The Effect of the 2004 and 2007 EU Enlargement on Pollution Intensities in EU Manufacturing Sectors

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Abstract

We study the effects of market integration on manufacturing emission intensities by using the example of the EU enlargements in 2004 and 2007. For this, we analyse a sub-sectoral panel with data on almost all EU member states from 1995 to 2015. We do not find evidence of within-EU pollution haven effects and find that trade integration has not overall led to an increase in new members' emission intensities, but it has led to a slight increase among old members. However, upon integrating further, the new members capital-intense sectors did increase their emissions compared to less capital-intense ones. We also find that the accession and its announcement have reduced the emission intensity for air pollutants in new member states. This outcome is further supported by productivity increases that were spurred by the accession and led to decreases in CO_2 intensities.

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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 natural experiment of the EU enlargement process of the 2000s to analyse these questions. We hereby pay close attention to potential heterogeneity between different manufacturing sectors.

The literature on the interplay of trade and environment has started with the analysis of one of the largest trade liberalization projects of the 1990s, NAFTA (Grossman & Krueger, 1991). It is thus surprising that little effort has been made to analyse questions on this matter in the context of one of the largest liberalization projects of the early 2000s, the EU enlargements in 2004 and 2007. In this enlargement process, thirteen Eastern European countries, of which eleven were former communist states, joined the EU and its single market. This paper aims to fill this gap by studying if the enlargement has led to changes in pollution and emission intensities in both new and old EU member states.

To answer this, we analyse a three-dimensional panel with data on a manufacturing level for almost all EU member states from 1995 to 2015. These data contain information on three different pollutants: carbon dioxide ($\mathrm{CO_2}$), sulphur oxides ($\mathrm{SO_x}$) and nitrogen oxides ($\mathrm{NO_x}$), whose intensities are defined per unit of value added. Analysing both a greenhouse gas ($\mathrm{CO_2}$) as well as (local) air pollutants is important, since regulation has historically been very different for greenhouses gases that pose an international externality, and for air pollutants that have more local(ized) effects and have thus experienced regulation for a longer time.

We base our analysis on the reduced form of the theoretical setup developed by Antweiler et al. (2001), adapted to our sectoral setting. We apply panel cointegration techniques, highlighting that long-run results are most crucial for both air pollution and global warming.

In doing so, we analyse the effect for the pooled manufacturing sector, as well as for each sub-sector individually, thus taking care of the heterogeneity between them. This heterogeneity is often assumed away by analysing average manufacturing or economy-wide pollution, even though studies such as Ederington et al. (2005) and Cole et al. (2005) have long shown the important differences between sectors based on their implicit costs of regulation and their ability to relocate production factors.[1]

The focus of this study is the estimation of two channels of the "induced composition effect" that predict a relocation of emissions, based on differences in comparative advantage within the EU. The first of these channels, the within-EU pollution haven hypothesis (PHH), predicts a relocation of pollution-intense production to less developed, new member states, based on their comparative advantage due to lower environmental regulation. The second channel, postulated by the factor endowment hypothesis

[1] Henceforth these two-digit manufacturing sub-sectors will for consistency be referred to as "sectors". If the average or the aggregate manufacturing sector is described, this will be explicitly stated.

(FEH), implies a relocation of capital, and with it of related emissions, towards already capital-abundant sectors that are mostly located in the old member states, which have an historically grown comparative advantage in capital-intense production.

In the pooled manufacturing analysis, we find no support for the PHH. We find a significant FEH effect among new member states, but not in the overall sample. This implies that, only among new members, manufacturing sectors that were already capital-abundant have increased their emission intensity relative to less capital-abundant ones due to further integration into the EU market. Still, for new members an overall increase in trade integration has had a negative, but insignificant effect on the median observation, while for old members, these overall effects are pointing in the opposite direction and are partly significant.

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 responsiveness to GDP per capita changes and thus seems to respond strongly to changes in income; both domestically as well as via the PHH. Purely focusing on the average, pooled estimation thus overshadows important differences between sectors that need to be taken into account when designing environmental policies.

Additional potential effects come from a shift in regulation. New member states have to fulfil the requirements outlined in the environmental acquise 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 an emission-decreasing effect for both air pollutants, but not for CO_2. This indicates that EU regulation for air pollutants has been more successful than the one for greenhouse gases.

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 analysis hints at a cleaning of the manufacturing sector in these states, but not in old member states. Additional regulation and productivity increases have further improved both air quality and the emission of greenhouse gases throughout the EU.

These findings are promising for future accession countries and show that pollution havens within the EU seem to be an unlikely outcome of an enlargement. These results could imply that EU environmental regulation is sufficiently homogenous between countries, but they could also indicate that dirty production moves to places outside the EU, where pollution is even cheaper. Our results 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 also play a role when designing within-EU regulation on trade and environment. These results are also important for processes of market integration in other areas of the world, for they show that integration does not have to imply pollution haven effects for poor countries that open up, given that environmental regulation between opening countries is sufficiently homogenous.

To the best of our knowledge, there are only two articles that analyse the effect of the EU enlargement on environmental outcomes. Zhu and Van Ierland (2006) estimate the effects of the EU enlargement on emissions with pre-accession data. We find support for their prediction that capital and thus emission-intense production moves towards already capital-abundant places, but can not confirm that this only presents a movement from East to West. Our study, however, focusses on within manufacturing sector changes, while Zhu and Van Ierland (2006) analyse the economy in a broader sense. We do not only update their analysis to post-accession data but also go into more detail in the trade channels and the manufacturing sector. Duarte and Serrano (2021) use input-output instead of trade data, focus on a smaller sample and on PM2.5 pollution. The authors find a significant cleaning in the new member states as a result of the EU enlargement, which is potentially partially explained by relocations to outside the EU. Our study comes to similar conclusions. We also add to their contribution, by providing more causal evidence than their comparative static estimation allows for.

