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Carbon Pricing and Competitiveness: Are they at Odds? – Environment Working Paper No. 152

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Keywords: Environmental regulation, Carbon pricing, Competitiveness, Carbon Markets

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Abstract

This paper reviews ex-post empirical assessments on the impact of carbon pricing on competitiveness in OECD and G20 countries in the electricity and industrial sectors. Most of these assessments find no statistically significant effects of carbon pricing or energy prices on different dimensions of competitiveness, including net imports, foreign direct investments, turnover, value added, employment, profits, productivity, and innovation. When statistically significant results have been found, the magnitude of such effects tends to be small - either positive or negative. Thus, concerns about negative short-term effects of carbon pricing on firms' or sectors' international competitiveness have not come to pass, at least to date. These findings are in part because carbon price levels have been low and because of exemptions to carbon taxes for industry, or generous levels of free allowances to firms covered by emissions trading schemes.

Keywords: Environmental regulation; Carbon pricing; Competitiveness; Carbon Markets

JEL Codes: H23; Q52; Q54, Q58

Resumé

Ce document passe en revue des évaluations empiriques *ex post* de l'impact de la tarification du carbone sur la compétitivité dans le secteur de l'électricité et dans l'industrie des pays de l'OCDE et du G20. La plupart de ces évaluations ne font pas apparaître d'effets statistiquement significatifs de la tarification du carbone ou des prix de l'énergie sur différents indicateurs de la compétitivité, parmi lesquels les importations nettes, les investissements étrangers directs, le chiffre d'affaires, la valeur ajoutée, l'emploi, les bénéfices, la productivité et l'innovation. Dans celles où de tels effets ont été constatés – positifs ou négatifs –, ils ont tendance à être de faible ampleur. Les craintes d'effets négatifs à court terme de la tarification du carbone sur la compétitivité internationale des entreprises ou des secteurs d'activité ne se sont donc pas vérifiées, du moins jusqu'à présent. Ce constat s'explique en partie par le niveau peu élevé des prix du carbone et les exonérations de taxe carbone accordées à l'industrie, ou par l'allocation généreuse de quotas gratuits aux entreprises dans le cadre des systèmes d'échange de quotas d'émission.

Mots clés : Régulation environnementale, prix du carbone, compétitivité, marchés du carbone

Codes JEL : H23; Q52; Q54, Q58

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All errors and inconsistencies remain the responsibility of the authors.

Executive Summary

This paper reviews information on the extent of carbon pricing in OECD and G20 countries, and explores its impact on different dimensions of competitiveness in the electricity and industrial sectors. The extent of carbon pricing has increased over the last few years, and includes some coverage of trade-exposed sectors. However, the effective price levels for GHG emissions from trade-exposed sectors are often very low, because of the carbon tax exemptions or free allocation of emissions allowances provided for these sectors. Indeed overall in OECD and G20 countries, almost two-thirds of industrial GHG emissions are unpriced, and only 2% are priced at 30 EUR/t CO2 or higher.

Competitiveness effects from environmental regulation are mainly due to differences in regulation between sectors, jurisdictions or countries rather than to the regulation itself. There are many different aspects to competitiveness, and the effects of carbon pricing on competitiveness can usefully be divided into first-order, second-order and third-order effects.

Differences in costs caused by environmental regulation, e.g. via carbon pricing or carbon abatement costs, represent a first-order effect on competitiveness. The scale of these can vary significantly within and between sectors. Second-order competitiveness effects include the pricing, cost, or output responses by firms that are affected by direct carbon pricing (first-order effects). Such responses can in turn impact the costs and therefore the competitiveness of firms in downstream sectors. Third-order competitiveness effects take place at a larger scale and include economic outcomes, technological outcomes, and international outcomes (e.g. trade and foreign direct investments). These are typically more complex to assess as they can be affected by more than one second-order effect and by actions or events in more than one jurisdiction. These can interact in different and sometimes complex ways. Importantly, technological outcomes, in particular those driven by innovation, can increase the competitiveness of firms in the long run.

Several ex-post empirical assessments of the impact of carbon pricing on competitiveness have been carried out. Most of these studies find no statistically significant effects of carbon pricing or energy prices on different dimensions of competitiveness, including net imports. When statistically-significant results have been found, the magnitude of such effects is small. This is not surprising because the effects of fluctuations in carbon and energy pricing are small compared to other trends.

The results from empirical studies on the impact of carbon pricing on selected economic variables are mixed, with most studies finding no statistically significant effects on employment or profits. Some studies have indicated that the effect of carbon pricing on productivity is positive, but small. A small positive impact of carbon pricing on innovation has also been noted.

Thus, concerns about negative short-term effects on carbon pricing on firms' or sectors' international competitiveness have not come to pass, at least to date. These findings are in part because carbon prices levied on industry have been low, either because of exemptions to carbon taxes, or because of generous levels of free allowances to firms covered by emissions trading schemes. Free allocation of allowances or carbon tax exemptions is likely to continue to be needed in some sectors while significant differences in carbon pricing exist between different jurisdictions.

Establishing a positive and stable carbon price (even if initially at a low level) will provide a clear signal of policy directions for participating firms. This may actually reduce risks to competitiveness in the longer-term if it reduces the risk that firms become "green laggards".

1. Introduction

Competitiveness refers to the capability of countries' economic sectors or firms to maintain market shares, to stay in business and to be profitable (Berger, 2008[1]). The deep decarbonisation needed in order to reach the temperature goals of the Paris Agreement means that the relative competitiveness of sectors may need to change over time, with low-emission sectors gaining market share and higher-emission sectors losing market share or perhaps even ceasing to exist. The environmental impact of changes in relative competiveness can be positive if these lead to lower-emission products gaining market share. Alternatively, changes in relative competitiveness can lead to negative environmental effects if they encourage a shift in the production of goods to areas with lower efficiency (i.e. more polluting technologies). This negative impact is referred to as "carbon leakage". Some emissions trading systems are explicitly designed to avoid carbon leakage (Nachtigall, 2019[2]).

There are many aspects to competitiveness: temporal, sectoral, domestic and international. Depending on the specific market structure and context, some of the following may be more or less important factors that are internal to a given industry or firm: turnover, total assets, investment, employment, technology, productivity and profits, levels of exports, levels of foreign direct investment, and levels of innovation.

