Import competition and firm-level CO_2 emissions

Jakob Lehr,*

February 15, 2022

Abstract

Using the German census of the manufacturing industry, I analyze the impact of import competition on carbon emissions per unit of sales (emission intensity). For that, I combine precise information on firm-level CO_2 emissions with sector-level trade flows. Looking at the period 1995 until 2017, I focus on the impact of the rise of eastern Europe and China while addressing the endogeneity of trade flows with an instrumental variable approach. The baseline results suggest that a 1pp increase in the import penetration ratio caused a reduction of the average firms' emission intensity by approximately 0.5%. The effect is larger for more emission-intensive firms and less export-oriented firms. These results imply that the rise of the joint East kept the average firm emission intensity 10% below the level it would have had in the absence of the East's rise. Finally, I do not find indication for reallocation of production towards more efficient firms.

PRELIMINARY VERSION — PLEASE DO NOT CITE OR CIRCULATE

Keywords: CO_2 emission intensity, Import competition, Manufacturing, Firms, Technological Change, Environment, Germany
JEL Classification: F18, O33, Q54, Q56

*Kiel Institute for the World Economy, Kiellinie 66, 24105 Kiel, Germany, jakob.lehr@ifw-kiel.de

[1]**Acknowledgement:** I acknowledge financial support provided by the Kiel Centre for Globalization. I hereby declare that no actual or potential competing interests exist. All errors are my own.

1 Introduction

How trade and globalization affect environmental performance and, in particular, climate change is an important and widely discussed topic (cf. Copeland and Taylor, 2004; Cherniwchan et al., 2017). While older studies have mostly focused at country or sector level effects (cf. Copeland and Taylor, 1994; Cole and Elliott, 2003) more recent work has emphasized the importance of the underlying firm-level response to trade and globalization (cf. Barrows and Ollivier, 2018; Gutiérrez and Teshima, 2018; Cherniwchan, 2017; Forslid et al., 2018). For instance, this research has explored the role of Foreign Direct Investment on firms' energy use (Brucal et al., 2019) or the effect of firms' exporting status on CO_2 intensity of production (Richter and Schiersch, 2017). Yet, little is known about how import competition affects firms' CO_2 emissions and emission intensity. My paper addresses this gap by analyzing the effect of import competition on CO_2 emissions per unit of sales in the German manufacturing industry.[1]

The role of competition in general and import competition in particular on firm-level productivity has received much attention in the literature. For example increasing competition might pose a threat to firms' survival and thus force managers to reduce slack (Schmidt, 1997). Indeed, previous empirical research that looks at firms in Europe has established a positive link between import competition and productivity and innovation (e.g., Holmes and Schmitz, 2001; Bloom et al., 2015; Shu and Steinwender, 2019; Chen and Steinwender, 2021). An abundant literature in environmental and energy economics has described the so called "energy efficiency paradox". This refers to the observation that firms systematically forego improvements in energy efficiency despite a positive net present value (DeCanio, 1993). Thus from the perspective of a manager who is in need to cut costs to ensure the firms' survival, improvements in energy efficiency might appear as a "a low hanging fruit". I therefore expect that fierce competition could have a negative effect on CO_2 intensity of production.

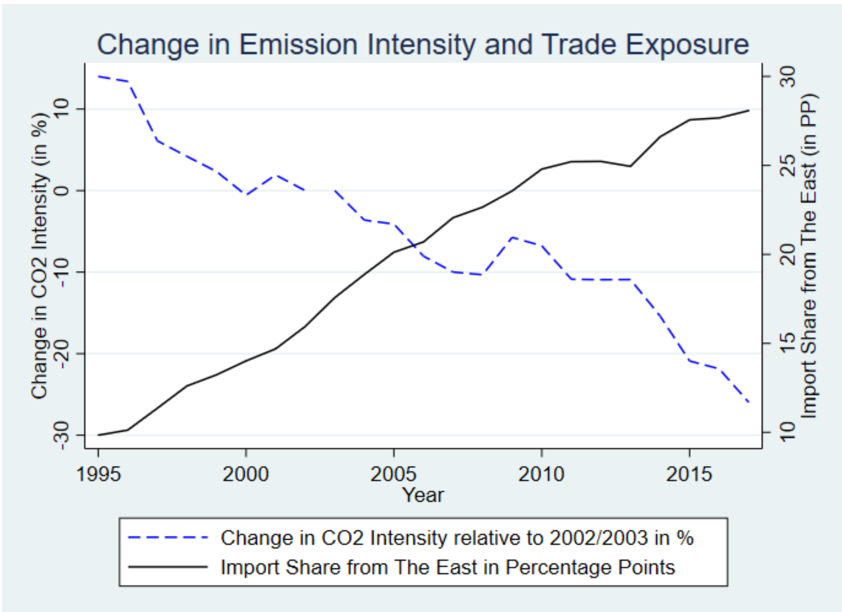
For the empirical analysis I combine the German census of the manufacturing industry with sector-level trade flows. The census data spans across more than two decades from 1995 until 2017, covers the universe of manufacturing plants with more than 20 employees ($\approx$ 40.000 plants annually), and provides, among other things, detailed information on plant-specific fuel

[1] In recent years, the German manufacturing sector emitted approximately 200 million tons of CO_2 annually, which is roughly one quarter of total emissions in Germany. These figures highlight the significance of the manufacturing sector's contribution to climate change and its central role in the German economy. The manufacturing sector in Germany absorbs more than 15% of Germany's labor force and contributes approximately one quarter to Germany's gross domestic product.

use. This information allows calculating CO_2 emissions based on fuel-specific conversion factors.

To identify the effect of import competition on emission intensity, I exploit the rise of China and eastern Europe as major actors in the world economy. A rising share of imported manufacturing goods in Germany originating from these regions (cf. Figure 1) is a manifestation of this process. Indeed the rise of the East coincided with a substantial decline in the ratio of total CO_2 emissions to gross output. For example between 1995 and 2017 CO_2 emissions per unit of sales declined by almost 40% while the share of imports from the East rose from 10% to almost 30% as can be seen from Figure 1. To uncover causal effects, I exploit the across sector variation in exposure to imports from the East, and I address the endogeneity of imports with an instrumental variable approach following Autor et al. (2014) and Autor et al. (2020).

Figure 1: Emission intensity and trade exposure



Notes: The Figure shows the evolution of total emission intensity (i.e. CO_2 emissions per unit of sales) relative to 2002/2003 and the change in the share of imports from China and eastern Europe (i.e. imports from "the East" divided by total imports) Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel and BAKI trade data, 1995-2017.

This paper relates to several strands in the literature. First and foremost it contributes to the literature on trade, globalization, and its effect on the environment.[2] By looking at the effect of import competition on CO_2 emission intensity in Germany, it relates closely to Gutiérrez and Teshima (2018) who study the effect of import competition on firms' energy efficiency, abatement expenditures and air pollution in Mexico. Using a measure of firms' exposure to output tariffs between 2000 - 2003, they find that energy efficiency increases with import com-

[2]See Cherniwchan (2017) and Copeland et al. (2021) for recent reviews of the literature linking trade to the environment.

petition while abatement expenditure decreases. Pollution levels around plants decrease when import competition increases, suggesting that the net effect of competition on environmental performance is positive. Cherniwchan (2017) studies the effect of trade liberalization in the context of the North American Free Trade Agreement (NAFTA) on US manufacturing plants' emissions of local pollutants (sulfur dioxide and particulate matter). He finds that lower Mexican tariffs lead to fewer emissions of SO_2 and PM10, which he attributes to the increased availability of emission-intensive intermediate inputs and export opportunities for American manufacturers. The latter effect, i.e., an environmental exporter-premium, has been documented in various other contexts, e.g., Richter and Schiersch (2017) show that exporting firms in Germany are less emission-intensive and that emission intensity decreases with an increasing export share. Similarly, Barrows and Ollivier (2021) show that emission intensity among Indian manufacturing firms decreases when demand in their export destinations goes up. However, the decline in emission intensity only partially off-sets the increase in total emissions resulting from higher production levels caused by the demand expansion.