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

In the first strand of literature, Antweiler et al. (2001) in their seminal contribution find support for both the FEH and the PHH, 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, based on the PHH.

We add to this literature in several directions. We are the first to bring the Antweiler et al. (2001) framework to a sectoral setting and furthermore the first to analyse it in a cointegration setting. 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.

In the second strand of literature, which analyses 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) analyse 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 can 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. This is an additional contribution to this literature.[2]

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

2 Theoretical background

The potential effects of the enlargements can be divided into effects on the emission intensity within each sector (or sub-sector) and effects on the composition of those within the entire manufacturing sector. 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. All described channels are also summarized in Figure 1.

2.1 Enlargement effects through induced composition

Opening up for trade affects pollution by altering the composition of sectors 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".

The PHH predicts that after opening up for trade, countries with lower environmental regulations will use their comparative advantage for pollution-intense production to further specialize in it, which would thus imply an increase in the overall emission intensity in these countries. Countries with lower environmental regulation generally coincide with lower income countries, which in turn correspond to new member states in the EU context.[3]. This implies that the PHH predicts an increase in emissions for new member states as a result of the enlargement, which indicates an emission leakage from old to new member states.[4]

[2] 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 exact opposite. Our differentiation between countries with different income levels can partly explain these mixed results.

[3] In the EU context, while some environmental regulations are based on the EU level (e.g. the ETS), environmental regulations between member states are still heterogeneous. See, for example, Bagayev and Lochard (2017) or the relation between an OECD measure of environmental stringency and GDP in Figure 4.

[4] 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, this should dampen the PHH effect. But even though relative incomes have been converging in the EU, one can see in Figure 3 that

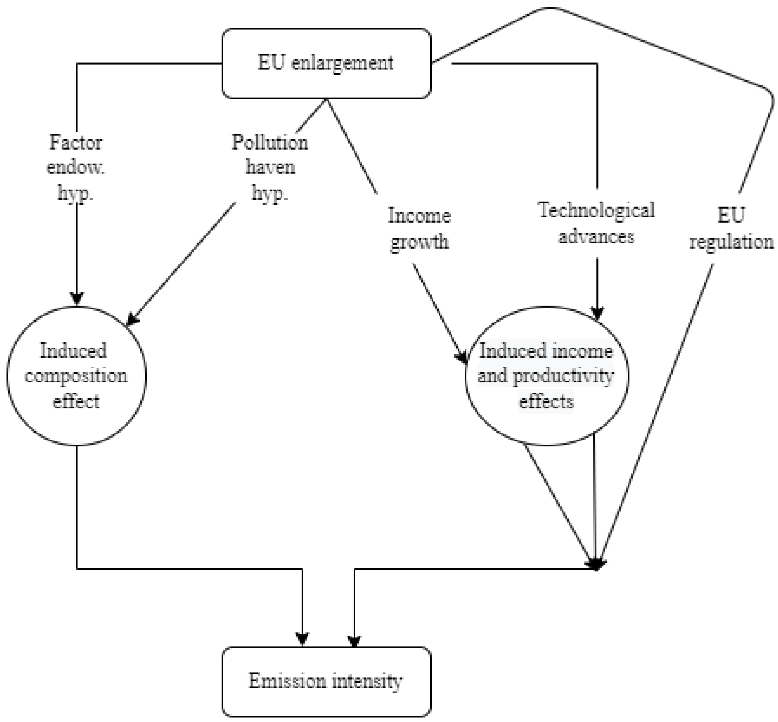


Figure 1: Direct and indirect effect of EU enlargement on emission intensities. The arrows towards a box represent a direct influence. The arrows with a box on itself represent that the influence is through the respective channel.

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

2.2 Enlargement effects through technology adoption and regulation

2.2.1 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 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 industrial pollution sphere. These regulations should affect

income levels between new and old member states are still far from each other, implying that this channel should be rather small.

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.

2.2.2 Income and productivity improvements

This paper does not make an attempt to quantify the effects that the enlargement has had on economic growth.[5] Instead, we estimate the secondary effects of these growth effects in income and productivity on emission intensities.

The postulated income effect goes through the changing preferences and related regulation of a society. Preferences over environmental cleanliness are generally assumed to increase with income (Antweiler et al., 2001, Cole and Elliott, 2003), thus also leading to tighter environmental regulations and a higher demand for "clean" products.[6] An idea that is also prominently reflected in the Environmental Kuznets Curve.

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 have also led to increases in production efficiency, which tends 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 sources.

3 Data sources and stylized facts

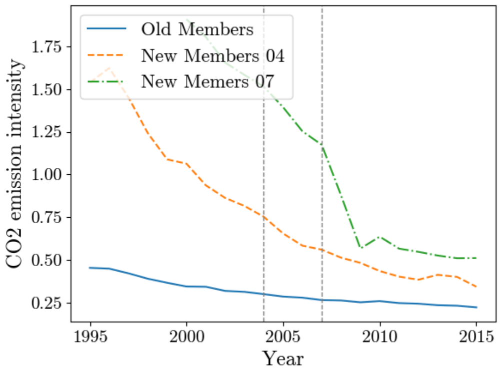
We use two data sources on emissions at their place of emittance, called emission inventories. For CO_2, we rely on "CO_2 emissions from fuel combustion - 2020 edition", provided by the International Energy Agency (IEA) (International Energy Agency, 2015), via the OECD. For SO_x and NO_x, we use data compiled in the context of the "Convention on Long-Range Transboundary Air Pollution" (CLRTAP). 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[7] database, 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, and trade data are taken from the OECD STAN database. Our final data set incorporates 23 or 22 EU member countries. For most countries data start in 1995 and span until 2015. More

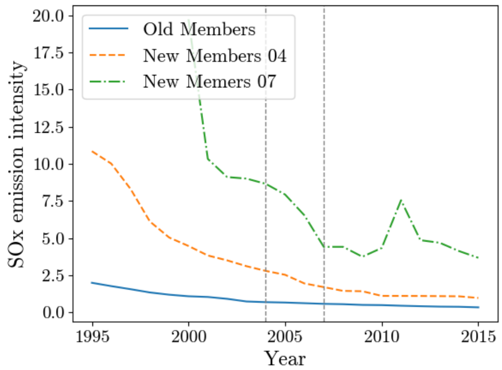
[5] For this, see for example Epstein and Jacoby (2014) or Campos et al. (2019).