Competitiveness of a country, sector and/or firm will also be affected by many external factors. These include megatrends, such as increased vehicle electrification, as well as trends in the costs of producing a specific product, such as changes in commodity prices. Carbon pricing is another such external factor. While it is an efficient policy mechanism to reduce emissions of greenhouse gases (GHG) (OECD, 2018[3]), carbon pricing can increase production costs both directly, e.g. by imposing a carbon tax or by requiring a firm to purchase emissions allowances, and indirectly, e.g. by increasing the costs of inputs such as electricity. Carbon pricing thus has the potential to impact the relative competitiveness of a country, sector or firm. This paper uses "carbon pricing" to refer to greenhouse gas emissions trading schemes (ETS), carbon taxes, or taxes on fossil fuels.

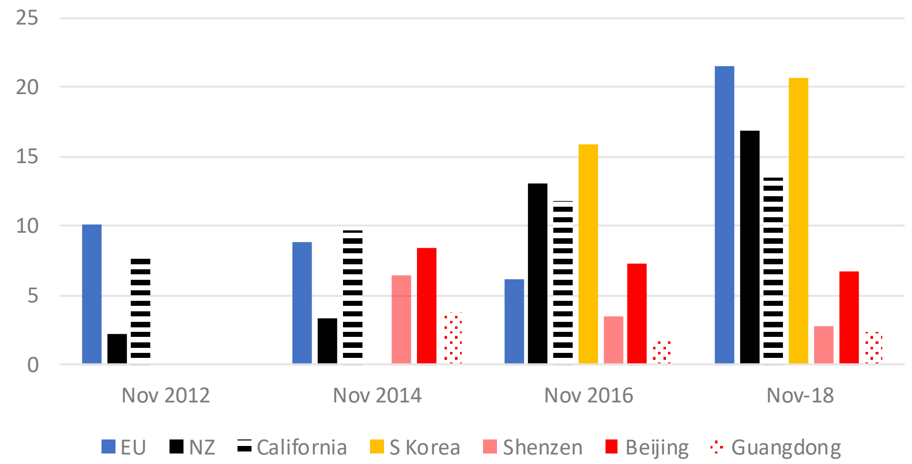
This paper reviews the extent of carbon pricing in OECD and G20 countries, and explores its impact on different dimensions of competitiveness in the electricity and industrial sectors. Most of the studies included in this review focus on the European Union, but there are also some examples from other jurisdictions. The European Union emissions trading scheme (EU ETS) was one of the first emissions trading schemes and has the longest time series of emissions trading data of emissions data. Moreover, the majority of research on competitiveness effects of carbon pricing relates to the EU ETS.

2. The extent of carbon pricing in OECD and G20 countries

The extent of carbon pricing has increased over the last few years, and includes some coverage of trade-exposed sectors, see e.g. (OECD, 2018[3]; World Bank and Ecofys, 2018[4]). Figure 1 highlights a growth in the number of emissions trading schemes, as well as the difference in their carbon prices at selected points in time. These price levels of different emissions trading schemes vary significantly over time both in absolute and relative terms. For example, prices in the EU ETS were just over 10 USD/t CO_2 in November 2012[1], dropped to under 6 USD/t CO_2 in 2013, and rose to more than 21 USD/t CO_2 in November 2018. In terms of relative carbon prices, EU ETS prices were more than double those of the Guangdong ETS in November 2014, but were almost ten times those of the Guangdong ETS in November 2018.

[1] Equals EUR 7,58 based on the exchange rate on 31 December 2012.

Figure 1: Carbon prices of selected emissions trading schemes at selected snapshots, (USD/t CO_2-eq)



Source: Authors, based on ICAP price monitor.

However, the effective price levels for GHG emissions from trade-exposed sectors can be much lower than the overall carbon price shown in Figure 1 above. For example, free allowances are distributed to sectors at risk of a loss of competitiveness in the Californian ETS. In the EU ETS, sectors deemed at risk of competitiveness loss also receive free allowances. Since 2013, the level of free allowances in the EU ETS is based on past production levels and product-specific carbon intensity benchmarks representing the 10% most carbon-efficient firms in each sector.

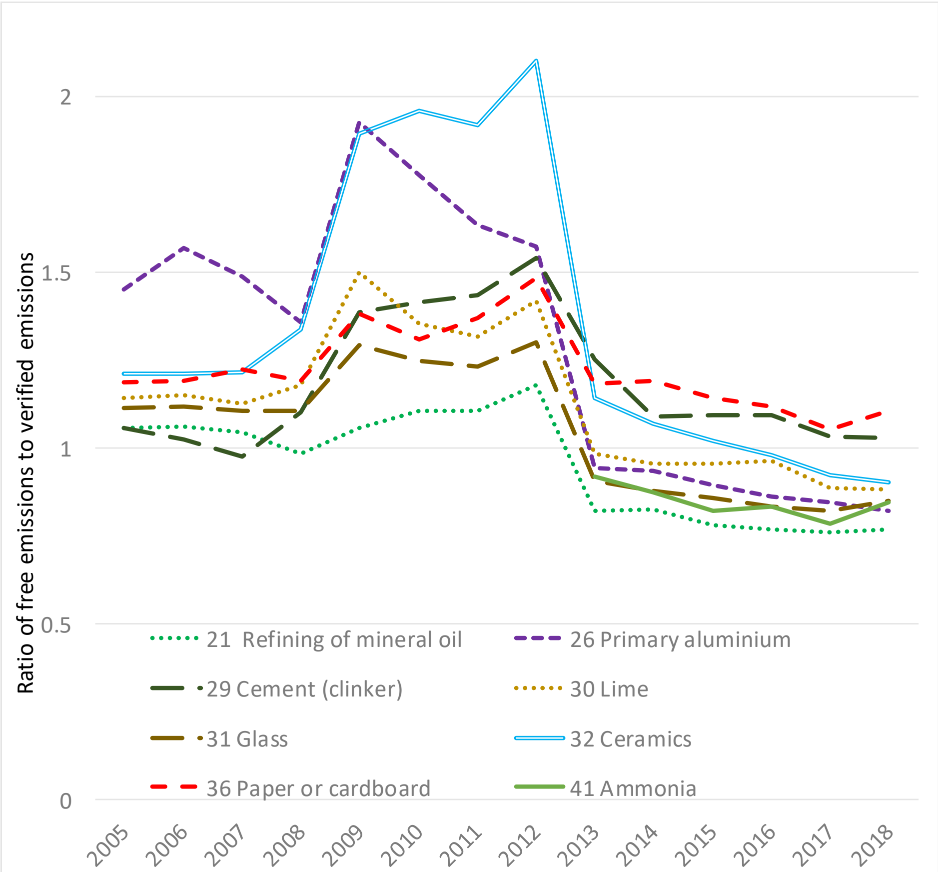
Indeed, Figure 2 shows that some non-electricity sectors in the EU ETS (e.g. cement, paper or cardboard) received more free allowances than their emissions until 2013. Since 2013, some sectors such as lime, aluminium, ceramics and glass have become net buyers of allowances. The method for calculating the level of free allowances should in theory lead to aggregate allocation below emissions for each sector. However, this is not observed for two reasons. Firstly, because the Historical Activity Level, which is used as a proxy for future production volumes, was often the production volume of before the economic crisis.[2] Second, carbon intensities have decreased over time, due to technology improvements. In order to remedy this issue in future, allocation benchmarks will be updated from 2021 onwards.