The paper further relates to the literature on the determinants of energy efficiency and the so-called "energy efficiency paradox" (e.g. DeCanio, 1993;Jaffe and Stavins, 1994; Gerarden et al., 2017). As described above, the paradox refers to an apparently sub-optimal firm behavior with regard to energy use. It also manifests itself in a large dispersion of energy intensities within narrowly defined sectors. The literature has identified several potential explanations for inefficient energy use such as managerial inability (e.g. Bloom et al., 2010; Martin et al., 2012), capital constraints (e.g. Levine et al., 2018; De Haas et al., 2021) or market conditions such as size (Forslid et al., 2018). By linking changes in the level of competition to changes in CO_2 intensity, I investigate a further determinant of energy efficiency.

More broadly my paper contributes to the literature investigating the effect of import competition from China and eastern Europe on the manufacturing sector in western industrialized countries.[3]. For instance, Bloom et al. (2015) relate changes in the share of Chinese imports at the sector level to firm-level innovation measures, documenting "trade induced technical change," i.e., technological upgrading, more patenting, and higher TFPR among European firms. Chen and Steinwender (2021) find positive effects of import competition on productivity among initially

[3]An abundant literature studies the labor market consequences, both on the regional an individual level e.g. Autor et al. (2013), Acemoglu et al. (2016) and Autor et al. (2014) look at the US and Dauth et al. (2014) analyze the case of Germany. These papers document negative effects of import competition on employment. For the US, the China shock appears to be most relevant, whereas, for Germany, the rise of Eastern Europe was more critical.

unproductive family owned firms in Spain. They provide evidence that competition force unproductive firms to eliminate X-inefficiencies and improve material usage. These results for firms operating in Europe stand in some contrast to findings by Autor et al. (2020) who analyze the change in imports from China on innovation measures among manufacturing firms in the US. They find a negative effect of increasing import competition on R&D expenditure and patenting. Indeed, the literature on import competition and innovation summarized by Shu and Steinwender (2019) finds ”largely positive evidence for such [import competition increasing innovation] in Europe, and mixed evidence for such in Northern America”.

Starting with a motivating exercises at the aggregate level, I decompose the three-digit-sector-level emission intensity in a ”between-firm” and a ”within-firm” component. I find that total sector level emission intensity is negatively related to imports from the East. The decomposition yields no indication for a negative effect of import competition on the covariance between emission intensity and market share which captures the ”between-firm” component. Thus, the sector level analysis suggests that within-firm changes drive the efficiency-enhancing effect of import competition on sectoral emission intensity instead of a reallocation of market shares towards more productive firms.

The main firm-level analysis confirms the result from the sectoral decomposition. Baseline estimates imply a decrease of emission intensity by approximately 0.5% in response to a 1pp increase in the share of imports from the East relative to baseline absorption (import penetration ratio). The negative effect of import competition on emission intensity is in line with findings for Mexico by Gutiérrez and Teshima (2018) which I introduced above. The reduction in emission intensity is driven by a fewer emissions while sales remain constant. The effect is centred on firms with above median emission intensity and larger for firms with below median export shares. While the first observation underlines the relevance of the effect for aggregate emission the second could be related to a relatively larger increase in competition due to imports for firms that primarily operated on the German market. In a robustness check I analyze the effect of import competition on emissions per unit of value-added, which I can calculate for a sub-sample of firms. This analysis yields quantitatively very similar results and at least partly address the concern that ”leakage” explains reductions in emission intensity of sales. The results are also robust to an alternative identification strategy based on gravity residuals.

The remainder of the paper is structured as follows: in section 2 I outline the empirical approach, and section 3 introduces the data-set, shows descriptive statistics, and provides first results at the sectoral level to motivate the main analysis. Main results from the firm-level analysis are presented in section 4 together with robustness checks and effect heterogeneities. Section 5 discusses the findings and concludes.

2 Empirical approach

To estimate the effect of import competition on firm-level outcomes consider the following regression specification.

$$y_{itz} = \beta_0 + \alpha IPR_{zt}^{East} + X_{itz} + \nu_i + \epsilon_{itz} \tag{1}$$

The dependent variable y_{itz} can be any outcome of firm i in year t operating in sector z. The vector X_{itz} contains strictly exogenous controls, and ν_i is a firm-level fixed effect. The coefficient of interest α captures the effect of an industry's exposure to imports from the East defined as total imports from the East in year t scaled with initial absorption (cf. Autor et al., 2020). Concretely, the "import penetration ratio" is defined as follows:

$$IPR_{zt}^{East} \equiv \frac{Imp_{zt}^{East}}{Y_{z,1995} + Imp_{z,1995} - Exp_{z,1995}} \tag{2}$$

Finally, ϵ_{itz} in eqation 1 is a random error term. I follow Bloom et al. (2015) by taking long differences (four years) which eliminates the firm fixed effect. The differenced equation reads as follows:

$$\Delta y_{itz} = \beta_0 + \alpha \Delta IPR_{zt}^{East} + \Delta X_{itz} + \Delta \epsilon_{itz} \tag{3}$$

To estimate a causal effect of the trade exposure of a sector on firm-level outcomes, I need to address the endogeneity of trade flows. For instance, demand conditions in Germany are expected to affect imports and firm behavior in Germany directly. Thus, I need to isolate the supply-driven increase in the import share, i.e., the component of the change in the import share caused by the arguably exogenous rise of China and eastern Europe. In order to do so, I employ an instrumental variable (IV) strategy similar to Autor et al. (2013) and Dauth et al. (2014). To instrument the import share from the East to Germany in industry z, I use the share of imports from the East in industry z to a set of other countries.[4]

$$IPR_{zt}^{Other \leftarrow East} \equiv \frac{Imp_{zt}^{Other \leftarrow East}}{Y_{z,1995} + Imp_{z,1995} - Exp_{z,1995}}$$

The idea is that part of the variation in the import share from the East to Germany is due to a rising comparative advantage of the East or lower trade costs. The instrument is relevant for this part of the variation as the rise of the East also affects trade flows to the other countries. The other part of the variation is due to domestic conditions inside Germany. As explained above, I need to separate out this component of the total change in import shares. Under the assumption that demand conditions in Germany are orthogonal to the demand conditions in the chosen set of other countries, the instrument separates the exogenous component of trade flows to Germany from the endogenous. Moreover, for the instrument to be valid, I need to assume that trade flows between the set of other countries and the East have no direct effect on German firms (exclusion restriction). These considerations need to guide the selection of an appropriate set of countries for the instrument group. I follow Dauth et al. (2014) who included Australia, Canada, Japan, Norway, New Zealand, Sweden, Singapore, and the United Kingdom. All of which are high-income countries but neither directly borders Germany nor is any of them a member of the European Monetary Union (EMU). Dauth et al. (2014) argue that demand conditions among neighboring countries are too similar and that the fixed exchange rate within the EMU might cause a violation of the exclusion restriction if changes in trade flows between other countries and the East directly affect Germany industries. Finally, for the instrument to work, it needs to be relevant, which can be tested however and is indeed confirmed by the first-stage results reported in section 4.

