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Erik Frohm,

Filippo Maria D'Arcangelo,

Tobias Kruse,

Mauro Pisu,

Urban Sila

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ENVIRONMENTAL POLICY STRINGENCY AND CO2 EMISSIONS - EVIDENCE FROM CROSS-COUNTRY SECTOR-LEVEL DATA

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ABSTRACT/RÉSUMÉ

Environmental Policy Stringency and CO2 emissions: Evidence from cross-country sector-level data

This paper provides empirical evidence on the short and long-term sectoral effect of environmental policy stringency on CO2 emissions, exploiting longitudinal data covering 30 OECD countries and more than 50 sectors. The analysis relies on the OECD Environmental Policy Stringency (EPS) index, a composite index tracking climate change and air pollution mitigation policies. Estimates obtained from panel regressions suggest that more stringent environmental policies are associated with lower emissions, that the effect builds over time and differs across sectors depending on their fossil fuel intensity. A one unit increase in the EPS index (about one standard deviation), is associated with 4% lower CO2 emissions in the sector with median fossil fuel intensity after two years and by 12% after 10 years. For sectors in the top decile of the fossil fuel intensity distribution, the estimates point to a decline in emissions by 11% after two years and 19% after ten years. Environmental policies targeted at energy, manufacturing and transport sectors have the largest potential impact on emissions. Illustrative policy scenarios based on these results indicate that achieving emission reductions consistent with net-zero targets will require raising the stringency of environmental policies more drastically and rapidly than in the past.

JEL codes: Q54, Q58, C23

Keywords: Environmental Policy Stringency; CO2 emissions; climate change; cross-country regression.

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Rigueur des politiques environnementales et émissions de CO2 : preuves issues de données sectorielles transnationales

Ce papier fournit des preuves empiriques sur l’effet sectoriel à court et à long terme de la rigueur des politiques environnementales sur les émissions de CO2, en exploitant des données longitudinales couvrant 30 pays de l’OCDE et plus de 50 secteurs. L’analyse s’appuie sur l’indice de rigueur des politiques environnementales (EPS) de l’OCDE, un indice composite qui suit les politiques d’atténuation du changement climatique et de la pollution atmosphérique. Les estimations obtenues à partir de régressions en panel suggèrent que des politiques environnementales plus strictes sont associées à des émissions plus faibles, que l'effet se renforce au fil du temps et diffère selon les secteurs en fonction de leur intensité en combustibles fossiles. Une augmentation d’une unité de l’indice EPS (pour un écart type environ) est associée à une réduction de 4 % des émissions de CO2 dans le secteur à intensité médiane des combustibles fossiles après deux ans et de 12 % après 10 ans. Pour les secteurs situés dans le décile supérieur de la répartition de l’intensité des combustibles fossiles, les estimations font état d’une baisse des émissions de 11 % après deux ans et de 19 % après dix ans. Les politiques environnementales ciblées sur les secteurs de l’énergie, de l’industrie manufacturière et des transports ont l’impact potentiel le plus important sur les émissions. Des scénarios politiques illustratifs basés sur ces résultats indiquent que pour parvenir à des réductions d’émissions conformes aux objectifs de zéro net, il faudra accroître la rigueur des politiques environnementales de manière plus drastique et plus rapide que par le passé.

JEL codes: Q54, Q58, C23

Mots clés: Rigueur de la politique environnementale ; Emissions de CO2; changement climatique; régression transnationale.

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Environmental Policy Stringency and CO2 emissions: Evidence from cross-country sector-level data

By Erik Frohm, Filippo Maria D'Arcangelo, Tobias Kruse, Mauro Pisu and Urban Sila[1]

Introduction

Since the 2015 Paris Agreement around 140 countries have pledged large reductions in greenhouse gas (GHG) emissions, with an increasing number of them committing to net-zero targets by 2050. However, policies to achieve these ambitious targets are lagging (IEA, 2021[1]). To fill this gap and fulfil their climate change mitigation obligations, countries are designing and implementing a diverse set of environmental policies (carbon prices, emissions trading systems, regulations, subsidies and public investments) (D'Arcangelo et al., 2022[2]; Blanchard, Gollier and Tirole, 2022[3]). These policies often overlap and interact in complex ways, resulting in complementarities and trade-offs, which may magnify or curtail overall effects on emissions and the economy.

A large literature, reviewed in Dechezleprêtre and Sato (2017[4]), Dechezleprêtre et al. (2019[5]) and Green (2021[6]), has focused on the effects of specific, mostly price-based policies, on GHG emissions and economic outcomes. Emphasis has been on carbon prices in specific countries, Sweden (Andersson, 2019[7]), France (Dussaux, 2020[8]) and the United Kingdom (Martin, de Preux and Wagner, 2014[9]), effective carbon rates across countries (D'Arcangelo et al., 2022[10]) or the effects of the EU Emissions Trading Scheme across countries (Wagner et al., 2018[11]; Känzig, 2022[12]; Kohlscheen, Moessner and Takáts, 2021[13]; Dechezleprêtre, Nachtigall and Venmans, 2023[14]).

This paper provides novel evidence on the short and long-term sectoral effect of increasing the environmental policy stringency (combining price-based and non-price-based measures) on CO_2 emissions and for a large sample of OECD countries. In so doing it answers the following questions: how long do environmental policies take to display their full effects? what sectors and fossil fuels are most affected by more stringent environmental policies? And how more stringent will environmental policies need to be to lower emissions in line with countries' ambitious emission-reduction targets?

Information on the stringency of environmental polices comes from the recently updated OECD Environmental Policy Stringency (EPS) index (Botta and Kozluk, 2014[15]; Kruse et al., 2022[16]). As

[1] Erik Frohm, Filippo Maria D'Arcangelo, Tobias Kruse, Mauro Pisu and Urban Sila are members of the OECD Economics Department. We thank Luiz de Mello, Alain de Serres, Douglas Sutherland, Mame Fatou from the Economics Department, Antoine Dechezleprêtre from the Directorate for Science, Technology and Innovation, Daniel Nachtigall from the Environment Directorate and delegates of Working Party No.1 (WP1) of the OECD Economic Policy Committee for their valuable suggestions and comments. The authors thank participants in the OECD brownbag seminar series and the OECD Berlin Centre seminar series. We thank Sisse Nielsen for excellent editorial assistance.

described in Section 2, the EPS index aggregates information on several environmental policy instruments in a single and comparable indicator across countries and over time. We combine the EPS index with country-sector data on output volumes from the Socio-Economic Accounts (SEA) (Timmer et al., 2015[17]) and CO_2 emissions and energy use from the Environmental Accounts (EA) (Corsatea et al., 2019[18]). These data contain information for 43 countries and 56 sectors over 2000–14. After merging databases, the econometric approach exploits variation within country-sectors for 30 OECD countries and more than 50 sectors.

A key finding presented in Section 3 is that the impact of the EPS index on CO_2 emissions rises gradually over time. This indicates that the substitution towards low-carbon technologies, the decline in abatement costs, the development and deployment of clean innovation and the exit of more polluting firms are gradual process that take time. For a sector with median fossil fuel intensity, a one-point increase in the EPS index (roughly the average ten-year increase in the EPS index across OECD countries over 2000–20 or about a standard deviation increase) is associated with a decline in CO_2 emissions by about 4% after two years and by about 12% after ten years. The impact is larger in sectors with higher fossil fuel intensity: for sectors in the top decile of the fossil fuel intensity distribution, the estimates point to a decline in emissions by 11% after two years and 19% after ten years. For sectors at the opposite end of the fossil fuel intensity distribution, the estimates are close to zero and statistically insignificant at the 10%-level.

Section 4 shows that the baseline results are robust to several checks. In addition, there is some tentative evidence that a lower regulatory burden in the economy, as captured by the OECD's Product Market Regulation (PMR) indicator (Nicoletti and Scarpetta, 2005[19]), can amplify the impact of environmental policies on emissions.

The analysis then proceeds in Section 5 to compute the "emission reduction potential" (ERP) of countries, sectors and fossil fuels leveraging the baseline empirical estimates. This part of the analysis is based on a hypothetical exercise whereby countries raise their EPS index to the level of the country with the most stringent environmental policies in 2020 (i.e., the 2020 environmental policy stringency frontier). Countries' ERP depends on their distance from the environmental policy stringency frontier, sectors' fossil fuel intensity and share in total domestic CO_2 emissions. As regards sectors, the energy supply sector (i.e., electricity, gas, and steam supply), manufacturing and transport are those with the largest scope to reduce emissions because of their high fossil fuel intensity and high share in total emissions. In terms of fuels, reducing coal use and natural gas, fuel oils and diesel have the largest potential to lower emissions. The contribution of sectors and fuels to countries' ERP vary significantly based on countries sectoral and energy-use mix. These results confirm and complement similar sector-specific empirical evidence from carbon pricing (D'Arcangelo et al., 2022[10]), while extending the analysis to non-pricing policies.

Finally, Section 6 provides policy simulations to illustrate the required change in environmental policies to lower emission by 2030 in line with the IEA's Net Zero Emission Scenario. The IEA's Net Zero Scenario provides a path for global energy-related CO_2 emissions to limit the global temperature rise to 1.5°C (IPCC, 2021[20]; IEA, 2022[21]). In this scenario, global energy-related emissions would have to decline by 30% between 2020 and 2030, before reaching net zero in 2050. Illustrative simulations suggest that, given the estimated response of emissions to change in the EPS index, only a rapid and drastic increase in environmental policy stringency (unobserved in any country henceforth) would yield sufficient progress in terms of emission reduction. Climate action should not be delayed, as mitigation policy takes time to fully produce effects on emissions,

Overall, these empirical results quantify the mitigation action, as captured by the OECD Environmental Policy Stringency index, needed at the country- and sector-level to meet the emission-reduction targets set by countries have set to achieve the Paris Agreement's goals. The results motivate further research to uncover specific policies' aspects that the framework used in this study cannot fully capture. A limitation of the OECD Environmental Policy Stringency index comes from the set of policies falling outside its coverage: the EPS focuses on policies aimed at curbing greenhouse gas emissions and local air pollution, and within this group of policies, it does not capture regulations for some specific sectors. For example, policies that regulate emissions from agricultural production are not included. In countries where agricultural production accounts for a relatively large share of total carbon emissions, the EPS may capture a relatively smaller share of the overall environmental policy mix. One important aspect concerns how to combine different policies to “get more bang from the buck” and therefore raise policies’ effectiveness. For instance, a comprehensive policy mix combining a broad-based carbon tax with well-designed incentives for clean-technology innovation and adoption might help to address multiple market failures, resulting in larger emission reduction for a given policy effort. Better understanding the nature and magnitude of these complementarities can guide policy choices.

Data and methodology

The analysis uses three main data sources. The Socio-Economic Accounts (SEA) (Timmer et al., 2015[17]), the Environmental Accounts (EA) (Corsatea et al., 2019[18]) and the OECD Environmental Policy Stringency index (EPS). The first two sources contain data on economic variables, energy use and CO_2 emissions for 56 sectors in 43 countries for each year between 2000 and 2014.[2] The third source contains country-level data on the EPS index as updated by Kruse et al. (2022[16]).