The level of carbon taxes levied on industry is also low or zero in the majority of cases. This is because while some countries have put carbon taxes in place, there are many exemptions for industrial sources.[3] The same holds true for excise taxes on fossil fuels which can be considered as implicit carbon taxes. Thus, overall in OECD and G20 countries, almost two-thirds of industrial GHG emissions are unpriced, and only 2% are priced at 30 EUR/t CO_2 or higher (Figure 3).

[2] The Historical Activity Level is calculated as the median (middle value) of the yearly production volume between 2005 and 2008 or the median of the production volume between 2009 and 2010. Free allocation after 2020 will be determined by the mean volume of production in 2014-2018.

[3] There are far fewer studies on the competitiveness impacts of carbon taxes compared to emission trading schemes, because industry is often exempt from high carbon tax rates. Also, identification strategies are more difficult, since a carbon tax generally covers all firms within a sector and has much less price variation over time.

Figure 2: Allocation factors calculated as the ratio of free allocations over verified emissions for the main subsectors in the EU ETS

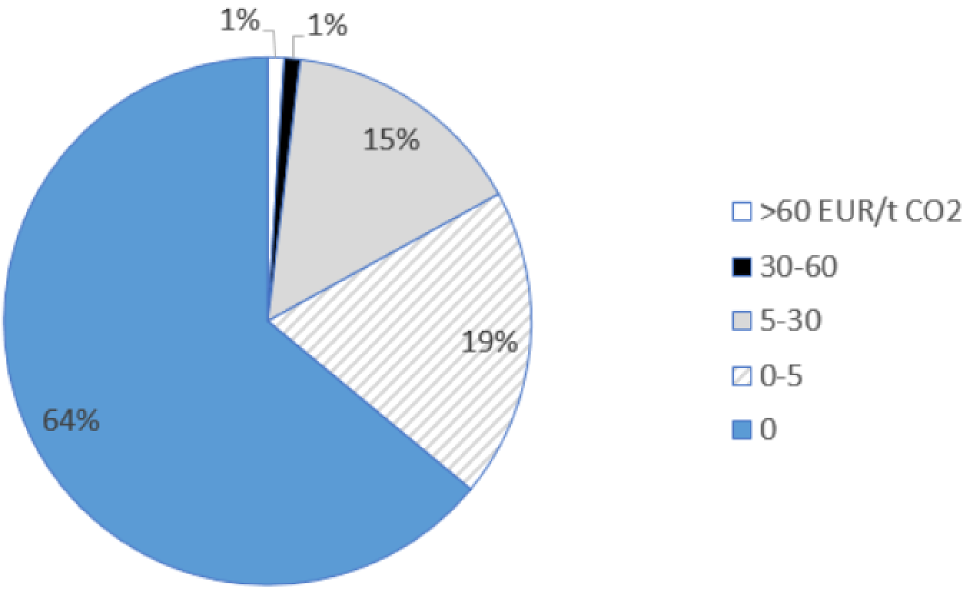


Source: CITL in EEA data viewer.

3. How does carbon pricing affect firms' competitiveness?

Competitiveness effects from environmental regulation are mainly due to *differences* in regulation between sectors or countries rather than to the regulation itself. Dechezleprêtre and Sato (2017[5]) distinguish, first, second and third order effects resulting from differences in regulations. Asymmetric environmental policy induces differences in costs as a first order effect. Next, firms respond to the regulation by adapting volumes, product prices (e.g. via cost pass through) and productive investments (second-order effects). These firm responses in turn affect broader economic outcomes (profits, employment, market structures), technological outcomes (product innovation, process innovation, input-saving technologies), international economic outcomes (trade flows, investment location), leading to third-order effects. It is important to note that many outcomes are interrelated. For example, input-saving innovation may decrease the cost of abatement, a change in profitability will affect investments, higher prices may affect the strategic positioning of the firm etc.

Figure 3: Proportion of OECD and G20 industrial CO_2 emissions priced at different levels in 2015



Source: (OECD, 2018[3]).

