	23,277	23,277	23,277	23,277
R-squared	0.924	0.919	0.975	0.981	0.974
Panel B: including NACE-specific linear and quadratic trends					
Aid	−0.012	−0.020	−0.056**	−0.063**	−0.044**
	(0.023)	(0.028)	(0.026)	(0.027)	(0.019)
Observations	23,277	23,277	23,277	23,277	23,277
R-squared	0.924	0.919	0.975	0.981	0.974
Panel C: post-2009 only					
Aid	−0.009	−0.020	−0.042*	−0.053**	−0.033*
	(0.021)	(0.027)	(0.023)	(0.026)	(0.018)
Observations	21,072	21,072	21,072	21,072	21,072
R-squared	0.932	0.927	0.979	0.983	0.978
Panel D: treatment occurring in 2012 only					

(*continued on next page*)

Table A4 (*continued*)

Dependent variable	(1)	(2)	(3)	(4)	(5)
	Turnover per employee	Total assets per employee	Turnover	Total assets	Employees
Aid	−0.022	−0.028	−0.064**	−0.070**	−0.042**
	(0.025)	(0.031)	(0.027)	(0.030)	(0.021)
Observations	22,930	22,930	22,930	22,930	22,930
R-squared	0.924	0.919	0.975	0.980	0.973

Note: ***p < 0.01, **p < 0.05, *p < 0.10. All regressions include firm, year and NACE-year fixed effects and country-specific controls (GDP per capita, debit-to-GDP ratio, gross electricity price for the consumption band 70k-150k MWh and emissions of greenhouse gases in CO2 equivalent).

Table A5
Effect of receiving aid on firms belonging to groups

Dependent variable	(1)	(2)	(3)	(4)	(5)
	Turnover per employee	Total assets per employee	Turnover	Total assets	Employees
Aid	−0.023	−0.034	−0.074***	−0.085***	−0.051***
	(0.021)	(0.030)	(0.025)	(0.029)	(0.020)
Firm in group	0.061	0.045	0.004	−0.012	−0.057
	(0.047)	(0.043)	(0.038)	(0.030)	(0.035)
Aid * Firm in group	0.064	0.082	0.109	0.127	0.045
	(0.078)	(0.088)	(0.071)	(0.081)	(0.062)
Lincom	0.041	0.048	0.035	0.042	−0.006
p-value	0.588	0.556	0.629	0.577	0.913
Observations	23,277	23,277	23,277	23,277	23,277
R-squared	0.924	0.919	0.975	0.981	0.974

Note: ***p < 0.01, **p < 0.05, *p < 0.10. 'Firm in group' is equal to one if the firm belongs to a group counting at least two firms and is equal to zero otherwise. 'Lincom' is the sum of the coefficients associated to 'Firm in group' and 'Aid * Firm in group'. 'p-value' is the corresponding p-value. All regressions include firm, year and NACE-year fixed effects and country-specific controls (GDP per capita, debit-to-GDP ratio, gross electricity price for the consumption band 70k-150k MWh and emissions of greenhouse gases in CO2 equivalent).

Table A6
Effect of receiving aid on firms belonging to sectors at high carbon leakage risk

Dependent variable	(1)	(2)	(3)	(4)	(5)
	Turnover per employee	Total assets per employee	Turnover	Total assets	Employees
Aid	−0.020	−0.035	−0.073**	−0.087***	−0.053**
	(0.027)	(0.033)	(0.031)	(0.033)	(0.022)
Aid * High Carbon Leakage Risk	0.036	0.065	0.074	0.103**	0.039
	(0.050)	(0.064)	(0.057)	(0.051)	(0.045)
Lincom	0.016	0.030	0.002	0.016	−0.014
p-value	0.712	0.579	0.972	0.682	0.721
Observations	23,277	23,277	23,277	23,277	23,277
R-squared	0.924	0.919	0.975	0.981	0.974

Note: ***p < 0.01, **p < 0.05, *p < 0.10. 'High Carbon Leakage Risk' is equal to one if the firm operates in one of the following sectors and is equal to zero otherwise: Mining of chemical and fertiliser minerals; Manufacture of coke oven products; Manufacture of other organic basic chemicals; Aluminium production; Copper production; Other non-ferrous metal production. 'Lincom' is the sum of the coefficients associated to 'High Carbon Leakage Risk' and 'Aid * High Carbon Leakage Risk'. 'p-value' is the corresponding p-value. All regressions include firm, year and NACE-year fixed effects and country-specific controls (GDP per capita, debit-to-GDP ratio, gross electricity price for the consumption band 70k-150k MWh and emissions of greenhouse gases in CO2 equivalent).

