MINISTÈRE
DE L'ÉCONOMIE,
DES FINANCES
ET DE LA SOUVERAINETÉ
INDUSTRIELLE ET NUMÉRIQUE
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Tresor-Economics

No. 323 • February 2023

Direction générale du Trésor

How Does the European Union's Carbon Market Impact Firm Productivity?

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- The European Union Emissions Trading System (EU ETS) was introduced in 2005 to reduce greenhouse gas (GHG) emissions from the electricity and heat generation sectors, energy-intensive industry sectors (e.g. refineries, metals, cement, chemicals, glass, polymers, paper, cardboard) and intra-EU commercial aviation. It lowers GHG emissions in a cost-effective manner, without favouring a particular technology. Installations regulated by the EU ETS are required to obtain allowances (either purchased on the market or allocated for free) that match their actual emissions, incentivising them to invest in decarbonising their production processes.

- Our paper seeks to examine the effect of the EU ETS on the productivity of firms regulated by the system. In the short term, it is reasonable to expect a negative effect, with the carbon price signal increasing costs, particularly for the production of emissions-intensive goods. However, the EU ETS also changes firms' investment plans by encouraging investment in low-carbon technologies. In the medium- to long-term, emissions costs can thus ultimately be reduced and firms' performance improved.

- The empirical literature on the subject offers inconclusive results which vary depending on the phases examined (e.g. the pilot phase of the EU ETS, which was relatively unrestrictive in terms of the price of the allowances compared with the most recent, more ambitious phase, see Chart to the right) and from country to country. An examination of manufacturing firms in France, Italy and Spain shows that the EU ETS was not detrimental (insignificant aggregate effect) to average productivity over the 2005 to 2017 period.

- Nevertheless, the system's effects are heterogeneous. Among the EU ETS-regulated firms we examined, its effects on productivity were more positive overall for firms close to the technology frontier or financially unconstrained firms, i.e. those best positioned to invest in decarbonisation.

Price of EU ETS allowances, 2005-2022

Source: investing.com and tradingeconomics.com.

Note: The chart shows the price of EU ETS allowances in euros per tonne of CO_2eq.

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1. The controversial relationship between performance and environmental regulation[1]

While there exists a multitude of literature on the topic, little consensus has been reached as to the impact of environmental regulation on macroeconomic variables such as gross domestic product (GDP), productivity, innovation, employment, investment and trade. According to neoclassical economics, more stringent environmental policies inflate production costs, which in turn damage economic performance. This negative relationship was contested for the first time in the early 1990s by the Porter hypothesis,[2] which states that well-designed environmental policies may encourage innovation and ultimately enhance productivity.[3]

The Porter hypothesis makes the implicit assumption that some profit opportunities are overlooked in an unregulated environment, meaning that firms do not always make optimal choices on their own. Palmer, Oates and Portney (1995)[4] attempt to explain why this is the case and make a distinction between (i) behavioural arguments, such as *strategic effects internal to the firm*, e.g. by assuming that managers are risk averse[5] or conservative[6] and, therefore, will underinvest; and (ii) strategic effects of competition between firms, e.g. spillover effects of R&D. Firms fail to adequately innovate because they are counting on others to do so, in order to benefit from the spillover effects. With these mechanisms at work, implementing environmental policies (including carbon pricing) encourages firms to invest more in R&D, ultimately improving the situation for all firms, as the benefits flow to the entire economy.[7]

Empirical work examining the relationship between environmental policies and productivity has led researchers to differentiate between direct impacts on innovation and the broader impacts on firm productivity. According to the "weak" version of the Porter hypothesis, environmental policies increase innovation, defined in the widest sense. According to the "strong" version of the hypothesis, environmental policies' positive impacts on productivity through innovation offset their negative impacts.[8] Today, the empirical literature has largely accepted the "weak" version of the hypothesis. For example, manufacturing firms regulated by the EU ETS are more likely to innovate, whether by integrating new equipment or changing production processes or, to some degree, the fuel being used. Such moderate technological change reduces emissions and is often characterised as environmental innovation.[9] On the other hand, few studies accept the "strong" version of the hypothesis. In any event, results depend on the scope of analysis (firm-, industry- or economy-wide level), the characteristics of a given firm (size, financing constraints) and the type of pollution covered by the policy.[10]

It is therefore believed that environmental policies have a positive impact on green innovation, i.e. innovation aimed at minimising the cost of regulated environmental inputs and outputs. However, such incentives to innovate may not be adequate to have an overall positive impact on productivity.

