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

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Tinbergen Institute Discussion Paper

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

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

Konstantin Sommer <sup>\*</sup>      Henri L.F. de Groot <sup>†</sup>      Franc Klaassen <sup>‡</sup>

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## Abstract

We study the effects of market integration on manufacturing emission intensities of CO<sub>2</sub>, SO<sub>x</sub>, and NO<sub>x</sub>. For this, we analyse the 2004 and 2007 EU enlargements in a sub-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 efficiency improvements have also contributed to cleaner manufacturing sectors here.

**JEL codes:** F15 F64 Q56

**Keywords:** Market Integration, EU Enlargement, Carbon Leakage, Pollution Havens, Emission Intensity

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 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 the 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 these, thirteen Eastern European countries, of which eleven were former communist states, joined the EU and its single market. This paper studies whether the enlargements have 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-sector level for almost all EU member states from 1995 to 2015. These data contain information on three different pollutants: carbon dioxide ( $\text{CO}_2$ ), sulphur oxides ( $\text{SO}_x$ ) and nitrogen oxides ( $\text{NO}_x$ ), whose emission intensities are defined per unit of value added. Analysing both a greenhouse gas ( $\text{CO}_2$ ) 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, while air pollutants have more local(ized) effects and have thus been regulated 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 global warming and air pollution.

In our analysis we either control for sectoral heterogeneity or explicitly estimate the results for each sector individually. Sectoral heterogeneity is often assumed away by analysing average manufacturing or economy-wide pollution, even though studies such as Bernard and Jones (1996) and Ederington 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.<sup>1</sup>

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 (FEH), implies a relocation of capital, and with it of related emissions, towards already capital-abundant sectors.

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<sup>1</sup> 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.

When pooling all manufacturing sectors into one panel, we find no support for the PHH and thus for within-EU leakage. We find a statistically significant FEH effect, although only 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. Note that this does not mean that integration increased emissions, as the FEH only presents a part of the overall trade-integration effect. For the median observation among the new members, an increase in trade integration has had a statistically insignificant effect. 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 acquis, adapt regulations on industrial 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, to a smaller degree, also for CO<sub>2</sub>. This indicates that EU regulation for air pollutants has been more successful than the one for greenhouse gases, and especially for SO<sub>x</sub> our results might explain a large share of the total reduction in emission intensities over the observed period.

Second-round effects of the enlargement through induced productivity enhancements have further reduced emission intensities in old and new member states. 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 a rather 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 (and thus related regulation), 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 analyse 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-

intense 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) analyse the economy in more aggregated sectors. 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 comes to 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 and 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 induced 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 find that trade can overall lower the concentration of sulfur dioxide ( $\text{SO}_2$ ). Cole and Elliott (2003) support this for  $\text{SO}_2$  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 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.

To 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. Both of these results are, however, statistically insignificant.<sup>2</sup>

Our paper also adds to the literature on the drivers of energy intensity within economies, and especially manufacturing sectors, and their convergence between countries (Mulder & De Groot, 2007; Voigt et al., 2014; Wang, 2013). We confirm the general notion that technological change can be a 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, 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 on emission intensities can be divided into several channels, which can be grouped into composition, regulation, and technology channels. 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, or in our case sectors within countries, with lower environmental regulations will use their comparative advantage for pollution-intense production to further specialize in it, which thus implies an increase in the overall emission intensity in these countries. Countries with lower environmental regulation generally coincide with lower income countries, which in turn

<sup>2</sup> Other studies, by Al-Mulali et al. (2015) and Kasman and Duman (2015) have included trade integration as an explanatory variable for CO<sub>2</sub> 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.