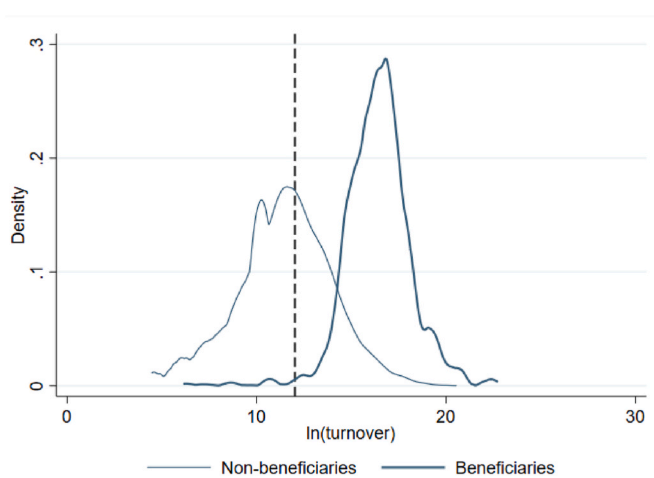

Fig. A1. Sample selection on turnover. Distribution of ln(turnover) for beneficiary and non-beneficiary firms. The vertical dashed line refers to the 1st percentile of the distribution for beneficiaries. This corresponds to 12.029 in logarithmic form, which is equivalent to the actual value of 16,762 EUR.

