The effects of market integration on pollution: an analysis of EU enlargements

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Abstract

We study the effects of market integration on manufacturing emission intensities of CO_2, SO_x, and NO_x. For this, we analyze the 2004 and 2007 EU enlargements in a sectoral panel with data on almost all EU member states from 1995 to 2015. We pay close attention to relevant channels of trade, regulation, and efficiency. Overall, the enlargements have resulted in a reduction of emission intensities in new member states: new regulations, which accession countries needed to adopt, have lowered pollution intensities strongly; induced improvements in productivity have further reduced them; and trade integration into the EU has had insignificant effects on emission intensities. We also do not find evidence of within-EU pollution haven effects and thus of leakage from old to new member states. For old members, trade integration, if anything, increased emission intensities, but productivity improvements have also contributed to cleaner manufacturing sectors here.

JEL codes: F15, F64, Q56
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Declarations of interest: none

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1 Introduction

What is the effect of market integration and trade liberalization on emission intensities in manufacturing sectors, and will it lead to pollution haven effects within these integrating markets? This study uses the quasi-natural experiment of the EU enlargement process of the 2000s to analyze these questions.

The literature on the interplay of trade and the environment has started with the analysis of the NAFTA trade liberalization in the 1990s (Grossman & Krueger, 1991). It is thus surprising that little effort has been made to analyze questions of trade and the environment in the context of one of the largest liberalization projects of the 2000s: the EU enlargements in 2004 and 2007. During these, thirteen Eastern European countries joined the EU. This paper studies whether these enlargements have led to changes in pollution and emission intensities, in both new and old EU member states.

We focus on the manufacturing industry, as we want to abstain from the very different pathways in other industries, like services or agriculture (see, for example, Bernard and Jones (1996) for an early remark on these differences). More specifically, we study changes within manufacturing in great detail by analysing 2-digit manufacturing industries; for convenience, we will call them "sectors" from this point onwards. We argue that enlargement-induced changes in production might have been an important driver of compositional changes within these sectors, thereby affecting their respective emission intensities. We both theoretically and empirically disentangle such effects from other effects that the enlargement might have had on the emission intensity in these sectors. In our empirical analysis, we take explicit care of potential heterogeneities between these sectors, which are often implicitly ignored, but which are very relevant for economic policy making and whose importance has long been highlighted in environmental studies (see, for example, Ederington et al. (2005)).

Our estimation is based on a three-dimensional panel with sectoral data on almost all EU member states from 1995 to 2015. These data contain information on three different pollutants: carbon dioxide (CO_2), sulphur oxides (SO_x) and nitrogen oxides (NO_x), whose emission intensities are defined per unit of sectoral value added. Analysing both a greenhouse gas (CO_2) as well as (local) air pollutants is important, as regulation has historically been very different for the two. Greenhouse gases pose an international externality but have few local effects, whereas air pollutants have more local(ized) effects and have thus been regulated relatively intensively for a longer time already. In our analysis, we apply panel cointegration techniques, highlighting that long-run results are most crucial for both global warming and air pollution.

We consider two channels of an "enlargement-induced composition effect" that predict a relocation of emissions, based on differences in comparative advantage within the EU (adopted from the trade-induced composition effect in Antweiler et al., 2001). The first of these channels, the within-EU pollution haven hypothesis (PHH), predicts a relocation of pollution-intensive production to new member states, based on their comparative advantage associated with lower environmental regulation. The second channel, postulated by the factor endowment hypothesis (FEH), implies a relocation of capital, and with it of related emissions, towards already capital-abundant sectors.

When studying our entire panel, we find no support for the PHH and thus for within-EU leakage. We find a statistically significant FEH effect, although mostly among new member states. So manufacturing sectors that were already capital-abundant increased their emission intensity compared to less capital-abundant ones due to further integration. Still, Trade integration overall had a statistically insignificant effect for the median observation among the new members. For old members the effect of increasing trade integration is also statistically insignificant, but points towards an increase in emission intensities.

Additional potential effects come from a shift in regulation. New member states had to fulfil the requirements outlined in the environmental acquise, adapt regulations on air pollution, and join institutions like the European Carbon Trading System (ETS) upon joining the EU. We find significant support that both becoming a candidate country and accessing the EU had a strong emission-decreasing effect for both air pollutants, and, with a smaller magnitude, also for CO_2. This indicates that EU regulation for air pollutants has been more successful than the one for greenhouse gases, and especially for SO_x our results explain a large share of the total reduction in emission intensities over the observed period.

Second-round effects of the enlargement through productivity enhancements have further reduced emission intensities in old and new member states. Enlargement-induced increases in national income have had an overall insignificant effect.

We thus conclude that the overall effect of the enlargement on emission intensities in new member states manufacturing sectors has been beneficial: the trade integration effect has been statistically and economically insignificant, but imposed regulation as well as efficiency improvements have contributed to cleaner manufacturing sectors. For old members, it is less clear, since trade integration had an increasing, albeit statistically insignificant, effect. Efficiency improvements, however, also reduced emission intensities here.

When analysing the sectors individually, we find one notable exception to the overall picture. The pulp and paper manufacturing consistently exhibits strong PHH effects. The sector also shows a strong, emission-decreasing, responsiveness to GDP per capita and thus seems to respond strongly to income, both domestically as well as via the PHH. Purely focusing on the pooled estimation can thus overshadow differences between sectors. Our results thus also highlight that any trade-related policy that affects environmental outcomes should pay close attention to sectoral differences within manufacturing. These variations are already appreciated in the current discussion on carbon border adjustments and should potentially also play a role when designing within-EU regulation on trade and environment.

To the best of our knowledge, there are only two articles that analyze the effect of the EU enlargement on environmental outcomes. Zhu and Van Ierland (2006) use general-equilibrium modelling to predict the enlargement's effect on emissions with pre-accession data. We find support for their prediction that capital and thus emission-intensive production moves towards already capital-abundant places, but we also show that this does not need to present a movement from East to West, but from capital-poor to capital-abundant places no matter their location. Our study, however, focusses on within manufacturing sector changes, while Zhu and Van Ierland (2006) analyze the economy in more aggregated industries. We also base our analysis on actual accession data and go into more detail on the separate trade channels.

The second study, by Duarte and Serrano (2021), uses input-output data, and focuses on PM2.5 pollution. The authors find a significant cleaning in the new member states as a result of the EU enlargement. Our study arrives at similar conclusions. Duarte and Serrano (2021) partially explain this by relocations to outside the EU, which might also explain parts of our findings. We add to their contribution by providing more causal evidence than their comparative-static estimation allows for, in a larger sample covering also old member states and both a greenhouse gas as well as air pollutants. We also decompose the enlargement's effect into several relevant channels, providing further insights into the underlying mechanisms.

The other related literature can roughly be divided into three strands: one using a similar methodology and thus estimating the composition effect of trade integration, one analysing environmental changes in the EU brought about by general world trade integration, and one studying energy intensity in manufacturing sectors.

In the first strand of literature, Antweiler et al. (2001) in their seminal contribution find support for both the FEH and the PHH, and thus for induced composition effects, and find that trade can overall lower the concentration of sulfur dioxide (SO_2). Cole and Elliott (2003) support this for SO_2 emissions and partly for three other pollutants. Frankel (2009), while addressing further endogeneity issues, supports the general notion that trade is either good or at least not harmful for the environment. Newer literature by Managi et al. (2009) adds to this by finding that while trade is good for the environment in OECD countries, it is pollution-increasing in non-OECD countries. More recently, Cherniwchan (2017) has shown that NAFTA has lowered plant level emissions in the US, using micro data.

We add to this literature in several ways. We are the first to bring the Antweiler et al. (2001) framework to a sectoral setting and the first to analyze it in a cointegration setting, taking seriously that environmental degradation is mainly a long-run phenomenon. We also add to the evidence that trade integration into a single market can lead to mixed outcomes for richer and poorer countries. We show that the FEH is prevalent even when only analysing a relatively well-developed market like the EU, but PHH effects are absent, potentially implying that dirty industry relocates to a place outside the single market. Our results are thus not at odds with the finding of PHH effects in other studies, since we focus on a single market, the EU, and do not exclude the possibility of leakage to outside the EU.

To the second strand of literature, which analyzes the relation between trade and the environment in the EU, we add the separation of relevant, opposing trade channels. Ho and Iyke (2019) and Tachie et al. (2020) analyze the effect of trade openness on emissions in different panels of European (not necessarily EU) economies. Ho and Iyke (2019) find that trade openness might decrease emissions up to a turning point, from which onward it becomes harmful to further open up for trade. Tachie et al. (2020) find that trade integration increases emissions. In our robustness section, we find some support for this: new members tend to decrease their emissions as a result of further world trade integration, while old members rather increase theirs. Both of these results are, however, statistically insignificant.[1]

Our paper also adds to the literature on the drivers of energy intensity, and their convergence between countries (Mulder & De Groot, 2012; Voigt et al., 2014; Wang, 2013). We confirm the general notion that technological change is an important driver of improvements, but also add insights on how trade integration can drive compositional changes that are likewise connected to changes in energy intensity.

The following section presents the theoretical background. Section 3 describes the data and presents some stylized facts; Section 4 explains the empirical strategy, Section 5 presents and discusses the results, and Section 6 provides multiple robustness checks. Finally, in Section 7 we present the conclusion of this research.

2 Theoretical framework

The potential effects of the enlargements on emission intensities can be divided into several channels. Before doing this, we start by using a standard decomposition of emission intensities to connect our effects to the composition and technique effects that are usually described in the literature.[2] We also use this decomposition to motivate why our study will largely analyze the technique effect, as this was the strongest driver of emission reductions in our data and in comparable studies. We then divide the enlargement-induced effect into composition, regulation, income, and productivity channels and use the remainder of this section to describe the potential effects through all outlined channels. All of these channels are also summarized in Figure 1.

2.1 Between and within-sector changes - composition and technique effects

Let EI be the emission intensity of the manufacturing industry in one country. We define it as emissions E divided by the scale of output V. In (1), we show how EI can be decomposed into two components by defining the aggregate intensity as the weighted sum of all sectoral intensities, weighted by their respective shares for all sectors i in the

[1] Other studies, by Al-Mulali et al. (2015) and Kasman and Duman (2015), have included trade integration as an explanatory variable for CO_2 levels in different panels of European countries. Al-Mulali et al. (2015) find that trade openness lowers emissions in the long run, while Kasman and Duman (2015) find the opposite. Our differentiation between countries with different income levels can partly explain these mixed results.

[2] Since we are analysing intensities (emissions divided by value added), we abstain from analysing scale effects that describe how an increase in the level of production mechanically translates into an increase in the embodied emissions. This is mainly done to avoid normative evaluations of increases in output, which might be desirable especially in the case of less developed countries.