The EPS index is an internationally comparable composite index of different environmental policy instruments, focussing primarily on climate change and air pollution policies. It covers 13 policy instruments grouped into the three sub-indices: market-based policies (taxes for CO_2, NOx, SOx and diesel fuel taxes, CO_2 certificates and renewable energy certificates), non-market-based instruments (emissions limit values for NOx, SOx, PM and sulphur content limits for diesel) and technology support measures (R&D expenditure and adoption support for wind and solar). The index ranges from zero (least stringent policies) to six (most stringent policies) and is available from 1990–20 for 40 countries. The stringency of environmental policies is measured in different units. A carbon price is for example measured in US dollar per tonne of CO_2 emissions, while a feed-in-tariff for solar or wind energy is measured in US dollar per kWh.

To aggregate several policy types into a composite index of policy stringency, their stringency needs to be measured on a common scale. To this end, a data-driven approach is taken so that threshold levels are determined by the distribution of observations. For each policy instrument, the raw data is ordered from the least to the most stringent observation. The lowest score of zero is assigned to observations with no policy in place. The remaining scores are assigned using the distribution of observations that have the policy in place. The highest score of six is assigned to observations with values above the 90th percentile of observations that have the respective policy implemented. To assign the remaining scores, the difference between the 90th and the 10th percentile is divided into five equal bins that define the thresholds.

After converting the raw policy stringency values into scores from zero to six, the scores are aggregated into the composite EPS index (see Figure A.1 in 7Annex A for details). Three main considerations guide the index structure and aggregation. First, each sub-index (market based, non-market based, technology support) receives an equal weighting. Countries use different combinations of policy instruments to regulate emissions. Some countries rely more on pricing instruments, such as carbon taxes, while others prefer to use non-market based policies, such as emission limits or standards. Second, each sub-index must be self-contained so that it functions as a stand-alone indicator, meaning that the policy weights within each sub-index add to one. Third, the policies within each sub-index are weighted equally. Kruse et al. (2022[16]) describe the index more in detail and provide basic statistics in addition to comparing it with other environmental policy measures or proxies. For example, the EPS correlates strongly with the World Economic Forum (WEF) Commitment to Sustainability index, a composite indicator scoring countries' regulation on energy efficiency, renewable energy, and participation in environmental treaties.

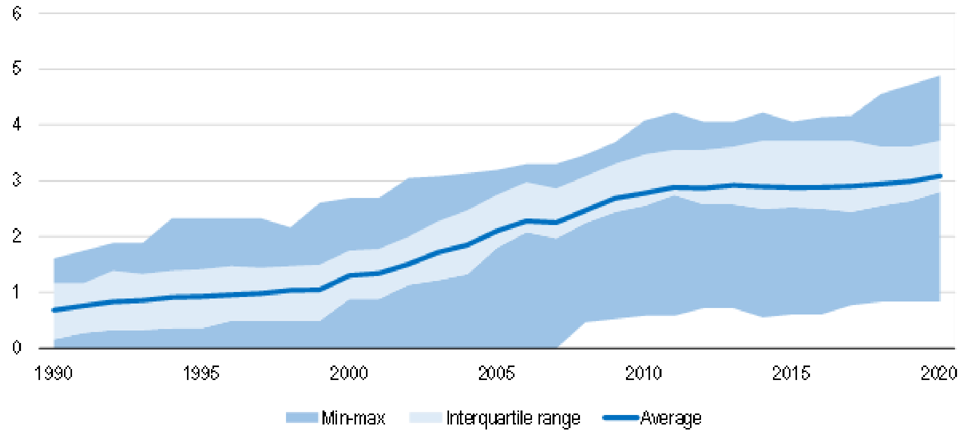
The EPS also correlates positively with industry energy prices, which are affected by energy and carbon taxes and other environmental policy instruments. However, energy prices only provide a partial picture by

[2] Both these databases accompany the 2016 version of the World-Input-Output-Tables. For each country, the database contains 840 sector-year observations (in total 36 120 country-sector-year observations).

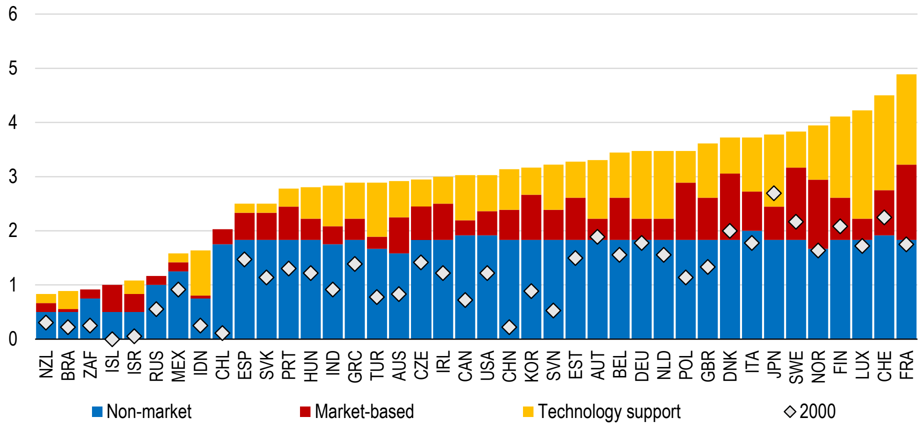
measuring market-based policies. Moreover, energy prices are also influenced by other factors not related to environmental policies, including business cycles and past investment decisions. The main benefit of the OECD EPS index is that it measures the stringency of a comprehensive set of environmental policies. Figure 1 shows that the EPS has increased across all OECD countries since the 1990s, although with significant differences across countries (panel A) and environmental policies (panel B).

Figure 1. The OECD Environmental Policy Stringency (EPS) Index over time and countries

Panel A: Change in EPS over time



Panel B: The EPS across countries in 2020 and 2000

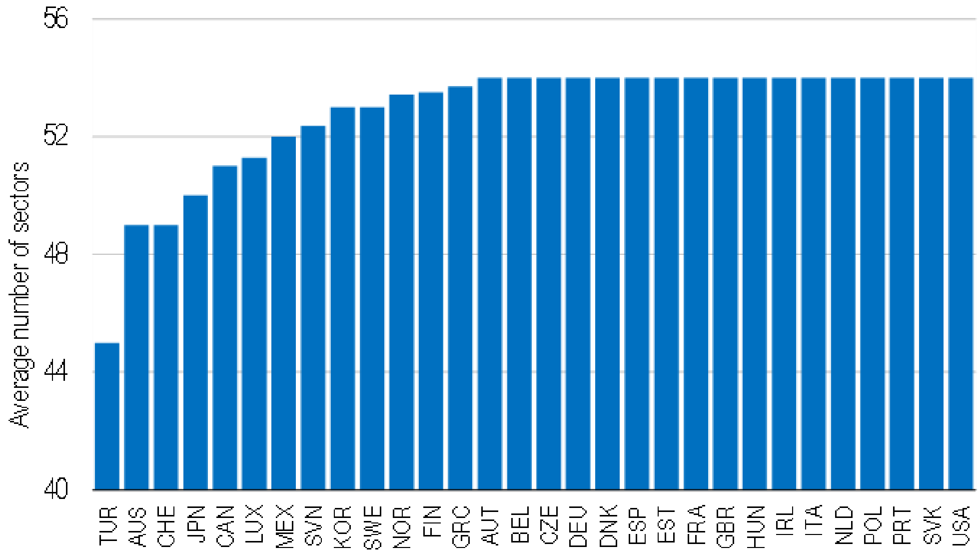


Note: The lower panel shows the level of the EPS in 2020 and the contribution of the three sub-indices to the total. Diamonds indicate the level of the EPS in 2020.
Source: OECD.

Overall, the database contains more than 22 000 observations for more than 50 (2-digit ISIC Rev.4) sectors in 30 OECD countries.[3] Figure 2 shows the countries and the number of sectors included in the database used for the empirical analysis, covering the 2000–14 period. Table 1 lists the variables and descriptive statistics.

[3] The sectors T and U (Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use as well as Activities of extraterritorial organizations and bodies) are excluded due to missing data for energy use, CO_2 emissions and several economic variables. In some countries, data is missing for some sectors for some variables and are thus dropped.

Figure 2. Number of sectors with available data per country



Note: The bars show the average number of sectors included in the sample for the baseline regression in Table 2 for each country. A sector in a year and country is one observation.
Source: OECD calculations.

Table 1. Variables used and descriptive statistics

Dimension	Variable	Unit	Source	Mean	Std-dev
Country-sector	CO_2 emissions	Log (kilotons)	EA (WIOD 2016)	5.9	2.6
Country	EPS	Index (0 to 6)	Kruse et al (2022)	2.6	0.8
Country-sector	Real output	Log (output volumes)	SEA (WIOD 2016)	4.6	0.2
Country	Real GDP	Log (constant values)	World Bank Indicators	27.9	2.4
Country-sector	Fossil fuel intensity	Share of fossil fuels (gasoline, diesel, fuel oil, natural gas, coal and other petrol's and gases) in total energy use	EA (WIOD 2016)	0.6	0.2

Note: The mean and standard deviation in the Table is computed for the sample in the baseline regression outlined in Table 2.

Empirical framework

The empirical approach models short- and long-term effects of EPS on CO_2 emissions. The estimates therefore capture cumulative effects of up to 10 years (the long run). [4] This choice is based on the premise that industries' full response to changes in environmental policies will materialise only with some lag as it takes time for firms to substitute alternative energy sources, change production processes or adopt clean technologies. The empirical specification is the following:

$$\ln\left(CO2_{cs,t}\right) = \sum_{k=0}^{10} \beta_k EPS_{c,t-k} + \sum_{k=0}^{10} \theta_k (EPS_{c,t-k} \times \bar{S}_{cs}) + Controls + \alpha_{cs} + \delta_t + \tau_c t + \tau_s t + \varepsilon_{cs,t} \quad (1)$$

where $CO2_{cs,t}$ is the outcome variable in logs (CO_2 emissions) in country c, sector s at year t. $EPS_{c,t}$ is the Environmental Policy Stringency index. $\bar{S}_{cs}$ is the average share of fossil fuels within each country-sector's

4 As EPS data is available from 1990, while emission data is only available from 2000, no observation is lost by having a rich lag structure on the independent variable.

energy use, computed over the 2000–14 period. The fossil fuels considered are gasoline, diesel, fuel oil, natural gas, coal and other petrol's and gases. $Controls$ include log real gross output (at the country-sector level) and log real GDP (at the country-level) to capture economic activity that also drive emissions. These controls are important to avoid that output shocks in these sectors confound the effect of EPS on emissions. At the same time, keeping output constant is tantamount to estimating the effect of EPS on emission intensities.

These results are robust to excluding controls or using alternative ones (Section 4.2). In the Appendix we also explore the results of regression (1) for employment instead of CO_2 emissions, following Dechezleprêtre et al. (2020[22]).[5] Country-sector fixed effects, α_{cs}, control for unobserved time invariant idiosyncratic differences and year fixed effects, δ_t, control for time varying shocks that are common across countries and sectors. Moreover, country-specific and sector-specific time-trends, whose growth rates are denoted by τ_c and τ_s, are included to control for unobservable secular determinants of the outcome variable.

The main variable of interest in (1) is the EPS index and its interaction with the fossil fuel intensity of the sector. The inclusion of the interaction term allows for heterogeneous effects of the EPS across sectors, with the fossil fuel intensity capturing the theoretical degree of exposure of the sector to the policy.[6] As the EPS consists predominantly of energy-, and environmental policies, the interaction with fossil fuel intensity is appropriate to create a sector level exposure to environmental policies. We expect that the impact of EPS is greater for sectors with a high fossil fuel intensity as the environmental damages that most policies captured by EPS index aim directly or indirectly at reducing fossil fuel use.