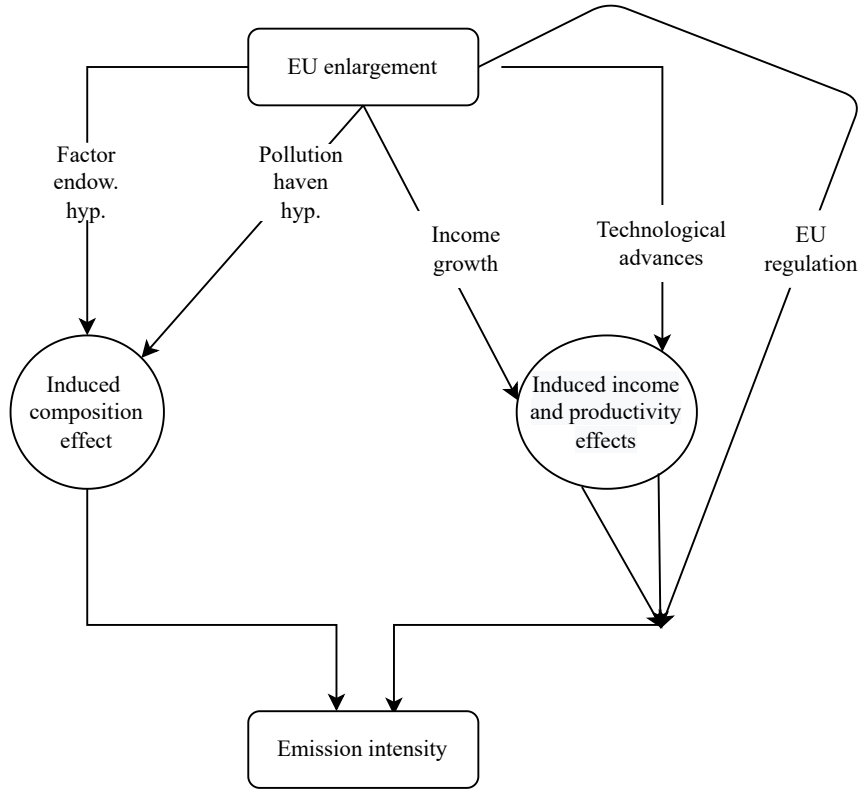


Figure 1: Direct and indirect effect of EU enlargement on emission intensities. The arrows towards a box represent a direct influence. The arrows with a box on itself represent that the influence is through the respective channel.

correspond to new member states in the EU context.<sup>3</sup> This implies that the PHH 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.<sup>4</sup>

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

<sup>3</sup> 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)

<sup>4</sup> 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 income levels between new and old member states are still far from each other, implying that this channel should be rather small.

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 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 industrial 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.

### **2.2.2 Income and productivity improvements**

This paper does not make an attempt to quantify the effects that the enlargement has had on economic growth.<sup>5</sup> 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 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 to stricter environmental regulations and a higher demand for “clean” products.<sup>6</sup> 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 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 sources.

## **3 Data sources and stylized facts**

We use two data sources on emissions at their place of emittance, called emission inventories. For CO<sub>2</sub>, we rely on “CO<sub>2</sub> emissions from fuel combustion - 2020 edition”, provided by the International Energy Agency (IEA) (International Energy Agency,

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<sup>5</sup> For this, see for example Epstein and Jacoby (2014) or Campos et al. (2019).

<sup>6</sup> Even though the evidence on the preference channel is partly debated (McConnell, 1997), the correlation between income and environmental regulation is clear.

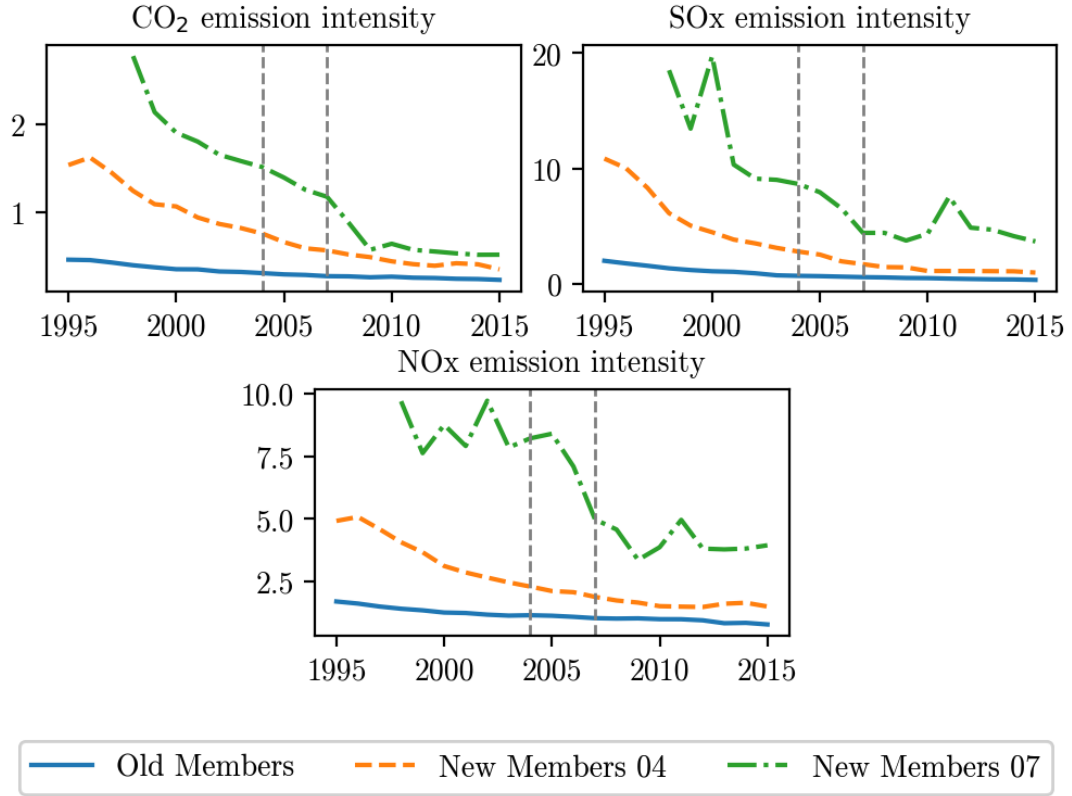


Figure 2: Emission intensity, in Gg per Million Euros of value added for CO<sub>2</sub> and per Thousand Euros for SO<sub>x</sub> and NO<sub>x</sub> (in 2010 Euros), average among sample members. Enlargement dates indicated by vertical bars.