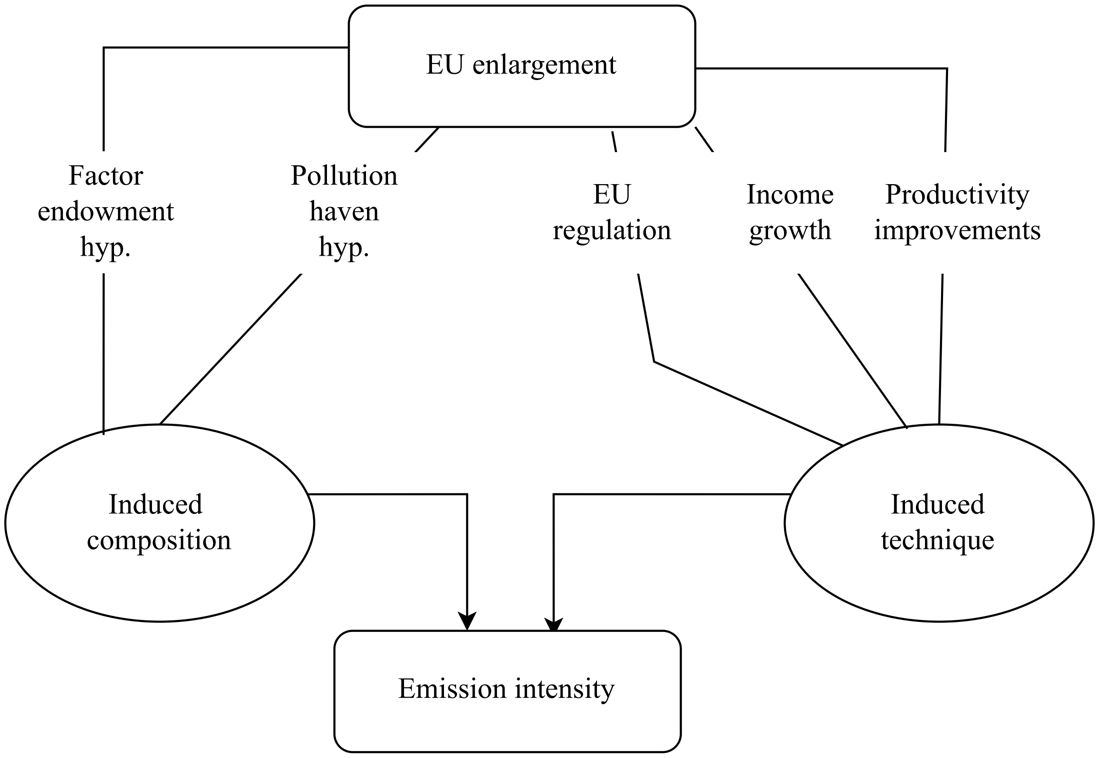

Figure 1: Channels through which the EU enlargement could have influenced emission intensities.

set $\mathcal{N}$ of manufacturing sectors:

$$EI = \sum_{i \in \mathcal{N}} \Phi_i EI_i. \tag{1}$$

The first component, $\Phi_i = \frac{V_i}{V}$, is the share of sector i in total manufacturing output, which reflects the composition of a nation's manufacturing industry. The second one is the technique part $EI_i = \frac{E_i}{V_i}$. It is defined as emissions per unit of output, or emission intensity, for sector i.

To describe a change in emission intensities, one can then totally differentiate (1) and get:

$$dEI = \sum_{i \in \mathcal{N}} EI_i d\Phi_i + \sum_{i \in \mathcal{N}} \Phi_i dEI_i. \tag{2}$$

The first part catches a change in emissions due to a change in the composition (where the sectoral changes are weighted by their respective emission intensities), or a between-sector effect. Since different sectors i have different emission intensities, changing the share of one sector on total output also changes the total emissions. The second part describes a change in the emission intensities per sector, a technique or within-sector change, keeping the composition between sectors fixed.

Previous literature (for example Brunel, 2017; Mulder & De Groot, 2012; Shapiro & Walker, 2018) has shown the relative importance of changes in the technique part over those in the compositional part, both in the US and the EU, usually attributing major improvements in emission levels to improvements in technology.[3] In our data, we find the same patterns, as shown in Appendix A. For this reason, this study will focus on technique changes, dEI_i, and we will only briefly discuss between-sector compositional changes, $d\Phi_i$, in Section 6.3.

It could be misleading, however, to conclude from the relatively low importance of compositional adjustments between sectors that changes in production patterns are irrelevant for pollution. This is because dEI_i is partly driven by compositional changes itself, only at a lower level. That is, dEI_i is driven by changes in all sub-sectors j in the set $\mathcal{K}$ of all respective sub-sectors that comprise i:

$$dEI_i = \sum_{j \in \mathcal{K}} ei_j d\phi_j + \sum_{j \in \mathcal{K}} \phi_j dei_j, \tag{3}$$

where we have left out the i index from the right-hand-side variables. Here ei_j is the sub-sector's emission intensity and ϕ_j is the sub-sector's output share on the output of the sector i.[4]

This paper will thus focus on the effects of the enlargement on EI_i through these compositional adjustments, $d\phi_j$, and through changes in sub-sector emission intensities, dei_j. The following subsections will describe these potential effects, and Section 4 will then describe how we aim to estimate each of these channels.

2.2 Enlargement-induced composition effects

Opening up for trade affects pollution by altering the composition of economic activity within an economy, based on the comparative advantage of this economy relative to its trading partners. This overall effect is a composite of two potentially competing channels, the pollution haven hypothesis (PHH) and the factor endowment hypothesis (FEH), and is usually referred to as the "induced composition effect", introduced by Antweiler et al. (2001).

The PHH predicts that after opening up for trade, countries, or in our case sectors within countries, with lower environmental regulations will use their comparative advantage for pollution-intensive production to further specialize in it, which thus implies an increase in the overall emission intensity in these sectors. Countries with lower environmental regulation generally coincide with lower income countries, which in turn correspond to new member states in the EU context.[5] This implies that the PHH

[3] In Shapiro and Walker, 2018 these could also get attributed to stricter regulation.
[4] This also contains an additional adjustments through entering and exiting firms' emission intensity, a channel that is stressed for example in Shapiro and Walker (2018) and Cherniwchan et al., 2017.
[5] In the EU context, while some environmental regulations are based on the EU level (e.g. the ETS),

predicts an increase in emissions for new member states as a result of the enlargement, indicating an emission leakage from old to new member states.[6]

The second hypothesis, the FEH, predicts that countries, or sectors, with a higher share of capital-intensive production will use their comparative advantage to specialize even more in such production after opening up for trade. Capital-intensive production is energy-intensive and thus pollution-intensive (Cole et al., 2005). The comparative advantage is now mostly on the side of the more developed countries, which are usually specialized in capital-intensive production. The FEH thus predicts a decrease in emission intensities for new member states due to the enlargement.

Even though the earlier ideas on the induced composition effect are based on changes between large sectors, there is little difference between the comparative advantage idea of those and of smaller manufacturing sub-sectors or even firms. Dirty firms in countries with weaker environmental regulation are likely to be also exporting to new markets after integration increases, and firms can direct their FDI towards places where they see the costs to be the lowest.

2.3 Enlargement-induced technique effects

2.3.1 EU regulation

To be eligible for EU membership, a country needs to comply with chapter 27 of the EU's Acquis Communautaire, which describes the necessary legislative steps for compliance with EU rules in the field of the environment. Additionally important is the European Emissions Trading System (ETS), in which all member states participate, as well as comparable EU-wide legislation in the manufacturing pollution sphere. These regulations should affect the emission intensities in new member states through technology adaption in the production processes. Since parts of these effects should materialise before the actual accession, this study controls for two steps in the enlargement process, namely becoming a candidate country and the accession itself.

2.3.2 Income growth

This paper does not attempt to quantify the effects that the enlargement has had on economic growth and development.[7] Instead, we estimate the effects that higher levels of income, spurred by the enlargement, might have had on emission intensities.

The postulated income effect goes through the changing preferences and related policies in a society. Preferences over environmental cleanliness are generally assumed to increase with income (Antweiler et al., 2001, Cole and Elliott, 2003), thus also leading

environmental regulations between member states are still heterogeneous. See, for example, Bagayev and Lochard (2017).

[6] The PHH is also influenced by the increase in income as a result of the enlargement, since the enlargement has led to a convergence effect in income levels, which should dampen the PHH effect. But even though relative incomes have been converging in the EU, one can see in Figure 3 that income levels between new and old member states are still far from each other.

[7] For this, see for example Epstein and Jacoby (2014) or Campos et al. (2019).

to stricter environmental regulations and a higher demand for "clean" products.[8] An idea that is also prominently reflected in the literature identifying these mechanisms, giving rise to an Environmental Kuznets Curve.

2.3.3 Productivity improvements

Furthermore, the accession to the common market has led to further competition and might thus have induced technological improvements (Bloom et al., 2016) and technology spillovers (Popp, 2011). Increases in manufacturing output spurred by the enlargement might also have led to increases in production efficiency, which tend to increase with output (Dinda, 2004). Such improvements in productivity are found, for example, by Campos et al. (2019). By focussing on manufacturing emissions, we are able to differentiate between economy-wide income and sector-specific productivity changes, a distinction that is usually hard to obtain when analysing more aggregate data.

3 Data sources and stylized facts

We use two data sources on emissions at their place of emittance, called emission inventories. For CO_2, we rely on "CO_2 emissions from fuel combustion - 2020 edition", provided by the International Energy Agency (IEA) (International Energy Agency, 2020), via the OECD. For SO_x and NO_x, we use data compiled in the context of the "Convention on Long-Range Transboundary Air Pollution" (CLRTAP), provided by the European Environment Agency (European Environment Agency, 2019). Both data sets give information on emissions for each country and year on a sectoral level.

For data on employment and capital input, we use the EU KLEMS database (Stehrer et al., 2019), which provides yearly data on a sectoral level for most EU countries from 1995 onwards. Data on GDP per capita and value added per sector are taken from Eurostat (Eurostat, 2019a, 2019b), and trade data are taken from the OECD STAN database (Organisation for Economic Co-operation and Development, 2019).

Our final data set incorporates 23 (for CO_2) or 22 (for air pollutants) EU member countries. For most countries, data start in 1995 and span until 2015. More information on the data sources and the definition and creation of our variables can be found in Appendix B.

Figure 2 shows the development of CO_2, SO_x, and NO_x emission intensities over time. It plots the average intensities for the respective sample of the whole manufacturing industry (one digit) and marks the two accession dates. One can see that emission intensities on the manufacturing level have been decreasing for all three pollutants and member groups since the beginning of the data range. Especially SO_x intensities have reduced greatly. This is driven by increases in value added, and especially by large

[8] Even though the evidence on the preference channel is partly debated (McConnell, 1997), the correlation between income and environmental regulation is clear.

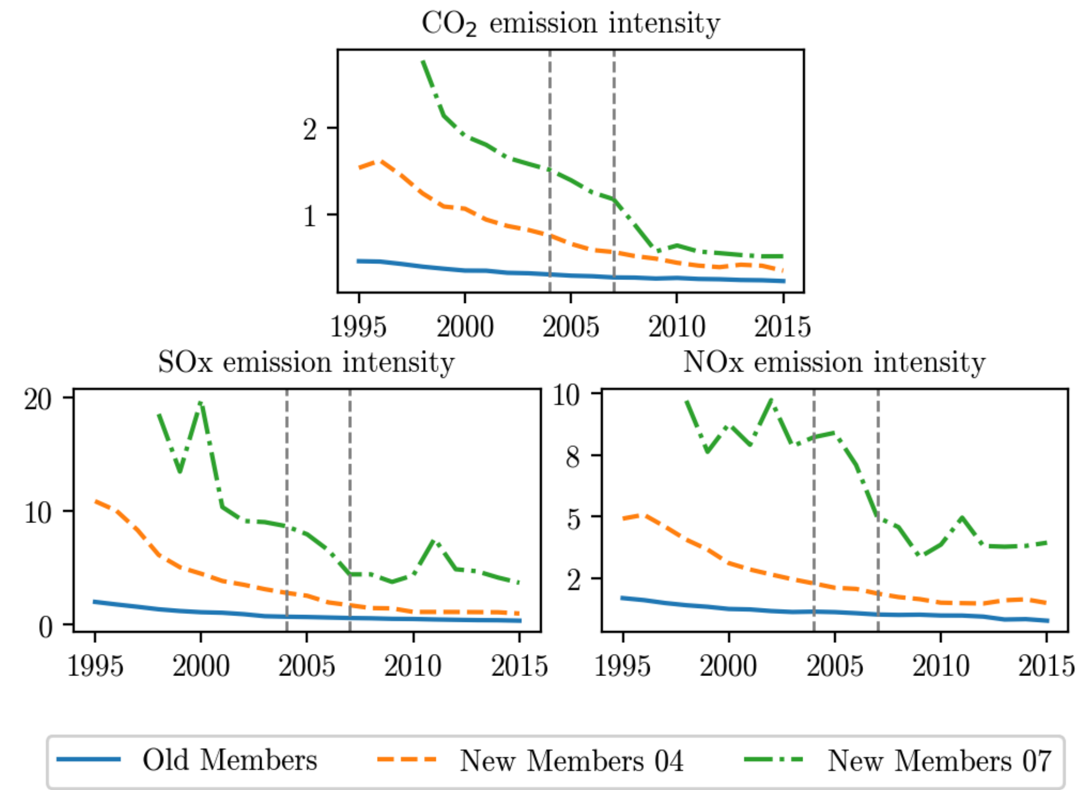

Figure 2: Emission intensity, in Gg per Million Euros of value added for CO_2 and per Thousand Euros for SO_x and NO_x (in 2010 Euros), average among sample members. Enlargement dates indicated by vertical bars.

decreases in emission levels. For CO_2 and NO_x, the decrease is smaller, but still substantial. Besides this, it becomes clear that emission intensities are much higher in new than in old member states, even though the series seem to converge.