Country-level CO_2 emissions as a dependent variable could be endogenous to environmental policies (economic policies that influence economic outcomes are in part decided in response to emissions in the country).[7] This study relies on sector-level data to diminish these concerns as country's overall environmental policies are unlikely to be based on sector-level emissions, though sector-level emissions are affected by environmental policies. Interacting our explanatory variable of interest (EPS) with sector-level fossil fuel intensity also reduces concerns of omitted variable bias. Any omitted variable would only pose a problem if its effect was mediated by (and in proportion to) fossil fuel intensity.

[5] The employment regression includes also the log real capital stock, log real wages and log real productivity per hour worked.

[6] Econometric specifications with interaction terms are commonly used in a wide range of applications, see for example (Rajan and Zingales, 1998[25]; De Soyres et al., 2021[26]; Albrizio, Koźluk and Zipperer, 2017[28]). A caveat of this approach is that some sectors using fossil fuels are exempt from environmental policies or even subsidised. The share of fossil fuel use is therefore only an approximate measure.

[7] In robustness checks in section 4.2, we add country-year and sector-year fixed effects to fully controls for all macroeconomic factors and sector-specifics shocks that affect emissions, employment and the EPS.

The effect of environmental policies on emissions

Table 2 presents the results from estimating equation (1). The results indicate that a permanent increase in the stringency of environmental policy reduces CO_2-emissions. Moreover, this impact builds over time and is larger for sectors with a higher fossil fuel intensity.[8]

Table 2. Regression results

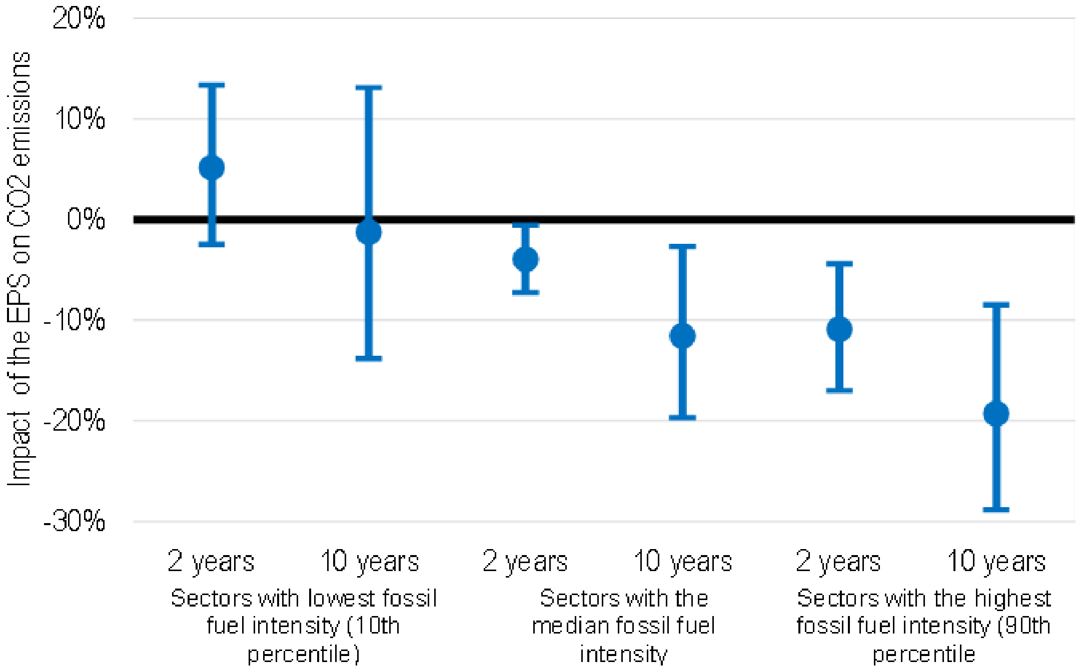
	$ln(CO2)_{cs,t}$
$EPS_{c,t}$	0.148** (0.064)
$EPS_{c,t} \times \bar{S}_{cs}$	-0.227** (0.100)
Linear combinations of parameter estimate associated with a unitary increase in EPS Upon impact, after 2 and 10 years for the median fossil fuel intensity	
At median fossil fuel intensity, immediate impact	0.007 (0.011)
At median fossil fuel intensity, after 2 years	-0.040* (0.021)
At median fossil fuel intensity, after 10 years	-0.123** (0.058)
Controls	
Log real gross output	0.389*** (0.063)
Log real GDP	0.306 (0.190)
Linear time-trends	Country, sector
Fixed effects	Country-sector and year
Clustered standard errors	Country-sector
Observations:	22,180
Adjusted R^2 / Within- R^2	0.963 / 0.179

Notes: *, ** and *** denotes statistical significance at 10%, 5% and 1%. The median fossil fuel intensity ($\bar{S}_{cs}$) is computed across sectors in the sample and is 0.62. The first two rows of the table report the contemporaneous effects (k=0). The controls are the linear combinations of t and t-1. The cumulative effect for 2 and 10 years are computed as linear combinations of the parameter estimates for the EPS and its interaction with the fossil fuel intensity for the relevant horizons (i.e., $\beta_0 + \beta_1 + \beta_2 + (\theta_0 + \theta_1 + \theta_2)\bar{S}_{cs}$ for the impact after two years).
Source: OECD calculations.

[8] The effects of the EPS on employment are shown in Annex 1. The effects on employment are markedly weaker and there is no statistically significant effect at the 10%-level for either the low or high fossil fuel use sectors. This evidence is in line with previous research that find small or negligible aggregate sectoral or employment effects (OECD, 2021[27]). For example, analysing the French carbon tax Dussaux (2020[8]) finds that employment in the most emission intensive sectors declines while employment in some sectors increases. Analysing the EU ETS Dechezleprêtre, Nachtigall and Venmans (2023[14]) find small negative impacts on employment for firms.

Figure 3 depicts the cumulative effect of a permanent one unit increase in the EPS index (i.e., the typical 10-year increase over the past 20 years or roughly one standard deviation change in the EPS across the sample) based on the estimates in Table 2. After two years, the increase in EPS is associated with 4% lower CO_2 emissions for sectors with the median fossil fuel intensity. This effect is statistically significant at the 10%-level. After 10 years, the impact is -12% (and significant at the 5%-level). For sectors with the highest fossil fuel intensities, the same change in the EPS reduces CO_2 emissions by 11% after two years and by 19% after ten years. The results are intuitive as sectors that rely less on fossil fuels for their total energy use are likely to be less impacted by EPS increases and have therefore less incentives to adopt technologies or change production practices to further reduce emissions. The cumulative impacts up to ten years are plotted in Figure A1 in Annex 1.

Figure 3. A higher EPS is associated with lower emissions



Note: The cumulative effect for two and ten years are computed as linear combinations of the parameter estimates for the EPS and its interaction with the fossil fuel intensity for the relevant horizons (i.e., $\beta_0 + \beta_1 + \beta_2 + (\theta_0 + \theta_1 + \theta_2)\overline{S}_{cs}$) for the impact after two years), computed with the Stata command nlcom. Standard errors are computed with the delta method. The lines are 90% percent confidence intervals and the dots are point estimates. Standard errors are clustered at the country-sector level. The figures report the cumulative effect across the years marked on the horizontal axis. Lowest is the 10th percentile of fossil fuel intensities and highest denotes country-sectors at the 90th percentile. The 10th percentile is 0.29 and 90th percentile is 0.90. The coefficient estimates are converted to % changes by taking the exponent, the impact after 10 years at the 90th percentile of fossil fuel intensity is $-19\% = (e^{-0.214} - 1)$.
Source: OECD calculations.

In terms of sectors, water and road transport, manufacture of pharmaceuticals and medical chemicals, manufacture of coke and refined petroleum products and fishing/aquaculture are among those with the highest fossil fuel intensities across many countries, (see Figure A2 in Annex A). In terms of countries, Australia, Korea and Mexico have more than one fifth of their sectors at or above the 90th percentile of fossil fuel intensity.

The EPS is an aggregate indicator that contains different policies. It covers market-based policies (taxes, permits and certificates), non-market-based instruments (performance standards) and technology support measures (R&D expenditure and adoption support for solar and wind). To investigate how different policies affect CO_2 emissions, equation (1) is estimated separately for the three indicators.

The point estimates from this exercise reveal that market-based policy stringency have the largest coefficient and non-market-based policy stringency the smallest (Table 3). The results are statistically significant only at the 10% level for sectors with high fossil fuel intensities after ten years. The result for technology support measures is statistically significant after two years, but not after ten, although its point estimate is close to the one of market-based policies. These results indicate that none of the EPS sub-indices has an effect as large effect as the aggregate EPS indicator and underline that a combination of environmental policies (market, non-market and technology support measures) could generate complementarities across policy instruments resulting in larger emissions reductions (D'Arcangelo et al., 2022[2]). Nonetheless, the coefficient estimates for the different sets of policies are not statistically different at conventional significance levels.

Table 3. Regression results for sub-indices of the EPS

	Market-based policies	Non-market policies	Technology support	Total EPS
At 10th perc. fossil fuel intensity, after 2 years	0.043 (0.042)	-0.018 (0.015)	0.069* (0.037)	0.050 (0.046)
At 10th perc. fossil fuel intensity, after 10 years	-0.145 (0.105)	-0.006 (0.012)	0.126 (0.078)	-0.013 (0.083)
At 90th perc. fossil fuel intensity, after 2 years	-0.074 (0.045)	0.005 (0.031)	-0.093*** (0.031)	-0.115*** (0.043)
At 90th perc. fossil fuel intensity, after 10 years	-0.163* (0.095)	-0.060* (0.031)	-0.112 (0.076)	-0.214*** (0.076)
Controls	Yes	Yes	Yes	Yes
Linear time-trends	Country, sector	Country, sector	Country, sector	Country, sector
Fixed effects	Country-year, sector-year	Country-year, sector-year	Country-year, sector-year	Country-year, sector-year
Clustered standard errors	Country-sector	Country-sector	Country-sector	Country-sector
Observations:	22,180	22,180	22,180	22,180
Adjusted R^2 / Within- R^2	0.963 / 0.178	0.963 / 0.178	0.963 / 0.182	0.963 / 0.179

Note: : *, ** and *** denotes statistical significance at 10%, 5% and 1%. Percentiles in fossil fuel intensity (S¯_cs) computed across sectors in the sample: the 10th percentile is 0.29 and 90th percentile is 0.90. The controls are the linear combinations of t and t-1. The cumulative effect for 2 and 10 years are computed as linear combinations of the parameter estimates for the EPS and its interaction with the fossil fuel intensity for the relevant horizons (i.e., $\beta_0 + \beta_1 + \beta_2 + (\theta_0 + \theta_1 + \theta_2)\overline{S}_{cs})$ for the impact after two years).
Source: OECD calculations.

Robustness checks and extensions

This section presents results from several robustness checks of the results, as well as an extension of the baseline analysis. Table 4 shows that the results in Section 3 are robust across different specifications and tests. The extension of the results to account for policies supporting business dynamism (measured by the OECD Product Market Regulation index) yields statistically inconclusive results.