2020), via the OECD. For SO<sub>x</sub> and NO<sub>x</sub>, 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<sub>2</sub>) 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 A.

Figure 2 shows the development of CO<sub>2</sub>, SO<sub>x</sub>, and NO<sub>x</sub> emission intensities over time. It plots the average intensities for the respective sample of the whole manufac-

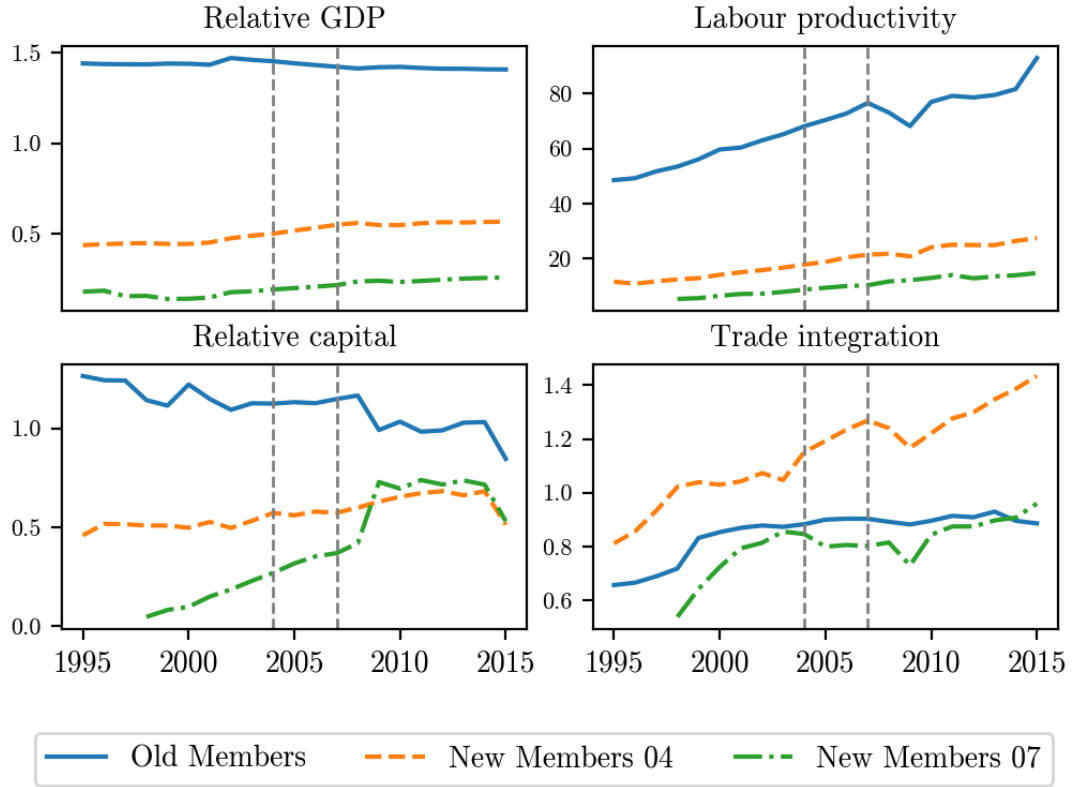


Figure 3: Panels (b),(c), and (d), for whole manufacturing sector, all lines represent averages among sample members. Labour productivity is in Million Euro per engaged person; exact definitions of variables in Section 4 and Appendix A. For illustrative purposes Ireland is excluded from the relative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

turing 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  $\text{SO}_x$  intensities have reduced greatly. This is driven by both increases in value added, but especially by large decreases in emission levels. For  $\text{CO}_2$  and  $\text{NO}_x$ , 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 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). In the discussion section we address this by using an integration measure that is weighted by the share in 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  $t$ , and is expressed in logarithmic form. For CO<sub>2</sub>, the one-digit manufacturing sector is divided into nine smaller, two-digit sectors, for 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:

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

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 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 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,  $\Lambda_{sct}$ , reflecting the change in emission intensity that is caused by increasing  $TI_{sct}$ . It is defined as:

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

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 predicted to be positive, through the PHH channel. Sectors with a high capital intensity are likewise expected to increase their emission intensity, through the FEH channel.

$\Omega_{ct}$  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.<sup>7</sup> Each of these dummies is zero up until the specific date and stays one thereafter:

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

Imposed regulations and standardization towards the EU imply that both  $\omega_1$  and  $\omega_2$  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 logarithmic GDP per capita.

$LP_{sct}$ , labour productivity, captures productivity changes and is sector-specific. It is defined as logarithmic 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, again in logarithmic form, and controls for the non-induced composition effect. The exact definition of the measure is given in Appendix A.

In  $e_{sct}$  we allow for a different fixed effect for each sector-country unit,  $\alpha_{sc}$ , and year,  $\alpha_t$ ,<sup>8</sup> as well as for linear trends for each sector,  $\tau_s t$ , and each country,  $\tau_c t$ :

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

with  $\varepsilon_{sct}$  as the idiosyncratic error term, assumed to be independent between units.

<sup>7</sup> Controlling for additional events like signing the accession treaty or joining the Euro, does not alter the results.