Figure 3 plots summary statistics of the overall manufacturing industry (one digit) as well as on relative income (country-wide). One can see that member states that joined in 2004 have a higher trade integration into the EU, while Romania and Bulgaria are less integrated. The fact that the new member states exhibit on average higher trade integration is partly due to the fact that their economies are much smaller and for larger economies within-country trade becomes over-proportionally important (Squalli & Wilson, 2011).[9] One can also see that, especially among the 2004 members, integration increased steadily over the whole period and especially after the enlargement.

The plots also back up the previously made claims on the postulated gap in GDP per

[9] In Section 6.1 we address this by using an integration measure that is weighted by the share in overall inter-EU trade of a country.

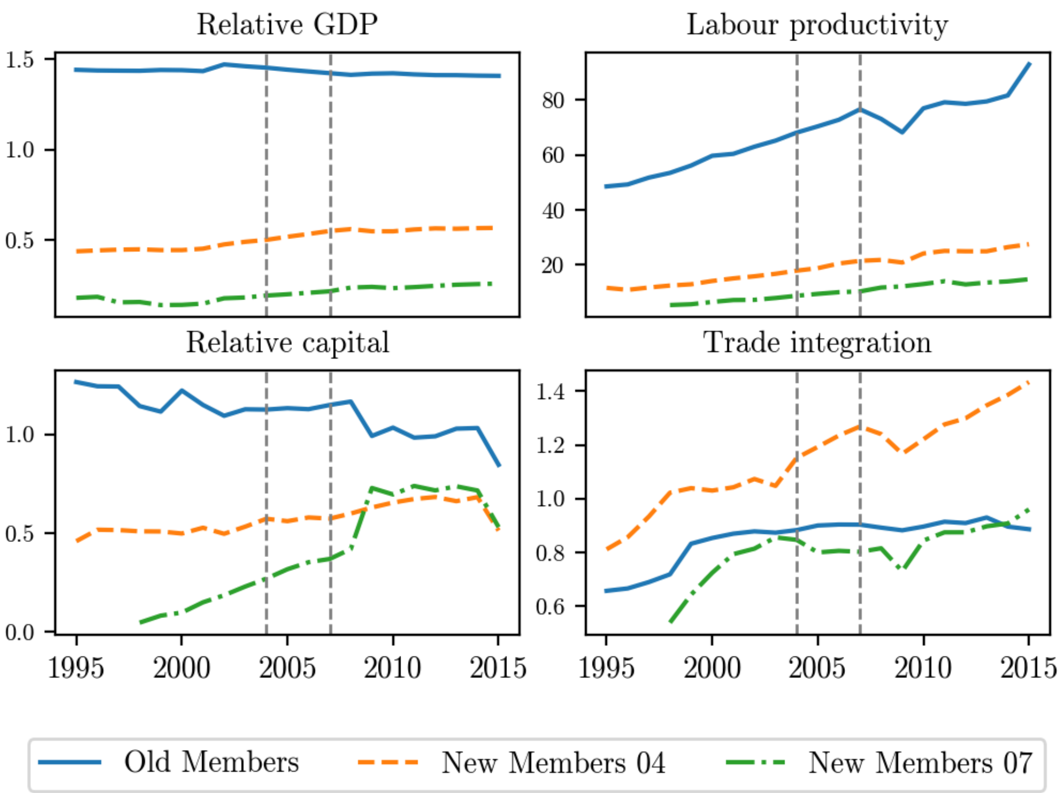

Figure 3: All lines represent averages among sample members. Except for relative GDP, all plots represent the whole manufacturing industry. Labour productivity is in Million Euro per engaged person; exact definitions of variables in Section 4 and Appendix B. For illustrative purposes Ireland is excluded from the relative capital chart, because it has much higher ratios than all other countries. Enlargement dates indicated by vertical bars.

capita between new and old member states as well as on the much lower capital to labour ratio in these countries. New member states have been catching up in both dimensions, but are still far from the older members. One can see that labour productivity has increased in all countries, but old member states still have much higher value added per engaged person.

4 Empirical strategy

The focus of this section is on the translation of the theoretical effects of Section 2 into empirically measurable variables. After outlining the long-run relation of interest, we describe the estimation technique and how it relates to the potential underlying endogeneity and dynamic structure in our data.

4.1 Model

Emission intensity, EI_{sct}, is defined as emissions over value added for sector s in country c at time t, and is expressed in logarithmic form. For CO_2, the one-digit manufacturing industry is divided into nine smaller, two-digit sectors, for local air pollutants into six. Appendix B gives a detailed list of these sectors.

The long-run-relation that we are interested in captures enlargement-induced effects in $d\phi_j$, from (3), through changes in within-sector composition, and in dei_j through changes in regulation, income and productivity:

$$\begin{aligned} EI_{sct} = & \underbrace{\Lambda_{sct} TI_{sct}}_{\textit{Induced composition}} + \underbrace{\Omega_{ct}}_{\textit{Regulation}} + \underbrace{\gamma_1 INC_{ct}}_{\text{Income}} + \underbrace{\gamma_2 LP_{sct}}_{\text{Productivity}} + \\ & \gamma_3 KL_{sct} + e_{sct}. \end{aligned} \tag{4}$$

We quantify the right-hand-side elements as follows. We model the accession process as a process of trade integration into the European market, measured by TI_{sct}. To purely measure the integration into the EU's single market, we sum imports from and exports to other EU countries. This sum is then divided by gross output and the total ratio is taken in logarithmic form. The resulting specification is close to the analysis of Antweiler et al. (2001), Cole and Elliott (2003) and Managi et al. (2009), and has three main advantages: it allows for a gradual integration into the single market, before and after the accession year; it makes the results comparable to those in the mentioned studies; and it captures heterogeneous impacts between countries and sectors.

To capture the PHH and FEH channels, we follow Antweiler et al. (2001), although within sectors. That is, we model the impact of TI on EI by

$$\Lambda_{sct} = \lambda_0 + \underbrace{\lambda_1 RINC_{ct}}_{\text{PHH}} + \underbrace{\lambda_2 RKL_{sct}}_{\text{FEH}}, \tag{4a}$$

where $RINC_{ct}$ is relative income (GDP per capita), and RKL_{sct} is relative capital intensity (capital input per hour worked), where relative refers in both cases to the EU average. If the PHH holds, then we expect countries with a lower GDP per capita to increase EI when increasing TI, so $\lambda_1 < 0$. If the FEH holds, then sectors that have a higher RKL are expected to increase their EI with increasing TI, so $\lambda_2 > 0$.

Ω_{ct} measures the direct effect of sticking to EU regulation and administration after initiating the accession process. For this, we include dummies that capture important steps in the enlargement process (Chen & Huang, 2016): becoming a candidate country and the accession itself.[10] Each of these dummies is zero up until the specific date and stays one thereafter:

$$\Omega_{ct} = \omega_1 d_{ct}^{candidate} + \omega_2 d_{ct}^{accession}. \tag{4b}$$

If imposed regulations and standardization towards the EU reduce emission intensity, then both ω_1 and ω_2 are negative.

[10] Controlling for additional events like signing the accession treaty or joining the Euro, does not alter the results.

INC_{ct} and LP_{sct} intend to jointly capture potential second round effects of the enlargement. In (4), INC_{ct}, country-wide income, should influence intensities on the sector level via preferences and regulation, and is defined as logarithmic GDP per capita. Higher incomes are expected to lower EI, and γ_1 is thus expected to be negative.

LP_{sct}, labour productivity, is defined as logarithmic value added per engaged person, as the most direct measure of productivity and thus technology. Labour productivity can also be understood as a proxy for efficiency-increasing investments that decrease the needed input per unit of output. We thus expect γ_2 to be negative. As our measure is sector-specific, we are able to split this part from the nation-wide income channel, which is usually hard to achieve if one only observes aggregate variables.

KL_{sct} measures the capital intensity of a sector, defined as capital input per hour worked, again in logarithmic form, and controls for the part of the sectoral composition that is not induced by the enlargement. A higher capital share should increase emissions, so we expect $\gamma_3 > 0$. The exact definition of the KL measure is given in Appendix B.

In e_{sct} we allow for a different fixed effect for each sector-country unit, α_{sc}, and year, α_t,[11] as well as for linear trends for each sector, $\tau_s t$, and each country, $\tau_c t$:

$$e_{sct} = \alpha_{sc} + \alpha_t + \tau_s t + \tau_c t + \varepsilon_{sct}, \tag{4c}$$

with ε_{sct} as the idiosyncratic error term, assumed to be uncorrelated across units.

4.2 Estimation method

Both for climate change and air pollution, insights into long-term relations are crucial and are thus also more frequently analyzed in the recent literature (for example in Al-Mulali et al., 2015; Kasman & Duman, 2015). We therefore analyze the model from a cointegration perspective and have collected data with a substantial time span of 21 years. This also avoids potential estimation bias from an endogeneity of trade and income, and potentially in other variables, as for the estimation of cointegrating relations the explanatory variables do not have to be exogenous. That emission intensity is cointegrated with our explanatory variables has already been shown for income and trade openness in Kasman and Duman (2015). We will study cointegration for all of our right-hand-side variables.

We start by analysing the stationarity properties in our data. Panel unit root tests indicate that our time series are I(1). We then test for potential cointegration between emission intensities and our above defined right-hand-side variables. Cointegration tests reject the null hypothesis of no cointegration in (4) for all three pollution variables.

[11] The sector-country fixed effects control for time-invariant omitted factors influencing pollution within a sector-country unit. These might include very old machinery e.g. as a consequence of being in the Eastern Block. The year fixed effects control for sector and country invariant omitted emission determinants such as the Financial or the Euro crisis, but also for price shocks on fuels such as oil or coal. They additionally take out some spatial autocorrelation.

Estimating the coefficients in (4) with OLS would then yield super-consistency, but potentially biased standard errors (Kao & Chiang, 2001). We thus rely on dynamic ordinary least squares (DOLS), first introduced by Saikkonen (1991). The DOLS approach has shown to lead to satisfactory results, as for example in Wagner and Hlouskova (2009), who show that DOLS outperforms all other studied techniques (like FMOLS) in one-dimensional cointegration relations.

The idea behind the approach is to extend (4) by the lags and leads of the first difference of all explanatory variables. We have tried several lead and lag structures, leading to comparable results, and we have decided to present the most commonly used extension with two leads and two lags. All of these steps are outlined in more detail in Appendix C, where one can also find the results and a discussion for the unit root and cointegration tests.

5 Results

This section presents the results of the DOLS estimation of (4), both for the whole sample, in which we constrain the coefficients to be homogeneous between sectors, as well as for each sector individually. We also add a discussion on the magnitude of the individual channels, by combining our analysis with results of other studies on the effect of the enlargement on our explanatory variables. All estimations include deviations for new members from the overall effect of all member states. These are estimated by interacting all variables with a dummy that is one for new members, and zero for old members. This allows us to study more specifically the enlargement effects on the most affected countries. In the tables, we only include some relevant deviations; for the omitted ones, we report the F-test for all omitted coefficients being zero. Almost all of them indicate joint insignificance, and if they are significant, there is no consistent pattern among the omitted deviations, which is why we decided not to report them.