Furthermore, composition effects may come into play, as high-emitting firms may be encouraged to relocate their production to other regions of the world where carbon prices are lower or regulations are less stringent, leading to what is known as carbon leakage – with uncertain impacts on the productivity of non-relocated production. Some

(1) This paper is the work of *Le Lab Trésor*.
(2) M. E. Porter (1991), "America's Green Strategy", *Scientific American*; M. E. Porter and C. Van der Linde (1995), "Toward a New Conception of the Environment-Competitiveness Relationship", *Journal of Economic Perspectives*, 9, 97-118.
(3) P. L. Girard, C. Le Gall, W. Meignan and P. Wen (2022), "Economic Growth and Decarbonisation", *Tresor-Economics*, No. 315.
(4) K. Palmer, W. E. Oates and P. Portney (1995), "Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?", *Journal of Economic Perspectives*, 9, 119-131.
(5) P. Kennedy (1994), «Innovation stochastique et coût de la réglementation environnementale», *L'Actualité économique*, 70(2), 199-209.
(6) P. Aghion, M. Dewatripont and P. Rey (1997), "Corporate Governance, Competition Policy and Industrial Policy", *European Economic Review*, 41, 797-805.
(7) A. Jacquemin and C. Aspremont (1988), "Cooperative and Noncooperative R&D in Duopoly with Spillovers", *American Economic Review*, 78(5), 1133-1137.
(8) P. L. Girard, C. Le Gall, W. Meignan and P. Wen (2022), "Economic Growth and Decarbonisation", *Tresor-Economics*, No. 315.
(9) B. Anderson, F. Convery and C. Di Maria (2011), "Technological Change and the EU ETS: The Case of Ireland", *IEFE Working Paper*, (43).
(10) T. Kozluk and V. Zipperer (2014), "Environmental Policies and Productivity Growth: A Critical Review of Empirical Findings", *OECD Journal: Economic Studies*, 2014/1.

research examines the risk that environmental policies could prompt carbon leakage to pollution havens.[11] A growing number of quantitative assessments identify this phenomenon[12] which undermines the effectiveness of environmental policies.[13]

2. The EU ETS

Introduced in 2005, the EU ETS operates in all EU Member States, as well as in Iceland, Liechtenstein and Norway, covering some 10,000 installations. In 2021, the EU ETS covered around 40% of emissions at EU-27 level, largely those from the electricity and heat generation sector (60%), followed by energy-intensive industry sectors (38%) and intra-European commercial aviation (2%).

In France, GHG emissions from the industrial sector covered by the EU ETS fell by 44% between 2005 and 2021,[14] and by 37% at EU level (on a like-for-like basis over the period). As for the French industrial sector, the decrease in GHG emissions since 2000 is mainly attributable to technical advances (improved "carbon efficiency"). In general, the likelihood of a firm investing in decarbonisation increases depending on several factors such as its size, its productivity and its use of decarbonised energy sources, but this chance also increases if the firm was included in the EU ETS over the 2013 to 2018 period.[15] [16]

The EU ETS is a cap and trade system. The total amount of GHGs that may be emitted by the installations regulated by the system is restricted by a cap on the number of emissions allowances available for allocation. This cap decreases each year based on a predetermined level, so as to ensure a reduction in covered emissions consistent with the EU's climate goals. Regulated installations must "return" one emissions allowance for every tonne of CO_2 equivalent (tCO_2eq) they emit (an allowance is equal to one tonne of GHG emissions). Allowances are either purchased during auctions on the common auction platform or allocated for free. They can also be traded among installations that produce less or more emissions than their allowance. The price of emissions allowances is set based on the supply of and demand for allowances on the market.

Since its initial implementation, the EU ETS has consisted of four operating phases: phase 1 (2005-2007), phase 2 (2008-2012), phase 3 (2013-2020) and phase 4 (2021-2030). The system has been enhanced with each successive phase, most notably through (i) the annual reduction in the cap on the number of allowances issued (in phase 1, the cap was set at Member State level; in phase 2, it was decreased by 6.5%; in phase 3, the national caps were replaced by a single EU-wide cap and an annual cap reduction of 1.74% was set; in phase 4, the reduction was increased to a rate of 2.2%), and (ii) the change in the default method of allocating allowances (allocated for free in phases 1 and 2, versus being obtained through auctions as of phase 3). In addition, the scope of activities and the types of GHGs covered have expanded over time. Each successive reform has thus further cemented the system's key role as an instrument that provides incentives for regulated installations to decarbonise by investing in low-carbon technologies that make low-emissions production chains possible.