<sup>8</sup> 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.

## 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 in Al-Mulali et al., 2015; Kasman & Duman, 2015). We therefore analyse the model 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.4, 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 (1), both for the aggregate 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 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 statistically 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 homogeneous), 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. 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 one-sidedness of the FEH (effect for new members: 0.25 (standard error of 0.14) for CO<sub>2</sub>, 0.63 (0.38) for SO<sub>x</sub>, and 0.23 (0.14) for NO<sub>x</sub>). This supports the FEH among this subset of countries, implying that capital-intense 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,  $\Lambda$ , 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). For new members, these elasticities, estimated by using the estimates of Table 1, are either negative, meaning that trade integration lowers emission intensities, or close to zero. This is illustrated in Figure 4, where  $\Lambda$  is plotted for each sector-country pair. The elasticities are 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<sub>2</sub> 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<sub>x</sub>, and insignificant for CO<sub>2</sub> and SO<sub>x</sub>.

The elasticity interpretation of  $\Lambda$  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<sub>x</sub> 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 acquire), as well as of joining the EU both implied a decline in intensities. For both air pollutants, at least one of the coefficients is statistically significant, which is not the



Table 1: Pooled estimation of (1), with intensities as dependent variables

	CO <sub>2</sub>	SO <sub>x</sub>	NO <sub>x</sub>
	(1)	(2)	(3)
<b>Induced composition</b>			
Trade Integration	−0.62 (0.52)	−0.31 (0.96)	0.07 (0.46)
TI*Relative GDP (PHH)	0.32 (0.36)	0.43 (0.66)	0.24 (0.35)
TI*Relative Capital (FEH)	0.09 (0.07)	0.01 (0.15)	−0.04 (0.11)
<i>Deviation new members</i>	0.16 (0.12)	0.61* (0.33)	0.27** (0.13)
<b>Enlargement steps</b>			
Candidate Status	−0.14 (0.16)	−1.08** (0.43)	−0.30* (0.16)
Accession	−0.10 (0.06)	−0.11 (0.11)	−0.17** (0.07)
<b>National income</b>			
GDP per capita	−0.12 (0.59)	−0.79 (2.19)	0.58 (1.29)
<i>Deviation new members</i>	0.24 (0.68)	−3.33* (1.76)	−0.70 (0.71)
<b>Sector productivity</b>			
Labour productivity	−0.89*** (0.13)	−1.03*** (0.24)	−1.06*** (0.13)
<i>Deviation new members</i>	−0.09 (0.16)	0.74*** (0.27)	0.58*** (0.14)
<b>Further controls</b>			
Capital intensity	0.04 (0.07)	−0.16 (0.18)	0.03 (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. New member states deviations for all variables are included in each regression; p-value for F-test on all omitted deviations given.