5.1 Baseline analysis

Table 1 presents the results for the main analysis from estimating (4) on our entire panel. We first discuss the coefficients related to the induced composition effect, the interactions of TI with relative income and relative capital intensity. The coefficients on the interaction with relative income have positive signs and are statistically insignificant. This speaks against the pollution haven hypothesis within the EU, which predicted a negative relationship. This might imply that environmental regulation was sufficiently homogenized between new and old member states (or expectations about environmental regulation were homogeneous), or that dirty production did not move towards new member states, because relocating further, to places with even lower environmental standards, was cheaper. We leave such form of leakage for future research.

The interactions with relative capital have ambiguous signs and are statistically insignificant as well. However, the deviations for new members imply a positive and statistically significant FEH effect for this subset of countries, considering the actual

Table 1: Estimation of (4), with emission intensities as dependent variables

	CO_2 Intensity	SO_x Intensity	NO_x Intensity
	(1)	(2)	(3)
Induced composition			
Trade Integration	−0.62	−0.31	0.07
	(0.52)	(0.96)	(0.46)
TI*Relative GDP (PHH)	0.32	0.43	0.24
	(0.36)	(0.66)	(0.35)
Deviation new members	−0.69	0.19	−0.74
	(0.95)	(3.01)	(0.75)
TI*Relative Capital (FEH)	0.09	0.01	−0.04
	(0.07)	(0.15)	(0.11)
Deviation new members	0.16	0.61*	0.27**
	(0.12)	(0.33)	(0.13)
Enlargement steps			
Candidate Status	−0.14	−1.08**	−0.30*
	(0.16)	(0.43)	(0.16)
Accession	−0.10	−0.11	−0.17**
	(0.06)	(0.11)	(0.07)
Development/Income			
GDP per capita	−0.12	−0.79	0.58
	(0.59)	(2.19)	(1.29)
Deviation new members	0.24	−3.33*	−0.70
	(0.68)	(1.76)	(0.71)
Sector productivity			
Labour productivity	−0.89***	−1.03***	−1.06***
	(0.13)	(0.24)	(0.13)
Deviation new members	−0.09	0.74***	0.58***
	(0.16)	(0.27)	(0.14)
Further controls			
Capital intensity	0.04	−0.16	0.03
	(0.07)	(0.18)	(0.10)
Other deviations F-test p-value	0.72	0.85	0.78
R-squared	0.47	0.46	0.57
Observations	2712	1646	1639

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Fixed effects and linear trends as in (4c). All models estimated with dynamic OLS, including two leads and lags of all explanatory variables. New member states deviations for all variables are included in each regression; p-value for F-test concerns all omitted deviations.

one-sidedness of the FEH (effect for new members: 0.25 (standard error of 0.14) for CO_2, 0.63 (0.38) for SO_x, and 0.23 (0.14) for NO_x). This supports the FEH among this subset of countries, implying that capital-intensive sectors in the new member states increased their emissions compared to capital-poor sectors, upon increasing their integration into the EU. Finding support for the FEH is in line with the notion of free capital movements within the EU and the results of previous papers, but it is noteworthy that capital accumulation forces are especially strong in new member states. One reason for this could be based on arguments on the decreasing marginal product of capital. So capital-rich sectors in the old members might have already been saturated with respect to their capital input.

The overall trade integration elasticity, Λ, for each sector depends on both the relative capital-intensity of the sector as well as the relative GDP per capita of the country it belongs to (as well as the coefficient of the non-interacted TI variable), as formalized in (4a). We thus estimate Λ_{sct} by combining the observations of those variables with the estimates in Table 1. The estimated elasticities, one for each sector-country pair, are plotted in Figure 4. For new members, they are either negative, meaning that trade integration lowers emission intensities, or close to zero. The elasticities are statistically insignificant for the median new member observation, indicated by the dark vertical confidence bars, but one can see the positive relation with relative capital, stemming from the significant FEH effect. For old members, the elasticities have mixed signs for CO_2 and are mostly positive for both air pollutants. The median old member effect is statistically insignificant at the 5 but not the 10 percent level for NO_x, and statistically insignificant for CO_2 and SO_x.

The elasticity interpretation of Λ implies, for example, that for the least capital-intensive sector (Estonia's Coke and refined petroleum products sector) a one percent increase in trade integration into the EU lowers SO_x intensities by about one percent and increases them by about a third of a percent for most sectors in the old member states.

The estimates of the enlargement steps, the second block in Table 1, reveal that the effects of becoming a candidate country (and thus having to follow the environmental acquise), as well as of joining the EU both imply a decline in intensities. For both air pollutants, at least one of the coefficients is statistically significant, which is not the case for CO_2, for which also the coefficient magnitudes are much smaller. This might indicate that EU regulation had a stronger bite on air pollution than on greenhouse gases, which is in line with a stronger focus of the acquise on air pollution than on greenhouse gases. The magnitude of these coefficients implies, for example, that the accession went together with a 17 percent reduction in emission intensities for NO_x; becoming a candidate country implied even larger reductions for both air pollutants.

Turning towards the second-round effects of income and productivity, the income coefficients are almost never statistically significant. The only exception is the deviation for new member states with SO_x intensities as dependent variable. The deviation coefficient of INC here is negative and large. This is likely due to the catch-up in pollution reduction in these countries, which was seemingly supported by increases in

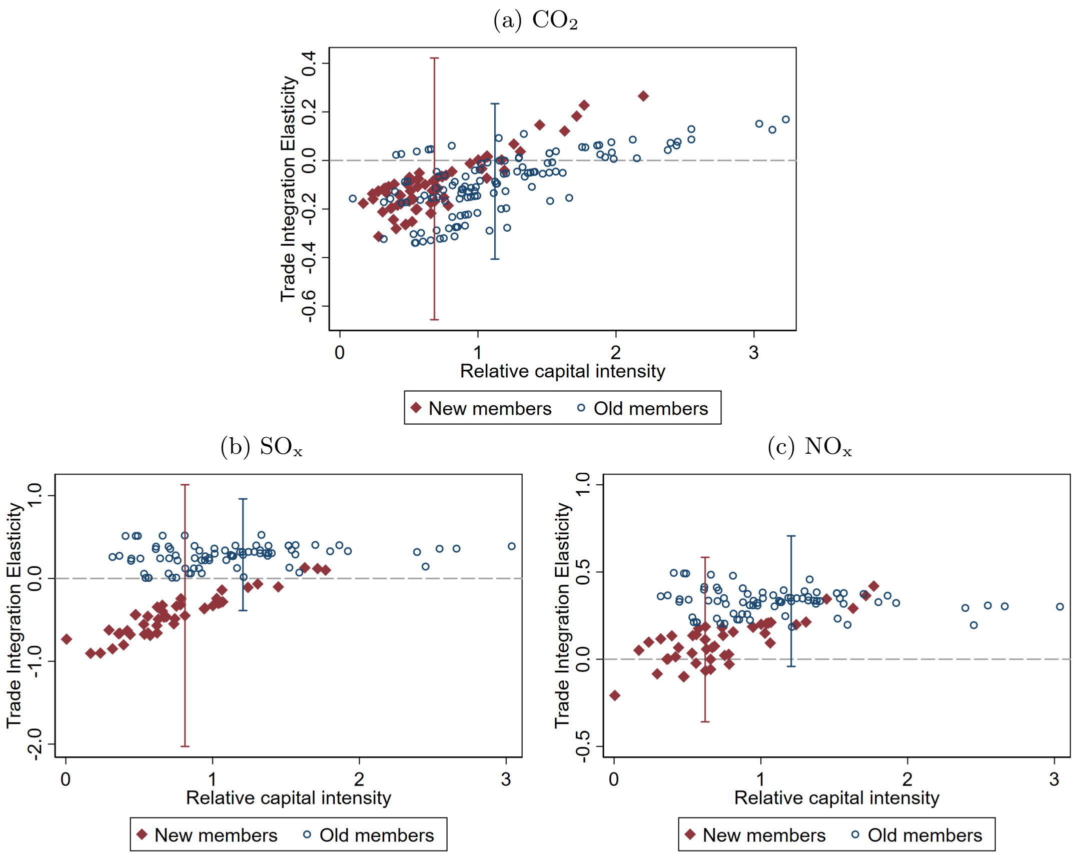

Figure 4: Trade elasticities (4a), based on coefficient estimates from Table 1. Each point represents the elasticity of one sector within one country, evaluated at its respective mean values of relative capital intensity and relative income over the sample period. Vertical lines are 95% confidence intervals for median elasticity for both groups, where the red line is for new member states. Largest relative capital intensity observation dropped for air pollutants to allow for better comparison.

development.

All estimated coefficients on labour productivity are negative, as expected. Overall, it has a coefficient estimate of around -1, implying that a one percent increase in labour productivity led to an about one percent reduction in emission intensities. It thus seems as if labour productivity enhancing investments came together with the adaption of cleaner technology. This effect is less pronounced for air pollutants in the new member states sub-sample, where the coefficient estimates are more positive, but only for SO_x the effect, -0.29, is not significantly negative any more. Seemingly, increases in productivity and potentially related investments did not translate into changes in emission intensities as strongly here.

5.2 Individual sector analysis

We now analyze the same regression (4), but individually for each sector, presented for each pollutant in Tables D1 to D3. Across sectors, there is some sign-heterogeneity in the PHH coefficients, further supporting the overall insignificance of this channel. The FEH coefficients also show mixed signs and the smaller sample sizes do not allow us to confirm our previous result on the FEH within new members. Overall, imposing parameter homogeneity, as in Table 1, seems a useful way to increase estimation precision.

There is one interesting outlier to the induced composition effect picture. Sector C17-C18, pulp and paper manufacturing, for which we find support for the PHH for all pollutants, with significant coefficient estimates in two cases. This implies that richer countries relative to poorer ones decrease their emission intensity when integrating further (only focussing on the PHH channel). The behaviour of the pulp and paper manufacturing is also notable when it comes to the income effect, where it shows significant and negative coefficients. This responsiveness is consistent with a strong reaction of the sector to environmental regulation, found by Söderholm et al. (2019). Excluding sector C17-C18 from the pooled estimation has virtually no effect on our results.

One exception to the negative income coefficients is, for both air pollutants, sector C19, coke and refined petroleum products, which has a positive INC coefficient. The sector also has a large and negative labour productivity coefficient, which is interesting, since this sector shows the lowest correlation between GDP per capita and sector-specific labour productivity. This might allow us to easier disentangle the two effects, showing that investments associated with increases in labour productivity are indeed responsible for a significant cleaning within the sector. The reasons for the potential emission increasing effect of GDP per capita might lie in the fact that EU refineries were forced to increase their processing intensity, associated with an increase in emissions, when providing higher regulated products and serving increased quality demand (Dastillung et al., 2008).

As in the pooled analysis, the enlargement coefficients are rarely significant for CO_2. For both air pollutants they still mostly indicate a negative impact. Labour productivity mostly has a negative effect on emission intensities, again with mostly less negative coefficient estimates for new members.

5.3 Overall enlargement-induced effect for new member states

We now put the coefficient estimates from the pooled analysis in Table 1 into perspective and estimate the magnitude of the enlargement effects through the outlined channels. We focus on the new member states. To do so, we take estimates from other studies to infer the enlargement effect on our explanatory variables (trade, income, and labour productivity) and then use our estimates of the effects of these variables on EI to derive the enlargement-induced effects on EI through the individual channels. We compare those to the decrease in manufacturing emission intensities, as computed from the data directly, between the announcement of the enlargement in 1998 and the last year in our panel, 2015. For the average manufacturing sector, this decrease from the first to the last year is between 64% and 81% for the three different pollutants. The decline is especially strong for SO_x.