3 Data, descriptive statistics and motivating exercises

3.1 Data

The main data source is the German census of the manufacturing industry called AFiD (Amtliche Firmendaten für Deutschland). The census data covers the universe of German industrial plants

[4]Ideally, I would like to use lagged absorption from the period before the rise of the East in the denominator of the instrument. However, due to data limitations this was not possible. The statistical office provides production data at the economic sector level, based on the sector classification from 1993, only since 1995. Before 1995 information on sectoral production is available for the sector classification from 1979 and a mapping between the classifications was not feasible.

with more than 20 employees. The data consists of different "modules" of which I combine *"AFiD Modul Industriebetriebe"* (industrial plants module) with *"AFiD Modul Energieverbrauch"* (energy use module). The industrial plants module contains economic variables such as gross output, sales abroad, number of employees and investment. The energy use module details plant-specific energy use by fuel type. Energy use is reported in physical units (kWh) and can thus be converted to CO_2 emissions based on fuel-specific conversion factors (c.f. Richter and Schiersch, 2017; Petrick et al., 2011). To calculate plant-level CO_2 emissions, I draw upon the conversion factors provided by the Umwelt Bundesamt (a Federal Agency).[5] One major caveat with the energy data is a break in the reporting between 2002 and 2003. The time series before and after 2003 is internally consistent. In my estimation, I make sure to exclude variation that results from the break in the reporting.[6] Finally, I aggregate plant-level information to the firm-level. The final firm-level data set is an unbalanced panel covering the years 1995 until 2017.

I supplement the main data with the so-called "*cost structure survey*" which is also part of the German census. The cost structure survey provides information on intermediate input expenditure, which allows calculating value-added. I estimate the effect of import competition on the emission intensity of value-added as a robustness check. Since the cost structure survey is an unbalanced panel, including most firms for four consecutive years only, the analysis of the effect of import competition on value-added is only feasible for a subsample of firms. This sampling procedure also dictates the choice of the differencing, i.e. taking longer than four-year differences would not be feasible with data.

I rely on the BAKI database for information on bilateral trade flows, which is constructed from the United Nations Commodity Trade Statistics Database (Comtrade) and provided by CEPII. The database reports trade flows at the 6-digit product level from the Harmonized System (HS) nomenclature. To merge the trade information to the firm-level data, I aggregate from the product level to the 3-digit economic sector level using the classification from 1993 (equivalent to NACE industry codes).[7]

[5] A table with the relevant information can be found here, last retrieved 18.11.2020. The table gives the fuel-specific time-varying CO_2 content per terajoule. This unit can be converted to CO_2 per kWh. We then multiply the fuel use in kWh with the respective conversion factor to obtain the CO_2 emissions. We take the average carbon content for electricity purchased from the grid system, which varies by year.

[6] For a detailed description of the energy use module as well as the change in reporting, see Petrick et al. (2011)

[7] To be precise, I first convert the product-level information from HS92 to SITC3 (conversion table was downloaded here) and then I map from SITC3 to the 3-digit industry classification using the same mapping as Dauth et al. (2014). The industry classification from 1993 was in place until 2008 with minor modifications in 2003. Therefore, I omit all firms from the analysis that were first observed only after 2008, since the economic sector based on the classification

Table 1: Descriptive statistics - firm level information

Variable	Mean	Std. Dev	p10	p50 (Median)	p90	N
Number of Employees	99	117.6	25	54	226	752197
Gross Output	17111.71	28799.70	1859.68	6553.98	43284.27	752197
Export Share	0.18	0.24	0	.07	0.56	752197
Total Energy (in MWh)	4575.96	22549.41	161.24	892.706	90110.92	752197
Total CO2 Emissions (in t)	1639.049	4966.97	66.64	418.04	3599.66	752197
Total electricity (in Mwh)	1872.07	5715.37	64.07	410.91	4219.11	752197

Notes: The table shows the average of respective variables from the period 1995-2017. Gross Output is in 1000 Euro, Energy use (total and Electricity) is in MwH and CO_2 Emissions in tons. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

3.2 Descriptive statistics

Table 1 shows summary statistics for firm-level variables pooled over the period 1995 until 2017. The average firm has close to 100 employees and generates approximately 17 million euros annual turnover. The median for both - employees and gross output - is considerably lower than the average (54 employees and 6.5 million turnover), indicating a right-skewed distribution. Similarly, the average export share amounts to 18%, while the median export share is only 7%. At the 90^{th} percentile, exports account for the majority of total sales (56%). In addition to indicators of economic performance, table 1 summarizes total energy use in megawatt-hours (Mwh), electricity use in Mwh, as well as total CO_2 emissions in tons (t). On average, firms used 4575 Mwh annually, of which approximately one-third was electricity purchased from the grid (1872 Mwh). The average firm's energy use caused 1639 tons CO_2 emissions. Comparing the median firm's energy use with the energy use at the 90^{th} percentile indicates that energy consumption and related emissions appear to be very concentrated (even more right-skewed than the econ. variables with a p90 to p50 ratio of approximately 10)

Table A2 in the appendix provides further information regarding the exposure of the German manufacturing sector to imports from the East. For instance, total manufacturing imports from China in 1995 amounted to only 8 billion USD, which corresponds to an import share of just 2%. Until 2017 this share rose to 9%, corresponding to imports worth 89 billion. Similarly, imports from eastern Europe rose from 32 billion USD ($\approx$8% of total imports) in 1995 to 200 USD in 2017, corresponding to an import share of close to 20%. These averages mask substantial variation across the 22 two-digit economic sectors, as can be seen in the last two rows of table A2: the share of imports from the joint East in the least exposed sector (manufacturing of tobacco products) was merely 1% in 1995. In contrast, the most exposed sector's import share amounted

from 1993 is unknown for these firms.

to 27% already (Textiles). Twenty-two years later, the import share from the East ranged from 11% in "manufacturing of chemicals and chemical products" to 58% in "Manufacturing of office machinery and computers". The initial import share in the chemical industry was 6% in 1995 and in "manufacturing of office machinery and computers" only around 3%. The rise in this sector was particularly driven by imports from China after its WTO accession. The import share in "manufacturing of tobacco products" increased to $\approx$ 51% in 2017 in this case driven by eastern Europe. This increase started in 2004 when the Eastern enlargement of the European Union happened. Indeed, between 1995 and 2017 the share of imports from the joined East rose in all sectors.

To verify that my measure of import penetration as defined in equation 2 in section 2 captures changes in competitive pressure, I project changes in the sectoral producer price indices (PPI) on changes in the import penetration ratio. An increase in competition is expected to depress domestic producers' markups and thus result in smaller price inflation. Results reported in table A1 are in line with this hypothesis. All estimates of the effect of changes in the IPR on changes in the sectoral PPI are negative and highly significant. Columns 1 and 2 of table 2 indicate that a 1pp increase in the IPR depresses the sectoral PPI by 0.4%. Using the change in levels yields qualitatively similar results.[8]

3.3 Motivating exercise: sectoral decomposition of emission intensity

Before I turn to the actual firm-level analysis of the effect of import competition on firms' emission intensity, I describe the evolution of aggregate emission intensity from 1995 until 2017. Following Olley and Pakes (1996) and Brucal et al. (2019), I decompose aggregate sector-level-emission-intensity in an unweighted mean and a covariance term that captures the association between firms' market share and their emission intensity. The following expression describes the decomposition:

$$\underbrace{W_{zt} = \sum_{i \in Z} s_{it} lnE_{it}}_{\substack{\text{Weighted } CO_2 \text{ Intensity} \\ \text{in Sector Z}}} = \underbrace{\overline{lnE_{zt}}}_{\substack{\text{Unweighted avg.} \\ \text{Intensity}}} + \underbrace{\sum_{i \in Z} (s_{it} - \overline{s_t})(lnE_{it} - \overline{lnE_t})}_{Covariance} \tag{4}$$

[8]The reference year of the PPI is 2010, i.e. the price index was set to 100 in 2010 for all sectors.

where s_{it} is the share of sales by firm i in total sales in sector z (i's market share) at time t, $\overline{lnE_{zt}}$ is the average emission intensity from all firms in sector z and $\overline{s_t}$ is the average market share in sector z.