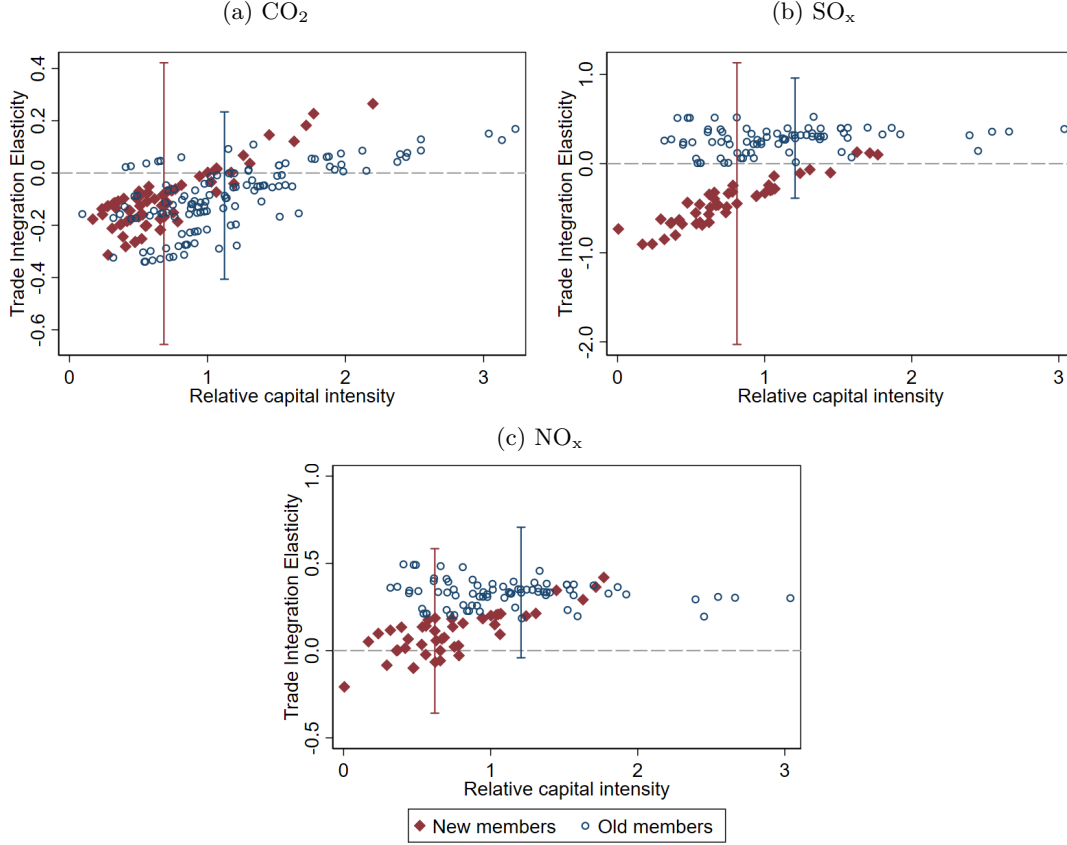


Figure 4: Trade elasticities (1a), based on coefficient estimates from Table 1. Each point represents the elasticity of one sector within one country, evaluated at its respective mean values of relative capital intensity and relative income over the sample period. Vertical lines are 95% confidence intervals 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.

case for  $\text{CO}_2$ , 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. The magnitude of these coefficients implies, for example, that the accession went together with a 16 percent reduction in emission intensities for  $\text{NO}_x$ ; 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  $\text{SO}_x$  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 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 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  $\text{SO}_x$  the effect 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 analyse the same regression (1), but individually for each sector, presented for each pollutant in Tables 7 to 9. Between 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.

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).<sup>9</sup> 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  $\text{CO}_2$ . For both air pollutants they still mostly indicate a negative impact. Labour

<sup>9</sup> 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.

productivity mostly has a negative effect on emission intensities, again with mostly less negative coefficient estimates for new members.

### 5.3 Discussion of overall enlargement-induced effect

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 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  $SO_x$ .

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.<sup>10</sup>

The largest effect comes from the estimated coefficients of the enlargement steps in (1b). Even though these estimates could of course also capture additional unobserved events that happened simultaneously, their size and significance for both air pollutants, and especially for  $SO_x$ , are striking. This is non-surprising, given the strong focus of the environmental acquire on air pollution. Several authors have pointed to the challenge that this part of the acquire 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.

It can thus be concluded 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. For old members, the effect of trade-integration points into the opposite direction, but the cleaning effect of  $LP$  for these countries is larger and always significant.

<sup>10</sup> Felbermayr et al. (2018) report estimates for several integration steps. We decided to choose 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.

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

	CO <sub>2</sub>	SO <sub>x</sub>	NO <sub>x</sub>
Average change in intensity	-69.21	-80.81	-63.89
<i>Contributions of:</i>			
Trade integration	-3.17 (6.25)	-12.03 (14.49)	1.35 (5.26)
Candidate status	-13.32 (13.45)	-65.96*** (14.62)	-26.24** (11.60)
Accession	-9.39* (5.52)	-10.54 (9.96)	-15.96*** (5.82)
GDP per capita	1.64 (10.61)	-43.37* (22.46)	-1.75 (17.09)
Labour productivity	-11.45*** (1.53)	-3.58 (3.78)	-5.75*** (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. We thus 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  $\Lambda_{sct}$  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  $\lambda_0$  this estimate is -0.12 for CO<sub>2</sub> (the sum of the reported -0.62 and the unreported deviation 0.50), -1.16 for SO<sub>x</sub>, and 0.13 for NO<sub>x</sub>; for  $\lambda_1$  it is -0.37 for CO<sub>2</sub>, 0.62 for SO<sub>x</sub>, and -0.50 for NO<sub>x</sub>,  $\lambda_1$  is then evaluated at the average relative income,  $RINC$ , (0.41); for  $\lambda_2$  the effect is 0.25 for CO<sub>2</sub>, 0.63 for SO<sub>x</sub>, and 0.23 for NO<sub>x</sub>, evaluated at the average relative capital intensity,  $RKL$ , (0.56). Contribution of candidate status and accession are based on coefficient estimates 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  $\gamma_1$  estimate is 0.11 for CO<sub>2</sub>, -4.12 for SO<sub>x</sub>, and -0.12 for NO<sub>x</sub>; for  $\gamma_2$  it is -0.97 for CO<sub>2</sub>, -0.29 for SO<sub>x</sub>, and -0.47 for NO<sub>x</sub>.

## 5.4 Robustness

We now present several specifications that test the robustness of our results from the pooled analysis. In Tables 10, 11 and 12 – 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 (1a) with:

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

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 do not discuss any non-linearities here.

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:

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

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  $\text{SO}_x$ .<sup>11</sup> 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.

## 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

<sup>11</sup> More information on the patterns in fixed effects and linear trends is available upon request.

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  $\text{CO}_2$ ,  $\text{SO}_x$ , and  $\text{NO}_x$  for almost all EU countries from 1995 to 2015. Our study thus contributes to the literature on trade and environment, market, and especially European, integration as well as on energy productivity in manufacturing.