Table 2: Percentage change in emission intensities of new member states, and enlargement-induced contributions of explanatory variables to this change.

	CO_2	SO_x	NO_x
Average change in intensity†	−69.21	−80.81	−63.89
Contributions of:			
Trade integration	−3.17	−12.03	1.35
	(6.25)	(14.49)	(5.26)
Candidate status	−13.32	−65.96***	−26.24**
	(13.45)	(14.62)	(11.60)
Accession	−9.39*	−10.54	−15.96***
	(5.52)	(9.96)	(5.82)
GDP per capita	1.64	−43.37*	−1.75
	(10.61)	(22.46)	(17.09)
Labour productivity	−11.45***	−3.58	−5.75***
	(1.53)	(3.78)	(1.71)

†Average percentage change from 1998 to 2015 of all included sectors.
Delta method standard errors in parentheses, $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.
Change in trade integration is based on Felbermayr et al. (2018), who estimate what "undoing" of previous integration steps would imply, where we chose the single market as our measure of the enlargement and not their estimated (larger) total effect as that would also incorporate effects of implementing the Euro, which not all members have done by now. We then use the opposite of their estimates, implying an increase in TI from the single market of 25.99 percent. The contribution presented in the table represents the prediction from such an increase in trade integration, using the estimates of Λ_{sct} in (1a), assuming everything else to stay unchanged. To derive the estimate, one needs the sum of the overall coefficient and the deviation for new members from Table 1; for λ_0 this estimate is –0.12 for CO_2 (the sum of the reported –0.62 and the unreported deviation 0.50), –1.16 for SO_x, and 0.13 for NO_x; for λ_1 it is –0.37 for CO_2, 0.62 for SO_x, and –0.50 for NO_x, λ_1 is then evaluated at the average relative income, $RINC$, (0.41); for λ_2 the effect is 0.25 for CO_2, 0.63 for SO_x, and 0.23 for NO_x, evaluated at the average relative capital intensity, RKL, (0.56).
Contribution of candidate status and accession are based on coefficient estimates, ω_i, of enlargement steps from Table 1 and calculated as $exp(\hat{\omega}_i) - 1$.
INC and LP changes are based on Campos et al. (2019). Estimated increase of INC through the enlargement is 14.80 percent; estimated LP increase 13.21 percent, based on whole economy. New members γ_1 estimate is 0.11 for CO_2, –4.12 for SO_x, and –0.12 for NO_x; for γ_2 it is –0.97 for CO_2, –0.29 for SO_x, and –0.47 for NO_x.

In Table 2, we look at how much the individual channels have contributed to that decline. It becomes clear that trade integration has not been a key driver, as the overall effect of trade integration is small and statistically insignificant for all three pollutants.

The largest effect comes from the estimated coefficients of the enlargement steps. Even though these estimates could of course also capture additional unobserved events that happened simultaneously, their size and significance for both air pollutants are striking. This is not surprising, given the strong focus of the environmental acquise on air pollution. Several authors have pointed to the challenge that this part of the acquise presented to candidate countries, which supports the plausibility of our results (Kapios, 2002; ten Brink, 2002).

While the effect of income is mostly statistically insignificant, the effect of induced increases in labour productivity is significantly negative for CO_2 and NO_x, implying an 11% or 6% decrease in emission intensities, respectively. As discussed before, this most likely implies that technology advances through investments or spillovers have substantially cleaned manufacturing sectors.

Overall, we find that 13 out of 15 contributions are negative, leading us to conclude that the overall effect of the enlargement on new members emission intensities was beneficial. The absence of a pollution-haven effect within Europe alleviates concerns of a detrimental effect of trade integration on poor countries' environment. Regulatory requirements as well as increases in productivity and income have significantly contributed to a cleaning of their manufacturing sectors.

6 Robustness

6.1 Alternative model specifications

We now present several specifications that test the robustness of our results from the pooled analysis. In Tables D4, D5 and D6 – one for each pollutant – we report five different specifications next to the baseline, with the latter reported in column one.

In column two, we extend the induced composition effect to allow for squared interactions, by replacing (4a) with:

$$\Lambda_{sct} = \lambda_0 + \underbrace{\lambda_1 RINC_{ct} + \lambda_2 RINC_{ct}^2}_{\text{PHH}} + \underbrace{\lambda_3 RKL_{sct} + \lambda_4 RKL_{sct}^2}_{\text{FEH}}. \tag{5}$$

For all three pollutants, the marginal effects, evaluated at the median observation, are in line with the coefficient estimates from the baseline, albeit with larger standard errors due to the additional coefficients to be estimated. The (unreported) estimates for the squared terms are economically small and almost all are statistically insignificant, which is why we leave out the squared terms from the baseline specification.

In columns three and four, we replace our variable TI_{sct}, capturing trade integration into the EU, by two alternatives. Column three uses trade integration into the world, motivated by the idea that joining the EU does not only allow for increased trade with other member states, but also leads to a reduction in trade barriers towards countries that have signed trade agreements with the EU. Column four uses a "composite trade share", introduced by Squalli and Wilson (2011), that adjusts for the fact that larger countries tend to have a smaller measure of trade openness, since they exhibit larger within-country trade. The measure is defined as:

$$TI_{sct}^{cts} = TI_{sct} * \frac{X_{sct} + I_{sct}}{\sum_j (X_{sjt} + I_{sjt})}, \tag{6}$$

where X and I are exports and imports, respectively, and j runs over all EU member states. Both measures lead to the same conclusions as before.

Columns five and six are motivated by a closer analysis of the fixed effects and linear trends that are included in the baseline analysis. In the baseline estimation, new members have lower fixed effects and higher linear trend coefficients than old members, especially for SO_x.[12] When controlling for more heterogeneous trends (per sector-country unit) or for country-specific income, INC, coefficients, this pattern vanishes. One can see in our robustness tables that allowing for such heterogeneities does not alter our results of interest.

6.2 Alternative measures of environmental regulation

In this section, we show that the absence of pollution-haven effects is not purely based on our measure of relative environmental stringency, relative GDP per capita. We thus substitute it for two alternative measures: a measure of energy prices, which is comprised by Sato et al. (2015) and varies on a sectoral level, and environmental tax revenue as a share of total tax revenue of a country (Eurostat, 2019c).

The results are in Table D7 and support our previous results. There is no support for the within-EU PHH in the sense that richer countries with high environmental stringency do not reduce their emissions when increasing their integration. However, new members with higher tax levels reduce their emission of air pollutants after integration. This could indicate that emissions are indeed moved to new members with even lower environmental taxes, or it could indicate some outsourcing to countries outside the EU. We again find some but small evidence for FEH effects among new member states. Other estimates stay qualitatively unaffected.

6.3 Aggregate manufacturing

This paper has so far focussed on changes in the technique part of manufacturing emission intensities in the EU, because these changes have been far more substantial than compositional ones, as seen in Figure A1 and in previous papers, as outlined in Section 2.1. It is, however, also noteworthy that positive compositional changes in Figure A1 are almost only found among the new members, grouped on the left of the horizontal axes. This hints at potential between-sector PHH effects, as this indicates that in these countries dirty manufacturing sectors got larger compared to clean ones.

For this reason, we present here a sensitivity analysis that captures trade-induced compositional changes both within and between sectors. To do so, we run the same regression as in (4), but on the aggregate manufacturing level, so for EI_{ct}.

The results for this are presented in Table D8. We focus on the PHH and FEH effects, which in this case capture both between and within-sector trade-induced composition changes (Φ and ϕ in (1) and (3)). The other coefficients are not of interest in this estimation, as they are driven by within sector changes and do not qualitatively differ from the results presented in Table 1.

[12] More information on the patterns in fixed effects and linear trends is available upon request.

We find some evidence for PHH effects among NO_x, as indicated by the significantly negative interaction between TI and $RINC$, implying that richer countries reduce their NO_x emissions when increasing TI, compared to poorer countries. This is in line with the descriptive decomposition in Figure A1. As we did not establish any PHH effect in Table 1, these changes are likely purely happening between manufacturing sectors and not within them. These effects are, however, absent for CO_2 and insignificant for SO_x, and together with the smaller sample size, we thus abstain from concluding that there is strong evidence of PHH effects.

We find evidence for an FEH effect, which is particularly strong among new members. This is in line with the results in the main analysis.

7 Conclusion

In this study, we analyze the effects of the Eastern EU enlargement process on the emission intensities in the manufacturing sectors of new and old member states. We disentangle different theoretical channels through which the enlargement could have influenced emission intensities; through induced changes in the sector composition as well as through advancements in regulation, income, and technology. In a panel cointegration setting, we analyze data on emission intensities for CO_2, SO_x, and NO_x for almost all EU countries from 1995 to 2015.

The overall trade integration elasticity of emission intensity is statistically insignificant. We find almost no support for pollution haven effects and thus for leakage channels within the EU. It thus might be that EU regulation was sufficiently homogenized to prevent within-EU leakage. On the other hand, we find significant evidence for the factor endowment hypothesis among new member states. Among those countries, capital-intensive sectors thus got dirtier relative to less capital-intensive ones.

We also show that becoming a candidate country and the accession itself had a decreasing effect on emission intensities. This effect is most likely driven by additional regulation that countries had to adopt for their accession. This effect is large for air pollutants and rather small for CO_2, which might come from stronger EU regulation for air pollutants than for greenhouse gases.

We additionally find that enlargement-induced increases in productivity had a decreasing effect on the emission intensities in manufacturing sectors; technology spillovers after the enlargement could thus be associated with investments that supported both efficiency and the environment. For changes in income, these effects point in the same direction, but are mostly insignificant.

When all these findings are combined, the results are promising for comparable processes of market integration. Less developed countries in such processes might benefit from opening up, not only through increases in trade, productivity spillovers, and GDP per capita, but also through a cleaning of their manufacturing industry. These results show that sufficient homogeneity in environmental regulation can prevent both leakage and pollution havens within opening markets.

It is, however, important to note that the fact that new member states rather decrease their emissions, as a result of trade integration, could also indicate that pollution moves from these countries to countries outside the EU, where regulation is sufficiently lower. This also implies that carbon leakage remains a valid threat to EU regulation, and that adequate trade policy should be considered when designing environmental policy within the EU.

An interesting conclusion from our research is that the factor endowment hypothesis is more likely to hold for countries in earlier stages of their development. If that is indeed based on arguments of a decreasing marginal return on capital, would be an interesting avenue for future research.

Another important conclusion stems from our analyze of sector differences. As the largest outlier, pulp and paper manufacturing shows a strong negative responsiveness to changes in income and shows significant support for the within-EU pollution haven hypothesis. This is one example that speaks for carefully designing environmental policy that is tailored to sectoral differences.

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A Decomposition into composition and technique changes

We here show that, in alignment with previous literature, within-sector technique changes account for the large majority of emission intensity changes within countries over time. To so so, we plot these changes next to the between-sector compositional changes for each country in Figure A1.

The issue in presenting changes in a decomposition exercise as in (2) is the choice of the scaling variable. For example, in the first term in (2) we are interested in the change in the technique component, but for this, one needs to scale each sector's technique change dEi_i by the sector's share on total output, Φ_i, as technological improvements in very small sectors add very little to the total intensity. The question is then about which Φ_i to chose: the one in the first year, in the last year, or some average Φ_i. As explained in Ang (2004) one can instead make use of the logarithmic mean Divisia index (also referred to as "Montgomery decomposition" in De Boer (2008)) that uses the logarithmic mean of a variable that is derived from both Φ_i and EI_i, which we will call W_i, and which can be used for scaling both the technique and the composition effect.