The aggregate weighted emission intensity in sector z (W_{zt}), i.e. the weighted sum of emission intensities among all firms operating in sector z, can be re-written as the average emission intensity from all firms in sector z, i.e. $\overline{lnE_{zt}}$ and the covariance term. A negative covariance implies higher market shares for more carbon-efficient firms (the inverse of carbon intensity) and thus reflects "allocative efficiency". Changes in this term capture a reallocation of market shares toward firms with higher carbon efficiency, and changes in the unweighted average emission intensity reflect changes in carbon efficiency within firms.

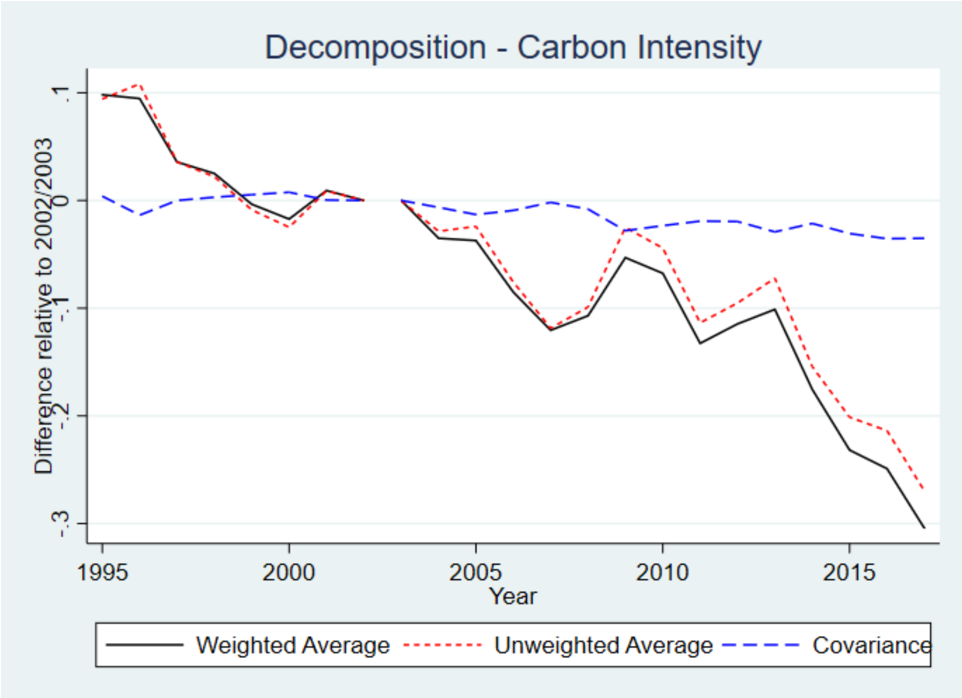
Figure 2 shows the evolution of the weighted average, the unweighted average, and the covariance term averaged across economic sectors. One can see that the weighted average decreased by approximately 40% between 1995 and 2017 as indicated by the solid black line. Interestingly, within-firm changes (dotted red line) drive this process almost entirely. Reallocation has played only a minor role in decreasing the weighted emission intensity, contributing at most four percentage points, as can be seen from the dashed blue line. The most visible drop in the covariance term happened between 2007 and 2009, coinciding with the financial crisis. The financial crisis caused the most significant contraction in manufacturing output in the history of the Federal Republic of Germany - and thus quite plausibly forced the least efficient firms to exit the market.

To get a first indication for the relation between carbon efficiency and import competition I regression relate the weighed emission intensities at the sector level as well as its components to the sector specific import shares from the East. The estimating equation I take to the data can be written as follows:

$$y_{zt} = \beta_0 + \beta_1 ImpSh_{zt}^{East} + \mu_z + \tau_t + \epsilon_{zt} \quad (5)$$

In table 2 I show results from an OLS estimation and from the IV approach introduced in section 2. Each regression includes three-digit-sector fixed effects as well as year dummies. Looking at the effect of imports on the weighted mean, one can see that the OLS result is insignificant. In contrast, the IV estimate points to decreasing sector-level emission intensity of 0.8% in response to a 1pp increase in the IPR from the East. Looking at the components of the total effect, one can see that within-firm changes, i.e., changes in the unweighted mean, drive the total effect. The

Figure 2: Decomposition of sectoral emission intensity



Notes: The figure shows the average across three digit sectors from a decomposition of total emissions (weighted average) in the unweighted average and and the covariance between market share and CO_2 intensity. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel and BAKI trade data, 1995-2017.

point estimate capturing the effect of import competition on the covariance term is very close to zero and insignificant.

4 Main results: firm-level effects

In this section, I first present my baseline results on the effect of import competition on firms' emission intensity. I then conduct a series of robustness and sensitivity checks. Finally, I analyze effect heterogeneities.

4.1 Baseline results

Table 3 presents the baseline results. The dependent variable is the four-year change in the logarithm of firms' emission intensities, and the explanatory variable is the corresponding change in the IPR from China and eastern Europe. Specifications reported in columns 1 to 6 are IV estimates, and column 7 shows OLS estimates for comparison. At the bottom of the table, I detail the fixed effects and controls included in each specification. In panel A, I do not control for any sectoral trends, but panel B controls for trends within twelve broadly defined industries (cf.

Table 2: Import Competition from the East and CO_2 Intensity - Sectoral Effects

	Weighted Mean		Unweighted Mean		Covariance	
	OLS	IV	OLS	IV	OLS	IV
Import Share	0.006	-0.008**	0.004	-0.009***	0.003	0.001
	[0.009]	[0.004]	[0.007]	[0.003]	[0.002]	[0.002]
Observations	2067	2067	2067	2067	2067	2067
F-Stat		62.74		62.74		62.74
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table shows results from IV and OLS regressions for three different dependent variables (given at the top of the table). "Weighted mean" is total emissions divided by total sales in sector z. "Unweighted Mean" is the average firms' CO_2 intensity in sector z. "Covariance" is the covariance between a firms' market shares and firms' CO_2 Intensity. Regressions include different sector level fixed effects before and after the change in the reporting of energy variables (before and after 2003). Standard errors are clustered at the sector level and given in paranthesis. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Autor et al., 2014; Autor et al., 2020). Standard errors were always clustered at the firm-level to account for within-firm auto-correlation and at the year-3-digit-sector-level (two-way clustering). In a robustness check, I show results with standard errors clustered at the 3-digit-sector-level only. At the bottom of panel A and B I report first-stage results (coefficient, standard errors and Kleibergen-Paap F-statisitc).

The point estimate from the specification in column 1 of panel A, which includes only year-fixed effects, indicates that a 1pp increase in the IPR leads to a statistically significant reduction of firms' emission intensity by -0.35%. Looking at first-stage results, one can see that the coefficient is well behaved, i.e., exports from the East to other countries are positively associated with German imports from the East. The Kleibergen-Paap F-statistic is well above any conventional threshold values underlining the instrument's relevance. In column 2, I further control for CO_2 intensity-decile-year fixed effects to purge shocks that might occur along the energy/CO_2 intensity distribution. Indeed one can see that controlling for emission intensity increases the point estimate to 0.0065. The first-stage results do not change meaningfully between any of the specifications in panel A. I then consecutively add sales- and export share-decile-year fixed effects (columns 3 and 4) to control for size and shocks that depend on the degree of firms' internationalization. Adding the exporter effect depresses the coefficient slightly, indicating a reduction of emission intensity by 0.57% in response to a 1pp increase in the IPR, but the effect remains highly significant. The point estimate in column 5, which includes year-federal state fixed effects, confirms that region-specific shocks do not drive the effect. Finally, in column 6, I control for firms' start-off period values, i.e., the emission intensity of each firm in the first year