Table 4. Robustness checks and extensions

Robustness check	Lowest fossil fuel intensities (10th percentile)	Highest fossil fuel intensities (90th percentile)
Baseline estimates	-1% (0.011)	-19%*** (0.076)
1) Pre-sample fossil fuel shares	-6% (0.080)	-23%*** (0.084)
2) More fixed effects	-9%* (0.053)	-25%* (0.167)
3) Other demand controls		
No controls	-2% (0.083)	-19%*** (0.078)
Domestic value added in foreign final demand	-3% (0.095)	-17%** (0.082)
Foreign demand, export-weighted imports of trading partners	-2% (0.100)	-18%** (0.085)
4) Only including lags of the explanatory variables	-2% (0.066)	-17%*** (0.065)
5) Excluding sectors with high CO_2 shares	6% (0.091)	-22%*** (0.096)
6) Quadratic time trends	-1% (0.082)	-19%*** (0.076)
7) Effects of non-environmental policies		
PMR above median (less competitive markets)	-2% (0.087)	-13%* (0.082)
PMR below median (more competitive markets)	-0% (0.145)	-27%*** (0.112)

Note: *, ** and *** denotes statistical significance at 10%, 5% and 1%. Standard errors are clustered at country-sector level. The lowest/highest are fossil fuels share in total energy use and are computed as percentiles across the full sample. 1) constructs the fossil fuel intensities for the year 2000 and this year is dropped from the estimation. 2) includes country-year and sector-year fixed effects. 3) drops real gross output as a control or swaps it for either domestic value added in foreign demand (deflated with value added prices) or foreign demand. 4) Includes only lags (k=1, 2,…10). 5) excludes sectors with shares in a country's CO_2 emissions above the 75th percentile (per country). 6) Swaps linear time-trends for quadratic time-trends and 7) includes interactions of the explanatory variables with the OECD's PMR indicator.
Source: OECD calculations.

1. *Using fossil fuel intensities computed with data from the pre-sample period*

Using the 2000–14 average sectoral fossil fuel share in the interaction with the EPS instead of the share observed in a given year alleviates concerns that the shift in the energy mix is caused by policy stringency itself. The latter could bias estimates away from zero, as higher EPS reduces exposure while affecting outcomes at the same time. Another way of constructing the fossil fuel intensity is to compute them on the first year of data, in our case 2000, and exclude this year from the estimation. This ensures that the sectoral exposure to EPS is “fixed in time” to a pre-sample period and changes in EPS do not affect the exposure variable as well. This robustness check comes at the cost of sacrificing any time-varying change in exposure not caused by changes in EPS, such as the progressive electrification of the manufacturing sectors. The results from this robustness check are economically and statistically like those in the baseline specification (Table 4).

2. *More comprehensive sets of fixed effects*

The baseline specification already controls for many unobserved factors. Yet, there might be remaining country and sectoral variables that confound the estimates. In this robustness check we therefore include country-year and sector-year fixed effects in lieu of the time-trends and real GDP. These additional fixed effects control for country- or sector-specific shocks that may be correlated with the EPS and CO_2 emissions and that the time-trends and real GDP fail to control for. For example, the fixed-effects capture aggregate demand and supply, economic policy or the evolution of energy prices. This specification does not identify the coefficient of EPS (as it is subsumed by the country-year fixed effects) but identifies only the interaction between EPS and fossil fuel intensities. The results in Table 4 shows that adding these fixed effects results in similar point estimates to those of the base specification but larger standard errors for the interaction of EPS with high fossil fuel intensities. The effect of EPS interaction term is significant only at 10% level.

3. *Other controls for demand*

The baseline specification controls for country-sector output volumes. In this robustness check real gross output and real GDP are first excluded from the regression while keeping the same sample as in the baseline regression. Table 4 shows that the impact of the EPS on CO_2 emissions is very similar for sectors with the lowest and highest fossil fuel intensities without controlling for gross output and real GDP. Second, real gross output at the country-sector level is substituted with a variable measuring each country-sector’s domestic value added in foreign final demand.[9] This variable capture part of production that is due to foreign demand and is more plausibly exogenous than real gross output. Third, a variable directly capturing foreign demand is included, i.e., the export-weighted imports of trading partners. In both these regressions, the coefficient on the EPS for sectors with the lowest and highest fossil fuel intensities is very similar as the baseline.

4. *Only including lags of the explanatory variables*

Using lags diminishes the risk of endogeneity. This robustness check excludes the contemporaneous values of the explanatory variables and only include lags (t-1 for the controls and k=1 to k=10 for the EPS and its interaction with the fossil fuel intensities). The estimated impact of the EPS is very close to the baseline regression.

5. *Removing sectors that contribute most to CO_2 emissions in a country*

Using sector-level instead of country-level data reduces the concern of reverse causality, i.e., that emissions drive environmental policy stringency. However, it does not eliminate the concerns, as some sectors with very large emissions can drive overall environmental policies. To ensure that this is not an issue in the analysis, this robustness check excludes large CO_2 emitting sectors in each country (defined as those whose share in a country’s total CO_2 emissions is at or above the 75th percentile). The results in Table 4 show that the baseline results are robust to removing the most polluting sectors from the estimation.

[9] The nominal values are deflated with each country-sectors value added deflators.

6. Including quadratic time trends instead of linear time trends

Substituting the linear trends for quadratic trends allows for non-linear trends at the national level or differences in the level of environmental policies. Substituting the linear trends for quadratic trends does not change the baseline results.

7. Investigating the effect of non-environmental policies

Other policies can facilitate firms' adjustment to changes in the business environment, including those caused by more stringent environmental policies. Policies that support business dynamism can encourage less polluting firms to gain market shares from more polluting ones, including through entry and exit; and pro-competition regulation can also encourage firms to be more efficient and able to adapt to price signals (Égert, 2016[23]). To investigate whether less stringent product market regulation is associated with a larger impact of the EPS, the baseline regression (1) is expanded to include the OECD's country-based Product Market Regulation (PMR) indicator (Nicoletti and Scarpetta, 2005[19]).[10] The PMR values are first averaged for the 2003, 2008 and 2013 vintages to overlap with the baseline sample. Second, a dummy is defined that indicates if a country in the sample has a PMR value below the sample median, and zero otherwise.[11] These dummies are interacted with the other explanatory variables in the baseline regression (1). Results are statistically inconclusive. The point estimates suggest that emissions decline more in countries with less stringent product market regulations, especially in sectors with higher fossil fuel intensities (Table 4). However, the point estimate for countries with less stringent product market regulation is not statistically different at 10% confidence level from that for countries with more stringent product market regulation.

[10] The PMR is an economy-wide indicator that vary from zero to six, where zero is the lowest level of PMR (least stringent regulation) and six the highest (most stringent regulation). The structure of the PMR is composed of two major regulatory areas: 1) state involvement in the economy and 2) barriers to entry and expansion affecting domestic and foreign firms. A lower value generally means that markets are more competitive, and a higher value that markets are less competitive.

[11] A lower PMR generally means that markets are more competitive, and a higher value that markets are less so.

Estimated emission reduction potential across countries

The results presented above show heterogeneous effects of the EPS across OECD country-sectors. The baseline estimates (Table 2 and Figure 2) combined with the data on each country-sector fossil fuel intensity and share in CO_2 emissions allows for quantifying countries' "emissions reduction potential" (ERP), associated with increasing the environmental policy stringency to a certain benchmark, and the sectors and fuels' contribution to it.

The estimated country-sector specific impact of a one unit increases in the EPS over 10 years is denoted as γ_{cs} as shown in (2). This is equal to the sum of the direct effects (β_k) and the interaction terms (θ_k) times the respective fossil fuel intensities ($\bar{S}_{cs}$).[12]

$$\gamma_{cs} = \sum_{k=0}^{10} \beta_k + \sum_{k=0}^{10} (\theta_k \times \bar{S}_{cs}) \qquad (2)$$

The ERP for country c is the cumulative reduction in emissions over a ten-year period associated with the increase in the EPS index to the benchmark. It is obtained as the weighted average across sectors of γ_{cs} (with weights w_{cs} set to each sector s share of CO_2 emissions in each country c in 2016) multiplied by the change in the EPS index (ΔEPS_c).[13]

$$ERP_c = \Delta EPS_c \times \sum_{s \in S} (\gamma_{cs} \times w_{cs}) \qquad (3)$$

Cross-country analysis

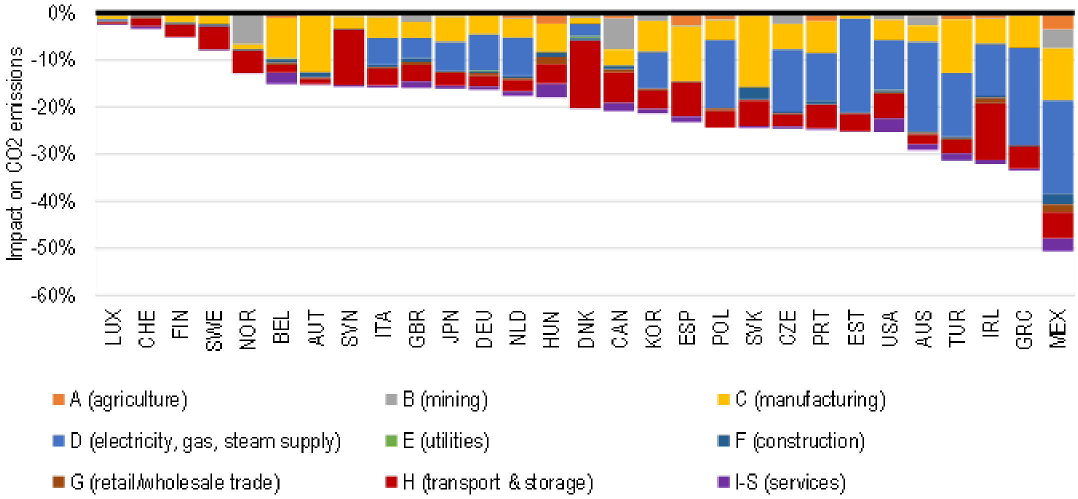
To illustrate the magnitude of the effects, Figure 4 shows the ERP from a change in the EPS to the benchmark country with highest EPS in 2020 i.e., the 2020 environmental policy stringency frontier (France). That is, each country is assumed to move toward the frontier level of the EPS and is assumed to remain on the new EPS level going forward. The EPS starting value for each country is that of 2020. Figure 4 panel A shows the estimated impacts at the country level with their broad-sector contributions (1-digit ISIC Rev.4). The five countries with the greatest ERP are Mexico, Greece, Ireland, Türkiye and Australia, mostly driven by their low EPS in 2020. However, while there is a tight correlation between size of the changes in the EPS and ERP, this is not the only determinant of the ERP. For example, Greece, Ireland and Türkiye all have a smaller change in the EPS than Slovakia, Spain, Portugal and Hungary, yet have larger ERP. This is due to the combination of their fossil fuel intensity and share of CO_2 emissions across sectors.

[12] Note that that $\bar{S}_{cs}$ comprises of different fossil fuels. The fuels considered are gasoline, diesel, fuel oil, natural gas, coal and other petrol's and gases. This means that the specific impact γ_{cs} can be further decomposed into each of those fossil fuels by considering the various fuels contribution to $\bar{S}_{cs}$ in a country-sector.