Both effects are then defined like this:

$$\begin{aligned}
Technique &= \sum_{i=1}^{I}(ln(ei_{it}) - ln(ei_{i0})) * \frac{W_{iT} - W_{i0}}{ln(W_{iT}) - ln(W_{i0})} \\
Composition &= \sum_{i=1}^{I}(ln(\phi_{it}) - ln(\phi_{i0})) * \frac{W_{iT} - W_{i0}}{ln(W_{iT}) - ln(W_{i0})} \\
W_{it} &= \frac{e_{it}}{VA_t} \\
\phi_{it} &= \frac{va_{it}}{VA_t} \\
ei_{it} &= \frac{e_{it}}{va_{it}},
\end{aligned} \tag{7}$$

where e is emissions, va is value added, and we assume $ln(W_{iT})-ln(W_{i0})$ to be non-zero. Subscript i refers to the manufacturing sector and we are interested in the decompositonal change from $t = 0$ to $t = T$. If the subscript i is omitted, it refers to the aggregate manufacturing (or the sum of all the manufacturing sectors with available data). For a derivation of this, we refer the interested reader to Ang (2004) or De Boer (2008).

One can see that in all countries the technique changes are much larger than the composition changes. This justifies our focus on estimating the former, that is, on estimating intensity changes within manufacturing sectors.

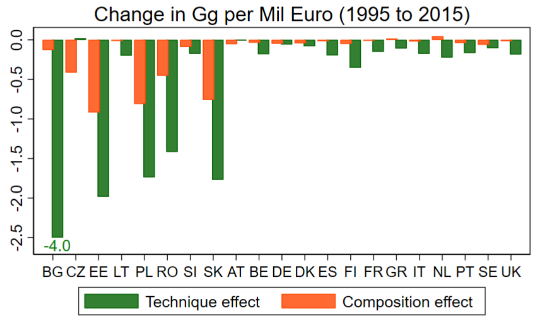
B Data details

B.1 Emission data

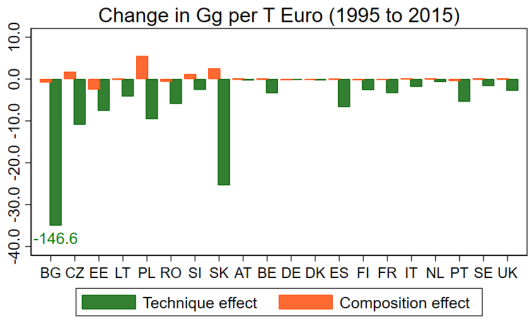
The IEA data contain information on emissions from fuel combustion, and in some sectors also add process-related emissions. The CLRTAP data supply emissions from energy, industrial processes and product use.[13]

[13] It is not possible to link the consumed, but not self-produced, energy of a sector to its producing source. This implies that our data set only contains data on self-produced energy as well as on emissions from industrial processes. It follows that data from energy consumption that is produced within the energy sector is excluded from the analysis.

(a) CO_2



(b) SO_x



(c) NO_x

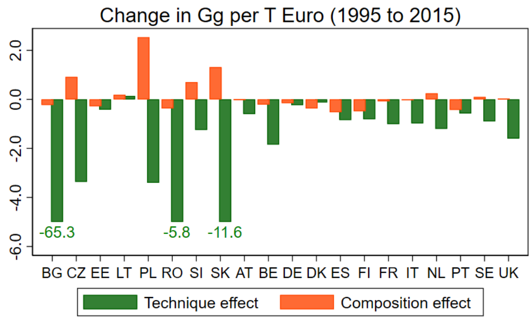


Figure A1: Composition and technique changes of manufacturing emission intensity by country. Change from 1995 to 2015. Calculation based on Montgomery decomposition, described in Appendix A. For very large changes the bar is cut off and the total change is indicated below the bar.

The IEA data is comparatively more easy to merge with other production data, since they use a similar classification as the production data, which are based on the NACE classification. In the conversion from the CLRTAP classifiers (IPC classification) to NACE some sectors get lost, which is why the sample on CO_2 is larger than the one on air pollutants. Table B1 lists for which pollutant and sector combination our panel contains data and the following subsections provide a description of the linking between the different data sets.

Table B1: NACE Rev.2 sector codes

NACE code	Sector Name	Available data
C10-C12	Food products, beverages and tobacco	CO_2, SO_x, NO_x
C13-C15	Manufacture of textiles, wearing apparel and leather	CO_2
C16	Manufacture of wood and of products of wood and cork, except furniture	CO_2
C17-C18	Manufacture of paper, pulp and paper products Printing and reproduction of recorded media	CO_2,SO_x, NO_x
C19	Coke and refined petroleum products	SO_x, NO_x
C20-C21	Chemicals and chemical products	CO_2,SO_x, NO_x
C23	Manufacture of other non-metallic mineral products	CO_2,SO_x, NO_x
C24	Manufacture of basic metals	CO_2
C24-C25	Basic metals and fabricated metal products, except machinery and equipment	SO_x, NO_x
C25-C28	Manufacture of computer, electronic and optical products, fabricated metal products, electrical equipment and machinery	CO_2
C29-C30	Manufacture of motor vehicles and other transport equipment	CO_2

B.2 Production data

Capital input in the KLEMS data, CAP, is calculated as the residual between value added and labour compensation (Stehrer et al., 2019). This implies that capital input, in the KLEMS data, represents a capital income share. Based on countries with available volume data, we calculate a price series for each sector and use this to transform the nominal capital input of the other countries, for which no nominal data is available, into real values. The following paragraphs describe this extrapolation.

CAP is implicitly defined as a the product of quantity (CAP_QI_{sct}) and price (CAP_P_{sct}). For some countries quantity data in index form, $CAP\_QI^{in}_{sct}$, is given. This data is in a first step used to extrapolate an average price index that is then used in a second step to convert capital input for all other countries into quantity terms. In order to do so, one needs to create an index of CAP_{sct}, CAP^{in}_{sct}. The extrapolated, sector-specific price series is then derived as:

$$CAP\_P^{ex}_{sct} = \frac{CAP^{in}_{sct}}{CAP\_QI^{in}_{sct}},$$

using the data with available quantity data. The mean of these prices in each year and sector combination $\overline{CAP\_P^{ex}_{st}}$ is then used to convert the nominal capital input data into real terms for countries without fully available quantity data. For countries with available data, the own extracted price is used such that

$$CAP\_QI_{sct} = \frac{CAP_{sct}}{CAP\_P^{ex}_{sct}} \text{ or}$$
$$CAP\_QI_{sct} = \frac{CAP_{sct}}{\overline{CAP\_P^{ex}_{st}}}.$$

The time series are now all in 2010 national currencies and PPPs are used to bring all series onto the same unit.

In order to derive the KL variable, CAP_QI_{sct} is divided by the number of hours worked by engaged people (employed and self employed) in a given year and sector, turning the measure into a capital to labour ratio. One could also use capital over labour input for it, but since for labour input we are again facing the problem of missing volume data one would have needed to extract average labour price series (comparable to wages). These are, however, likely to differ between new and old member states. A pure measure of hours worked is thus less likely to incorporate measurement error problems.

To calculate the relative series, $RINC$ and RKL, GDP per capita in each country is divided by the GDP per capita EU-28 average and the capital intensity is divided by the sector specific mean of available data points. For $RINC$ in the sector specification, we only take the mean over all countries for which we also have data for that particular sector to ensure consistency.

Greece was unavailable in the CLTRAP data set and is therefore only included in the CO_2 data set. Malta, Latvia, Cyprus and Hungary were dropped in both data sets, due to large data gaps in their time series. For consistency, we have dropped Luxembourg in the main analysis, since its relative income presents a large outlier in all dimensions. The results do not change when it is included in any form. Data points were dropped if their capital input value was given by a negative number.[14]

B.3 Mapping between different data sources

The sector classification in the CLTRAP data sets is based on the IPCC common reporting framework (CRF) that differs from the classification of all other data sources used. These are based on the "statistical classification of economic activities in the European Community" (NACE). Trade data is classified in the ISIC Rev.4. A direct mapping between NACE and ISIC is possible so that no data was lost in merging the trade data to the other data.

The mapping between the IPCC CRF and the EU NACE classification is based on a mapping published by the European Environmental Agency (EEA) as Annex 1

[14] This occurs as a result of the derivation as the residual between value added and labour input and might indicate negative profits in these sectors. It might, however, also indicate either negative rental prices or mismeasurement.

to Eurostat (2015). Where several NACE sectors were assigned to one CRF sector or where the mapping was country specific, the data was not used. Table B2 summarizes all the mappings undertaken. For IEA data, the mapping is considerably easier, since it is based on the ISIC classification system, where sectors are corresponding to the NACE two digit sectors. Iron and Steel was combined with non-ferrous metals to NACE sector C24. These sectors mostly contain the emissions classified under CRF section 1, and in some cases also for section 2, as outlined in the respective data description.

KLEMS data is for three sectors less specific than the emissions data. For sectors C16, C17-C18, and C23, we thus replaced the KLEMS data with direct Eurostat data on production and employment. This data are the source for all KLEMS data and are thus similar. Unfortunately, the capital input data are only available from EU KLEMS and so the capital labour ratio for sectors C22-C23 were assigned to the capital labour ratio of sector C23, and the same was done for C16-C18 to C17-C18 as well as C16. These inaccuracies should largely be controlled for by the included fixed effects.

Table B2: Mapping between CRF and NACE sectors

NACE	**CRF**	**Sector Name**
C10-C12	1.A.2.e,2.H.2	Food products, beverages and tobacco
C17-C18	1.A.2.d,2.H.1,2.D.3.h	Manufacture of paper and paper products and Printing and reproduction of recorded media
C19	1.A.1.b,1.B.1.b	Coke and refined petroleum products
C20-C21	1.A.2.c, 2.A.4.b, 2.B, 2.D.3.g	Chemicals and chemical products
C23	1.A.2.f, 2.A.1-2.A.3, 2.A.4.a, 2.A.4.c	Manufacture of other non-metallic mineral products
C24-C25	1.A.2.a, 1.A.2.b, 2.C	Basic metals and fabricated metal products, except machinery and equipment
C	1.A.2, 2, 1.B.1	Whole Manufacturing sector

C Unit root and cointegration tests

We here analyze the stationarity properties in our data, and then test for potential cointegration between emission intensities and our right hand side variables, in (4).

The universe of panel unit root tests is a large and diverse one. We rely on the literature on second generation unit root tests that take into account cross sectional dependence within the panel. We thus start by applying Pesaran (2004)'s test for cross-sectional correlation in the residuals of an ADF regression of each variable.

Table C1 shows the results of the cross-sectional dependence test, in the CD-headed columns, for all independent and dependent variables. One can see that all variables show signs of cross-sectional dependence.

We thus rely on Pesarans cross-sectionally augmented IPS (CIPS) test (Pesaran, 2007) to test for non-stationarity in our time series. This test is in essence an extension of the Im et al. (2003) test. It implies running an ADF regression, which is augmented with the cross-sectional mean and its lags. The test statistic is then an average over the individual ADF statistics.

One can see that, with two exceptions, for all dependent variables and independent variables the CIPS test does not reject the null hypothesis of non-stationarity in levels. For NO_x intensities, this also happens when we drop Lithuania from the sample and for LP if we drop Lithuania, the test does also only reject at the 10, but not the 5 percent level any more. The fact that for all variables the test clearly reject the null when the variables are taken in first differences, makes us confident that the underlying processes are indeed I(1) and since dropping Lithuania has no effect on our main results, we present the results of the full sample. These conclusions allow us to move further to cointegration testing.

To confirm the existence of a cointegration relation in (4), we rely on the results of two different cointegration tests and several specifications of these. We use both the Pedroni (2004) and Westerlund (2005) tests. Both tests practically run regression (4)[15] and then check for stationarity in the residuals of this regression. Both tests share the freedom that the cointegration relationship might be panel specific, as well as that the null hypothesis is the absence of a cointegration relationship. The Pedroni (2004) test has as the alternative hypothesis that all panels are cointegrated, while the Westerlund (2005) test only has the hypothesis that some panels are cointegrated. We include a trend in all specifications and demean the variables in some cases to partly control for cross-sectional dependence. For further details on these tests we refer to the respective literature.