The overall trade integration elasticity of emission intensity is statistically insignificant. We find 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-intense sectors thus got dirtier relative to less capital-intense 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  $\text{CO}_2$ , 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 national 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, but also through a cleaning of their manufacturing sector. 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 analyse of inter-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 Data details

### A.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.<sup>12</sup>

The IEA data is 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<sub>2</sub> is larger than the one on air pollutants. Table 3 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 3: NACE Rev.2 sector codes

NACE code	Sector Name	Available data
C10-C12	Food products, beverages and tobacco	CO <sub>2</sub> , SO <sub>x</sub> , NO <sub>x</sub>
C13-C15	Manufacture of textiles, wearing apparel and leather	CO <sub>2</sub>
C16	Manufacture of wood and of products of wood and cork, except furniture	CO <sub>2</sub>
C17-C18	Manufacture of paper, pulp and paper products Printing and reproduction of recorded media	CO <sub>2</sub> , SO <sub>x</sub> , NO <sub>x</sub>
C19	Coke and refined petroleum products	SO <sub>x</sub> , NO <sub>x</sub>
C20-C21	Chemicals and chemical products	CO <sub>2</sub> , SO <sub>x</sub> , NO <sub>x</sub>
C23	Manufacture of other non-metallic mineral products	CO <sub>2</sub> , SO <sub>x</sub> , NO <sub>x</sub>
C24	Manufacture of basic metals	CO <sub>2</sub>
C24-C25	Basic metals and fabricated metal products, except machinery and equipment	SO <sub>x</sub> , NO <sub>x</sub>
C25-C28	Manufacture of computer, electronic and optical products, fabricated metal products, electrical equipment and machinery	CO <sub>2</sub>
C29-C30	Manufacture of motor vehicles and other transport equipment	CO <sub>2</sub>

<sup>12</sup> 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.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 the product of quantity ( $CAP\_QI_{sct}$ ) and price ( $CAP\_P_{sct}$ ). For some countries quantity data in index form,  $CAP\_QI_{sct}^{in}$ , 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:

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

using the data with available quantity data. 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

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

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, 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<sub>2</sub> 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.<sup>13</sup>

### 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 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 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 4 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.

### A.4 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.

<sup>13</sup> 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 4: 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

Table 5 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  $\text{NO}_x$  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)<sup>14</sup> 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

<sup>14</sup> The enlargement dummies were hereby omitted.

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.

The cointegration results in Table 6 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 5: 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 <sub>2</sub> Intens	36.57	0.00	−2.58	−2.65	−4.71	−2.70
SO <sub>x</sub> Intens	24.10	0.00	−2.57	−2.65	−4.36	−2.70
NO <sub>x</sub> 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.

Table 6: Panel cointegration tests for (1), with different dependent variables; Emission intensities

	Pedroni - ADF		Pedroni - PP		Westerlund	
	Test stat	p-value	Test stat	p-value	Test stat	p-value
CO <sub>2</sub>	−12.76	0.00	17.55	0.00	3.94	0.00
SO <sub>x</sub>	−7.39	0.00	14.95	0.00	−2.12	0.02
NO <sub>x</sub>	−8.94	0.00	7.06	0.00	3.71	0.00
Demeaned						
CO <sub>2</sub>	−9.76	0.00	17.57	0.00	5.70	0.00
SO <sub>x</sub>	−12.86	0.00	14.17	0.00	−2.13	0.02
NO <sub>x</sub>	−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

Table 7: Sector-specific estimates of (1) for CO<sub>2</sub> intensities

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

Table 8: Sector-specific estimates of (1) for SO<sub>x</sub> intensities

	(1) C10-C12	(2) C17-C18	(3) C19	(4) C20-C21	(5) C23	(6) C24-C25
<b>Induced composition</b>						
Trade Integration	2.01 (4.82)	1.81 (2.85)	-0.83 (1.02)	5.98*** (2.00)	-0.32 (1.38)	6.52 (4.42)
TI*Relative GDP (PHH)	0.44 (4.08)	-1.55 (2.16)	1.75 (1.04)	-4.08* (2.33)	2.56* (1.44)	-2.78 (2.67)
TI*Relative Capital (FEH)	0.83 (1.55)	-0.12 (0.80)	0.17*** (0.05)	-1.58 (1.30)	0.64 (1.02)	1.20 (1.28)
<i>Deviation new members</i>	-0.03 (0.68)	2.09** (0.86)	-0.20 (0.16)	-1.33 (1.61)	1.03 (0.66)	-3.08 (2.20)
<b>Enlargement steps</b>						
Candidate Status	0.27 (0.50)	-2.89*** (0.53)	0.37 (0.29)	-1.73** (0.75)	-1.22*** (0.43)	-1.88** (0.76)
Accession	0.42 (0.33)	-0.17 (0.31)	-0.98*** (0.29)	0.32 (0.40)	-0.53** (0.22)	-0.22 (0.22)
<b>National income</b>						
GDP per capita	9.40 (9.62)	-9.91* (5.51)	7.86** (3.05)	-6.46 (5.57)	9.60 (6.38)	-2.97 (2.37)
<i>Deviation new members</i>	-3.59 (2.77)	-9.79** (4.60)	2.05 (2.31)	-5.16 (3.31)	-6.82 (4.53)	3.97** (1.87)
<b>Sector productivity</b>						
Labour productivity	-2.23** (0.79)	1.34 (1.52)	-1.36*** (0.29)	-1.69 (1.76)	-1.19 (1.60)	-1.23 (0.78)
<i>Deviation new members</i>	0.26 (1.44)	5.06*** (1.40)	0.24 (0.16)	1.24 (1.47)	-0.10 (0.84)	-0.71 (0.86)
<b>Further controls</b>						
Capital intensity	1.84 (1.72)	-1.35 (1.38)	0.91*** (0.24)	0.27 (1.10)	0.98 (0.79)	-0.04 (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 7.