Table 3: Baseline results - Log of emission intensity

	IV						OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline specifications							
Coefficient	-0.0035***	-0.0065***	-0.0063***	-0.0057***	-0.0057***	-0.0058***	-0.0003
Standard Error	0.0009	0.0011	0.0011	0.0010	0.0010	0.0010	0.0004
P-Value	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.3741
First-stage coefficient	0.309	0.307	0.307	0.301	0.301	0.301	
Standard Error	0.0314	0.0318	0.0318	0.0320	0.0318	0.0319	
Kleibergen-Paap F-statistic	96.82	93.18	93.10	88.73	89.62	89.18	
Panel B. Control for industry trends							
Coefficient	-0.0032***	-0.0041***	-0.0040***	-0.0040***	-0.0039***	-0.0041***	-0.0013
Standard Error	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0009
P-Value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.1709
First-stage coefficient	0.309	0.275	0.275	0.274	0.274	0.274	
Standard Error	0.0314	0.339	0.0339	0.0339	0.0338	0.0339	
Kleibergen-Paap F-statistic	65.43	65.89	65.85	65.15	65.95	65.17	
Year dummy	Yes	No	No	No	No	No	No
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	No	Yes	Yes	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	No	Yes	Yes	Yes	Yes
Region-year-dummy	No	No	No	No	Yes	No	No
Start-off-period values	No	No	No	No	No	Yes	No
Observations	345772	345772	345772	345772	345772	345772	345772

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (6) show results from 2SLS estimations and column (7) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions scaled with firms' sales (emission intensity). The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification first-stage coefficients, corresponding standard errors and the Kleibergen-Paap F-statistic is reported. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

in which the firm was observed. Again the point estimate remains stable.

For comparison, column 7 shows the results from an OLS regression which includes the same set of fixed effects as the IV estimation in column 4. The OLS coefficient is close to zero and statistically insignificant. A positive bias of the OLS appears plausible: as domestic demand expands, increasing production beyond cost-efficient quantities can still be profitable for firms. Similarly, firms might also offer products that are not part of their core competencies in periods of high demand. Therefore, emission intensity is likely to increase as demand expands and at the same time, imports will increase too, causing a positive OLS bias.

As explained above, all regressions shown in panel B. include trends for twelve broadly defined industries.[9] Controlling for industry trends absorbs some useful variation to identify the effect. Losing this variation also causes first stage results to become weaker, for example, the first stage coefficient drops slightly, and the F-statistic drops by approximately one-third to around 65. Still, the second stage results remain negative and highly significant. With only year fixed effects (column 1), the point estimate suggests that a 1pp increase in the IPR causes a reduction of firms' emission intensity by 0.32%. Adding fixed effects by year and CO_2-intensity-decile increases the point estimate to 0.0041. Any further fixed effects do not change the point estimate in a quantitatively relevant way, as can be seen from columns 2-6. In sum, adding industry trends decreases the effect size by about one-third. Still, the effect remains statistically significant and quantitatively meaningful. As expected, the positive bias of the OLS coefficient remains.

Overall, the baseline results as presented in table A4 lead to the conclusion that import competition from the East caused a reduction of firms' emission intensity. In principle, import competition could affect the nominator, i.e., energy use and related emissions, and the denominator of emission intensity, i.e., sales. As hypothesized in the introduction, import competition is expected to

[9]In the aggregation of industries, I follow Autor et al. (2014) and Autor et al. (2020) closely who control for trends within 11 industries. Given that they were able to map imports to much narrower industries (almost 400 as opposed to less than 90 three-digit industries in Germany), specifications in Panel B are rather demanding. Specifically, I combine *"Manufacture of food products and beverages"* with *"Manufacture of tobacco products"*; *"Manufacture of textiles"* with *"Manufacture of wearing apparel; dressing and dyeing of fur"* and *"Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harr"*; *"Manufacture of pulp, paper and paper products"* with *"Publishing, printing and reproduction of recorded media"*; *"Manufacture of coke, refined petroleum products and nuclear fuel"* with *"Manufacture of chemicals and chemical products"*; *"Manufacture of basic metals"* with *"Manufacture of fabricated metal products, except machinery and equipment"*; *"Manufacture of office machinery and computers"* with *"Manufacture of electrical machinery and apparatus n.e.c."* and *"Manufacture of radio, television and communication equipment and apparatus"* and *"Manufacture of medical, precision and optical instruments, watches and clocks"*; *"Manufacture of motor vehicles, trailers and semi-trailers"* and *"Manufacture of other transport equipment n.e.c."*. Further industries are *"Manufacture of furniture; manufacturing n.e.c."*, *"Manufacture of machinery and equipment n.e.c"*, *"Manufacture of other non-metallic mineral products"* and *"Manufacture of wood and of products of wood and cork, except furniture; manufacture"*.

make firms search for margins to optimize and reduce costs to remain competitive. Therefore, I expect energy use and emissions to decrease in response to tougher competition and sales to be depressed or remain stable. To unpack the effect on emission intensity, I estimate the effect of import competition on the log of CO_2 emissions and the log of sales separately. Table A4 in the appendix shows the results for CO_2 emissions and table A5 for sales. The effect on emissions is negative across all specifications. Instrumental variable results in panel A of table A4 range between -0.0019 and -0.0049. The specification with only year-fixed effects (column 1) yields the smallest coefficient, and the specification, which includes federal-state by year-fixed effects (column 5), gives the largest effect. In panel B, the effects remain negative but including industry trends depresses the size significantly. The coefficients from the IV estimation range between -0.0004 and -0.0016. These point estimates are somewhat smaller than the estimated effect on emission intensity, indicating that import competition's effect on sales must be positive. Indeed, table A5 confirms this: all baseline estimates show positive coefficients from 0.0007 to 0.0022, with the largest coefficient being statistically significant at the 5% level. The inclusion of industry trends inflates the effect suggesting an increase in firm sales between 0.22% to 0.3% in response to a 1pp increase in import exposure. This result is rather surprising, and I will expand on it in the next subsection, which tests the robustness and sensitivity of the baseline results.

4.2 Robustness and Sensitivity

To first check the sensitivity of my baseline results, I consecutively drop two-digit sectors to rule out that a single sector drives my effects. The negative effect on emission intensity turns out to be robust to excluding individual sectors.[10] However, upon the exclusion of *"manufacturing of radio, television and communication equipment and apparatus"* (WZ-32 from German classification of economic activity), the point estimate drops in quantitatively relevant magnitude. Therefore, I reproduce all results discussed so far using the sample without WZ-32. Specifically, table A6, A7 and A8 show the results for emission intensity, total CO_2 emissions and sales. The number of observations drops by a little less than 4000 to 341998. The effect on total emissions increases slightly but remains qualitatively unchanged. In contrast, the effect of import competition on sales differs in important ways. For example, instead of positive and partly significant effects as

[10]The largest coefficient is estimated when WZ-29 *manufacturing of machinery and equipment* is drooped. Then, the point estimate is 0.0065 with a corresponding standard error of 0.0012. The number of observations is 287628. The smallest coefficient is estimated when WZ-32 *"manufacturing of radio, television and communication equipment and apparatus"* is omitted. Then the point estimate is -0.004, the standard error is 0.008 and the number of observations is 341998.

reported in table A5 for the total sample, I find negative or zero effects once WZ-32 is dropped. Specifically, in panel A of table A8 all IV estimates are negative and mostly statistically significant ranging from -0.0014 to -0.0034 depending on the set of controls. Looking at panel B, one can see that the inclusion of industry trends shrinks the IV coefficients close to zero, and they become insignificant. Coefficients from the OLS are both (panel A. and B.) positive and significant, which is in line with the expected bias as discussed in subsection 4.1.