The new estimates[17] presented in this paper (see below) concern the 2005 to 2017 period, during which there were generally very low carbon prices on the market (below €10/tCO_2eq between 2012 and 2018). As the EU ETS was enhanced and entered new phases, carbon prices increased sharply (see Chart on page 1). They reached €30/tCO_2eq in 2019 and have followed a sustained upward trajectory, rising to €98/tCO_2eq in August 2022, due to the post-COVID economic recovery and the planned reform of the emissions allowance market discussed in the "Fit for 55" package, which will bolster the EU's climate ambition.

(11) M. C. McGuire (1982), "Regulation, Factor Rewards, and International Trade", *Journal of Public Economics*, 17(2), 335-54.
(12) F. Misch and P. Wingender (2021), "Revisiting Carbon Leakage", *IMF Working Paper*, 21/207.
(13) W. L'Heudé, M. Chailloux and X. Jardi (2021), "A Carbon Border Adjustment Mechanism for the European Union", *Tresor-Economics*, No. 280.
(14) Data extracted from the European Environment Agency.
(15) A. Bornstein and R. Faquet (2021), "Decarbonising Industry in France", *Tresor-Economics*, No. 291.
(16) Data extracted from the European Environment Agency.
(17) A. Alla (2022), "European Union's Emissions Trading System and Productivity: Firm-Level Evidence for France, Italy and Spain", *Document de Travail de la DG Trésor*, No. 2022/3.

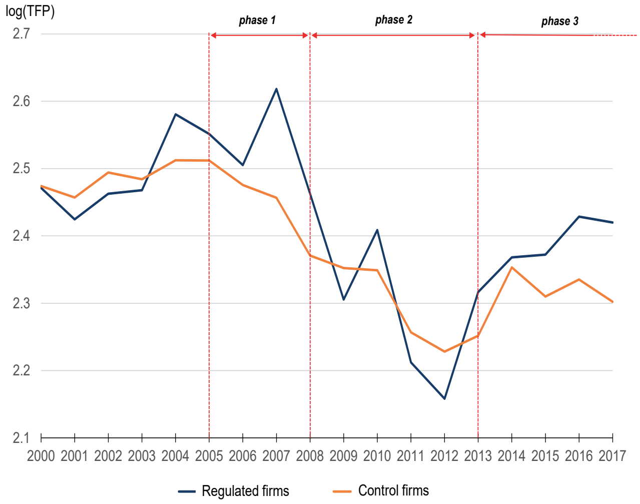
3. Methodology and data

We set out to examine the impact of the EU ETS on manufacturing firms' productivity in three EU countries – France, Italy and Spain – for the 2000 to 2017 period (Box 1).[18] The variable of interest is total factor productivity (TFP),[19] which is measured as outlined in Box 2.

As the EU ETS primarily covers industrial installations with significant production capacity, the firms regulated by the system are larger than the average-sized firm in their respective industries. The traditional method used to assess the EU ETS consists of identifying the "treated" (i.e. regulated) firms, establishing a control group of unregulated firms resembling the treatment group and then estimating an EU ETS-specific impact using the difference-in-differences method. This approach assumes that, for the "treated" firms, the introduction of this regulation is comparable to an exogenous shock.

To underscore the causal impact of the EU ETS on these firms' productivity, we match each "treated" firm to a comparable control group (Box 1). Then, we apply the difference-in-differences method to the two matched samples (Box 3). Chart 1 shows the changes in the TFP of regulated and control firms over the period analysed.

Chart 1: Changes in the TFP of regulated and control firms, by EU ETS phase



Source: Amadeus/Orbis and Union Registry databases.

Notes: The chart shows the mean logarithm of TFP over the 2000 to 2017 period. TFP is estimated at firm level using a Cobb-Douglas production function by regressing the value added of firms on capital and labour production inputs as well as on intermediate inputs, which are used as a proxy for unobserved productivity shocks. The resulting TFP estimates should be interpreted with caution since they capture changes in both mark-ups and productivity.

How to read this chart: In 2007, at the end of phase 1 of the EU ETS, regulated firms had an estimated logarithm of TFP of 2.62 on average.