[6] Even though the evidence on the preference channel is partly debated (McConnell, 1997), the correlation between income and environmental regulation is clear. This can also be seen in Figure 4, where we show that the relation between GDP and an OECD measure of environmental regulation is such that wealthier countries have much higher regulation levels.

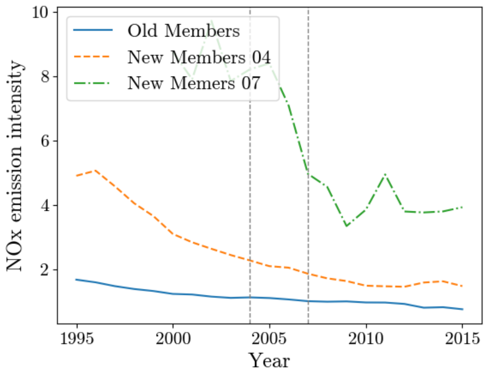
[7] EU level analysis of capital (K), labour (L), energy (E), materials (M) and service (S) inputs.



(a) CO_2 intensity, Manufacturing sector



(b) SO_x intensity, Manufacturing sector



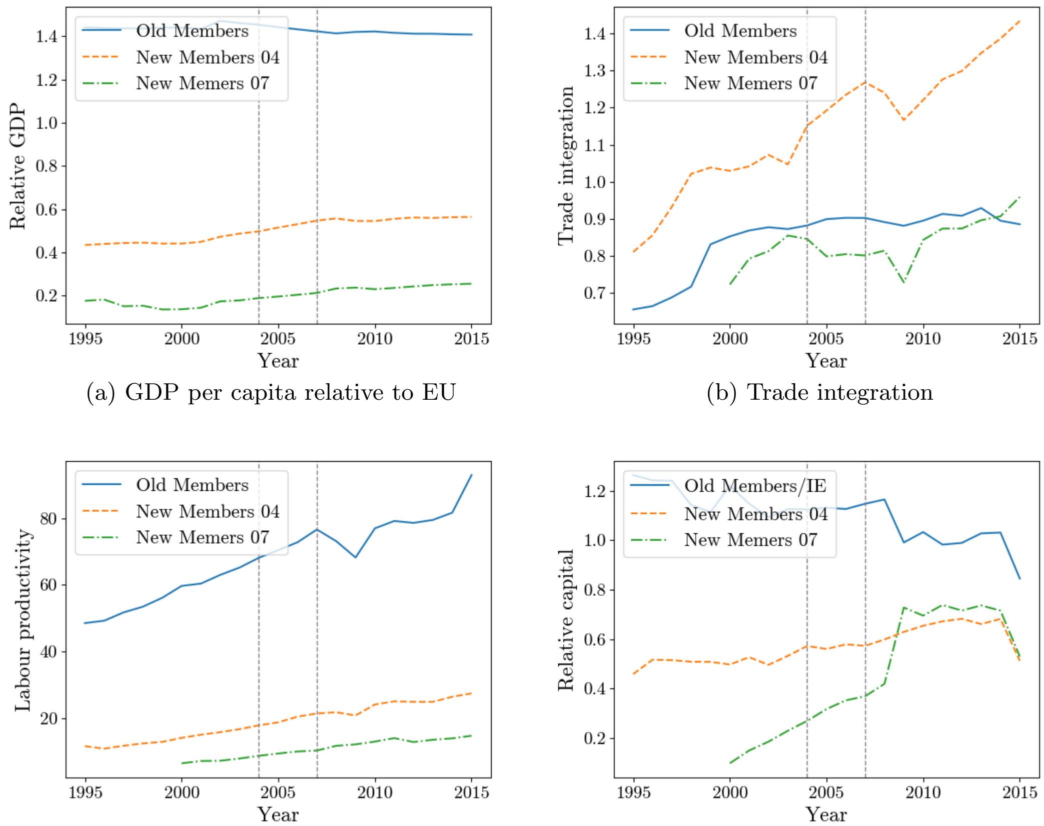
(c) NO_x intensity, Manufacturing sector

Figure 2: Emission intensity, in Gg per unit of value added (in 2010 Million Euros for CO_2 and Thousand Euros for SO_x and NO_x), average among sample members

information on the data sources and the definition and creation of our variables can be found in Appendix A.

Figure 2 shows the development of CO_2, SO_x, and NO_x emission intensities. It plots the average intensities for the respective sample of the whole manufacturing sector (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 dramatically. This is driven by both increases in value added, but especially by large 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 convergence.

Figure 3 plots summary statistics of the overall manufacturing sector (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



(a) GDP per capita relative to EU

(b) Trade integration

(c) Labour productivity

(d) Capital to labour ratio relative to EU

Figure 3: Panels (b),(c), and (d), for whole manufacturing sector, all lines represent averages among sample members. Labour productivity is in Million Euro per engaged person; exact definitions of variables in Appendix A. For illustrative purposes Ireland is excluded from the relative capital chart, because it has much higher ratios than all other countries.

less integrated. The fact that the new member states exhibit on average higher trade integration is mostly due to the fact that their economies are much smaller and for larger economies within-country trade becomes over-proportionally important (Squalli & Wilson, 2011). In the discussion section we address this by using an integration measure that is weighted by the share on overall inter-EU trade of a country. One can nevertheless 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 capita between new and old member states as well as on the much lower capital 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 the previous section into empirically measurable variables. After outlining the long run relation of interest, we describe the used estimation technique.