Over the period 1995 to 2017, the sector *"manufacturing of radio, television and communication equipment and apparatus"* has been subject to rapid technological changes, quality upgrading, and falling prices. Because of this development, the producer price index in this sector is an outlier. The average PPI in the manufacturing sector increased moderately from 94 in 1995 to 107 in 2017 (indexed to 100 in 2010), while the average PPI in WZ 32 collapsed from 217 to 89 in the same period. This change in the PPI introduces the variation in deflated sales that causes the significant effect of imports on firms' sales. Against the backdrop of the fundamental changes in this sector which are reflected in the PPI evolution, I regard a comparison of deflated sales as a measure of physical output over time as problematic. Thus, results including WZ32 need to be interpreted cautiously and in order to not base any further conclusion on the inclusion of observations from WZ32, I drop corresponding firms for the remainder of this analysis.

4.2.1 Single plant firms

The assignment of multi-plant firms to one sector is not always unambiguous, e.g., if plants of similar size measured by sales operate in different sectors. To ensure that the results do not depend on multi-plant firms and the peculiarities associated with them, I re-estimate the effect of import competition on emission intensity for single plant firms only. Single plant firms constitute the vast majority of firms in the sample ($\approx$ 90%). In table A3 I report the results. For the sake of readability, I omit some specifications from the table. Upon comparing results for single plant firms only with those from the full sample, it can be ruled out that multi-plant firms affect the results in any meaningful way. Indeed, the point estimates obtained from single plant firms only are almost identical to the full sample results as reported in table A6. I, therefore, proceed with the full sample.

4.2.2 Emission intensity of value added

An obvious concern with this analysis is "carbon leakage". For instance, the increase in imports from the East could be high carbon content inputs in domestic firms' production process. If these inputs used to be produced by the domestic firms themselves and outsourced once the opening up of the East allowed firms to do so, the emission intensity of sales would decline. To (partially) address this concern, I estimate the effect of import competition on the emission intensity of value-added. In the scenario sketched above, value-added would decline. Thus, the emission intensity of value-added would remain unchanged or even increase despite a decrease in emission intensity of sales.

The analysis of the effect of import competition on value-added is feasible only for a subsample of firms, which provide information on material inputs. Table 4 shows the results on the effect of import competition on the emission intensity of value-added. The number of observations drops to approximately 70000, but the point estimates in table 4 are quantitatively very similar to those describing the effect of emission intensity of sales. Specifically, the baseline results indicate that a 1pp increase in the IPR induces an approximate 0.6% decrease in firms' emission intensity. Conditioning on industry trends depresses the coefficient by about one-third, similar to previous estimates. When unpacking the effect, I find that import competition did not affect the logarithm of value-added; thus, the decrease in emission intensity of value-added results from fewer emissions.

The results presented here suggest that the effect on the emission intensity of sales is not a result of carbon leakage. Of course, this analysis does not imply that the imports do not also include intermediate inputs. For example, imports from the East could displace imports from other countries. Also, imports from the East in the three-digit sector x could still be inputs in the three-digit sector y.

4.2.3 Gravity based estimation

To analyze the sensitivity of my results towards the identification strategy, I follow Autor et al. (2013) and Dauth et al. (2014), in implementing an alternative identification strategy based on gravity residuals. The idea behind this approach is to use the hypothetical increases in imports from the East, which is implied by the increase in the East's export capacity (its comparative

Table 4: Subsample analysis - CO_2 emission per value added

	IV			OLS
	(1)	(2)	(3)	(7)
Panel A. Baseline Results				
Coefficient	-0.0066***	-0.0061***	-0.0056***	-0.0045***
Standard Error	0.0013	0.0013	0.0013	0.0008
P-Value	0.0000	0.0000	0.0000	0.0000
Kleibergen-Paap F-statistic	218.1	223.5	217.5	
Panel B. Control for Industry Trends				
Coefficient	-0.0042***	-0.0037***	-0.0036***	-0.0016**
Standard Error	0.0014	0.0013	0.0013	0.0008
P-Value	0.0025	0.0055	0.0061	0.0388
Kleibergen-Paap F-statistic	157.2	160.1	160.8	
CO_2 intensity-decile-year-dummy	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	Yes	Yes
Observations	70007	70007	70007	70007

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (3) show results from 2SLS estimations and column (4) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions per value added. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification I report the Kleibergen-Paap F-statistic. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

advantage and trade costs) vis a vis Germany. I outline the approach and specific steps in some detail in section A in the appendix and refer to Autor et al. (2013) for an in-depth discussion.

As the hypothetical change in imports is obtained from the change in the East's export capacity, unobserved domestic conditions in Germany do not contaminate it. I can thus simply relate changes in firms' emission intensities to the hypothetical change in import penetration using OLS. Table 5 shows the results from the gravity-based approach. The explanatory variable is the change in hypothetical imports from the East relative to domestic absorption in the baseline period expressed in pp. Thus, the interpretation of the coefficient is similar to the IV approach. The baseline results without industry trends (columns 1 to 3) are quantitatively closely aligned with the IV estimates in table A6. Conditioning on industry trends shrinks the coefficient and yields only marginally significant effects. Specifically, the coefficient in column 6 suggests that a 1pp increase in the explanatory variable reduces firms' emission intensity by 0.12%. Overall, the alternative gravity-based approach results strengthen the causal interpretation of the main results.

Table 5: Gravity based estimates - Log of CO_2 intensity

	(1)	(2)	(3)	(4)	(5)	(6)
Coefficient	-0.0050***	-0.0051***	-0.0043***	-0.0011	-0.0012	-0.0012*
Standard Error	0.0007	0.0007	0.0007	0.0008	0.0008	0.0008
P-Value	0.0000	0.0000	0.0000	0.1476	0.1005	0.0999
CO_2 intensity-decile-year-dummy	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	Yes	Yes	No	Yes	Yes
Export share-decile-year-dummy	No	No	Yes	No	No	Yes
Industry Trends	No	No	No	Yes	Yes	Yes
Observations	341998	341998	341998	341998	341998	341998

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

4.3 Effect Heterogeneity

In the subsequent paragraphs, I look at heterogeneities both with respect to the import shock, i.e. I distinguish between imports from eastern Europe and imports from Chian and with respect to firm characteristics. Specifically, I interact the trade shock with dummies for firms emission intensity, their export share and size to gauge the quantitative significance of the effect and to get some indication of potential mechanisms.

4.3.1 Eastern Europe vs. China

In this subsection, I look at the change in import penetration from China and eastern Europe separately (table 6). I present results from the baseline specification which includes year by sales-decile, CO_2 intensity-decile and export share-decile fixed effects. Column 1 and 2 in panel A shows the results from the IV estimation when the IPR from China is the dependent variable. The point estimate in column 1 is similar to the main result indicating that a 1pp increase in the IPR from China induces a 0.53% reduction in emission intensity and similarly the point estimate in column 2, which includes industry trends, is also comparable to the main effect. For both specifications, the Kleibergen-Paap F-statistic is strong.

Looking at the effect of imports from Eastern Europe, as reported in column 3 and 4, one can see a large and highly significant negative effect on emission intensities from both specifications, i.e. with and without industry trends. However, these effects need to be interpreted cautiously: first, as one can see from the bottom of panel A, the first stages are weak with the F-statisitcs below 10. Second, when looking at the effect on sales (not reported), I find positive point estimates which become quantitatively larger after conditioning on industry trends.[11] Dauth et al. (2014) emphasize the role of intra-industry trade between Germany and Eastern Europe and the correlation between industry imports from the East and German exports to the East in the same industry. Therefore, the positive effect on sales which depresses emission intensity, might partly result from correlated German export opportunities. The integration of Eastern European economies in German firms' value change, for example via FDI from Germany, further challenges the identification. For instance, productivity improvements in Germany might increase exports from German foreign affiliates in Eastern Europe.