Box 1: Data

Our data is extracted from two sources:

- The Amadeus/Orbis database, which provides financial data on manufacturing sector firms in France, Italy and Spain from 2000 to 2017. We use the years prior to the introduction of the EU ETS (2000-2004) in the estimates as a way to assess the difference *before and after* regulation. Indeed, the difference-in-differences method compares the changes in outcomes before and after regulation between a treatment group and a control group.
- The Union Registry,[a] which records data on 508 firms regulated by the EU ETS from 2005 onwards, including the Amadeus/Orbis sample of firms.

In the sample of "treated" firms, the following six manufacturing sectors dominate: food (25%), paper and cardboard (17%), other non-metallic mineral products (13%) – including the production of cement and glass – chemicals (8%), metallurgy (7%) and metal products (5%). We match this (unbalanced) sample of "treated" firms to a control group based on a propensity score, i.e. the conditional probability of assignment to a particular treatment (the EU ETS) given observed covariates. We estimate the propensity score using a logit model, based on (i) the total assets of firms, (ii) the average TFP from 2000 to 2004, and (iii) the firm's two-digit NACE[b] (sector) code.

a. We use the "List of Operators in the EU ETS", updated in April 2022: https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/union-registry_en
b. NACE is the statistical classification of economic activities in the European Community. It groups together structures based on their commercial activities.

(18) These three countries were selected based on the quality of the data for the period: S. Kalemli-Özcan, B. Sorensen, C. Villegas-Sanchez, V. Volosovych and S. Yesiltas (2015), "How to Construct Nationally Representative Firm Level Data from the Orbis Global Database: New Facts and Aggregate Implications", *NBER Working Paper,* no. 21558.
(19) TFP is the portion of output not explained by the amount of capital and labour inputs used in production.

The analysis is run on a sample of manufacturing sector firms, with a variable coverage across countries and years, characteristic of the Amadeus/Orbis database. Bajgar et al. (2020)[c] show that "firms in Orbis are disproportionately larger, older and more productive, even within each size class" when the OECD's MultiProd project is used as a benchmark, "which draw[s] on official microdata representative of the entire firm population". The results of estimates produced using the Amadeus database may therefore incorporate composition effects that are impossible to identify, meaning the results should be interpreted with caution.

c. M. Bajgar, G. Berlingieri, S. Calligaris, C. Criscuolo and J. Timmis (2020), "Coverage and Representativeness of Orbis Data", *OECD Science, Technology and Industry Working Papers*.

Box 2: "Revenue-based TFP" as a proxy measure for TFP

We estimate TFP at firm level using the method developed by Levinsohn and Petrin (2003).[a] This involves first estimating a Cobb-Douglas production function by regressing the value added of firms on capital and labour production inputs as well as on intermediate inputs, which are used as a proxy for unobserved productivity shocks:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + s_t(k_{it}, m_{it}) + u_{it} \qquad (1)$$

where y_{it} is firm *i's* value added in period *t*, k_{it} is capital, l_{it} is labour, m_{it} represents intermediate inputs and $s_t(k_{it}, m_{it})$ proxies ω_{it}, the unobserved productivity shock.

Ideally, firm-level value added should be deflated by firm-level production prices. Since this data is not available, we adopt an alternative method. Our analysis controls for sector-level prices through sector-time fixed effects.[b] This method, used by default, has the disadvantage of incorporating firm-specific mark-ups in the measure of TFP which must then be interpreted as *revenue-based TFP*.[c] If the "treated" firms are able to pass their costs on to customers, this will show up in the fixed effect (if all firms in the sector are "treated") or in firm-specific TFP (if only some firms are "treated" in a given sector).

After estimating the production function, the firm-level proxy for TFP (incorporating potential increases) ω_{it} is recovered as follows:

$$\omega_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} \qquad (2)$$

a. P. Levinsohn and A. Petrin (2003), "Estimating Production Functions Using Inputs to Control for Unobservables", *Review of Economic Studies*, 70(2), 317-341.
b. L. Foster, J. Haltiwanger and C. Syverson (2008), "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?", *American Economic Review*, 98(1), 349-425.
c. C. Syverson (2011), "What Determines Productivity?", *Journal of Economics Literature,* 49(2), 326-365.