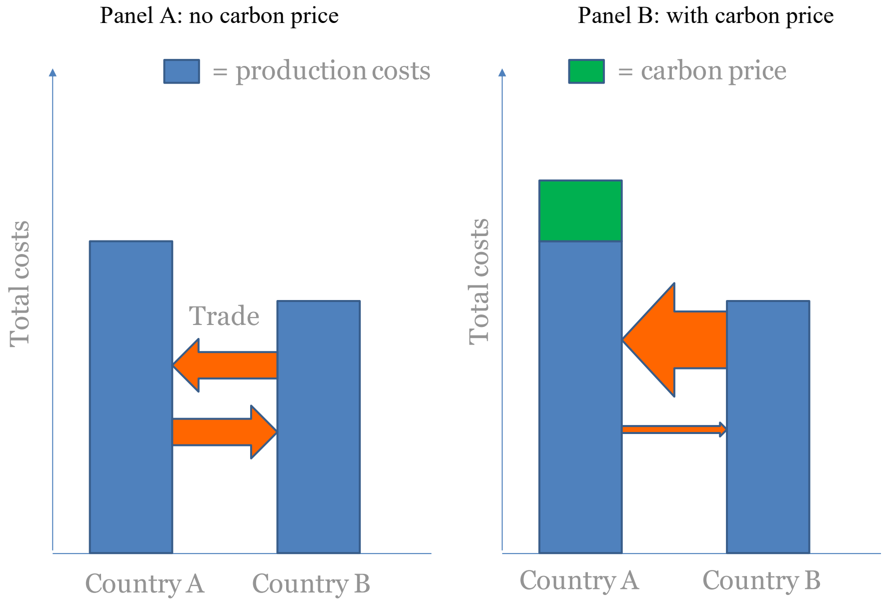
3.1. First-order effects

Differences in costs caused by environmental regulation, e.g. via carbon pricing, would represent a first-order effect on competitiveness, (Figure 4). These first-order effects are potentially large, because energy costs for heavy industry (traditionally met by GHG-intensive energy sources) can represent a large proportion of total production costs. Such first-order effects include GHG abatement costs and direct carbon costs.

There is a wide variety of possible GHG abatement opportunities and costs; these vary between and within sectors. For example, firms can invest in energy efficiency, switch to lower-carbon fuels, or substitute other inputs. Under a carbon price, firms have an incentive to avoid those emissions that can be abated at a cost below the carbon price. This is also the case when firms receive free allocation above their emissions, because every abated tonne of CO_2 allows to sell an extra allowance. In other words, allocations create an opportunity cost which is the same for under- as well as over-allocated firms. Therefore, as a first approximation, free allocation does not affect the incentive for abatement (Coase, 1960[6]). Venmans (2016[7]) shows, however, that firms perceive an allocation below actual emissions as a stronger incentive to abate compared to an allocation above emissions.[4] A marginal abatement cost function expresses the idea that when a company is close to business as usual emissions, reducing emissions tends to be cheap. But to the extent that a company has already realised the 'low hanging fruits', further reductions will come at a larger cost. Studies find that the EU ETS reduced emissions by around 10%, corresponding to 200 mt CO_2 /year (Martin, Muûls and Wagner, 2016[8]).

[4] The main reason is a perceptional bias. "An implication of the endowment effect is that people treat opportunity costs differently than 'out of pocket' costs. Foregone gains are less painful than perceived losses. Endowment effects are predicted for property rights acquired by historic accident or fortuitous circumstances, such as government licences, landing rights, or transferable pollution permits" (Kahneman, Knetsch and Thaler, 1990[55]). Next, cash costs also have a different risk profile compared to opportunity costs. Cash costs are more likely to lead to bankruptcy than opportunity costs.

Figure 4: Schematic illustration of first-order competitiveness effects



Source: Authors.

Direct carbon costs occur if firms covered by emissions trading schemes receive fewer free allowances than their emissions, and would therefore need to buy emissions allowances. As outlined above, ETS whose coverage includes trade-exposed and carbon-intensive firms, apply a significant level of free allocation of allowances to such firms. This limits the direct carbon costs to such firms. Figure 2 highlights that the level of free allocation in the EU ETS exceeded 100% for some sectors. In such cases, the EU ETS actually provided a direct benefit to participating firms.

As the carbon intensity of producing different outputs varies, so does their direct carbon cost (EUR/t output). Table 1 highlights the carbon intensity and direct carbon costs for a selection of outputs, assuming a fully auctioned price of 30 EUR/t CO_2. Carbon intensities correspond to the current product benchmarks in the EU ETS, estimated to be the carbon intensity of the 10% most carbon efficient plants. They include direct CO_2 or other GHG emissions ("scope 1"), not the indirect emissions from electricity production ("scope 2").

Table 1: Carbon intensities and direct carbon costs for selected products in the EU ETS (assuming a fully auctioned price of 30 EUR/t CO_2eq)

Product name	GHG intensity (tCO_2eq per tonne of product)	Direct carbon cost (EUR per tonne of product)
Ammonia	1.619	49
Aluminium	1.514	45
Hot metal (liquid iron)	1.328	40
Lime	0.954	29
Grey cement clinker	0.766	23
Fine paper	0.318	10
Nitric acid	0.302	9
Coke	0.286	9
Uncoated carton board	0.237	7
Sintered ore	0.171	5
Roof tiles	0.144	4
Long fibre kraft pulp	0.06	2
Plaster	0.048	1

Source: European Commission (2011[9]), Decision 2011/278/EU determining transitional Union-wide rules for harmonised free allocation of emission allowances pursuant to Article 10a of Directive 2003/87/EC of the European Parliament and of the Council.

3.2. Second-order effects

Second-order competitiveness effects include the pricing, cost, or output responses by firms who are affected by direct carbon pricing (first-order effects). For example, firms with little international competition can pass through abatement costs and the costs of purchasing any emission allowances to the final consumer. Cost-pass through can exceed 100% of real costs, because free allowances induce opportunity costs, which are part of marginal costs and can be included in sales prices. This led to large windfall profits in the electricity sector in the ETS, which received free allocations between 2005 and 2012 (Sijm et al., 2008[10]).

Such actions can impact the costs, and therefore competitiveness, of firms in downstream sectors. For example, cost pass-through by electricity generators increases costs for other industrial producers. Such cost rises will be particularly significant for large electricity consumers such as the aluminium sector.[5] The EU ETS provides the possibility for member states to compensate electricity-intensive producers. The EU ETS State Aid Guidelines lay out criteria for Member States to compensate for the rise of indirect costs for electricity-intensive to prevent significant risk of carbon leakage while minimizing the competition distortion in the internal market (European Commission, 2012[11]). The Guidelines determine eligible sectors[6] and maximum amounts for compensation of indirect carbon costs. The maximum amount of aid is decreasing over time and depends on the CO_2 emissions factor (tCO_2/MWh), the CO_2 price in the EU ETS, the product-specific electricity consumption efficiency benchmark and the output of the eligible installation. As of 2018, the Commission has approved 12 compensation schemes in 11 Member States, including