The cointegration results in Table C2 show a clear rejection of the null hypothesis of no cointegration in all tests and specifications. This motivates analysing a cointegration regression, as outlined in the main body.

[15] The enlargement dummies were hereby omitted.

Table C1: Cross-sectional dependence and unit root tests for variables in levels and first differences

	CD		CIPS - level		CIPS - FD	
	Test stat	p-value	Test stat	5% CV	Test stat	5% CV
CO_2 Intens	36.57	0.00	−2.58	−2.65	−4.71	−2.70
SO_x Intens	24.10	0.00	−2.57	−2.65	−4.36	−2.70
NO_x Intens	29.01	0.00	−2.72	−2.65	−4.59	−2.70
TI	41.53	0.00	−2.47	−2.65	−4.36	−2.70
KL	70.25	0.00	−2.46	−2.65	−4.17	−2.70
LP	148.00	0.00	−2.85	−2.65	−4.35	−2.70
GDP	34.07	0.00	−2.36	−2.67	−2.77	−2.73
TI*RINC	39.22	0.00	−2.36	−2.65	−4.33	−2.70
TI*RKL	34.66	0.00	−2.49	−2.65	−4.54	−2.70

Both CIPS tests include one lag of the variable in the ADF regression, as well as a linear trend.

Table C2: Panel cointegration tests for (4)

	Pedroni - ADF		Pedroni - PP		Westerlund	
	Test stat	p-value	Test stat	p-value	Test stat	p-value
CO2	−12.76	0.00	17.55	0.00	3.94	0.00
SOx	−7.39	0.00	14.95	0.00	−2.12	0.02
NOx	−8.94	0.00	7.06	0.00	3.71	0.00
			Demeaned			
CO2	−9.76	0.00	17.57	0.00	5.70	0.00
SOx	−12.86	0.00	14.17	0.00	−2.13	0.02
NOx	−13.55	0.00	7.11	0.00	3.71	0.00

Test statistic for Pedroni - ADF test is the Augmented Dickey-Fuller statistic, test statistic for Pedroni - PP test is the Modified Phillips-Perron statistic. Trends were included in all tests. Common null hypothesis of no cointegration relation.

D Additional tables

Table D1: Sector-specific estimates of (4) for CO_2 intensities

	(1) C10-C12	(2) C13-C15	(3) C16	(4) C17-C18	(5) C20-C21	(6) C23	(7) C24	(8) C25-C28	(9) C29-C30
Induced composition									
Trade Integration	-0.13	-0.43	-2.52	5.64^{*}	-0.28	0.16	-3.30^{**}	-0.22	0.02
	(1.62)	(2.51)	(2.06)	(2.74)	(1.39)	(0.34)	(1.24)	(1.32)	(0.94)
TI*Relative GDP (PHH)	-0.22	0.69	1.52	-3.88^{***}	1.03	-0.03	2.30^{***}	-1.04	-0.30
	(1.12)	(1.39)	(1.79)	(1.20)	(1.07)	(0.37)	(0.77)	(1.04)	(0.53)
TI*Relative Capital (FEH)	0.71^{**}	0.11	0.69	-0.23	-0.65	0.12	-0.04	0.39	-0.55
	(0.29)	(0.22)	(0.65)	(0.85)	(0.56)	(0.21)	(0.55)	(0.38)	(0.37)
Deviation new members	0.05	0.24	-0.82	0.91^{*}	1.43^{*}	-0.18^{*}	-0.15	0.87	-0.05
	(0.22)	(0.29)	(0.64)	(0.52)	(0.71)	(0.10)	(0.16)	(0.72)	(0.29)
Enlargement steps									
Candidate Status	0.02	-0.16	0.48^{**}	-1.73^{***}	-0.48	-0.33^{***}	0.43^{*}	0.04	0.04
	(0.14)	(0.28)	(0.17)	(0.34)	(0.48)	(0.06)	(0.21)	(0.14)	(0.30)
Accession	-0.03	0.05	0.03	-0.20	0.23	-0.13	-0.08	-0.12	-0.32
	(0.07)	(0.15)	(0.26)	(0.18)	(0.25)	(0.08)	(0.11)	(0.15)	(0.23)
Development/Income									
GDP per capita	-0.08	1.21	-1.09	-6.56^{**}	2.26	0.23	-0.97	-1.23	3.05^{**}
	(1.36)	(1.63)	(3.37)	(2.71)	(1.86)	(0.80)	(1.14)	(0.95)	(1.32)
Deviation new members	-0.28	-0.82	0.47	-2.17	-0.97	-0.20	1.51^{*}	2.16^{**}	-2.97^{*}
	(0.59)	(1.18)	(1.57)	(2.46)	(1.20)	(0.60)	(0.77)	(0.88)	(1.63)
Sector productivity									
Labour productivity	-1.96^{***}	-0.07	0.96	0.16	-0.27	-0.36	-0.86^{***}	-1.56^{***}	-1.50^{***}
	(0.51)	(0.55)	(0.98)	(1.34)	(0.75)	(0.21)	(0.19)	(0.44)	(0.35)
Deviation new members	0.83^{**}	-0.49	0.95	2.69^{***}	-0.17	0.67^{**}	-0.39^{**}	-0.15	0.23
	(0.35)	(0.46)	(0.58)	(0.90)	(0.59)	(0.27)	(0.17)	(0.43)	(0.41)
Further controls									
Capital intensity	1.08^{***}	-0.04	0.65	-0.28	-0.42	0.10	-0.20	0.73^{*}	0.50^{**}
	(0.33)	(0.26)	(0.55)	(0.71)	(0.49)	(0.19)	(0.17)	(0.36)	(0.23)
Other deviations F-test p-value	0.87	0.19	0.00	0.03	0.55	0.12	0.57	0.05	0.91
R-squared	0.87	0.85	0.78	0.74	0.77	0.83	0.88	0.88	0.85
Observations	310	287	285	314	295	321	301	304	295

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Fixed effects and linear trends as in (4c). All models estimated with dynamic OLS, including two leads and lags of all explanatory variables. The regressions are run on the sample of all available member states. NACE sector codes as in Table B1. New member states deviations for all variables are included in each regression; p-value for F-test on all omitted deviations given.

Table D2: Sector-specific estimates of (4) for SO_x intensities

	(1) C10-C12	(2) C17-C18	(3) C19	(4) C20-C21	(5) C23	(6) C24-C25
Induced composition						
Trade Integration	2.01	1.81	−0.83	5.98***	−0.32	6.52
	(4.82)	(2.85)	(1.02)	(2.00)	(1.38)	(4.42)
TI*Relative GDP (PHH)	0.44	−1.55	1.75	−4.08*	2.56*	−2.78
	(4.08)	(2.16)	(1.04)	(2.33)	(1.44)	(2.67)
TI*Relative Capital (FEH)	0.83	−0.12	0.17***	−1.58	0.64	1.20
	(1.55)	(0.80)	(0.05)	(1.30)	(1.02)	(1.28)
Deviation new members	−0.03	2.09**	−0.20	−1.33	1.03	−3.08
	(0.68)	(0.86)	(0.16)	(1.61)	(0.66)	(2.20)
Enlargement steps						
Candidate Status	0.27	−2.89***	0.37	−1.73**	−1.22***	−1.88**
	(0.50)	(0.53)	(0.29)	(0.75)	(0.43)	(0.76)
Accession	0.42	−0.17	−0.98***	0.32	−0.53**	−0.22
	(0.33)	(0.31)	(0.29)	(0.40)	(0.22)	(0.22)
Development/Income						
GDP per capita	9.40	−9.91*	7.86**	−6.46	9.60	−2.97
	(9.62)	(5.51)	(3.05)	(5.57)	(6.38)	(2.37)
Deviation new members	−3.59	−9.79**	2.05	−5.16	−6.82	3.97**
	(2.77)	(4.60)	(2.31)	(3.31)	(4.53)	(1.87)
Sector productivity						
Labour productivity	−2.23**	1.34	−1.36***	−1.69	−1.19	−1.23
	(0.79)	(1.52)	(0.29)	(1.76)	(1.60)	(0.78)
Deviation new members	0.26	5.06***	0.24	1.24	−0.10	−0.71
	(1.44)	(1.40)	(0.16)	(1.47)	(0.84)	(0.86)
Further controls						
Capital intensity	1.84	−1.35	0.91***	0.27	0.98	−0.04
	(1.72)	(1.38)	(0.24)	(1.10)	(0.79)	(0.56)
Other deviations F-test p-value	0.01	0.00	0.05	0.11	0.02	0.18
R-squared	0.87	0.78	0.96	0.67	0.55	0.78
Observations	283	304	193	278	304	284

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
For further notes, we refer to Table D1.

Table D3: Sector-specific estimates of (4) for NO_x intensities

	(1) C10-C12	(2) C17-C18	(3) C19	(4) C20-C21	(5) C23	(6) C24-C25
Induced composition						
Trade Integration	1.31	3.24**	0.25	2.99	0.96	0.12
	(2.09)	(1.32)	(0.55)	(2.15)	(1.00)	(3.55)
TI*Relative GDP (PHH)	0.72	−3.03**	0.82	−2.89*	0.53	−0.66
	(2.05)	(1.26)	(0.72)	(1.66)	(0.76)	(2.34)
TI*Relative Capital (FEH)	−0.20	0.34	−0.11	−0.00	−1.04**	1.21
	(0.66)	(0.94)	(0.07)	(0.57)	(0.38)	(1.08)
Deviation new members	−0.02	0.86*	−0.19*	1.45*	−0.03	−0.57
	(0.29)	(0.49)	(0.10)	(0.72)	(0.30)	(0.84)
Enlargement steps						
Candidate Status	0.15	−0.86***	0.03	0.61*	−0.22*	−0.25
	(0.24)	(0.27)	(0.15)	(0.33)	(0.11)	(0.29)
Accession	0.00	−0.10	−0.33	−0.14	−0.35***	−0.28
	(0.13)	(0.16)	(0.21)	(0.11)	(0.10)	(0.17)
Development/Income						
GDP per capita	9.00	−7.28**	2.80**	−2.20	3.19**	−2.57
	(6.78)	(3.19)	(1.31)	(1.89)	(1.41)	(2.03)
Deviation new members	−2.49	−1.22	1.49	1.18	−3.02**	2.93**
	(1.75)	(1.52)	(1.05)	(1.37)	(1.15)	(1.38)
Sector productivity						
Labour productivity	−1.81***	0.03	−1.24***	−0.15	−0.80**	−0.69
	(0.47)	(1.15)	(0.15)	(0.79)	(0.36)	(0.46)
Deviation new members	0.99	0.62	0.14	−0.35	0.56*	0.14
	(1.00)	(0.67)	(0.08)	(0.55)	(0.28)	(0.45)
Further controls						
Capital intensity	0.23	0.21	0.34*	−0.11	−0.26	−0.03
	(0.59)	(0.63)	(0.19)	(0.67)	(0.31)	(0.31)
Other deviations F-test p-value	0.32	0.03	0.12	0.10	0.00	0.01
R-squared	0.77	0.74	0.98	0.84	0.87	0.70
Observations	283	303	193	278	293	289

Cluster robust standard errors in parentheses, $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
For further notes, we refer to Table D1.