4.1 Estimating equation

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

The long run relation we are interested in follows the reduced form of Antweiler et al. (2001) and is adapted to our sectoral setting and the enlargement steps:

$$\begin{aligned} EI_{sct} = \underbrace{\Lambda_{sct} TI_{sct}}_{Induced\ composition} + \underbrace{\Omega_{ct}}_{Enlargement\ steps} + \\ \underbrace{\gamma_1 INC_{ct}}_{\text{Income}} + \underbrace{\gamma_2 LP_{sct}}_{\text{Productivity}} + \gamma_3 KL_{sct} + e_{sct}. \end{aligned} \tag{1}$$

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. 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 continuous integration into the single market, before and after the accession year; it makes the results comparable to the mentioned studies, and it allows for heterogeneous estimates between countries and sectors.

Following Antweiler et al. (2001), the TI_{sct} measure is interacted with relative income (GDP per capita), $RINC_{ct}$, and relative capital intensity (capital input per hour worked), RKL_{sct}, where relative refers in both cases to the EU average. This is to measure both the within-EU PHH and the FEH effects. We will, in detail, analyse the trade integration elasticity, Λ_{sct}, reflecting the change in emission intensity that is caused by increasing TI_{sct}. It is defined as:

$$\Lambda_{sct} = (\lambda_0 + \underbrace{\lambda_1 RINC_{ct}}_{\text{PHH}} + \underbrace{\lambda_2 RKL_{sct}}_{\text{FEH}}). \tag{1a}$$

This method in fact allows for a different effect of trade integration on emission intensities for each combination of relative income and relative capital intensity. For sectors in a country with low income this effect is thus predicted to be positive, through the PHH channel. Sectors with a high capital intensity are likewise expected to increase their emission intensity.

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.[8] Each of these dummies is zero up until the specific date and stays one thereafter:

$$\Omega_{ct} = \omega_1 d_{ct}^{candidate} + \omega_2 d_{ct}^{accession}. \tag{1b}$$

Imposed regulations and standardization towards the EU imply that both ω_1 and ω_2 should be negative, thus emission intensity decreasing.

In (1), INC_{ct}, country-wide income, should influence intensities on the sector level via preferences and regulation, and is defined as GDP per capita.

LP_{sct}, labour productivity, captures productivity changes and is sector-specific. It is defined by value added per engaged person, as the most direct measure of productivity and thus technology. We are able to split this sectoral part from the nation-wide income channel, which is usually hard to achieve if one only observes aggregate variables. INC_{ct} and LP_{sct} thus jointly capture potential second round effects of the enlargement. Labour productivity can also be understood as a proxy for efficiency-increasing investments that decrease the needed input per unit of output.

KL_{sct} measures the capital intensity of a sector, defined as capital input per hour worked, and captures the non-induced composition effect. The exact definition of the measure is given in Appendix A.4.

In e_{sct} we allow for a different fixed effect for each sector-country unit, α_{sc}, and year, α_t,[9] as well as for linear trends for each sector, $\tau_s t$, and each country, $\tau_c t$:

$$e_{sct} = \alpha_{sc} + \alpha_t + \tau_s t + \tau_c t + \varepsilon_{sct}, \tag{1c}$$

with ε_{sct} as the idiosyncratic error term, assumed to be independent between units. All variables, except for the relative income and relative capital intensity, are in natural logarithms and the coefficients can thus be interpreted as elasticities.

4.2 Estimation method

Both for climate change and air pollution, insights into long-term relations are crucial and are thus also more frequently analysed in the recent literature (for example Al-Mulali et al. (2015) or Kasman and Duman (2015)). We therefore analyse the model

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

[9] The sector-country fixed effects control for 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 time effects on emissions such as the Financial or the Euro crisis, but also for price shocks on fuels such as oil or coal in specific years. They additionally take out some spatial autocorrelation.

from a cointegration perspective and have collected data with a substantial time span of 21 years.

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

Estimating the coefficients in (1) with OLS would then lead super-consistent estimates, 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 (1) 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 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 A.5, where one can also find the results and a discussion for the unit root and cointegration tests.

5 Results

This section will present the results of the DOLS estimation of (1), both for the aggregate sample, in which we constrain the coefficients to be homogenous between sectors, as well as for each sector individually. All estimations include deviations for new members from the overall effect. These are estimated by interacting all coefficients 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.

5.1 Pooled sector analysis

Table 1 presents the results for the pooled analysis. 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 insignificant. This speaks against the pollution haven hypothesis within the EU, which predicted a negative relationship. This might either imply that environmental regulation was sufficiently homogenized between new and old member states (or expectations about environmental regulation were homogenous), or that dirty production did not move towards new member states, because relocating further, to places with even lower environmental standards, was cheaper. Overall, these two explanations are not mutually exclusive and might both explain parts of the results. Estimating carbon leakage to outside the EU is an active research area.

The interactions with relative capital have ambiguous signs and are insignificant as well. However, the deviation for new members are significant and positive for both air pollutants. For all three pollutants, the total FEH effect for new members is positive; also for CO_2 this total FEH effect becomes significant at the 10 percent level. This supports the FEH among this subset of countries, implying that capital-intense sectors in the new member states increase 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 already be saturated with respect to their capital input.