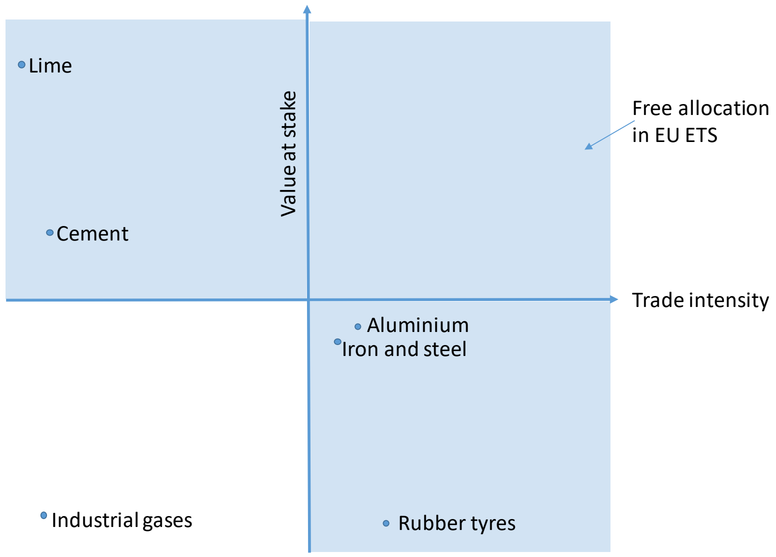
[5] Even if aluminium producers produce their own electricity, they will have to buy auctioned emission allowances for their electricity production.

[6] Eligible sectors are specified in Annex II of the Guidelines and include, inter alia, aluminium production, lead, zinc and tin production, manufacture of paper and paperboard.

France, Germany, Spain and the United Kingdom (European Commission, 2018[12]). The aggregate compensation in 2017 amounted to EUR 694 mill. Euro, benefiting primarily the chemical sector, non-ferrous metal sector and iron and steel sector.

On the other hand, firms in sectors with strong international competition (such as some heavy industries) will not fully pass through carbon costs, because an increase in sales prices will impact sales volumes.[7] The direct and indirect pass-through costs are important for assessing the potential competitiveness impacts of sectors. Figure 5 highlights the variation between selected sub-sectors for value at stake and trade intensity. Sectors with a high value at stake, i.e. the ratio between carbon costs and value added, and/or a high trade intensity are vulnerable to competitiveness impacts due to carbon pricing. The EU applies free allocation to sectors that have a 1) value at stake above 30% or 2) trade openness[8] above 30% or 3) value at stake above 5% and trade openness above 10%. There is however disagreement over the relevance of these criteria, because carbon-intensive firms with low trade openness are better able to pass through costs (Clò, 2010[13]).

Figure 5: Value at stake vs trade intensity for selected sectors



Source: Authors.

3.3. Third-order effects

Third-order competitiveness effects include broader economic outcomes, technological outcomes, and international outcomes. These are typically more complex to assess as they can be affected by more than one second-order effect from more than one jurisdiction, which can interact in different and potentially unpredictable ways. For example, increasing energy costs can impact employment via two channels. On the one hand, increasing production costs may lead firms to raise product prices, resulting in lower product demand and thus lower levels of employment. On the other hand, abating emission may increase the demand for labour relative to business as usual.

[7] Firms with high international competition may still chose to increase prices and lower their market share. Even without international competition, cost pass through also depends on market structure (monopoly power). Cost pass through is therefore an imperfect measure of international competitiveness.

[8] Defined as $\frac{import + export}{turnover + import}$, including only the extra-European trade.

Technological outcomes, in particular those driven by innovation, are potentially important as they can increase the competitiveness of firms in the long run. Theoretical literature argues that there are many barriers to product innovation, including behavioural and organisational barriers, and that environmental regulation can help to overcome them (Ambec, Cohen and Elgie, 2013[14]). Porter and van der Linde (1995[15]) hypothesise ("Porter Hypothesis") that "internationally competitive firms are not those with the cheapest inputs or the largest scale, but those with the capacity to improve and innovate continually". The five potential channels through which environmental regulation can improve competitiveness have been identified by Porter and van der Linde (1995) as:

- Signalling to firms about likely resource inefficiencies;
- Focussing on information gathering and raising corporate awareness;
- Reducing uncertainty that green investments will be valuable;
- Creating pressure which promotes innovation and progress;
- Levelling the transitional playing field.

However, evidence to support this hypothesis is inconclusive. For example, Cohen and Tubb (2018[16]) did a meta-analysis on 103 studies with quantitative results. They found that 45% of these studies report results that are insignificant, 29% report positive results, and 26% report negative results. Dechezleprêtre and Sato (2017[5])'s review of the relevant literature also argues that there is no convincing empirical evidence for a significant increase of competitiveness caused by environmental regulation.

4. Empirical evidence of competitiveness impacts from carbon pricing

Most ex-post empirical studies find no statistically significant effects of carbon pricing or energy prices on different dimensions of competitiveness. This is in contrast to the result of many ex-ante simulations which predict the effect of unilateral carbon prices on competitiveness based on economic modelling (Carbone and Rivers, 2017[17]). Ex ante studies typically find negative impacts of diverging carbon prices, notably for energy-intensive trade-exposed (EITE) sectors. This section reviews the results of ex-post studies on key economic variables, i.e. the third-order effects mentioned above: trade; foreign direct investment; employment; turnover; value added; assets; investment; productivity; profits and innovation.

4.1. International outcomes: Net imports and Foreign Direct Investments

Trade patterns measured through net imports are the most direct way to investigate international competitiveness effects and carbon leakage. Both relocation of firms abroad and the gain of market share of foreign firms at the expense of regulated domestic firms would lead to an observable change in the import/export ratio of carbon intensive goods.

Several studies have been done on the effect of emissions trading on net imports, but find no effects. Most studies have focussed on the EU ETS. This includes a study analysing trade from and to 66 world regions, for 25 manufacturing sectors in 2004 (before the introduction of the EU ETS), 2007 and 2011 (Naegele and Zaklan, 2019[18]). Similarly, looking at carbon leakage within multinational firms, there is no evidence that the EU ETS caused a shift of emissions within firms from the EU to the rest of the world (Dechezleprêtre et al., 2014[19]), or that there has been an effect on net imports in the aluminium sector (Reinaud (2008[20]), Sartor (2012[21]), Healy, Schumacher and Eichhammer (2018[22])) or in the cement and iron and steel sectors (Branger, Quirion and Chevallier, 2014[23]).