Given the weak first stage in the IV specification for eastern Europe and further shortcomings, I also report the results from the, to some extent complementary, gravity based estimates. For China, the point estimates from both specifications are smaller than the IV results but remain statistically significant. Similarly for eastern Europe the effects are slightly depressed without industry trends but much smaller for the specification that accounts for industry trends. Since the gravity approach measures the rise of eastern Europe's export capacity relative to Germany (see A in the appendix), the much smaller coefficient as compared to the IV specification re-enforces the concern that the IV approach partly picks up German exports to eastern Europe. Overall, the results in Panel B of table lend credence to the negative effects reported in panel A but cast some doubts on the magnitude of the effect estimated for Eastern Europe.

4.3.2 Firm characteristics

Table 7 investigates effect heterogeneities with respect to firm's characteristics. To so I interact the trade shock with above-median-dummies for CO_2 intensities, export shares and size. The control variables vary depending on the interaction to not absorb too much useful variation. All models are fully interacted, i.e. all fixed effects / controls were also interacted.

Column 1 shows the effect of import penetration interacted with firms' CO_2 intensity. I omit the CO_2 intensity-decile fixed effects since they would absorb all the variation in the interaction effect and condition on start-off period values instead. One can see that the main effect, while still being negative, becomes small and statistically insignificant. Instead, the interaction is negative

[11] Concretely, the point estimate without industry trends is 0.0017 with a standard error of 0.0055. Once I condition on industry trends, the point estimate equals 0.0047 with a corresponding standard error of 0.0057. The point estimate with CO_2 emissions as dependent variable equal -0.0065 without and -0.0036 with industry trends.

Table 6: China vs. Eastern Europe - CO_2 Intensity

	China		Eastern Europe	
	(1)	(2)	(3)	(4)
Panel A. IV Results				
Coefficient	-0.0053***	-0.0030**	-0.0082***	-0.0083**
Standard Error	0.0012	0.0012	0.0023	0.0035
P-Value	0.0000	0.0131	0.0000	0.0167
Kleibergen-Paap F-statistic	221.6	184.5	6.219	4.857
Panel B. Gravity based estimates				
Coefficient	-0.0036***	-0.0019*	-0.0061***	-0.0019**
Standard Error	0.0014	0.0010	0.0008	0.0008
P-Value	0.0094	0.0546	0.0000	0.0221
Industry Trends	No	Yes	No	Yes
Observations	341998	341998	341998	341998

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. All regressions include CO_2 intensity-decile-year-dummies, Sales-decile-year-dummies and Export share-decile-year-dummies. Column (1) to (3) show results from 2SLS estimations and column (4) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions per value added. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification I report the Kleibergen-Paap F-statistic. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

and highly significant. While there exists still large variation in firms' emission intensity within the group of firms above the median (cf. table 1), this result result still suggests that the effect of import competition is quantitatively relevant for aggregate emissions. It is also not surprising that firms' for which energy is not a relevant input in the production process do not consider energy efficiency as a viable tool to cut costs and thus improve competitiveness.

In column 2 I show the interaction between import competition and firms' integration in the global economy, measured by firms' export share. I omit the export share decile-year fixed effect from the specification. The point estimates show a large negative main effect and a significant positive interaction effect. This implies that firms' with below median export intensity responded stronger to the increase in competition. Still, the sum of main and interaction effects is negative, pointing to a decrease in emission intensity, also among more export oriented firms. Differing degrees of export activity might alter the effect of changes in import penetration on changes in the level of competition that firms face. For example, a firm that operated only on the German market might be more effected by an increase in imports as compared to a German firm that has always sold its products globally. This differential effect of changes in import penetration offers a possible interpretation of the heterogeneity shown in column 2.

The interaction between import competition and firm size is reported in column 3. The interaction effect precisely estimated zero effect indicating that imports affected smaller and larger firms alike.

Finally, column 4 interacts the change in import exposure with a dummy for three digit sectors with high import shares in 1995. One might expect, that the competitive environment is less affected by increasing imports from the East in sectors that were already relatively open. While the sign of the point estimate is consistent with this idea, the coefficient lacks statistical significance, also due to high standard errors.

When interpreting the heterogeneity presented above, account should be taken of the fact that part of the variation is driven by across sector differences. For instance, the most energy efficient steel producer will still emit more CO_2 per unit of sales than the least efficient textile company. Thus the heterogeneity with regard to emission intensity speaks more to the relevance of the effect of import competition on emissions for aggregate emissions and less to differential effects depending on firms ”CO_2 productivity”. The least efficient firms within their respective sectors might be the ones with the largest potential for improvements, therefore, one could hypothesize that efficiency improvements are concentrated among them. To analyze heterogeneities within three digit sectors, I split the sample by within sector quantiles of emission intensity, export shares and size. Results are plotted in Figure A1 for the baseline specification (green) and the specification that accounts for industry trends (blue). Subfigure 2(a) shows the effect by emission intensity quantile, which does not show a clear pattern. All effects are negative, of similar magnitude and at least marginally significant. Still it is worth noting that, in line with the story sketched above, point estimates from the most efficient quantile are comparably small and those from the least efficient quantile are the largest. For within sector export share quantiles the point estimates are less stable. This is also related to very different numbers of observations within quantiles. In particular firms with small export shares appear to have a smaller survival rate. Effects across size groups are again rather similar. If anything, larger firms tend to have higher improvements in efficiency.

Table 7: Effect Heterogeneity - CO_2 Intensity

	(1)	(2)	(3)	
Main effect	-0.0002	-0.0052**	-0.0039***	-0.0039***
	(0.0008)	(0.0011)	(0.0008)	(0.0011)
Interaction - CO2 intensity	-0.0023***			
	(0.0008)			
Interaction - Export intensity		0.0021*		
		(0.0011)		
Interaction - Size			0.0001	
			(0.0008)	
Interaction - High Imp. Sh.				0.0008
				(0.0015)
Kleibergen-Paap F-statistic	57.12	73.25	135.4	85.78
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes
Sales-decile-year-dummy	Yes	Yes	No	Yes
Export share-decile-year-dummy	Yes	No	Yes	Yes
Observations	340000	340400	340092	341998

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. The table reports main and interaction effects. The set of fixed effects differs depending on the interaction variable. All fixed effects were also interacted with the "above-median dummy". The regression in column 1 further includes start-off period values of the dependent variable. The dependent variable is the four-year change in log of firms' CO_2 emissions per sales. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2006 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

5 Discussion and conclusion

In this paper, I analyze the effect of import competition on firm-level emission intensity. To do so, I combine comprehensive firm-level data from the German manufacturing industry with sector-level trade flow. I focus on the rise of China and eastern Europe between 1995 and 2017. Using an instrumental variable strategy, I provide evidence that increasing import competition is associated with higher energy efficiency of production which translates into fewer CO_2 emissions per unit of sales. This effect is driven by within firm changes, i.e. I do not find indication for between firm reallocation. The baseline specification for my firm-level analysis implies a decrease of the emission intensity of production by 0.5% for a 1pp increase in the import penetration ratio. Between 1995 and 2017 the import penetration from the East increased by approximately 20pp, thus the increase in competition kept emission intensity 10% below the level it would have had in the absence of the rise of the East.

While I cannot completely rule out that carbon leakage via high carbon content imports contributed to the decrease in emission intensity, my analysis on the effect of import competition on emission intensity of value added does not provide any indication for leakage. Similarly, I do not find that the share of value added in gross output declined in response to import competition. Increasingly available information on firm-product specific imports could make an in-depth analysis of changes in the composition of firms imports feasible.

My results are in line with parts of the international trade literature which tends to find positive effects of import competition on European firms' productivity (Shu and Steinwender, 2019). For Spain, Chen and Steinwender (2021) find that, in particular, family-managed firms responded to import competition by improving material use which translates into higher productivity. Given that firms' energy use is often regarded as inefficient ("energy-efficiency-paradox") a similar mechanism appears plausible. Measures of management practices could be used in future research to understand how the improvement in energy efficiency were achieved. From a policy perspective the key message of this paper is that pro-competitive policies can lead to environmental benefits via more efficient energy use and hence fewer emissions. This message is likely to be relevant beyond trade policy.