The overall trade integration elasticity, Λ_{sct}, for each sector is determined by 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 non-interacted TI coefficient), as formalized in (1a). These elasticities are either negative or close to zero for new members, as can also be seen in Figure 5. They are always insignificant for the median observation, but one can see the clear relation with relative capital, which stems from the significant FEH effect. For old members, they have mixed signs for CO_2 and are mostly positive for both air pollutants. The median old member effect is insignificant at the 5, but not the 10 percent level for NO_x, and insignificant for CO_2 and SO_x.

The elasticity interpretation of Λ_{sct} implies, for example, that for the least capital-intense 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 half a percent for the most capital abundant sector (Germany's Coke and refined petroleum products sector).

The estimates of the enlargement steps reveal for air pollutants that the effects of becoming a candidate country as well as of joining the EU imply a decline in intensities. That is not the case for CO_2 , which indicates that EU regulation had a stronger bite on air pollution than on greenhouse gases. The magnitude of these coefficients implies that the accession went together with a 16 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 significantly negative and large. This is likely due to the catch up in pollution reduction in these countries, which was seemingly supported by increases in national income.

All estimated coefficients on labour productivity are negative, as expected. In the full sample, 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

Table 1: Pooled estimation of (1)

	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)
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)
National 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	0.88	0.68	0.56
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 (1c). All models estimated with dynamic OLS, including two leads and lags of all explanatory variables. Deviations for all coefficients included in each regression; p-value for F-test on all omitted deviations given.

with the adaption of cleaner technology.

This does not seem to be the case for both air pollutants in the new member states sample, where the coefficient estimates are significantly more positive. Seemingly, increases in productivity and potentially related investments did not translate into changes in emission intensities as strongly here. It could be that improvements in labour productivity here did imply a shift towards more capital-intense production instead of a mere improvement in efficiency. This would be consistent with our finding of the FEH effect among these members, as well as with a documented increase in capital-intensity in these countries by Walheer (2018). But why we find this effect only for air pollutants and not for CO_2 would be an interesting question for future research.

5.2 Individual sector analysis

We now analyse the same regression (1), but individually for each sector.

Between sectors, there is some sign-heterogeneity in the PHH coefficients, further supporting the overall insignificance of this channel. The overall FEH coefficients also show mixed signs, but the new members deviations that are significant are positive again; even though there are also some negative, insignificant estimates among them. The corresponding trade elasticities can also be seen in Figure 6. They show similar patterns as before, where one can again see an upwards trend among new members with increasing relative capital, even though it is less pronounced. The median sector in old members has a significantly positive trade integration elasticity for SO_x.

There is one interesting outlier to the induced composition effect picture. Sector C17-C18, pulp and paper manufacturing, for which we find significant support for the PHH for all pollutants. 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 consistently 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).[10] Excluding sector C17-C18 from the pooled estimation, does not change any of 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

[10] The authors also find that the sector shows little response to the EU ETS, which is not at odds with our results, since our measure of regulation is determined by GDP, which has no influence on the ETS price, which is uniform between member states.

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, especially for SO_x. Labour productivity mostly has a negative effect on emission intensities, again with mostly less negative coefficient estimates for new members. For both air pollutants, sometimes the omitted deviations for new members become jointly significant, but there is no consistent patter among those, which is why we decided not to report them.

5.3 Robustness

We now present several specifications that test the robustness of our results. In Tables 2, 3 and 4, we report five different specifications next to the baseline.

In column two, we extend the induced composition effect to allow for squared interactions, by replacing (1a) with

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

For all three pollutants, the marginal effects, evaluated at the median observation, are in line with the coefficient estimates from the baseline. The additional coefficient estimates increases the standard errors, but the direction and magnitude of the effect stay the same and the conclusion of the FEH effect among new members stays consistent. The squared terms are economically small and statistically insignificant (see Table 12).

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:

$$TI_{sct}^{cts} = TI_{sct} * \frac{X_{sct} + I_{sct}}{\sum_j (X_{sjt} + I_{sjt})}, \tag{3}$$

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.[11] 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 significantly alter our results.

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

Table 2: Robustness tests CO_2.

	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)
National 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, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Fixed effects and linear trends as in (1c), except for column 5. All models estimated with dynamic OLS, including two leads and lags of all explanatory variables. Column 2 replaces (1a) with (2), column 3 and 4 replace TI, by either integration into world trade or by the CTS measure, (3). Column 5 adapts (1c) by more heterogenous trends, and column 6 adds country specific INC (GDP per capita) estimates.

† The coefficients in column 2 for TI*Relative Capital and TI*Relative GDP are the marginal effects for increasing TI and $RINC/RKL$ in $\lambda_1 TI * RINC + \lambda_2 TI * RINC^2$ and $\lambda_3 TI * RKL + \lambda_4 TI * RKL^2$ from (2), evaluated at the median relative income and capital intensity. For the new members deviation the median for their sample is chosen. The respective standard errors are computed using the delta method. The corresponding coefficient estimates can be found in Table 12.

‡ INC coefficient estimates in column 6 represent the average INC_c coefficient for all members, and for all members minus the new member average for the deviation respectively. All INC_c coefficient estimates for column 6 can be found in Figure 7.

Table 3: Robustness tests SO_x.

	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)
National 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 tablenotes see Table 2.

Table 4: Robustness tests NO_x.

	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)
National 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 tablenotes see Table 2.

6 Conclusion

In this study, we analyse 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 and technology. In a panel cointegration setting, we analyse data on emission intensities for CO_2, SO_x, and NO_x for almost all EU countries from 1995 to 2015.

We find no support for pollution haven effects and thus for leakage channels within the EU. It thus might be that EU regulation is 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, capital-intense sectors thus got dirtier compared to less capital-intense ones. We do not find that capital and emissions moved from new to old member states. The overall trade integration elasticity is rather negative, but insignificant, for new members, and positive and partially significant for old members.