Few studies find statistically significant effects from carbon pricing on net imports, and when they do, effects are relatively small in magnitude and can be either positive or negative. For the EU ETS, Petrick and Wagner (2014[24]), find that the EU ETS increased net exports of regulated sectors on aggregate in Germany by 9% to 18%, meaning that German firms improved their competitiveness due to the EU

ETS. Conversely, Bouttabba and Lardic (2017[25]) find a modest increase of the EU carbon price on net imports, more so in the steel than in cement sector. Outside the EU, Aldy and Pizer (2015[26]) investigate trade effects in the USA from fuel price fluctuations, concluding that a hypothetical carbon price of USD 15/ton CO_2 would lead to a 0.8% increase in imports in energy-intensive sectors.[9]

Foreign Direct Investment (FDI) measures the flow of capital across national borders and reflects the expectations of firms about the profitability of foreign versus domestic investments. On the one hand, an increase in outward FDI can be a proxy for the extent to which carbon pricing leads to "offshoring". Offshoring may be driven by firms' perception that carbon prices will hamper future profits and will make the country less attractive as a manufacturing base. On the other hand, if carbon pricing leads to a positive competitiveness effect (e.g. through innovation, higher productivity or resource efficiency), firms may prioritise domestic investments at the expense of FDI.

The evidence for the impact of the EU ETS on FDI is so far mixed and based on a small number of European countries. Borghesi, Franco & Marin (2018[27]) investigate Italian firms and find the ETS increased both the number of subsidiaries opened outside the EU and increased the turnover in these subsidiaries. Both effects are more pronounced for competition-exposed sectors. In contrast, Koch and Basse (2016[28]) focus on German firms and do not find an effect on FDI both in general and for sectors deemed at risk of carbon leakage.

Carbon prices can increase outward FDI, but the effects are small and tend to be heterogeneous across sectors. Both Dlugosch and Koźluk (2017[29]) and Garsous and Koźluk (2017[30]) use energy prices as proxy for carbon pricing and environmental policy stringency in general for assessing the impact on FDI. Dlugosch and Koźluk (2017[29]) find that increases in domestic energy prices lead to a decline in domestic investment across all manufacturing sectors and to an increase in outward FDI from firms operating in high-energy sectors. The findings of Garsous and Kozluk (2017[30]) suggest that a 10% increase in domestic energy prices leads to an increase of 0.5 percentage points in the ratio between foreign and total assets (from a mean of 14%), indicating an increase in outward FDI.

The effects of carbon pricing and fluctuations in energy prices are quite small compared to other trends and structural policies (Figure 6). Changes in energy prices historically explain a very small part of changes in domestic investment. Other factors, such as macroeconomic trends or changes in employment protection legislation had a much larger effect on the investment ratio (domestic investment over total assets) between 2000 and 2011 than energy prices.

4.2. Economic outcomes: Turnover, value added, total assets, investment, employment, productivity and profit

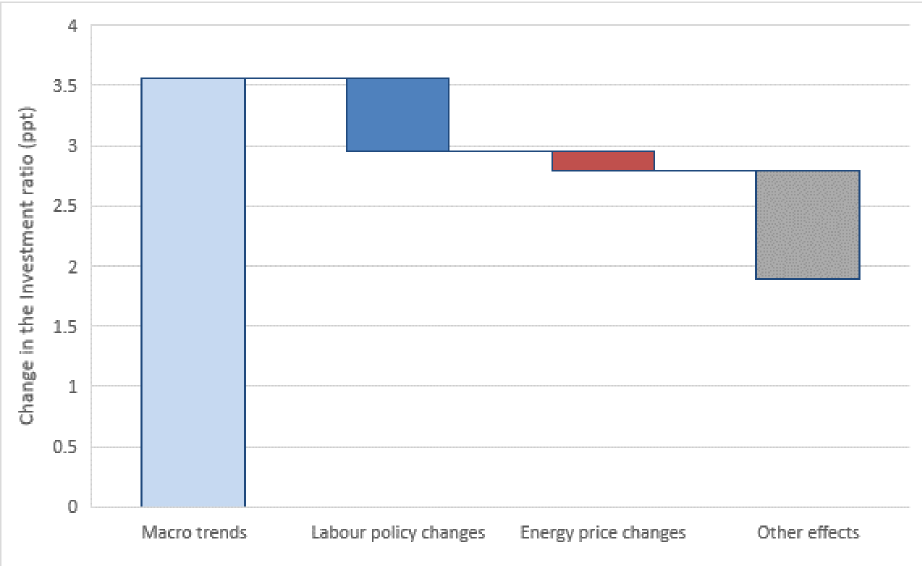
The results from empirical studies on the impact of carbon pricing on selected economic variables are mixed, with most studies finding no statistically significant effects. Figure 7 lists several recent studies that robustly apply state-of-the-art econometric techniques. The datasets used for most studies allow the authors to investigate the effect of carbon pricing on many economic variables simultaneously. Most studies do not find a statistically significant effect from carbon pricing on variables such as turnover, value added, total assets, investment, and employment, meaning that the current design of pricing schemes have had no detrimental impact on proxies for competitiveness.

[9] For the RGGI in the Northeastern USA, Fell and Maniloff (2018[56]) find that the carbon market has led to changes in electricity trade patterns, estimating that Pennsylvania and Ohio - which are not part of RGGI, but have grid connections to RGGI states - increased their production by as much as 10%. Their results indicate that RGGI induced a reduction in coal-fired generation in RGGI states and an increase in natural gas electricity generation in RGGI-surrounding regions.

Carbon pricing has recently been assessed as having a positive effect on the turnover of regulated firms. Turnover (value of sales) and value added (value of sales minus costs of intermediary inputs) is a proxy for the market share of firms subject to international competition. Finding a positive impact of carbon pricing on turnover can be the result of cost pass through of carbon (opportunity) costs as a result of efficiency gains. This will be discussed further below.

Carbon pricing tends to increase total assets and investments. Finding a positive effect of carbon pricing on investment and total assets is in line with firms investing in abatement technology (see second-order effect above). Many abatement options require investments in more modern fixed assets, e.g. better insulated kilns, variable speed drive motors, and installations for heat recovery. On the other hand, expectations about lower production levels and profitability may hamper investment. Only one out of the six studies in our sample find a negative effect whereas three report a positive effect, one finds effects to be mixed and one could not find a statistically significant effect.