Table 9: Sector-specific estimates of (1) for NO<sub>x</sub> intensities

	(1) C10-C12	(2) C17-C18	(3) C19	(4) C20-C21	(5) C23	(6) C24-C25
<b>Induced composition</b>						
Trade Integration	1.31 (2.09)	3.24** (1.32)	0.25 (0.55)	2.99 (2.15)	0.96 (1.00)	0.12 (3.55)
TI*Relative GDP (PHH)	0.72 (2.05)	-3.03** (1.26)	0.82 (0.72)	-2.89* (1.66)	0.53 (0.76)	-0.66 (2.34)
TI*Relative Capital (FEH)	-0.20 (0.66)	0.34 (0.94)	-0.11 (0.07)	-0.00 (0.57)	-1.04** (0.38)	1.21 (1.08)
<i>Deviation new members</i>	-0.02 (0.29)	0.86* (0.49)	-0.19* (0.10)	1.45* (0.72)	-0.03 (0.30)	-0.57 (0.84)
<b>Enlargement steps</b>						
Candidate Status	0.15 (0.24)	-0.86*** (0.27)	0.03 (0.15)	0.61* (0.33)	-0.22* (0.11)	-0.25 (0.29)
Accession	0.00 (0.13)	-0.10 (0.16)	-0.33 (0.21)	-0.14 (0.11)	-0.35*** (0.10)	-0.28 (0.17)
<b>National income</b>						
GDP per capita	9.00 (6.78)	-7.28** (3.19)	2.80** (1.31)	-2.20 (1.89)	3.19** (1.41)	-2.57 (2.03)
<i>Deviation new members</i>	-2.49 (1.75)	-1.22 (1.52)	1.49 (1.05)	1.18 (1.37)	-3.02** (1.15)	2.93** (1.38)
<b>Sector productivity</b>						
Labour productivity	-1.81*** (0.47)	0.03 (1.15)	-1.24*** (0.15)	-0.15 (0.79)	-0.80** (0.36)	-0.69 (0.46)
<i>Deviation new members</i>	0.99 (1.00)	0.62 (0.67)	0.14 (0.08)	-0.35 (0.55)	0.56* (0.28)	0.14 (0.45)
<b>Further controls</b>						
Capital intensity	0.23 (0.59)	0.21 (0.63)	0.34* (0.19)	-0.11 (0.67)	-0.26 (0.31)	-0.03 (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 7.

Table 10: Robustness tests for CO<sub>2</sub> intensities

	Base	Squared	World	CTS	Trends	INC <sub>c</sub>
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Induced composition</b>						
Trade Integration	−0.62 (0.52)	−0.73 (1.15)	−0.66 (0.43)	−0.13 (0.26)	−0.41 (0.61)	−0.57 (0.51)
TI*Relative GDP (PHH)	0.32 (0.36)	0.40† (0.55)	0.31 (0.31)	0.02 (0.20)	0.36 (0.42)	0.26 (0.34)
TI*Relative Capital (FEH)	0.09 (0.07)	0.16† (0.10)	0.08 (0.07)	0.06 (0.07)	0.13 (0.09)	0.10 (0.07)
<i>Deviation new members</i>	0.16 (0.12)	0.23† (0.18)	0.19 (0.12)	−0.05 (0.07)	0.08 (0.10)	0.16 (0.12)
<b>Enlargement steps</b>						
Candidate Status	−0.14 (0.16)	−0.17 (0.15)	−0.15 (0.15)	−0.16 (0.15)	−0.19 (0.16)	−0.16 (0.16)
Accession	−0.10 (0.06)	−0.10 (0.06)	−0.10 (0.06)	−0.09 (0.06)	−0.09 (0.06)	−0.10 (0.07)
<b>National income</b>						
GDP per capita	−0.12 (0.59)	−0.11 (0.61)	−0.29 (0.51)	−0.13 (0.60)	−0.11 (0.60)	−0.57‡ (0.65)
<i>Deviation new members</i>	0.24 (0.68)	0.23 (0.70)	0.39 (0.65)	0.24 (0.67)	−0.00 (0.71)	0.18‡ (0.32)
<b>Sector productivity</b>						
Labour productivity	−0.89*** (0.13)	−0.88*** (0.13)	−0.89*** (0.13)	−0.84*** (0.14)	−0.63*** (0.19)	−0.90*** (0.14)
<i>Deviation new members</i>	−0.09 (0.16)	−0.10 (0.16)	−0.11 (0.16)	−0.08 (0.15)	0.27 (0.25)	−0.08 (0.16)
<b>Further controls</b>						
Capital intensity	0.04 (0.07)	0.03 (0.07)	0.00 (0.07)	0.07 (0.07)	0.02 (0.09)	0.04 (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 (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 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 (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.