Box 3: Econometric method

We estimate the following equation:

$$TFP_{isct} = \beta_0 + \beta_1 Post_t * id_{isc} + \gamma X_{isct} + FE_i + FE_{st} + u_{isct}$$

where TFP_{isct} is the logarithm of TFP of firm *i*, sector *s*, country *c*, year *t*. $Post_t$ equals 1 from 2005 onwards and id_{isc} equals 1 for "treated" firms (i.e. those regulated by the EU ETS). X_{isct} is a set of time-varying characteristics of the firm (sales, long-term debt, tangible fixed assets, number of employees), FE_i is a firm-level fixed effect and FE_{st} is a sector-time fixed effect. The latter fixed effect captures in particular sector-level price variations. Errors u_{isct} are clustered at the sector level.

We then refine this baseline estimate to examine how the impact of the EU ETS varies depending on the different phases of the EU ETS, sector, country, firm size and its assumed financial constraints, as measured by its interest payments.[a]

a. M. Cincera and A. Santos (2022), "Determinants of Financing Constraints", *Small Business Economics*, 58, 1427-1439.

4. The impact of the EU ETS on firm productivity

4.1 Heterogeneous impacts depending on firm characteristics

Our results[20] suggest that, for the three countries examined between 2005 and 2017, the EU ETS was not, on average, detrimental to firm productivity (as defined in Box 2), as it had an insignificant aggregate impact. Its impacts have, however, proven to be highly heterogeneous, as confirmed by the existing literature.[21]

- Firm size: Where we estimate the equation separately by quintile of firm size (proxied by the mean number of employees over the period covered), the EU ETS has a positive and significant impact on TFP for firms in the third to fifth quintiles, while the impact is negative for firms in the first quintile. This finding, which should be interpreted with caution (see below), may be due to several factors:
  - Larger firms could more easily absorb the cost of complying with the EU ETS, particularly its fixed costs (e.g. administrative, market intelligence).
  - Larger firms, contrary to their smaller counterparts, were able to reallocate their production to their most efficient EU ETS-regulated installations. The relocation of emissions-intensive activities is also easier for large firms that already have operations in multiple continents.
  - Larger firms may be better able to pass on the cost of complying with the EU ETS further down the value chain.[22]

Without a more thorough analysis of the composition effects, our results mainly serve as a qualitative indication of the impacts of the EU ETS on productivity depending on firm characteristics. Additionally, the data used does not provide information on the emissions intensity of firms by sector or on the share of their allowance allocated for free. For instance, it is likely that the "treated" firms in the first quintile of size are relatively more emissions intensive; otherwise, they would not have the level of absolute emissions that determines whether a firm is regulated by the EU ETS.

- Initial productivity: In line with the findings of Albrizio et al. (2017),[23] the analysis suggests that the closer firms are to the technology frontier (defined as the average TFP of the top 5% firms [with the highest TFP] for each sector, by year), the more positive (and significant) the impact of the EU ETS on productivity. This finding is consistent with the previous one, as frontier firms are frequently larger, particularly in the sample of EU ETS-regulated firms.
- Financial constraints: The EU ETS appears to have a positive impact on productivity for the least indebted firms, whereas it has a negative impact for the others. This finding may be due to the significant decarbonisation investments promoted by the EU ETS.
- Sector: The sign and the significance of the estimated impact of the EU ETS on the proxy for TFP differ from sector to sector, which could primarily be explained by the different methods for allocating allowances[24] or by various ways to pass the cost of complying with the EU ETS on to customers.[25]

(20) For details, see A. Alla (2022), "European Union's Emissions Trading System and Productivity: Firm-Level Evidence for France, Italy and Spain", *Document de Travail de la DG Trésor*, no. 2022/3.
(21) C. Di Maria and J. Jaraité (2011), "Efficiency, Productivity and Environmental Policy: A Case Study of Power Generation in Europe", *Fondazione Eni Enrico Mattei*. A. Löschel, B. Lutz and S. Managi (2019), "The Impacts of the EU ETS on Efficiency and Economic Performance – An Empirical Analysis for German Manufacturing Firms", *Resource and Energy Economics*, 56, 71-95. M. Klemetsen, K. Rosendahl and A. Jakobsen (2020), "The Impacts of the EU ETS on Norwegian Plants' Environmental and Economic Performance", *Climate Change Economics*, 11(1). G. Marin, M. Marino and C. Pellegrin (2018), "The Impact of the European Emission Trading Scheme on Multiple Measures of Economic Performance", *Environmental and Resource Economics*, 71(2), 551-582.
(22) Given the lack of firm-level data on the sales prices of goods, an increase in the mark-up cannot be differentiated from the rise in TFP for the data used.
(23) S. Albrizio, T. Kozluk and V. Zipperer (2017), "Environmental Policies and Productivity Growth: Evidence Across Industries and Firms", *Journal of Environmental Economics and Management,* 81, 209-226.
(24) European Roundtable on Climate Change and Sustainable Transition (ERCST) (2022), "State of the EU ETS Report".
(25) See, for example, European Commission (2015), "Ex-post Investigation of Cost Pass-through in the EU ETS". See CE Delft (2021), "Additional Profits of Sectors and Firms From the EU ETS 2008-2019" for a review of the literature (Annex A).