Figure 6. Increases in energy prices explain a very small part of changes in the investment ratio



Note: The chart shows the effect of macroeconomic trends, energy price changes, employment protection legislation changes and other factors on domestic investment between 2000 and 2011.
Source: Dlugosch and Kozluk (2017[29]).

Carbon pricing studies to date have not shown a negative effect on aggregate employment (Figure 7). Carbon pricing can impact employment via two channels. First, increasing production costs may force firms to increase product prices, resulting in lower product demand and thus lower levels of employment. Second, abating emissions through installing abatement technologies increases the demand for labour in the first place relative to business as usual. Empirically, most studies find an insignificant effect of the EU ETS on employment. When effects of the EU ETS on employment have been noted, they tend to be small ranging from a decrease 2% (Marin, Marino and Pellegrin (2018[31]) for phase I of the EU ETS) to an increase of 1.5% (Commins et al. (2011[32]) for phase I). However, phase I of the EU ETS has seen very low carbon prices at the end and may not be representative for the EU ETS over subsequent and future periods.

Carbon pricing has been found by most studies to increase productivity (Figure 7). Environmental regulation increases innovation (see below) which will improve productivity, i.e. the efficiency of turning inputs (labour, capital and natural resources) into output. The effect on total factor productivity are found to be either small ((Calligaris, Arcangelo and Pavan, 2018[33]), (Commins et al., 2011[32])) or statistically insignificant (Löschel, Lutz and Managi, 2018[34]). Many studies find large increases in labour productivity measured as value added per unit of labour of up to 26% (Klemetsen, Rosendahl and Jakobsen, 2016[35]). This reflects the results reported above as the effect on employment tends to be very small while turnover increased.

The ability of sectors to pass through costs differs considerably between economic sectors. Sectors with low international competition can pass through their carbon costs on sales prices and firms can be expected to preserve both their profit margin and incentive for future investment. In contrast, sectors subject to strong international competition cannot fully pass through carbon costs because an increase in sales prices will have a strong effect on sales. Cost-pass through rates have been found to be around 30% in the cement sector (de Bruyn et al. (2015[36])), between 55 and 85% in the iron and steel sector (de Bruyn et al. (2015[36])) and above 80% in the petrochemical sector (Alexeeva-Talebi, 2011[37]). Generally, a higher market concentration seems to be associated with a higher ability to pass through costs (de Bruyn et al. (2015[36])).

Carbon pricing has not been found to negatively impact profits, but differences between sectors exist. While abatement costs as well as direct and indirect carbon costs decrease profits and hamper future investments, free-allocation may at the same time have increased profits of regulated firms.[10] Most ex-post studies do not find effects of the EU ETS on profits overall ((Dechezleprêtre, Nachtigall and Venmans, 2018[38]), (Abrell, Ndoye Faye and Zachmann, 2011[39])). However, Abrell, Ndoye Faye and Zachmann (2011[39]) find an increase for the electricity and heat sector and a decrease for non-metallic mineral products, pointing to the fact that the electricity sector may have been in a better position to pass through the carbon costs to end-users.[11]

4.3. Technological outcomes: Innovation

Carbon pricing drives innovation in clean technologies to a large extent, in some cases even without crowding out innovation for other technologies. Innovation is the key channel to strengthen the competitiveness of firms in the long-run. The empirical evidence on the impact of carbon pricing or energy prices is most robust: all studies so far report statistically significant increases in patenting in response to carbon pricing (Calel and Dechezleprêtre (2016[40]) for the EU ETS, Cui, Zhang and Zheng (2018[41]) for China) or energy prices ((Ley, Stucki and Woerter, 2016[42]) and (Aghion et al., 2016[43]) for OECD countries). Notably, Calel and Dechezleprêtre (2016[40]) find that EU ETS regulated firms increased green patents by 10% compared to their non-regulated European peers, while not crowding out patenting for other technologies. Ley, Stucki and Woerter (2016[42]) find that a 10% increase in energy prices in OECD countries increases the number of green innovations by 3.4% and the ratio of green innovation to non-green innovations by 4.8%.

[10] There are two ways in which free allocation may increase profits. The first is because free allowances create an opportunity cost and may therefore be passed through in sales prices, as was observed in electricity markets (Sijm et al., 2008[10]). Second, if free allocation exceeds emissions, the income of selling allowances may exceed abatement costs.

[11] There are several studies looking at how stock market prices of regulated firms react to carbon price variations. This gives an insight in investor's expectations about the effect of carbon prices on future profits. In general, the relationship between stock market returns and carbon prices depends on sectors and phases, though relationships are more often positive than negative (Venmans (2015[57]), Pereira da Silva et al. (2016[58]) and Moreno and Pereira de Silva (2016[59])). For electricity producers, studies find a positive relationship between carbon price variation and stock market returns during the first phase, indicating that investors expected firms to gain from the EU ETS (Oberndorfer, 2008[60]), (Veith, Werner and Zimmermann, 2009[61]), (Mo, Zhu and Fan, 2012[62])). For the second phase, some studies find a positive relationship (Pereira da Silva, Moreno and Carvalho, 2016[58]) whereas others find a negative relationship (Tian et al., 2016[63]). In the third phase, the relationship between carbon prices and stock returns was not statistically insignificant (Moreno and Pereira da Silva, 2016[59]).