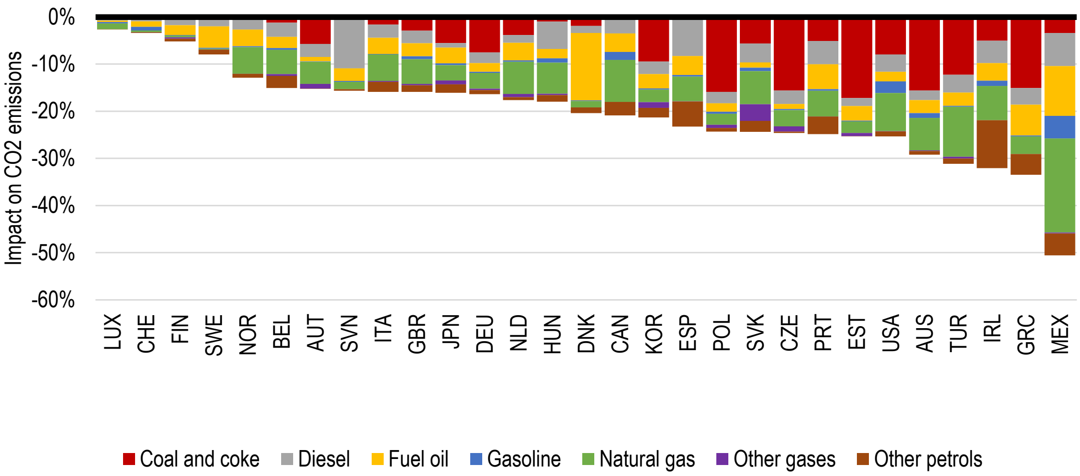
[13] Sectoral impacts are only considered in the ERP if they are statistically significant at the 10%-level.

Figure 4. Emission reduction potential from moving towards the 2020 environmental policy stringency frontier

Panel A: Sector contribution



Panel B: Fuels contribution



Note: % cumulative impact and percentage point contributions by sectors/fuels after 10 years. The ERP is determined, as shown in equation (3), by: 1) distance of the EPS to the best performer in 2020 (France); 2) the fossil fuel intensity of sectors; 3) the sectors share in total CO_2 emissions.
Source: OECD calculations.

Across countries, the contribution of sectors to the ERP is generally the highest in the energy supply sector, manufacturing, and transport. However, there are large differences across countries: for example, in Mexico, Greece and Türkiye, much of the emissions reduction potential is in the energy supply sector. For other countries like Slovakia, Austria or Belgium, the emissions reduction potential is primarily in manufacturing and in others, such as Denmark, Slovenia and Sweden, the emissions reduction potential is mostly attributable the transport sector.

We can also decompose the emissions reduction potential by fuel types (Figure 4 panel B).[14] This exercise suggest that emission reductions can mainly be achieved by curtailing the use of coal, reflecting its high

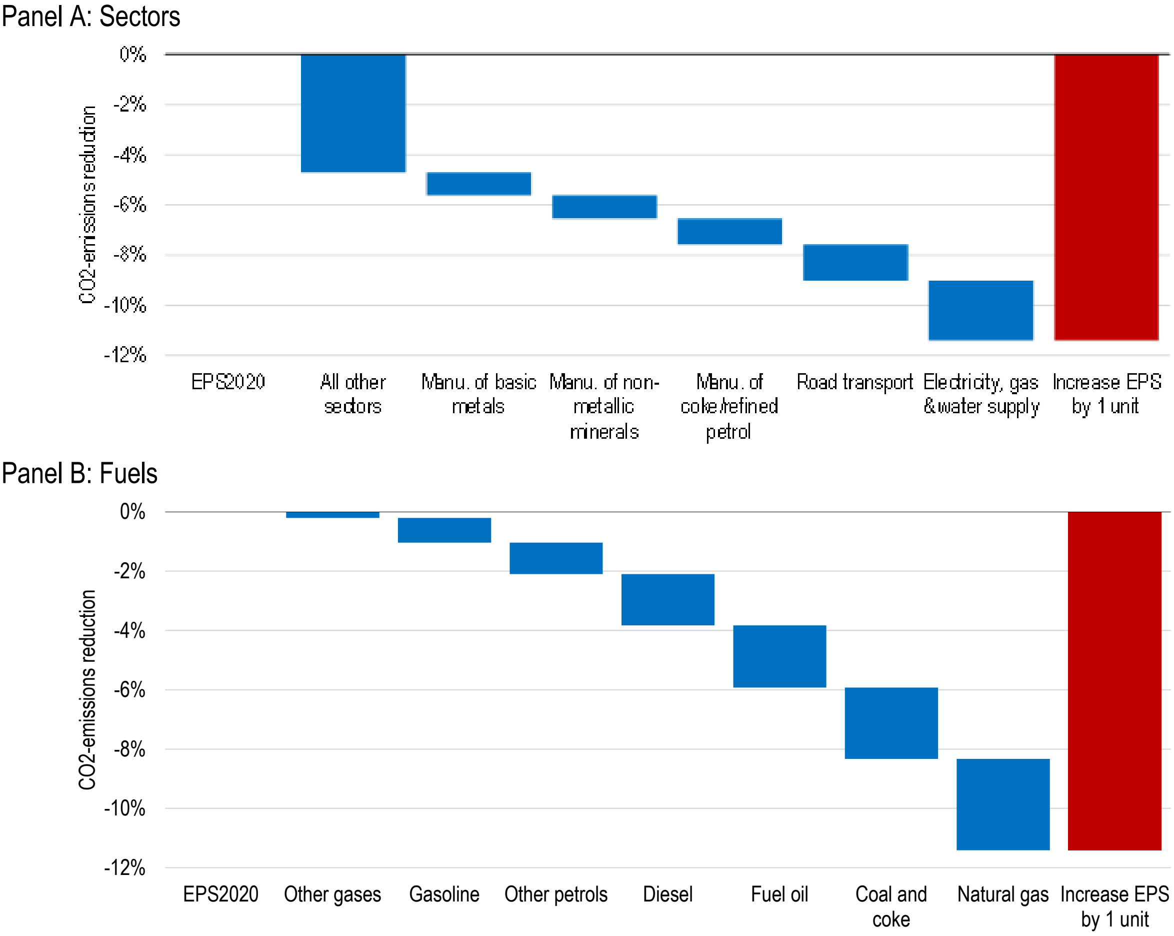
[14] This is achieved by computing each sector-level reduction potential, $\Delta EPS_c \times \gamma_{cs}$, applying it to each fuel type employed in the sector and then aggregating the effect by fuel type at the country level. One limitation of this approach is that is assumes a fixed fuel mix within the sector.

carbon content. There are however marked differences across countries in terms of the emission reduction potential by fuels. Natural gas is the largest contributor to the ERP of Mexico. In Türkiye both coal and natural gas play a large role. In Greece phasing out coal would contribute significantly to reducing carbon emissions. In these countries, the energy sector has a large scope to reduce emissions due to a high reliance on fossil fuels. Diesel use (in transport) is instead the largest contributor to ERP of Slovenia, while fuel oils, mainly from maritime transport sectors, have a large role in Denmark and Sweden.

Country-sector analysis

In this sub-section we present more detailed sector-by-sector analysis within countries building on the ERP shown above. For illustration, here we focus on the OECD average (Figure 5), while Annex 2 presents country specific figures. The analysis is based on a more detailed sectoral classification than what is used in Figure 3 (2-digit ISIC Rev.4 instead of 1-digit). It focusses on the top five sectors and all other sectors (or alternatively fossil fuels). To facilitate comparison across countries, the ERP is computed considering a one-point increase in EPS.

Figure 5. Sectors' emission reduction potential for the OECD average



Note: Notes: The figure shows the emission reduction potential associated with a one-unit increase in the EPS for the OECD average after 10 or more years. The patterned bars show the contribution of each sector (fuel) to the total impact (solid bars) on CO_2 emissions, derived from the estimation of (1). In panel A, the x-axis shows the sectors. In panel B the x-axis shows the fuels.
Source: OECD calculations

As seen in Figure 5 panel A, for the OECD average the ERP is greatest in the energy sector, road transport and manufacture of coke/refined petroleum products, manufacture of metals and non-metallic metal products. Figure 5 panel B further shows that reducing the use of natural gas, and coal and coke has the largest scope to lower emissions. Fuel oils, often used in maritime transport, and diesel used in road transport, also show a large potential contribution to reduce emissions.

6 Illustrative forward-looking emission reduction scenarios

The analysis below provides forward-looking policy scenarios up to 2030 based on the regression estimates presented above. The computations rely on the full set of dynamic impacts of the EPS over ten years ($k = 0,1,2, \dots ,10$) on CO_2 emissions, as well as the aggregations outlined above.[15]

The analysis considers three possible illustrative scenarios with increasing ambition:

i. an acceleration in the OECD-average EPS index compared with recent trends; in this scenario the OECD-average EPS index returns to the 2000-10 growth rate.

- an even more ambitious policy path where OECD governments significantly tighten environmental policies to raise the OECD-average EPS to the level it would have reached in 2030 if it had continued in the 2000-10 trend.
- this scenario is based on the IEA's Net Zero Emission (NZE) scenario, which envisages global energy-related emissions to decrease by 30% between 2020 and 2030, before reaching net zero in 2050 (IEA, 2021[1]). This scenario yields the increase in environmental policy stringency needed to reduce CO_2 emissions by 30% by 2030 (relative to 2020 levels).

The results show that the two hypothetical paths based on historical changes in the EPS (i and ii) would not meet the target of reducing CO_2 emissions by 30% by 2030 (Figure 6). Only scenario (iii) (purple diamonds) is consistent with this target, which would imply policy changes that are considerably more ambitious than what has been the case in the past.

The results may seem to be dispiriting but warrant some considerations. First, the scenarios are not predictions but rather illustrations of the potential impact of EPS changes on emission reductions. These scenarios do not incorporate any technological improvements that are likely to lower the cost of low-carbon technologies and energy sources. To the extent that costs of clean technologies and production practices continue to decline (possibly at an increasing pace), the scenarios above may underestimate the emission reductions further strengthening of environmental policies may achieve. These results echo recent empirical evidence showing that policies to markedly decrease abatement costs need to be combined with steady increases in carbon prices to put emissions on a downward path consistent with meeting the net-zero targets (D'Arcangelo et al., 2022[10]).

Second, the exercise assumes that the EPS has an exhaustive coverage of future environmental policies. It is not clear whether future policies and their inclusion in the index would change the estimated impact of the EPS index on emissions. To the extent that policies are likely to first target sectors in which emission reductions are easier to achieve (i.e., low abatement costs), future policies may reduce emissions less rapidly than past policies as they may target sectors with hard-to-abate emissions. At the same time, policies could reinforce each other, so that future policies may reduce emissions more rapidly than what

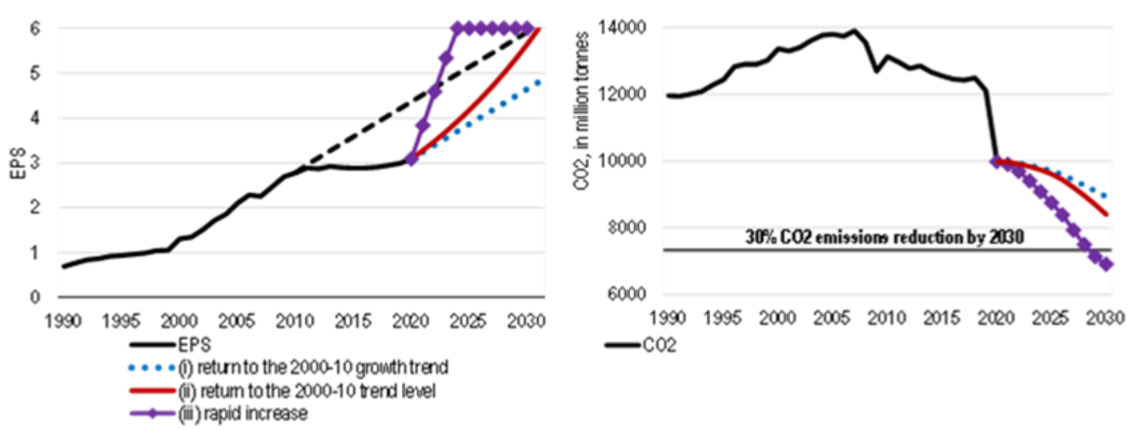
[15] The cumulative impact is not statistically significant at the 5-year and 8-year horizon at the 10% statistical significance level for some countries. The impacts are linearly interpolated for those two horizons by taking the average of the preceding and following values. Including the statistically insignificant impacts for these two horizons do not change the overall picture.

experienced in the past. Moreover, there may be non-linear threshold effects in the relationship between environmental policies and emissions. For example, if after reaching a specific level of carbon pricing, clean technologies become more competitive compared to fossil fuel technologies, the adoption of low-carbon alternatives may be faster than what has been observed at low levels of carbon pricing, accelerating the reduction in emissions. Finally, fossil fuel intensities and the contribution of sectors to national CO_2 emissions could change over time, which could alter the estimated effects.