We furthermore analyse inter-sector differences in these elasticities. As the largest outlier, pulp and paper manufacturing shows a strong responsiveness to changes in income and shows significant support for the within-EU pollution haven hypothesis. The fact that we can not establish homogenous effects between all sectors speaks for carefully designing environmental policy that is tailored to sectoral differences.

We also show that, on top of the above-mentioned effects and additional controls, 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 stronger for air pollutants than for CO_2, which might come from stronger EU regulation for those than for greenhouse gases.

We additionally find that increases in productivity had a decreasing effect on the emission intensities in manufacturing sectors, at least for CO_2; technology spillovers after the enlargement could thus be associated with investments that supported both efficiency and the environment. For changes in national income these effects point in the same direction, but are mostly insignificant.

When all these findings are combined, the results are promising for future candidate countries, which might benefit from an accession not only through increases in trade, productivity spillovers, and GDP, but also through a cleaning of their manufacturing sector. These results are equally important for comparable projects of market integration elsewhere in the world and show that sufficient homogeneity in environmental regulation can prevent both leakage and pollution havens within these 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 interesting question arising from our research is why labour productivity has a different effect for new an old members and if this indeed related to further capital accumulation in new member states.

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A Data details

A.1 Emission data

The IEA data contain information on emissions from fuel combustion, but in some sectors also adds process related emissions. The CLRTAP data supply emissions from energy, industrial processes and product use.[12]

The IEA data is more easy to merge with other production data, since it uses a similar classification as the production data, which is 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. The following subsections also provide a description of the linking between the different data sets.

A.2 Production data

Capital input 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 into real values. Details on this extrapolation can be found in the subsection A.4. Data on GDP per capita and value added are in Euro 2010 prices. Trade data includes sector-specific data on imports and exports. In this study, we aggregate the total imports and exports from and to other EU countries for each sector.

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.[13]

The list of sectors used in the analysis is given in Table 5.

A.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

[12] 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.

[13] 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.

Table 5: NACE Rev.2 sector codes

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

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 set.

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 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 6 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 only and the same for C16-C18 to C17-C18 as well as C16. These inaccuracies should largely be controlled for by the included fixed effects.

A.4 Definition of production variables

Capital input (CAP) in EU KLEMS is defined as
$Value\ added - Labour\ input$ (Stehrer et al., 2019). This implies that CAP is implicitly 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_{sct}^{in}. The extrapolated, sector-specific price series is then derived as:

$$CAP\_P_{sct}^{ex} = \frac{CAP_{sct}^{in}}{CAP\_QI_{sct}^{in}}$$

The mean of these prices in each year and sector combination $\overline{CAP\_P_{st}^{ex}}$ 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

$$CAP\_QI_{sct} = \frac{CAP_{sct}}{CAP\_P_{sct}^{ex}}$$

or

$$CAP\_QI_{sct} = \frac{CAP_{sct}}{\overline{CAP\_P_{st}^{ex}}}$$

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,

Table 6: 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

we only take the mean over all countries for which we also have data for that particular sector to ensure consistency.

A.5 Unit root and cointegration tests

We analyse here the stationarity properties in our data, and then test for potential cointegration between emission intensities and our in (1) defined right hand side variables.

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, which is likely to be present in our cross-country panel data. We thus start by applying Pesaran (2004)s test for cross sectional correlation in the residuals of an ADF regression of each variable.

Table 7 shows the results of the cross-sectional dependence, as well as the CIPS unit root test 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 famous 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 both 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. Also for all other variables, the test rejects the null in first differences, implying that our variables are I(1), allowing us to move further to cointegration testing.

To confirm the existence of a cointegration relation in (1), 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 (1)[14] 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 the null hypothesis: no 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 the interested readers to the respective literature.

[14] The enlargement dummies were hereby omitted

Table 7: 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
CO2 Intens	36.57	0.00	-2.58	-2.65	-4.71	-2.70
SOx Intens	24.10	0.00	-2.57	-2.65	-4.36	-2.70
NOx 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
VA	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*RGDP	39.22	0.00	-2.36	-2.65	-4.33	-2.70
TI*RCAP	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.

The cointegration results in Table 8 show a clear rejection of the null hypothesis of no cointegration in all tests and specifications. This clearly motivates analysing a cointegration regression, as outlined in the main body.

Table 8: Panel cointegration tests for (1), with different dependent variables; Emission intensites

	Pedroni - ADF		Pedroni - PP		Westerlund	
	test statistic	p-value	test statistic	p-value	test statistic	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