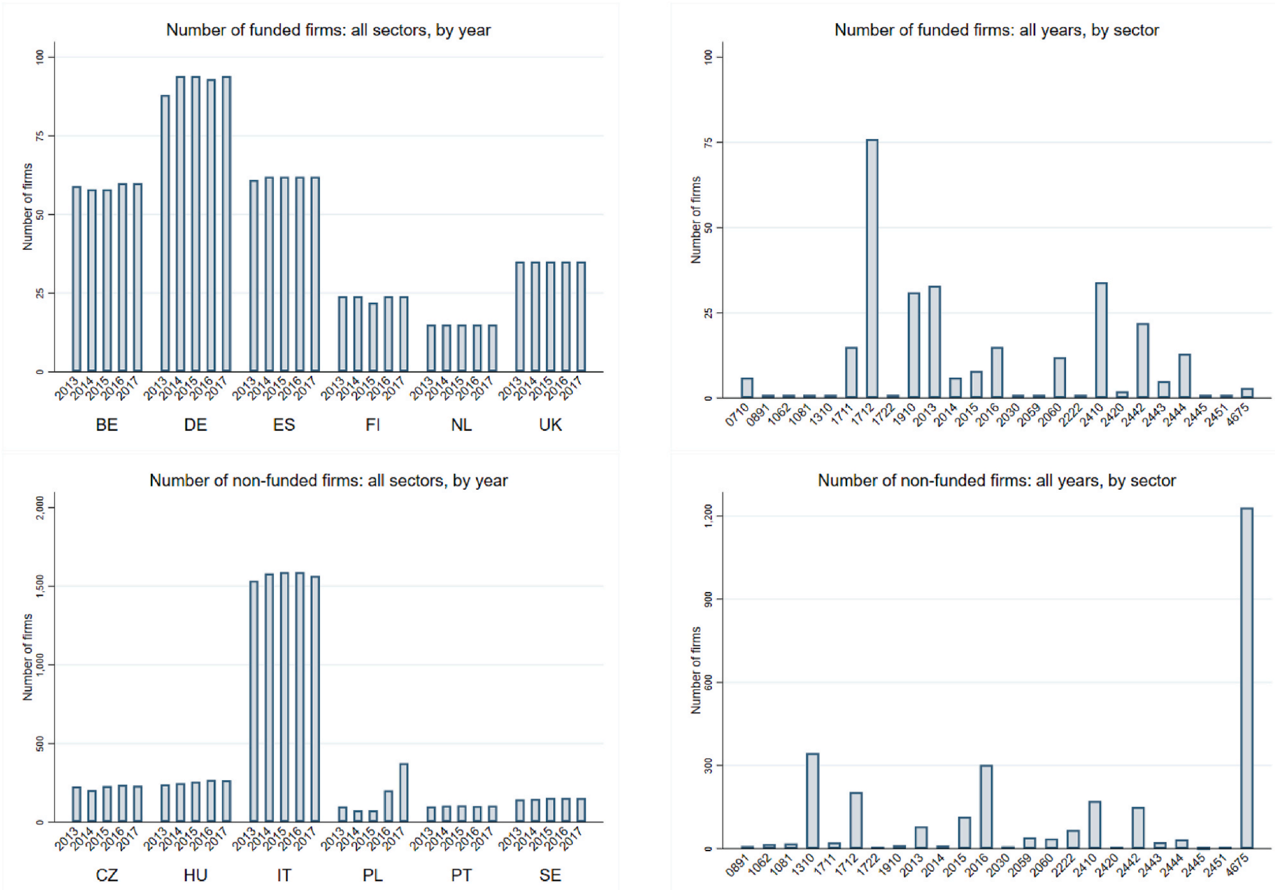

Fig. A2. Number of funded and non-funded firms, all sectors.

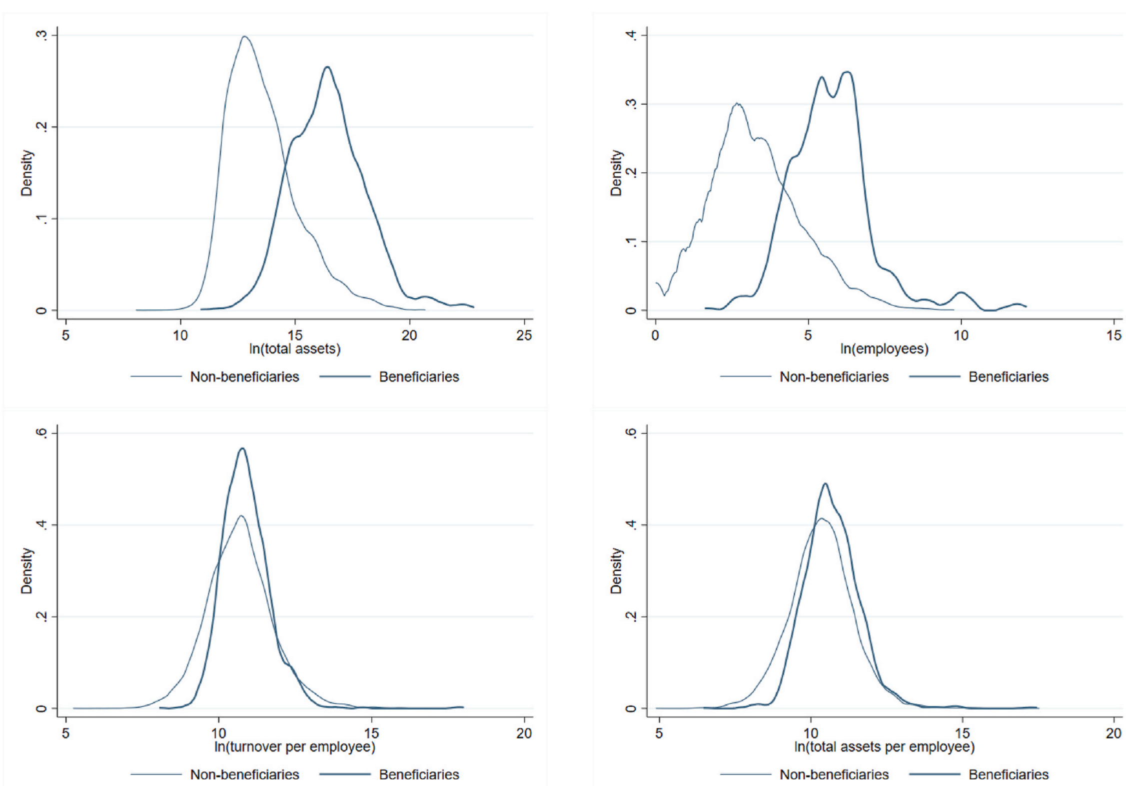

Fig. A3. Distribution of performance indicators by group.