Figure 7. Studies reporting effects from carbon pricing on turnover, value added, assets, investment, productivity and profit

Authors	Year	Country	Policy	Sectors	Period	Sample Size	Explained variable (left hand side): Turnover & Value Added	Total Assets & Investment	Employment	Productivity	Profit
Makridou et al.	(2019[44])	EU	ETS	Manufacturing	2006-2014	3952 ETS firms, no non-ETS					For energy efficient firms
Dong et al.	(2019[45])	China	ETS	Manufacturing	2006-2015	30 provinces (6 with ETS)	Effect on GDP				
Marin, Marino, Pellegrin	(2018[31])	EU	ETS	Manufacturing	2002-2012	792 ETS firms, 2500 non ETS	Turnover +7%, only phase II (2008-2012)	Gross fixed capital formation/assets +1,5%	-2% phase I (2005-2007) only	Labour productivity (VA/L) +5%	Markup +1,5% in phase I and +3% in phase II
Löschel, Lutz, Managi	(2018[34])	Germany	ETS	Manufacturing	2003-2012	520 ETS firms, > 10000 non-ETS				Total factor productivity Insignificant overall, + 1% in paper industry	
Dechezleprêtre et al.	(2018[38])	EU	ETS	Manufacturing	2003-2013	1,787 ETS firms; 1,280 non-ETS	Turnover +16,7%	Total Assets +8,1%	Insignificant		Insignificant
Calligaris et al.	(2018[33])	Italy	ETS	Manufacturing	2005-2013	662 ETS firms, >3000 non ETS		Insignificant	Insignificant	Total factor productivity (TFP) increases	
Yamazaki	(2017[46])	Canada	Tax	All sectors	2001-2013	68 industries in 6 provinces			Overall: +0,7%, decrease in 6 energy-intensive industries.		
Lutz	(1016[47])	Germany	ETS	Manufacturing	1999-2012	400 regulated, 15000 in total				Total factor productivity +1 % to +2%	
Klemetsen et al.	(2016[35])	Norway	ETS	Manufacturing	2001-2013	150 ETS firms, 515 non-ETS	Value added +24%			Labour productivity +26%	
Jaraite & Di Maria	(2016[48])	Lithuania	ETS	Manufacturing	2003-2010	330 ETS firms, 271 non-ETS		Total Assets increase, but decrease in phase I			Insignificant
Lundgren	(2015[49])	Sweden	ETS	Pulp and Paper	1998-2008	100 firms				Total factor productivity	
Aldy & Pizer	(2015[26])	US	Energy price	Manufacturing	1972-2005	450 subsectors industries	A 10% increase in fuel prices reduces output by 0.8%				
Wagner et al.	(2014[50])	France	ETS	Manufacturing	2000-2010	287 ETS firms, 287 non-ETS	Value added insignificant	Large impact during phase II (2008-2010)	Insignificant at firm level, but negative on installation level		
Petrick & Wagner	(2014[24])	Germany	ETS	Manufacturing	2000-2010	400 ETS firms, 280 non-ETS	Turnover +5% to +7%		Insignificant		
Martin, dePreux, Wagner	(2016[51])	UK-CCL	Tax	Manufacturing	1999-2004	4000 plants			Insignificant	Total factor productivity insignificant	
Albrizio, Kozluk & Zipperer	(2014[52])	OECD	EPS	Manufacturing	1990-2010	19 countries, 10 sectors				Productivity increases for highly productive firms.	
Yu	(2013[53])	Sweden	ETS	Energy sector	2004-2006	113 regulated, 1000 in total					Insignificant in 2005, -1% in 2006
Chan, Li & Zhang	(2013[54])	EU	ETS	Cement, iron, electricity	2001-2009	5873 ETS and non-ETS firms	Electricity (+30%), cement and iron & steel insignificant		Insignificant		
Commins et al.	(2011[32])	EU	ETS & Tax	Manufacturing	1996-2007	160,000 firms		Investment : negative for tax, -1,6% for ETS	Temporary increase for tax; +1,5% for ETS	Total factor productivity: negative (tax); -3,2% (ETS)	Return On Capital: negative for tax; -4,7% for ETS

Note: The colour schemes indicates whether carbon pricing had a positive (green), negative (red), statistically insignificant (yellow) or mixed (blue) effect on the outcome variables of regulated versus non-regulated states, sectors, firms, or installations.
Source: Authors.

5. Summary and questions for further discussion

Limited effects of carbon pricing on short-term competitiveness have been found to date. When effects have been found, they are small (either positive or negative). This demonstrates that concerns about negative short-term effects of carbon pricing on firms' or sectors' international competitiveness have not come to pass, at least to date. However, these findings are in part because carbon prices levied on industry have been low, either because of exemptions to carbon taxes, or because of generous levels of free allowances to firms covered by emissions trading schemes. There is therefore no experience to date on how the competitiveness of energy-intensive industries could be affected in the absence of free allocation of allowances or at substantially higher carbon price levels, although ex-ante studies indicate that levels of carbon leakage could be significant.

Table 2: Overview of ex post studies on the effect of a carbon tax, ETS or energy price variation on different dimensions of competitiveness in industrial sectors*

	Negative	Insignificant	Positive	Mixed
Net imports	1	6	3	0
Foreign Direct Investment	0	1	3	0
Turnover and value added	1	4	3	2
Total assets and investment	1	1	3	1
Employment	1	6	1	3
Productivity	1	1	6	1
Profit	1	2	2	2
Innovation	0	0	4	0

Note: *Number of studies which report negative, positive, insignificant or mixed results for all industrial sectors on aggregate (according to a 10% significance level).
Source: Authors.

Free allocation of allowances (or carbon tax exemptions) is likely to continue to be needed in some sectors while significant differences in carbon pricing exist between jurisdictions. However, there is no agreement on which sectors should benefit, or on what level of free allowances is appropriate. The level of optimal free allocation will vary depending on the stringency of carbon constraints, the carbon price, as well as the level of trade exposure for specific products. Allocating free allowances based on a benchmark performance standard in terms of GHG per unit output instead of allocation based on past emission levels - would reduce perverse incentives for keeping emission levels high.

Setting up carbon pricing schemes (even if the initial price is low) and smoothing out the significant price variability noted to date in emissions trading systems will provide a clearer policy signal to participating firms. It may be more politically acceptable to establish a carbon pricing system with a low initial carbon price, and then raise it over time – as has occurred in the trading systems in place e.g. in the EU, South Korea, New Zealand and Shenzen. Further, postponing the introduction of carbon pricing may entail competitiveness risks if it means that firms become "green laggards". A price stability mechanism (potentially including a price floor and/or ceiling) will thus provide a stable incentive to invest in GHG abatement. A price stability mechanism can also increase the stringency of the system if, as in the EU ETS, it is used to reduce the number of allowances in circulation.

Carbon pricing has a positive effect on innovation, but effects on long-run competitiveness remain inconclusive. Innovation is key to drive the low-carbon transition in many sectors. Carbon pricing has been found to drive private money into innovation of low-carbon technologies, which equip firms for international competition in the long-run – when carbon price levels increase. However, this competitive advantage in the long-run has not (yet) materialised into economic outcomes.

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