Table D4: Robustness tests for CO_2 intensities

	Base	Squared	World	CTS	Trends	INC_c
	(1)	(2)	(3)	(4)	(5)	(6)
Induced composition						
Trade Integration	−0.62	−0.73	−0.66	−0.13	−0.41	−0.57
	(0.52)	(1.15)	(0.43)	(0.26)	(0.61)	(0.51)
TI*Relative GDP (PHH)	0.32	0.40†	0.31	0.02	0.36	0.26
	(0.36)	(0.55)	(0.31)	(0.20)	(0.42)	(0.34)
TI*Relative Capital (FEH)	0.09	0.16†	0.08	0.06	0.13	0.10
	(0.07)	(0.10)	(0.07)	(0.07)	(0.09)	(0.07)
Deviation new members	0.16	0.23†	0.19	−0.05	0.08	0.16
	(0.12)	(0.18)	(0.12)	(0.07)	(0.10)	(0.12)
Enlargement steps						
Candidate Status	−0.14	−0.17	−0.15	−0.16	−0.19	−0.16
	(0.16)	(0.15)	(0.15)	(0.15)	(0.16)	(0.16)
Accession	−0.10	−0.10	−0.10	−0.09	−0.09	−0.10
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Development/Income						
GDP per capita	−0.12	−0.11	−0.29	−0.13	−0.11	−0.57‡
	(0.59)	(0.61)	(0.51)	(0.60)	(0.60)	(0.65)
Deviation new members	0.24	0.23	0.39	0.24	−0.00	0.18‡
	(0.68)	(0.70)	(0.65)	(0.67)	(0.71)	(0.32)
Sector productivity						
Labour productivity	−0.89***	−0.88***	−0.89***	−0.84***	−0.63***	−0.90***
	(0.13)	(0.13)	(0.13)	(0.14)	(0.19)	(0.14)
Deviation new members	−0.09	−0.10	−0.11	−0.08	0.27	−0.08
	(0.16)	(0.16)	(0.16)	(0.15)	(0.25)	(0.16)
Further controls						
Capital intensity	0.04	0.03	0.00	0.07	0.02	0.04
	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)	(0.08)
Other deviations F-test p-value	0.88	0.85	0.81	0.61	0.49	0.90
R-squared	0.47	0.48	0.48	0.47	0.69	0.48
Observations	2712	2712	2712	2712	2712	2712

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
For estimation details, see notes of Table 1. Column 2 replaces (4a) with (5), column 3 and 4 replace TI, by either integration into world trade or by the CTS measure, (6). Column 5 adapts (4c) by more heterogeneous trends, and column 6 adds country specific INC (GDP per capita) coefficients.
† The coefficients in column 2 for TI*Relative Capital and TI*Relative GDP are the marginal effects for increasing TI and $RINC$ or respectively RKL in (5), evaluated at the median relative income and capital intensity. For the new members deviation the median for their sample is chosen. The standard errors are computed using the delta method.
‡ Estimates for the national income block in column 6 represent the average INC_c coefficient.
Estimates of squared terms and country specific coefficients underlying columns 2 and 6 respectively are available upon request.

Table D5: Robustness tests for SO_x intensities

	Base	Squared	World	CTS	Trends	INC_c
	(1)	(2)	(3)	(4)	(5)	(6)
Induced composition						
Trade Integration	−0.31	1.19	0.48	−0.31	1.77	−0.77
	(0.96)	(2.29)	(1.26)	(0.61)	(1.53)	(1.00)
TI*Relative GDP (PHH)	0.43	0.09†	−0.27	0.17	−0.37	0.71
	(0.66)	(0.99)	(0.90)	(0.41)	(1.28)	(0.69)
TI*Relative Capital (FEH)	0.01	−0.06†	0.02	0.23	−0.10	0.02
	(0.15)	(0.26)	(0.20)	(0.17)	(0.13)	(0.15)
Deviation new members	0.61*	0.62†	0.71*	0.37***	0.42**	0.58*
	(0.33)	(0.59)	(0.43)	(0.14)	(0.20)	(0.34)
Enlargement steps						
Candidate Status	−1.08**	−0.98**	−1.00**	−1.00***	−1.05**	−0.84**
	(0.43)	(0.43)	(0.42)	(0.36)	(0.47)	(0.38)
Accession	−0.11	−0.11	−0.13	−0.13	−0.06	−0.18
	(0.11)	(0.11)	(0.11)	(0.10)	(0.11)	(0.11)
Development/Income						
GDP per capita	−0.79	−0.47	−1.63	−0.68	−0.84	−1.60‡
	(2.19)	(2.23)	(2.16)	(1.78)	(2.78)	(2.26)
Deviation new members	−3.33*	−3.77**	−2.95*	−2.88	−2.82	−2.37**‡
	(1.76)	(1.75)	(1.70)	(2.05)	(1.72)	(1.03)
Sector productivity						
Labour productivity	−1.03***	−1.03***	−1.01***	−1.03***	−0.75**	−1.02***
	(0.24)	(0.23)	(0.23)	(0.23)	(0.30)	(0.24)
Deviation new members	0.74***	0.73***	0.68**	0.90***	0.32	0.73***
	(0.27)	(0.27)	(0.27)	(0.30)	(0.30)	(0.27)
Further controls						
Capital intensity	−0.16	−0.16	−0.18	0.05	−0.14	−0.19
	(0.18)	(0.19)	(0.16)	(0.20)	(0.29)	(0.22)
Other deviations F-test p-value	0.68	0.77	0.59	0.53	0.36	0.91
R-squared	0.46	0.47	0.46	0.46	0.66	0.47
Observations	1646	1646	1646	1646	1646	1646

Cluster robust standard errors in parentheses, $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.
For further notes, we refer to Table D4.

Table D6: Robustness tests for NO_x intensities

	Base	Squared	World	CTS	Trends	INC_c
	(1)	(2)	(3)	(4)	(5)	(6)
Induced composition						
Trade Integration	0.07	−0.22	0.01	0.18	1.71*	−0.31
	(0.46)	(1.12)	(0.50)	(0.34)	(0.93)	(0.49)
TI*Relative GDP (PHH)	0.24	0.24†	0.20	0.12	−0.84	0.54
	(0.35)	(0.47)	(0.41)	(0.24)	(0.82)	(0.39)
TI*Relative Capital (FEH)	−0.04	−0.06†	−0.04	−0.04	−0.15**	−0.05
	(0.11)	(0.17)	(0.15)	(0.06)	(0.06)	(0.11)
Deviation new members	0.27**	0.23†	0.37**	0.17**	0.21**	0.26**
	(0.13)	(0.23)	(0.17)	(0.07)	(0.10)	(0.13)
Enlargement steps						
Candidate Status	−0.30*	−0.29*	−0.27**	−0.32*	−0.38**	−0.25*
	(0.16)	(0.16)	(0.13)	(0.16)	(0.18)	(0.13)
Accession	−0.17**	−0.17**	−0.17**	−0.15**	−0.15**	−0.17***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)
Development/Income						
GDP per capita	0.58	0.62	0.36	−0.03	−0.35	0.26‡
	(1.29)	(1.36)	(1.28)	(1.23)	(1.52)	(1.54)
Deviation new members	−0.70	−0.75	−0.61	−0.53	−0.38	−0.58‡
	(0.71)	(0.71)	(0.68)	(0.62)	(0.74)	(0.52)
Sector productivity						
Labour productivity	−1.06***	−1.05***	−1.04***	−1.04***	−0.87***	−1.06***
	(0.13)	(0.13)	(0.13)	(0.12)	(0.17)	(0.14)
Deviation new members	0.58***	0.60***	0.53***	0.59***	0.28**	0.57***
	(0.14)	(0.14)	(0.13)	(0.14)	(0.12)	(0.14)
Further controls						
Capital intensity	0.03	0.03	0.01	0.03	−0.05	0.00
	(0.10)	(0.11)	(0.08)	(0.08)	(0.10)	(0.12)
Other deviations F-test p-value	0.56	0.74	0.55	0.42	0.36	0.53
R-squared	0.57	0.57	0.57	0.58	0.73	0.58
Observations	1639	1639	1639	1639	1639	1639

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
For further notes, we refer to Table D4.

Table D7: Alternative stringency measures, as given in first row of table

	Energy prices			Environmental tax revenue		
	(1) CO_2	(2) SO_x	(3) NO_x	(4) CO_2	(5) SO_x	(6) NO_x
Induced composition						
Trade Integration	2.07	−2.92	−1.90	0.20	−1.20	−0.11
	(1.42)	(4.45)	(1.81)	(0.29)	(0.74)	(0.33)
TI * Relative Stringency (PHH)	−2.24	2.82	2.31	−0.39	1.44*	0.51
	(1.41)	(4.23)	(1.74)	(0.23)	(0.79)	(0.34)
Deviation new members	3.48	8.59	0.36	0.42	−3.40**	−0.93**
	(2.28)	(6.14)	(1.73)	(0.55)	(1.42)	(0.41)
TI*Relative Capital (FEH)	0.05	0.62	0.11	0.08	−0.01	−0.03
	(0.07)	(0.38)	(0.27)	(0.06)	(0.15)	(0.10)
Deviation new members	0.01	1.15**	0.21	0.14	0.55*	0.22**
	(0.15)	(0.55)	(0.28)	(0.10)	(0.30)	(0.11)
Enlargement steps						
Candidate Status	−0.16	−0.90	−0.41**	−0.14	−1.28***	−0.36**
	(0.18)	(0.57)	(0.17)	(0.15)	(0.44)	(0.14)
Accession	−0.12*	−0.08	−0.06	−0.10*	−0.18	−0.15**
	(0.07)	(0.17)	(0.09)	(0.06)	(0.12)	(0.07)
Development/Income						
GDP per capita	0.44	−0.53	0.03	−0.14	−2.42	−0.17
	(0.55)	(2.78)	(1.58)	(0.55)	(2.03)	(1.16)
Deviation new members	−0.02	−5.13*	−2.05*	0.17	−2.11	−0.32
	(1.02)	(2.72)	(1.05)	(0.69)	(1.71)	(0.73)
Sector productivity						
Labour productivity	−1.10***	−0.34	−0.27	−0.90***	−1.07***	−1.05***
	(0.20)	(0.64)	(0.37)	(0.13)	(0.23)	(0.13)
Deviation new members	0.06	1.62**	0.24	−0.08	0.67**	0.55***
	(0.29)	(0.73)	(0.29)	(0.16)	(0.26)	(0.13)
Further controls						
Capital intensity	0.09	0.03	−0.02	0.03	−0.17	0.05
	(0.08)	(0.35)	(0.17)	(0.07)	(0.19)	(0.10)
Other deviations F-test p-value	0.26	0.05	0.08	0.67	0.17	0.54
R-squared	0.50	0.48	0.55	0.47	0.46	0.57
Observations	2286	1091	1079	2712	1646	1639

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
For further notes, we refer to Table 1.

Table D8: Estimation of (4), on aggregate manufacturing data. Intensities as dependent variables.

	CO_2	SO_x	NO_x
	(1)	(2)	(3)
Induced composition			
Trade Integration	0.55	−0.10	2.15**
	(0.61)	(0.99)	(0.89)
Deviation new members	−2.05**	0.90	−1.90*
	(0.77)	(1.53)	(1.05)
TI*Relative GDP (PHH)	0.17	−0.15	−1.74**
	(0.53)	(0.45)	(0.63)
Deviation new members	2.82**	−2.29	−0.51
	(1.18)	(2.92)	(1.02)
TI*Relative Capital (FEH)	−0.38***	0.92***	−0.17
	(0.12)	(0.23)	(0.16)
Deviation new members	1.77***	1.44**	1.83***
	(0.39)	(0.65)	(0.24)
Enlargement steps			
Candidate Status	−0.01	−0.20**	−0.04
	(0.07)	(0.08)	(0.06)
Accession	−0.14	−0.04	−0.14
	(0.09)	(0.07)	(0.08)
Development/Income			
GDP per capita	−0.02	1.03	0.66
	(0.51)	(0.98)	(0.74)
Sector productivity			
Labour productivity	−0.93***	−0.75	−1.60***
	(0.30)	(0.55)	(0.33)
Further controls			
Capital intensity	−0.02	0.56***	0.14
	(0.15)	(0.16)	(0.19)
Other deviations F-test p-value	0.50	0.16	0.94
R-squared	0.87	0.92	0.93
Observations	365	347	347

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Fixed effects and linear trends as in (4c). All models estimated with dynamic OLS, including one lead and lag of all explanatory variables. Fewer deviations for new members included due to smaller sample size.