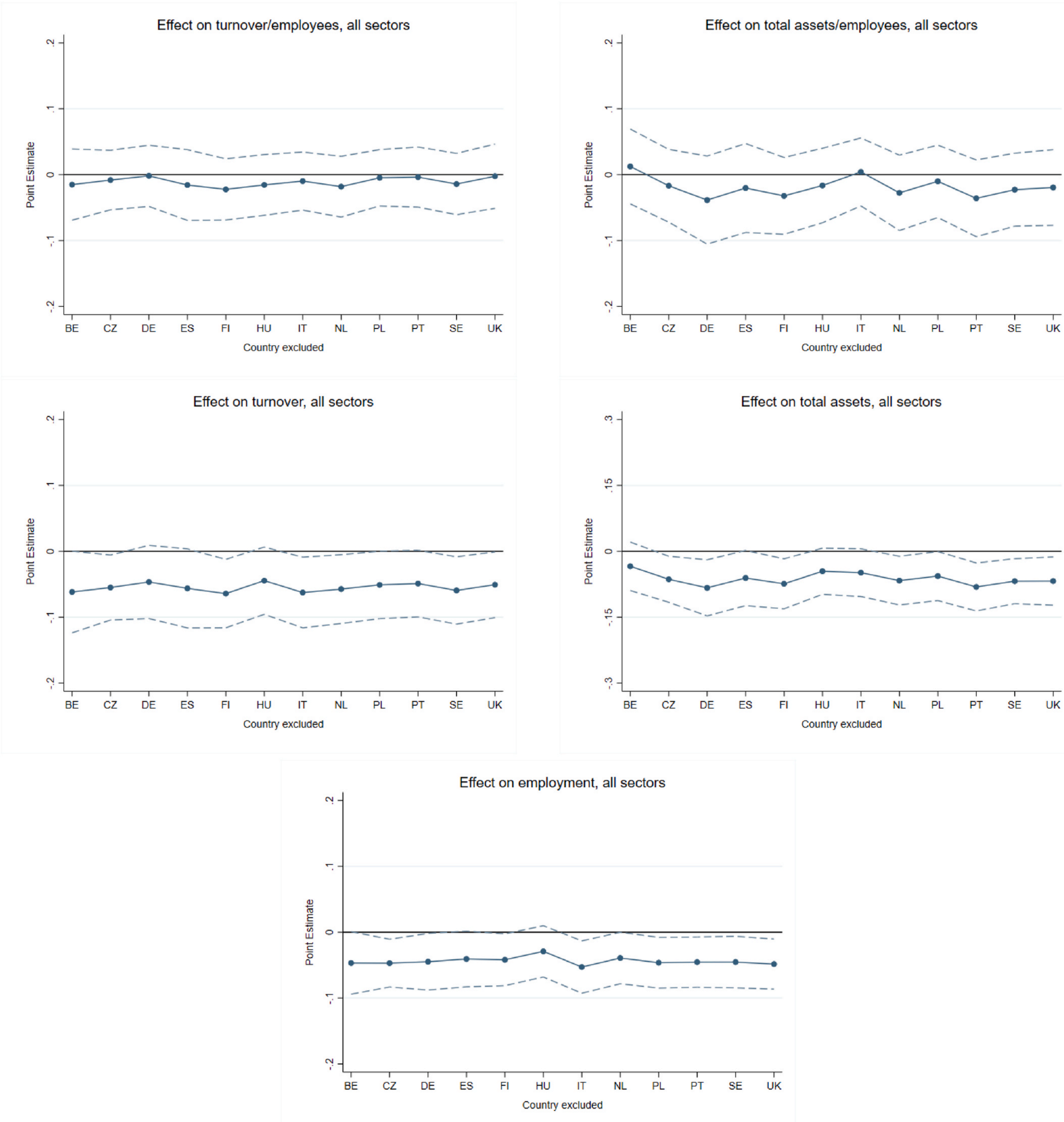

Fig. A4. Effect of receiving aid on firm performance, excluding countries one by one. The horizontal axis reports the country excluded from the estimation. Coefficients (blue dots) estimated as from Equation (1). Dashed lines represent 95% confidence intervals.