Figure 6. Drastic and rapid increase in environmental policy stringency is necessary to lower emissions

Panel A: Paths for the EPS

Panel B: CO_2 paths



Note: The lines in panel A show illustrative paths of the OECD average EPS and the same-coloured lines in panel B show the CO_2 impact associated with each illustrative path of the EPS. These estimates are obtained from using the full set of dynamic impact of the EPS (k=0,1,2,…,10) and its interaction with the fossil fuel intensities, for each year's change in the EPS implied by the trends. The horizontal line in panel B shows the 30% CO_2 reduction by 2030 compared to 2020 (IPCC, 2021[20]; IEA, 2022[21]).
Source: OECD calculations.

Conclusions and policy implications

This paper provides novel results on the estimated effect of changes in environmental policy stringency on emissions, covering more than 50 sectors in 30 OECD countries from 2000–14. The results show that stricter environmental policies can significantly reduce emissions. The impact of stricter environmental policies varies by fossil fuel intensity of sectors. A one unit increase in the EPS reduces emissions in sectors with median (high) fossil fuel intensity by 4% (11%) in the short run and 12% (19%) in the longer term.

The empirical results can be used to characterise countries' emission reduction potential (ERP) through illustrative scenarios, in which countries increase the stringency of environmental policy towards the 2020 environmental policy stringency frontier. The ERP varies across countries. Mexico, Greece and Ireland have the largest scope to reduce emissions due to a combination of factors including distance from the environmental policy stringency frontier, and the sectoral and energy-use mix. Energy supply, manufacturing and transport are the sectors contributing the most to the ERP on average across OECD countries. Across fuels, curtailing the use of coal, coke and crude and natural gas, followed by fuel oil, diesel and gasoline, have the largest potential contribution to reduce total emissions.

The analysis can be useful to inform policymaking and provide guidance on how ambitious environmental policies need to become over time to achieve emission reduction targets. Reaching net zero emissions by 2050 and limiting warming to 1.5℃, requires rapid increase in the stringency of environmental policy. The analysis in this paper indicates that environmental policy stringency will need to increase significantly and more rapidly than what has been observed in the past on average across OECD countries.

Future extensions of the empirical framework could be used to investigate several questions relevant for policymakers, such as the interaction of economic and environmental policies in more detail and explore how environmental policies may shift emissions to other jurisdictions ("leakage") through global supply chains. Furthermore, the role of policy interactions is limited in this paper by employing a unique composite index of stringency. With the increased availability of more granular and comparable data on environmental policies, further work could investigate how they interact, both generating synergies and trade-offs.

A note of caution remains. Empirical studies make use of historical correlations. While this type of analyses provides valuable insights based on past data, the increases in environmental policy stringency needed to meet carbon neutrality targets may lie far outside of observed past changes. Low-hanging fruits of energy savings and resource reallocation might have already been exploited and further emission reductions might require either drastic increase environmental policy stringency or radical technology changes or both. At the same time, non-linearities in technological advancements along with well-designed mitigation policy mixes addressing multiple market failures could drastically reduce abatement costs and increase the effectiveness of mitigation policies. All this adds to the uncertainty about the possible effects of future policy changes. Another limitation of the study is that it is limited to CO_2 emissions as comprehensive country-sector data for other important greenhouse gas emissions does not currently exist. The limitation of the OECD EPS index comes from the set of policies falling outside its coverage as it captures only 13 environmental policy instruments.

Continued empirical evaluation of environmental policies – both within countries and cross-country studies – is necessary to help governments to design and implement policies yielding emission reduction and economic growth. For example, increasing the stringency of policies that complement those covered by the EPS may help reaching the net zero targets faster than implied by the illustrative forward-looking policy scenarios considered in this paper. Future work may need to consider a broader set of climate policies, such as the recently developed Climate Actions and Policies Measurement Framework (Nachtigall et al., 2022[24]).

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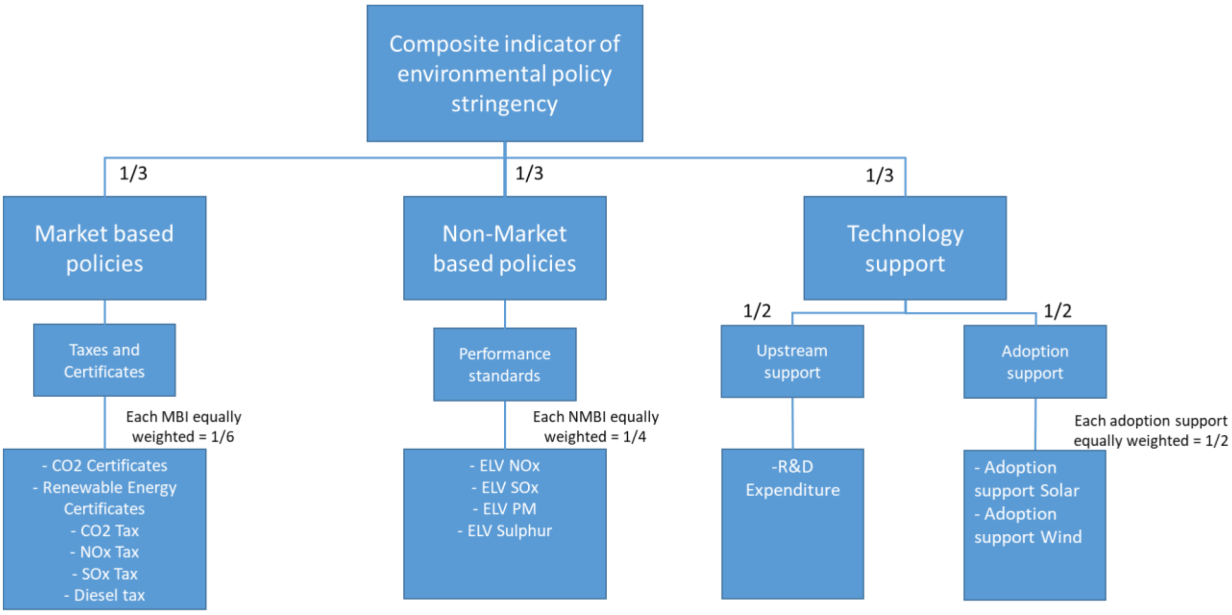
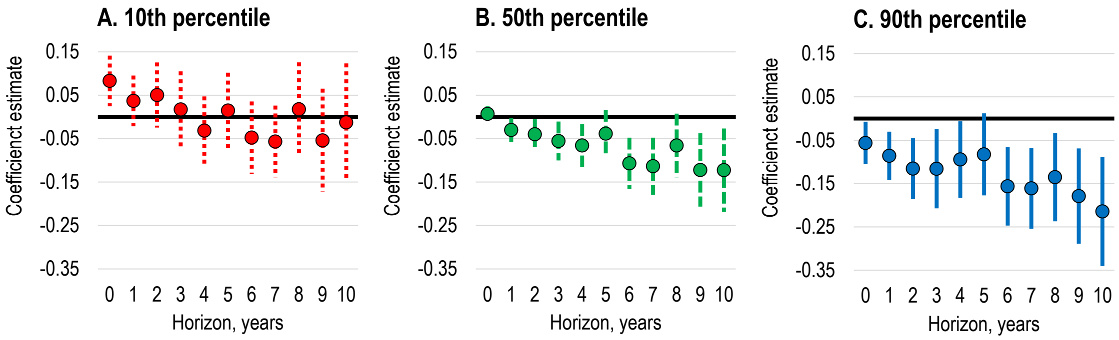
Annex A. : Additional tables and figures

Figure A.1. The structure of Environmental Policy Stringency indicator (EPS)



Source: Kruse et al. (2022[16])

Figure A.2. Cumulative impacts of the EPS for different fossil fuel intensities



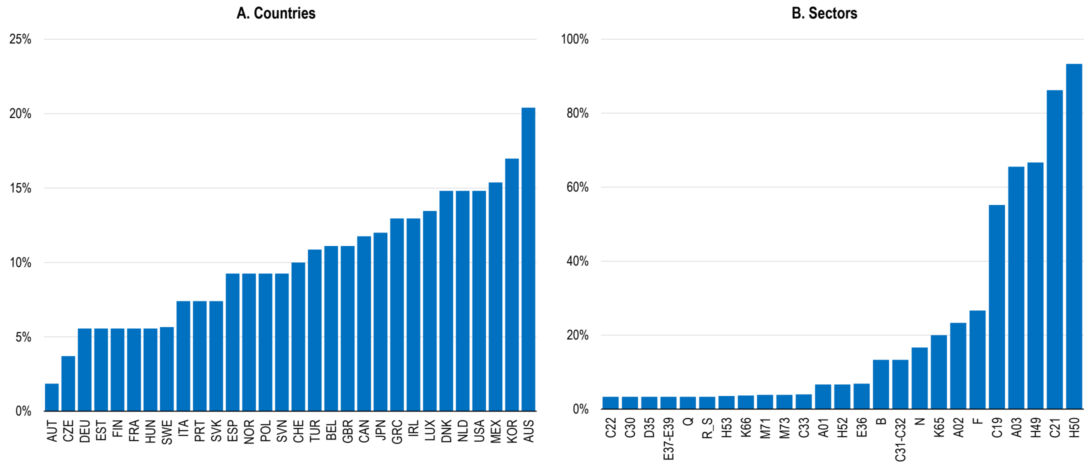
Notes: The lines are 90% confidence intervals and the dots are point estimates. Standard errors are clustered at the country-sector level. The figures report the cumulative effect across the years marked on the horizontal axis. The 10th percentile is 0.29 and 90th percentile is 0.90.
Source: OECD calculations.

Table A.1. Regression results for employment

	$ln(EMPE)_{cs,t}$
$EPS_{c,t}$	0.019* (0.009)
$EPS_{c,t} \times \bar{S}_{cs}$	-0.029* (0.015)
Linear combinations of parameter estimate associated with a unitary increase in EPS Upon impact, after 2 and 10 years for the median fossil fuel intensity	
At median fossil fuel intensity, immediate impact	0.001 (0.003)
At median fossil fuel intensity, after 2 years	0.004 (0.005)
At median fossil fuel intensity, after 10 years	0.019 (0.014)
Controls	
Log real gross output	0.452*** (0.025)
Log real GDP	0.362*** (0.052)
Log real capital stock	0.151*** (0.026)
Log real wages/hour	-0.288*** (0.029)
Log real value added/hour	-0.392*** (0.034)
Linear time-trends	Country, sector
Fixed effects	Country-sector and year
Clustered standard errors	Country-sector
Observations:	22,180
Adjusted R^2 / Within- R^2	0.963 / 0.179

Notes: *, ** and *** denotes statistical significance at 10%, 5% and 1%. The median fossil fuel intensity ($\bar{S}_{cs}$) is computed across sectors in the sample and is 0.62. The first two rows of the table reports the contemporaneous effects (k=0). The controls are the linear combinations of t and t-1. The cumulative effect for 2 and 10 years are computed as linear combinations of the parameter estimates for the EPS and its interaction with the fossil fuel intensity for the relevant horizons (i.e., $\beta_0 + \beta_1 + \beta_2 + (\theta_0 + \theta_1 + \theta_2)\bar{S}_{cs}$ for the impact after two years).
Source: OECD calculations.