B Additional tables and figures

B.1 Relation between income and environmental regulation

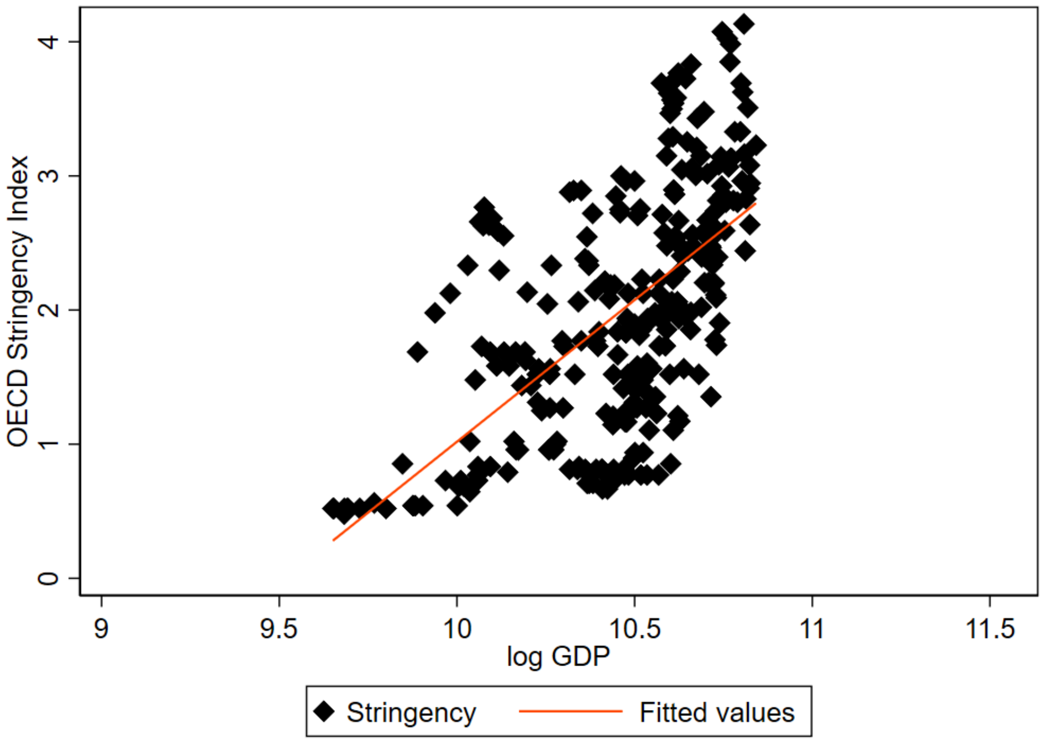
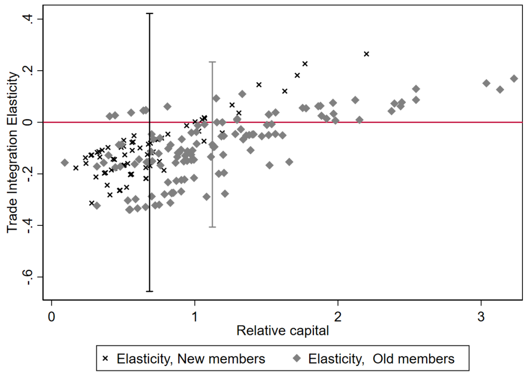
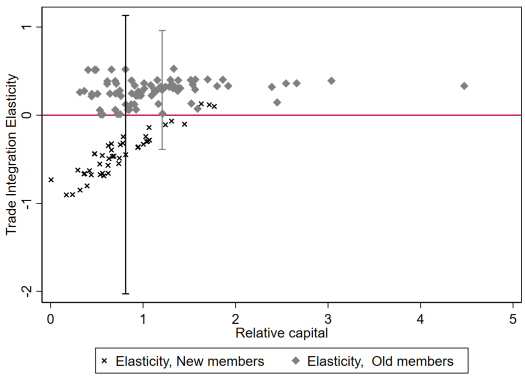


Figure 4: Relation between national income and an OECD measure of environmental stringency (Botta & Koźluk, 2014). Plotted for all EU countries, over the entire sample period.

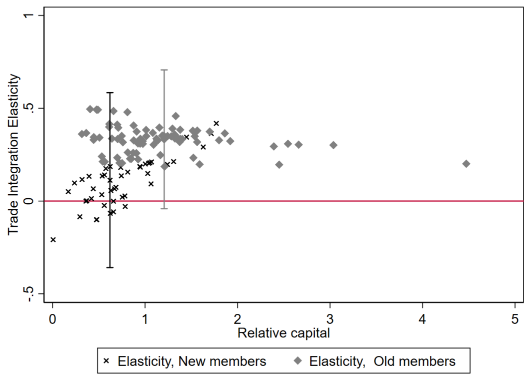
B.2 Trade elasticities plots - pooled analysis



(a) CO_2



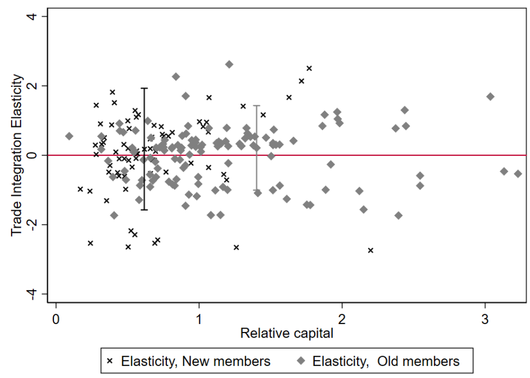
(b) SO_x



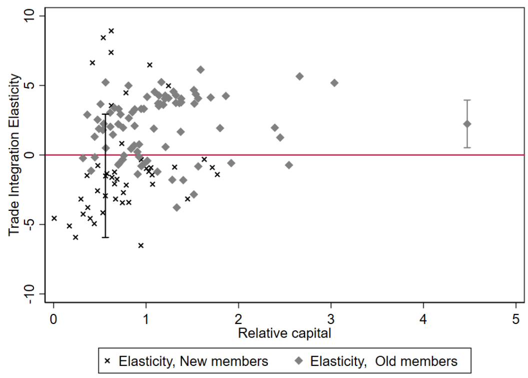
(c) NO_x

Figure 5: Trade elasticities, (1a), by country and sector, for mean values of relative income and relative capital intensity over the sample period. 95% confidence interval for median elasticity for both groups given. Elasticity estimates are based on the coefficients from the pooled estimation, (1), corresponding to Table 1. Each point represents one sector within one country. Each country has one relative income but a different relative capital intensity for each sector.