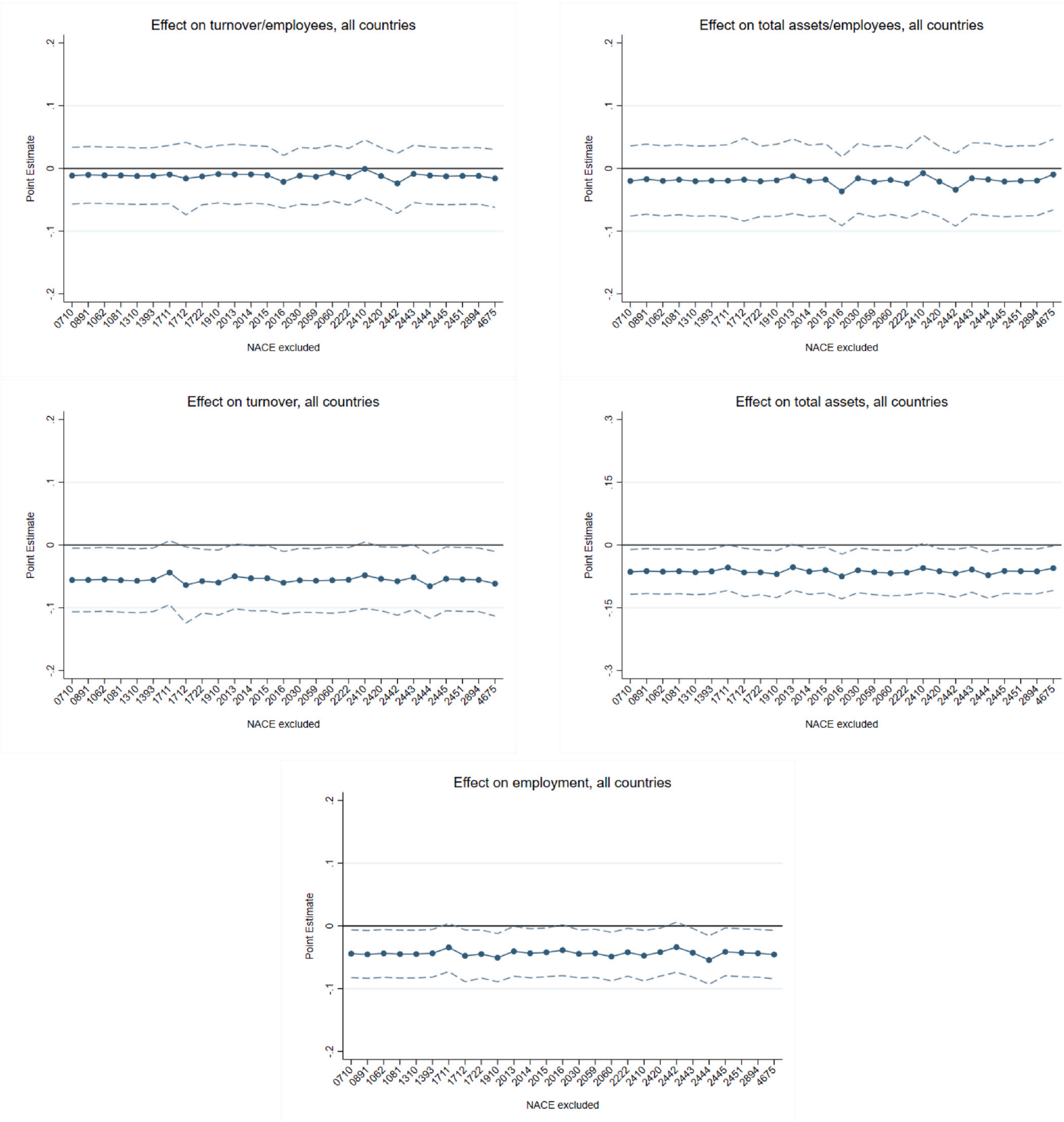

Fig. A5. Effect of receiving aid on firm performance, excluding sectors one by one. The horizontal axis reports the sector excluded from the estimation. Coefficients (blue dots) estimated as from Equation (1). Dashed lines represent 95% confidence intervals.

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