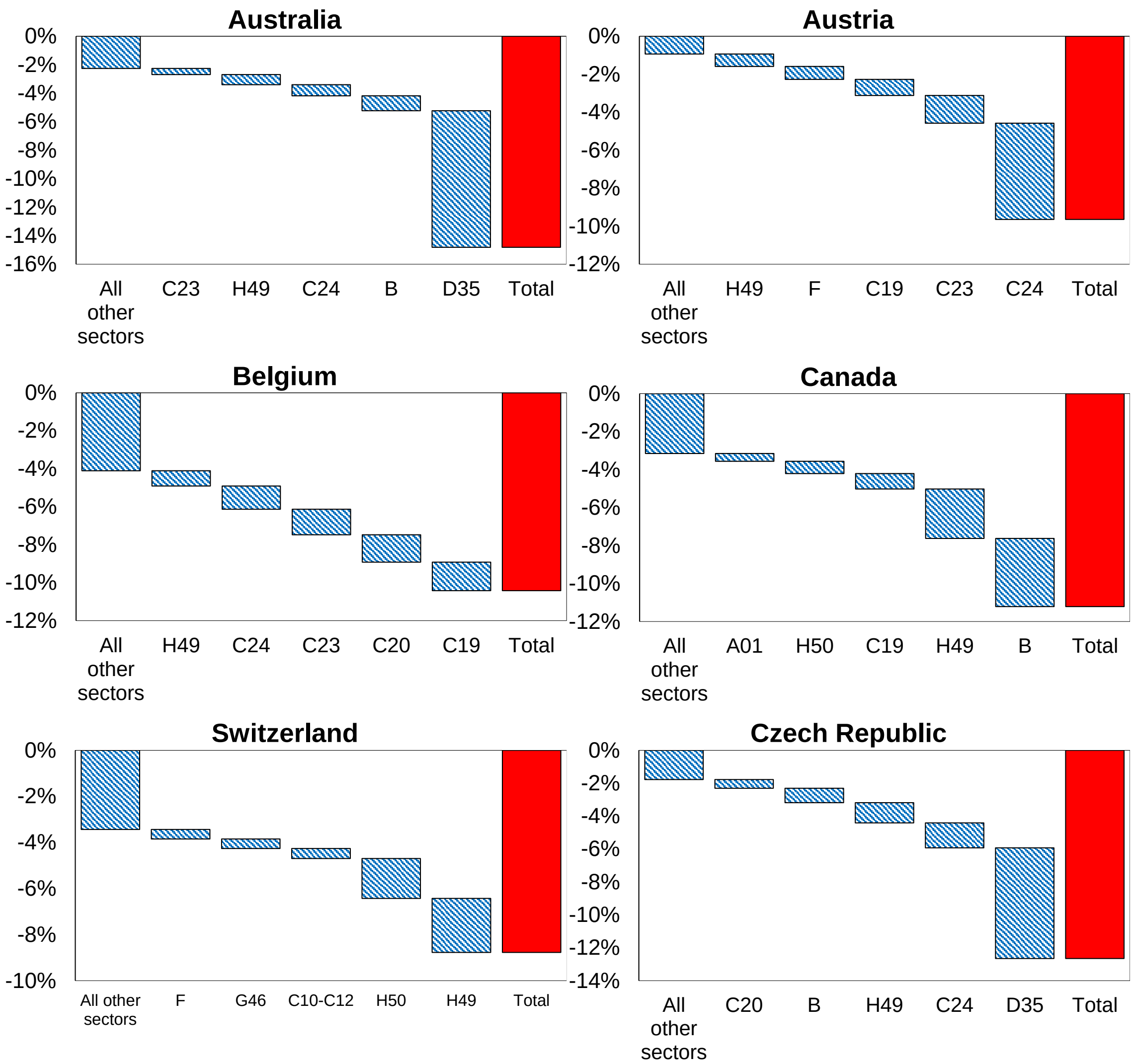
Figure A.3. Share of observations at or above the 90th percentile of fossil fuel intensities across countries and sectors

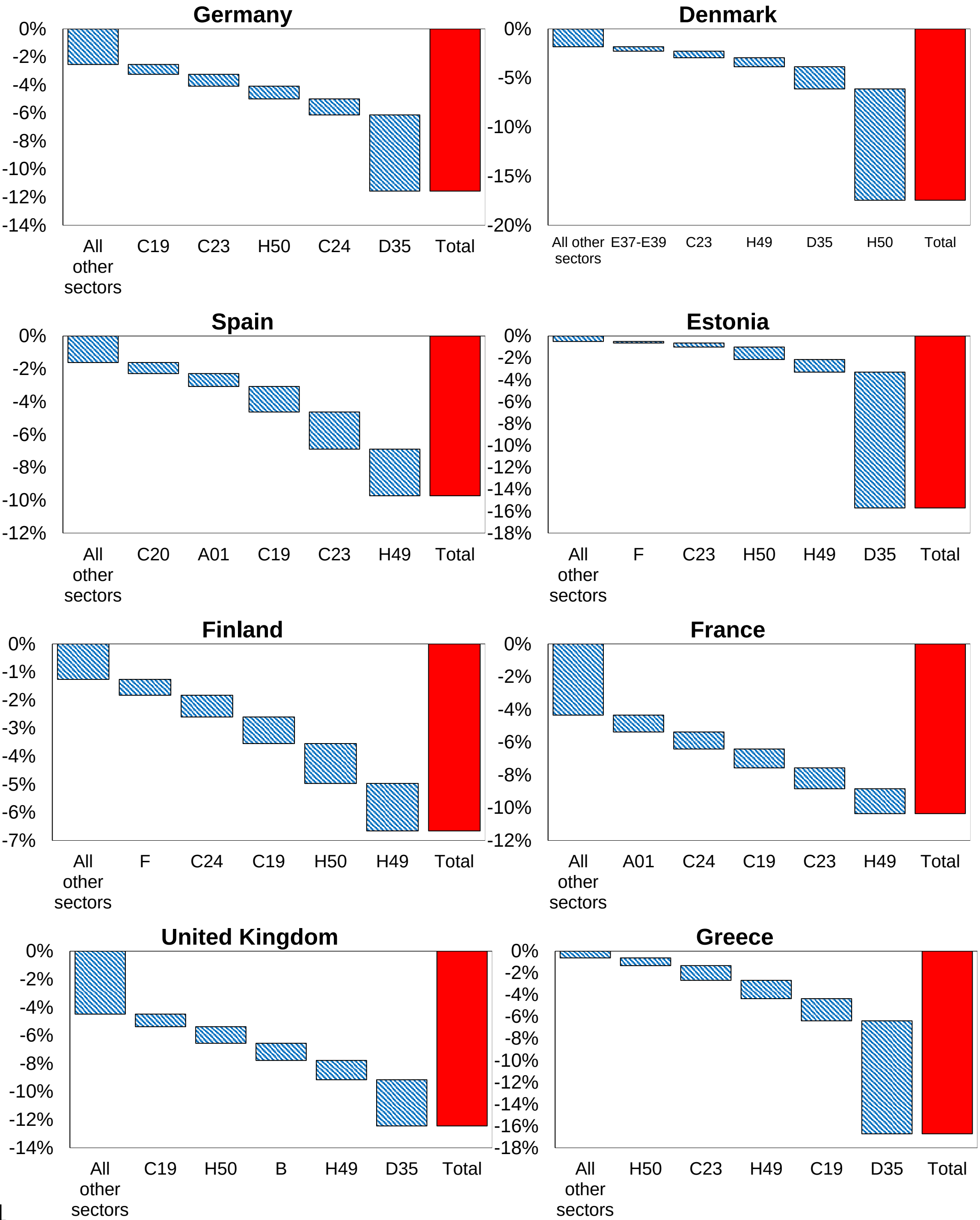


Notes: Figure A (B) plot the share of sectors (countries) in a country (sector) that are at or above the 90th percentile of fossil fuel intensity.
Source: OECD calculations.

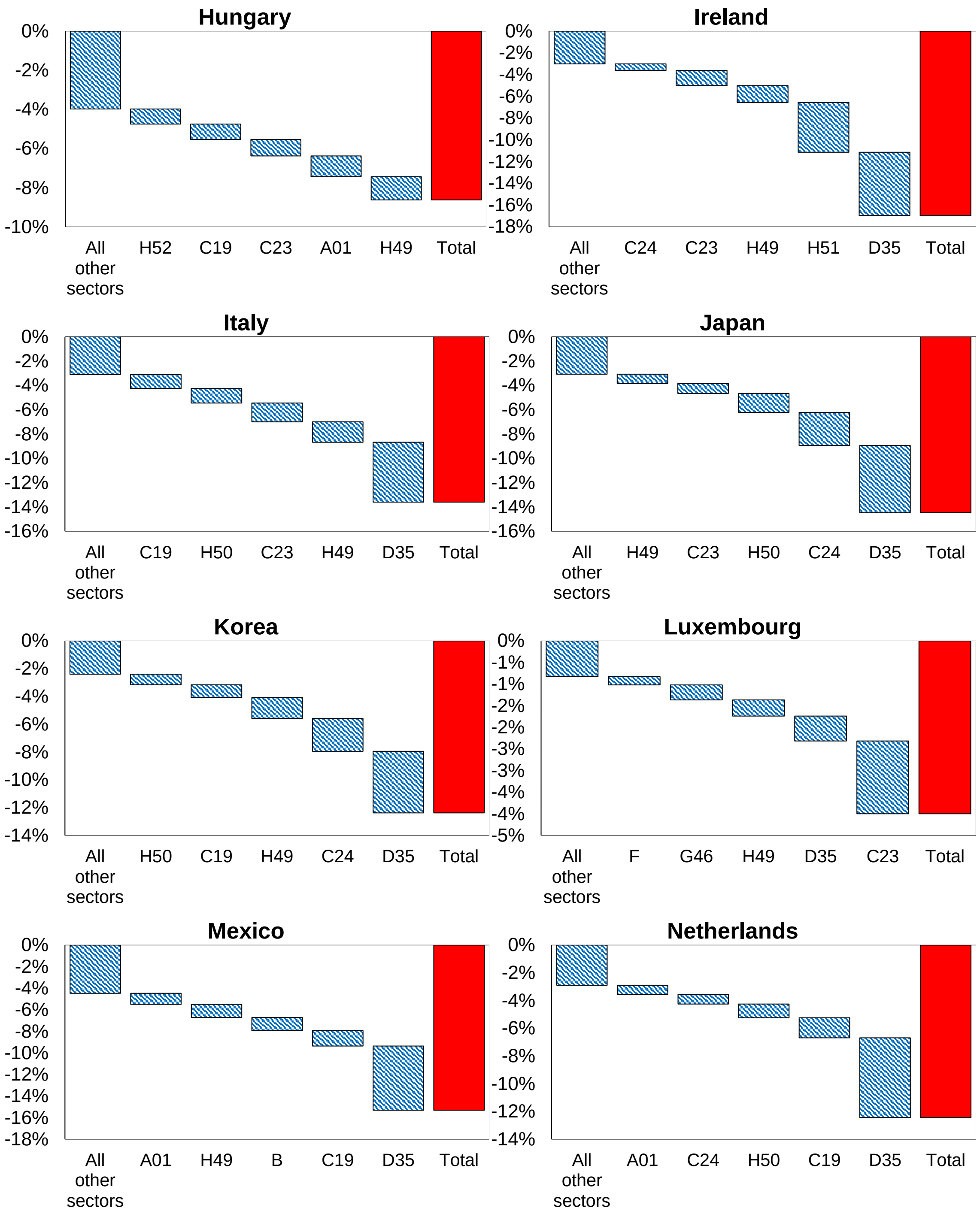
Annex B. : Within country results

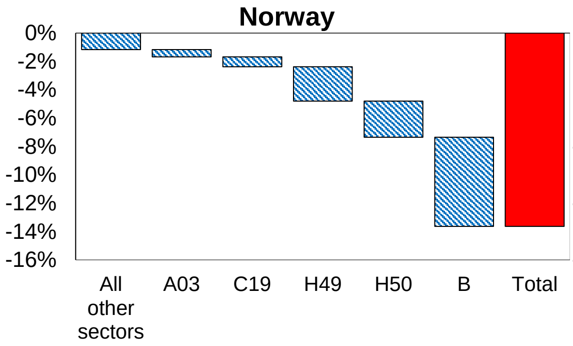
Figure B.1. Impacts of one unit increase in the EPS on the top 5 emitting sectors and all others