- Country: The estimated impact of the EU ETS on the productivity of French regulated firms is positive and significant, whereas the impact is insignificant in Spain and Italy. However, it is difficult to determine whether this finding reflects different characteristics among the firms assessed in France and those in Spain and Italy, or a different coverage of these firms in the Amadeus/ Orbis database.

4.2 Underlying mechanisms

To understand the mechanisms by which the EU ETS can impact the TFP of some firms, we examined the impact of the EU ETS on regulated firms' fixed assets, total assets, turnover, value added and employment. Our analysis was differentiated by phase of the EU ETS, as the scheme changed markedly from phase to phase, whether in terms of the price of allowances (see Chart on page 1) or how the system works (see Section 2).

Our results (Table 1) suggest a positive and significant impact of the EU ETS on the turnover and value added of firms regulated in phases 2 and 3. By contrast, the impact is negative and significant on employment in phase 1, which suggests a reallocation of the labour force, likely from the most emissions-intensive installations or firms to the least polluting.

These results may indicate that the positive impact the EU ETS has on larger, more productive and less financially constrained firms could result in part from a selection effect in phase 1. Such an effect may be caused by the market exit of the most underperforming firms, but the analysis we performed was not aimed at highlighting this type of effect. As mentioned in Box 2, an alternative explanation for these results could be that the largest and most productive firms were able to pass their higher marginal costs (due to carbon prices) on to their customers further down the value chain, ultimately inflating their turnover.[26]

Table 1: Impact of the EU ETS on firms' economic performance criteria, by phase

	(TFP)	(FASS)	(TASS)	(REV)	(VA)	(EMP)
EU ETS * phase 1	0.04	–0.02	–0.03	0.09*	0.00	–0.09***
	(0.03)	*(0.05)*	*(0.02)*	*(0.05)*	*(0.03)*	*(0.03)*
EU ETS * phase 2	0.01	–0.01	–0.04	0.18***	0.11**	–0.02
	(0.03)	*(0.06)*	*(0.03)*	*(0.03)*	*(0.05)*	*(0.04)*
EU ETS * phase 3	0.01	–0.01	–0.04	0.19***	0.11*	–0.01
	(0.03)	*(0.08)*	*(0.04)*	*(0.05)*	*(0.06)*	*(0.04)*
Constant	–1.30***	3.75***	5.13***	6.57***	5.95***	0.08
	(0.15)	*(0.26)*	*(0.20)*	*(0.10)*	*(0.10)*	*(0.24)*
Firm control variables	Yes	Yes	Yes	Yes	Yes	Yes
Phase dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
Sector-time FE	No	No	No	No	No	No
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.93	0.96	0.98	0.97	0.97	0.96
N	12,739	17,971	18,116	13,820	13,653	13,777
No. of clusters	24.00	24.00	24.00	24.00	24.00	24.00

Notes: Standard errors are clustered at the sector level. Regressions include a sector fixed effect, a firm fixed effect and a dummy variable for each EU ETS phase. The dependent variables are as follows: TFP: total factor productivity; FASS: fixed assets; TA: total assets; REV: turnover; VA: value added; EMP: employment. The resulting TFP estimates should be interpreted with caution since they capture changes in both mark-ups and productivity (see Box 2). ***p<0.01,**p<0.05,*p<0.1.

How to read this table: Firms regulated by the EU ETS saw their turnover rise by 9% as a result of the implementation of the carbon market in phase 1.

(26) European Commission (2015), "Ex-post Investigation of Cost Pass-through in the EU ETS".

Publisher:
Ministère de l'Économie,
des Finances
et de la Souveraineté
industrielle et numérique
Direction générale du Trésor
139, rue de Bercy
75575 Paris CEDEX 12

Publication manager:
Agnès Bénassy-Quéré

Editor in chief:
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(01 44 87 18 51)
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English translation:
Centre de traduction
des ministères économique
et financier

Layout:
Mimose Mellia
ISSN 1777-8050
eISSN 2417-9620

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