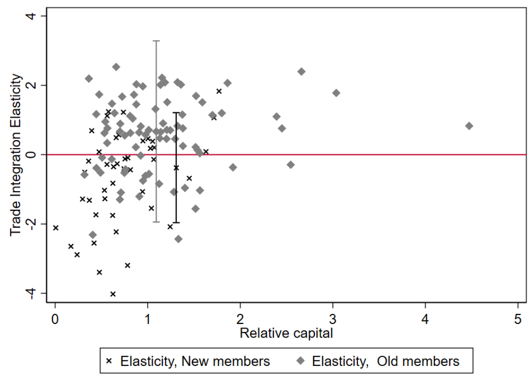
B.3 Sector individual results



(a) CO_2



(b) SO_x



(c) NO_x

Figure 6: Trade elasticities, (1a), by country and sector, for mean values of relative income and relative capital intensity over the sample period. 95% confidence interval for median elasticity for both groups given. Elasticity estimates are based on the coefficients from regressions on each individual sector, Tables 9, 10, and 11. Each point represents one sector within one country. Each country has one relative income but a different relative capital intensity for each sector.

Table 9: Sector-specific estimates of (1) for CO_2 emission 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)
National 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 (1c). 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 5. Deviations for all coefficients included in each regression; p-value for F-test on all omitted deviations given.

Table 10: Sector-specific estimates of (1) for SO_x emission 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)
National 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, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$
Fixed effects and linear trends as in (1c). 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 5. Deviations for all coefficients included in each regression; p-value for F-test on all omitted deviations given.

Table 11: Sector-specific estimates of (1) for NO_x emission 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)
National 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, $*p < 0.10$, $**p < 0.05$, $***p < 0.01$
Fixed effects and linear trends as in (1c). 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 5. Deviations for all coefficients included in each regression; p-value for F-test on all omitted deviations given.

C Additional tables and figures

Table 12: Coefficients relating to induced composition effect, corresponding to column (2) in Tables 2, 3, and 4

	CO_2 Intensity	SO_x Intensity	NO_x Intensity
	(1)	(2)	(3)
Induced composition			
Trade Integration	−0.73	1.19	−0.22
	(1.15)	(2.29)	(1.12)
TI*Relative GDP (PHH)	0.14	−2.15	1.02
	(1.71)	(3.65)	(1.85)
TI*Relative GDP squared (PHH)	0.13	1.08	−0.38
	(0.61)	(1.44)	(0.75)
TI*Relative Capital (FEH)	0.26*	−0.10	−0.06
	(0.16)	(0.34)	(0.21)
TI*Relative Capital squared (FEH)	−0.06	0.02	0.00
	(0.04)	(0.05)	(0.03)
Deviation for new members			
Trade Integration	0.57	−2.94	0.71
	(1.40)	(3.40)	(1.22)
TI* Relative GDP (PHH)	−0.42	5.85	−3.63
	(4.06)	(10.60)	(3.74)
TI* Relative GDP squared(PHH)	−0.82	−5.07	3.20
	(3.77)	(10.49)	(4.05)
TI*Relative Capital	0.27	0.61	0.20
	(0.26)	(0.85)	(0.31)
TI* Relative Capital squared (FEH)	−0.03	0.00	0.02
	(0.06)	(0.17)	(0.06)
N	2712	1646	1639

Cluster robust standard errors in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$
All coefficients related to induced composition effect from column 2 in Tables 2, 3, and 4.

Figure 7: Coefficient estimates of country specific INC_c coefficients from full samples, belonging to Tables 2, 3, and 4

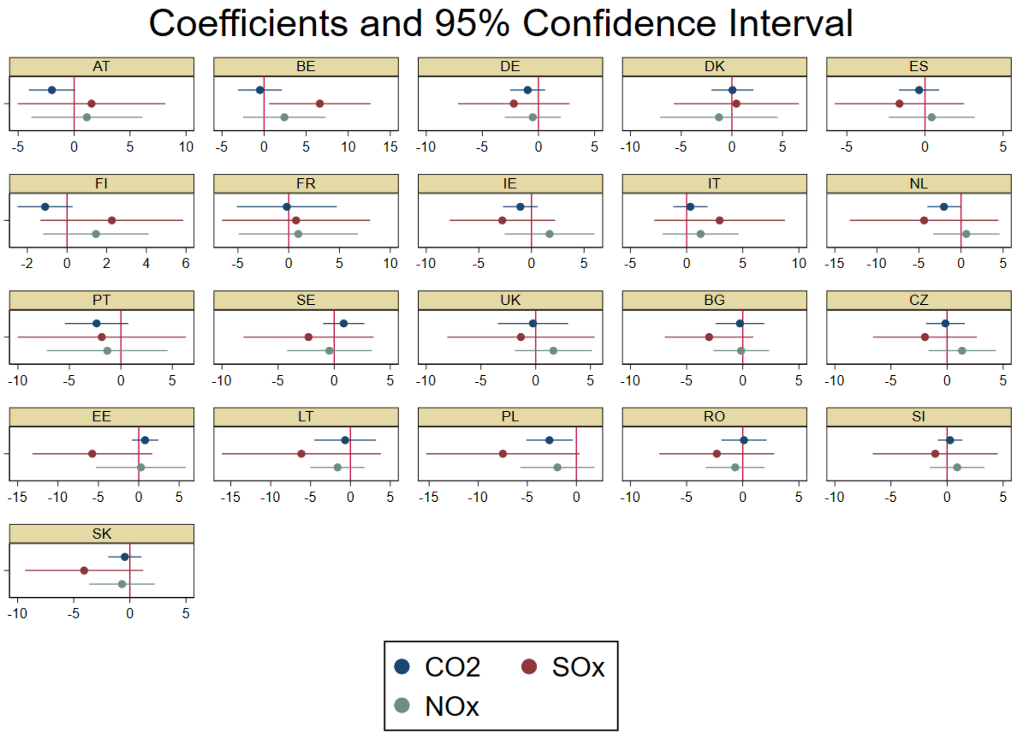


Table 13: Country Abbreviations

Abbreviation	Country
AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finnland
FR	France
GR	Greece
HU	Hungary
HR	Croatia
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxemburg
LV	Latvia
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SK	Slovakia
SE	Sweden
SI	Slovenia
UK	United Kingdom