‡ Estimates for the national income block in column 6 represent the average *INC<sub>c</sub>* coefficient.

Estimates underlying columns 2 and 6 are available upon request.

Table 11: Robustness tests for SO<sub>x</sub> intensities

	Base	Squared	World	CTS	Trends	INC <sub>c</sub>
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Induced composition</b>						
Trade Integration	−0.31 (0.96)	1.19 (2.29)	0.48 (1.26)	−0.31 (0.61)	1.77 (1.53)	−0.77 (1.00)
TI*Relative GDP (PHH)	0.43 (0.66)	0.09† (0.99)	−0.27 (0.90)	0.17 (0.41)	−0.37 (1.28)	0.71 (0.69)
TI*Relative Capital (FEH)	0.01 (0.15)	−0.06† (0.26)	0.02 (0.20)	0.23 (0.17)	−0.10 (0.13)	0.02 (0.15)
<i>Deviation new members</i>	0.61* (0.33)	0.62† (0.59)	0.71* (0.43)	0.37*** (0.14)	0.42** (0.20)	0.58* (0.34)
<b>Enlargement steps</b>						
Candidate Status	−1.08** (0.43)	−0.98** (0.43)	−1.00** (0.42)	−1.00*** (0.36)	−1.05** (0.47)	−0.84** (0.38)
Accession	−0.11 (0.11)	−0.11 (0.11)	−0.13 (0.11)	−0.13 (0.10)	−0.06 (0.11)	−0.18 (0.11)
<b>National income</b>						
GDP per capita	−0.79 (2.19)	−0.47 (2.23)	−1.63 (2.16)	−0.68 (1.78)	−0.84 (2.78)	−1.60‡ (2.26)
<i>Deviation new members</i>	−3.33* (1.76)	−3.77** (1.75)	−2.95* (1.70)	−2.88 (2.05)	−2.82 (1.72)	−2.37**‡ (1.03)
<b>Sector productivity</b>						
Labour productivity	−1.03*** (0.24)	−1.03*** (0.23)	−1.01*** (0.23)	−1.03*** (0.23)	−0.75** (0.30)	−1.02*** (0.24)
<i>Deviation new members</i>	0.74*** (0.27)	0.73*** (0.27)	0.68** (0.27)	0.90*** (0.30)	0.32 (0.30)	0.73*** (0.27)
<b>Further controls</b>						
Capital intensity	−0.16 (0.18)	−0.16 (0.19)	−0.18 (0.16)	0.05 (0.20)	−0.14 (0.29)	−0.19 (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 10.

Table 12: Robustness tests for NO<sub>x</sub> intensities

	Base	Squared	World	CTS	Trends	INC <sub>c</sub>
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Induced composition</b>						
Trade Integration	0.07 (0.46)	-0.22 (1.12)	0.01 (0.50)	0.18 (0.34)	1.71* (0.93)	-0.31 (0.49)
TI*Relative GDP (PHH)	0.24 (0.35)	0.24† (0.47)	0.20 (0.41)	0.12 (0.24)	-0.84 (0.82)	0.54 (0.39)
TI*Relative Capital (FEH)	-0.04 (0.11)	-0.06† (0.17)	-0.04 (0.15)	-0.04 (0.06)	-0.15** (0.06)	-0.05 (0.11)
<i>Deviation new members</i>	0.27** (0.13)	0.23† (0.23)	0.37** (0.17)	0.17** (0.07)	0.21** (0.10)	0.26** (0.13)
<b>Enlargement steps</b>						
Candidate Status	-0.30* (0.16)	-0.29* (0.16)	-0.27** (0.13)	-0.32* (0.16)	-0.38** (0.18)	-0.25* (0.13)
Accession	-0.17** (0.07)	-0.17** (0.07)	-0.17** (0.07)	-0.15** (0.07)	-0.15** (0.06)	-0.17*** (0.06)
<b>National income</b>						
GDP per capita	0.58 (1.29)	0.62 (1.36)	0.36 (1.28)	-0.03 (1.23)	-0.35 (1.52)	0.26‡ (1.54)
<i>Deviation new members</i>	-0.70 (0.71)	-0.75 (0.71)	-0.61 (0.68)	-0.53 (0.62)	-0.38 (0.74)	-0.58‡ (0.52)
<b>Sector productivity</b>						
Labour productivity	-1.06*** (0.13)	-1.05*** (0.13)	-1.04*** (0.13)	-1.04*** (0.12)	-0.87*** (0.17)	-1.06*** (0.14)
<i>Deviation new members</i>	0.58*** (0.14)	0.60*** (0.14)	0.53*** (0.13)	0.59*** (0.14)	0.28** (0.12)	0.57*** (0.14)
<b>Further controls</b>						
Capital intensity	0.03 (0.10)	0.03 (0.11)	0.01 (0.08)	0.03 (0.08)	-0.05 (0.10)	0.00 (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 10.