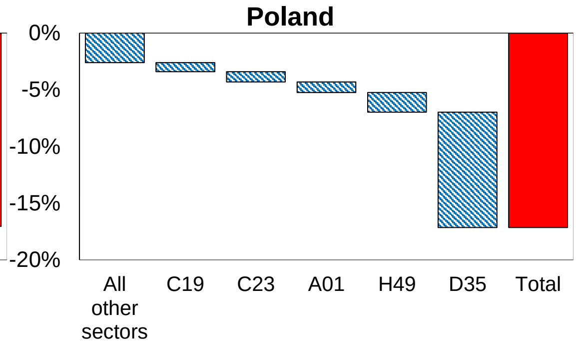


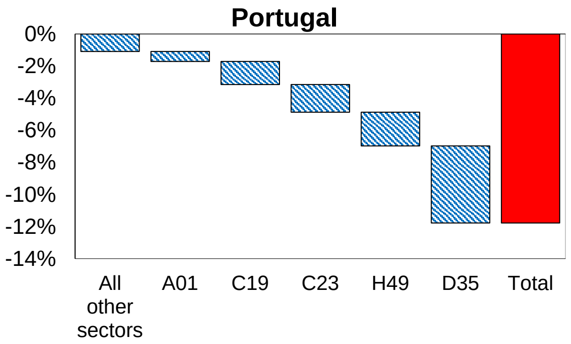

Germany
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
All other sectors
C19
C23
H50
C24
D35
Total
Denmark
0%
-5%
-10%
-15%
-20%
All other sectors
E37-E39
C23
H49
D35
H50
Total
Spain
0%
-2%
-4%
-6%
-8%
-10%
-12%
All other sectors
C20
A01
C19
C23
H49
Total
Estonia
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
-18%
All other sectors
F
C23
H50
H49
D35
Total
Finland
0%
-1%
-2%
-3%
-4%
-5%
-6%
-7%
All other sectors
F
C24
C19
H50
H49
Total
France
0%
-2%
-4%
-6%
-8%
-10%
-12%
All other sectors
A01
C24
C19
C23
H49
Total
United Kingdom
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
All other sectors
C19
H50
B
H49
D35
Total
Greece
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
-18%
All other sectors
H50
C23
H49
C19
D35
Total

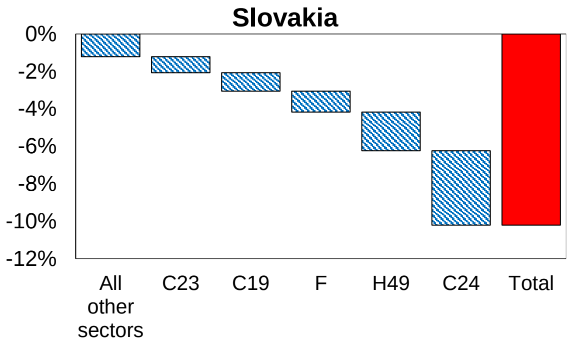
1

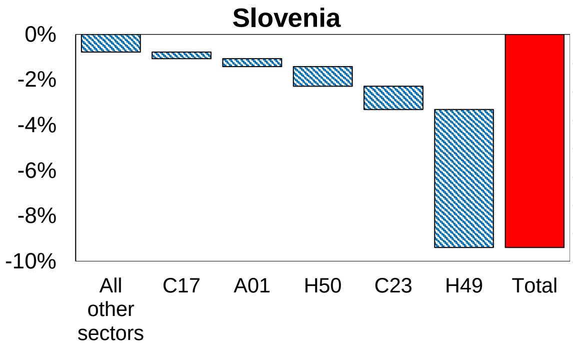

Hungary
0%
-2%
-4%
-6%
-8%
-10%
All other sectors
H52
C19
C23
A01
H49
Total
Ireland
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
-18%
All other sectors
C24
C23
H49
H51
D35
Total
Italy
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
All other sectors
C19
H50
C23
H49
D35
Total
Japan
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
All other sectors
H49
C23
H50
C24
D35
Total
Korea
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
All other sectors
H50
C19
H49
C24
D35
Total
Luxembourg
0%
-1%
-1%
-2%
-2%
-3%
-3%
-4%
-4%
-5%
All other sectors
F
G46
H49
D35
C23
Total
Mexico
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
-18%
All other sectors
A01
H49
B
C19
D35
Total
Netherlands
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
All other sectors
A01
C24
H50
C19
D35
Total

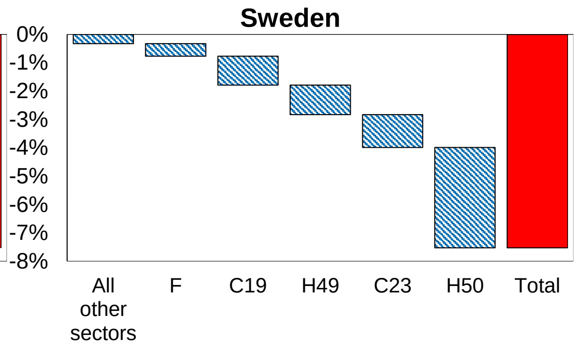

Norway
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
All other sectors
A03
C19
H49
H50
B
Total

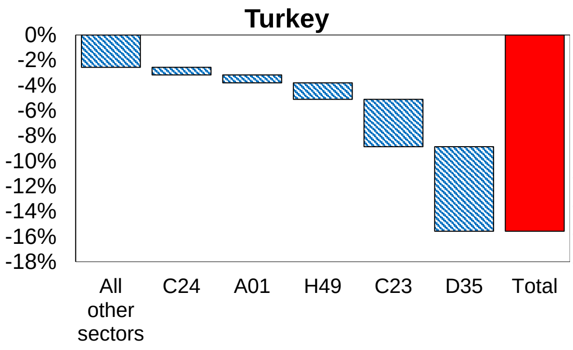

Poland
0%
-5%
-10%
-15%
-20%
All other sectors
C19
C23
A01
H49
D35
Total

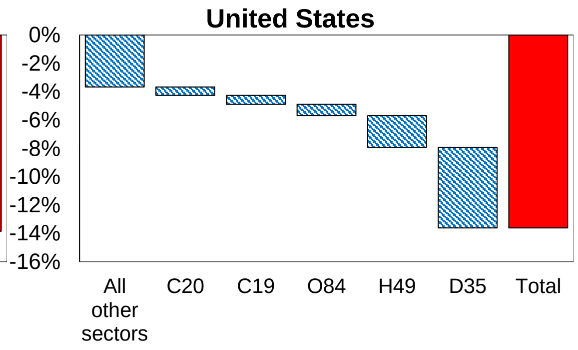

Portugal
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
All other sectors
A01
C19
C23
H49
D35
Total


Slovakia
0%
-2%
-4%
-6%
-8%
-10%
-12%
All other sectors
C23
C19
F
H49
C24
Total


Slovenia
0%
-2%
-4%
-6%
-8%
-10%
All other sectors
C17
A01
H50
C23
H49
Total


Sweden
0%
-1%
-2%
-3%
-4%
-5%
-6%
-7%
-8%
All other sectors
F
C19
H49
C23
H50
Total


Turkey
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
-18%
All other sectors
C24
A01
H49
C23
D35
Total


United States
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
All other sectors
C20
C19
O84
H49
D35
Total

Notes: The dashed bars show the impact on emissions reduction from each sector and the solid bar the total effect. The sector abbreviations are from ISIC Rev 4. A01=Crop and animal production, hunting and related service activities, A02= Forestry and logging. A03= Fishing and aquaculture, B= Mining and quarrying, C10-C12= Manufacture of food products, beverages and tobacco, C13-C15=Manufacture of textiles, apparel and leather and related products, C16=Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials, C17=Manufacture of paper and paper products, C18=Printing and reproduction of recorded media, C19=Manufacture of coke and refined petroleum products, C20=Manufacture of chemicals and chemical products, C21=Manufacture of pharmaceuticals, medicinal chemical and botanical products, C22=Manufacture of rubber and plastics product, C23=Manufacture of other non-metallic mineral products, C24=Manufacture of basic metals, C25=Manufacture of fabricated metal products, except machinery and equipment, C26=Manufacture of computer, electronic and optical products, C27=Manufacture of electrical equipment, C28=Manufacture of machinery and equipment n.e.c., C29=Manufacture of motor vehicles, trailers and semi-trailers, C30=Manufacture of other transport equipment, C31-C32=Manufacture of furniture and other manufacturing, C33=Repair and installation of machinery and equipment, D35=Electricity, gas, steam and air conditioning supply, E36=Water collection, treatment and supply, E37-E39=Sewage, Waste collection, treatment and disposal activities; materials recovery. Remediation activities and other waste management services, F=Construction, G45=Wholesale and retail trade and repair of motor vehicles and motorcycles, G46=Wholesale trade, except of motor vehicles and motorcycles, G47=Retail trade, except of motor vehicles and motorcycles, H49=Land transport and transport via pipelines, H50=Water transport, H51=Air transport, H52=Warehousing and support activities for transportation H53=Postal and courier activities, I=Accommodation and food service activities, J58=Publishing activities, J59-J60=Motion picture, video and television programme production, sound recording and music publishing activities. Programming and broadcasting activities, J61=Telecommunications, J62-J63=Computer programming, consultancy and related activities. Information service activities, K64=Financial service activities, except insurance and pension funding, K65=Insurance, reinsurance and pension funding, except compulsory social security, K66=Activities auxiliary to financial service and insurance activities, L68=Real estate activities, M69-M70=Legal and accounting activities. Activities of head offices; management consultancy activities, M71=Architectural and engineering activities; technical testing and analysis, M72=Scientific research and development, M73=Advertising and market research, M74-M75=Other professional, scientific and technical activities. Veterinary activities, N=Administrative and support service activities, O84= Public administration and defence; compulsory social security, P85=Education, Q=Human health and social work activities, R_S=Arts, entertainment and recreation. Other service activities.
Source: OECD calculations.