References

Acemoglu, Daron et al. (2016). "Import Competition and the Great US Employment Sag of the 2000s". In: *Journal of Labor Economics* 34.S1, S141–S198. DOI: 10.1086/682384. eprint: https://doi.org/10.1086/682384.

Anderson, James E. and Eric van Wincoop (Mar. 2003). "Gravity with Gravitas: A Solution to the Border Puzzle". In: *American Economic Review* 93.1, pp. 170–192. DOI: 10.1257/000282803321455214.

Autor, David et al. (Sept. 2020). "Foreign Competition and Domestic Innovation: Evidence from US Patents". In: *American Economic Review: Insights* 2.3, pp. 357–74. DOI: 10.1257/aeri.20180481.

Autor, David H. et al. (Oct. 2013). "The China Syndrome: Local Labor Market Effects of Import Competition in the United States". In: *American Economic Review* 103.6, pp. 2121–68. DOI: 10.1257/aer.103.6.2121.

Autor, David H. et al. (Sept. 2014). " Trade Adjustment: Worker-Level Evidence *". In: *The Quarterly Journal of Economics* 129.4, pp. 1799–1860. DOI: 10.1093/qje/qju026. eprint: https://academic.oup.com/qje/article-pdf/129/4/1799/30631720/qju026.pdf.

Barrows, Geoffrey and Hélène Ollivier (2018). "Cleaner firms or cleaner products? How product mix shapes emission intensity from manufacturing". In: *Journal of Environmental Economics and Management* 88.C, pp. 134–158.

– (2021). "Foreign demand, developing country exports, and CO2 emissions: Firm-level evidence from India". In: *Journal of Development Economics* 149, p. 102587. DOI: https://doi.org/10.1016/j.jdeveco.2020.102587.

Bloom, Nicholas et al. (2010). "Modern Management: Good for the Environment or Just Hot Air?*". In: *The Economic Journal* 120.544, pp. 551–572. DOI: https://doi.org/10.1111/j.1468-0297.2010.02351.x. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1468-0297.2010.02351.x.

Bloom, Nicholas et al. (Sept. 2015). "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity". In: *The Review of Economic Studies* 83.1, pp. 87–117. DOI: 10.1093/restud/rdv039. eprint: https://academic.oup.com/restud/article-pdf/83/1/87/17417082/rdv039.pdf.

Brucal, Arlan et al. (2019). "Good for the environment, good for business: Foreign acquisitions and energy intensity". In: *Journal of International Economics* 121, p. 103247. DOI: https://doi.org/10.1016/j.jinteco.2019.07.002.

Chen, Cheng and Claudia Steinwender (2021). "Import competition, heterogeneous preferences of managers, and productivity". In: *Journal of International Economics* 133, p. 103533. DOI: https://doi.org/10.1016/j.jinteco.2021.103533.

Cherniwchan, Jevan (2017). "Trade liberalization and the environment: Evidence from NAFTA and U.S. manufacturing". In: *Journal of International Economics* 105, pp. 130–149. DOI: https://doi.org/10.1016/j.jinteco.2017.01.005.

Cherniwchan, Jevan et al. (2017). "Trade and the Environment: New Methods, Measurements, and Results". In: *Annual Review of Economics* 9.1, pp. 59–85. DOI: 10.1146/annurev-economics-063016-103756. eprint: https://doi.org/10.1146/annurev-economics-063016-103756.

Cole, Matthew A. and Robert J.R. Elliott (2003). "Determining the trade–environment composition effect: the role of capital, labor and environmental regulations". In: *Journal of Environmen-*

tal Economics and Management 46.3, pp. 363–383. DOI: https://doi.org/10.1016/S0095-0696(03)00021-4.

Copeland, Brian R. and M. Scott Taylor (Aug. 1994). "North-South Trade and the Environment*". In: *The Quarterly Journal of Economics* 109.3, pp. 755–787. DOI: 10.2307/2118421. eprint: https://academic.oup.com/qje/article-pdf/109/3/755/5203090/109-3-755.pdf.

– (Mar. 2004). "Trade, Growth, and the Environment". In: *Journal of Economic Literature* 42.1, pp. 7–71. DOI: 10.1257/002205104773558047.

Copeland, Brian R et al. (May 2021). *Globalization and the Environment*. Working Paper 28797. National Bureau of Economic Research. DOI: 10.3386/w28797.

Dauth, Wolfgang et al. (2014). "THE RISE OF THE EAST AND THE FAR EAST: GERMAN LABOR MARKETS AND TRADE INTEGRATION". In: *Journal of the European Economic Association* 12.6, pp. 1643–1675. DOI: https://doi.org/10.1111/jeea.12092. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jeea.12092.

De Haas, Ralph et al. (2021). *Managerial and financial barriers to the net-zero transition*. BOFIT Discussion Papers 6/2021. Bank of Finland, Institute for Economies in Transition.

DeCanio, Stephen J. (1993). "Barriers within firms to energy-efficient investments". In: *Energy Policy* 21.9, pp. 906–914. DOI: https://doi.org/10.1016/0301-4215(93)90178-I.

Forslid, Rikard et al. (2018). "Why are firms that export cleaner? International trade, abatement and environmental emissions". In: *Journal of Environmental Economics and Management* 91, pp. 166–183. DOI: https://doi.org/10.1016/j.jeem.2018.07.006.

Gerarden, Todd D. et al. (Dec. 2017). "Assessing the Energy-Efficiency Gap". In: *Journal of Economic Literature* 55.4, pp. 1486–1525. DOI: 10.1257/jel.20161360.

Gutiérrez, Emilio and Kensuke Teshima (2018). "Abatement expenditures, technology choice, and environmental performance: Evidence from firm responses to import competition in Mexico". In: *Journal of Development Economics* 133, pp. 264–274. DOI: https://doi.org/10.1016/j.jdeveco.2017.11.004.

Holmes, Thomas and James Schmitz (Feb. 2001). "A Gain From Trade From Unproductive to Productive Entrepreneurship". In: *Journal of Monetary Economics* 47, pp. 417–446. DOI: 10.1016/S0304-3932(01)00044-7.

Jaffe, Adam B. and Robert N. Stavins (1994). "The energy paradox and the diffusion of conservation technology". In: *Resource and Energy Economics* 16.2, pp. 91–122. DOI: https://doi.org/10.1016/0928-7655(94)90001-9.

Levine, Ross et al. (Mar. 2018). *Bank Liquidity, Credit Supply, and the Environment*. Working Paper 24375. National Bureau of Economic Research. DOI: 10.3386/w24375.

Martin, Ralf et al. (2012). "Anatomy of a paradox: Management practices, organizational structure and energy efficiency". In: *Journal of Environmental Economics and Management* 63.2, pp. 208–223. DOI: https://doi.org/10.1016/j.jeem.2011.08.003.

Olley, G. Steven and Ariel Pakes (1996). "The Dynamics of Productivity in the Telecommunications Equipment Industry". In: *Econometrica* 64.6, pp. 1263–1297.

Petrick, Sebastian et al. (2011). "Energy Use Patterns in German Industry: Evidence from Plant-level Data". In: *Jahrbücher für Nationalökonomie und Statistik* 231.3, pp. 379–414. DOI: doi:10.1515/jbnst-2011-0306.

Richter, Philipp M. and Alexander Schiersch (2017). "CO2 emission intensity and exporting: Evidence from firm-level data". In: *European Economic Review* 98, pp. 373–391. DOI: https://doi.org/10.1016/j.euroecorev.2017.07.011.

Schmidt, Klaus M. (1997). "Managerial Incentives and Product Market Competition". In: *The Review of Economic Studies* 64.2, pp. 191–213.

Shu, Pian and Claudia Steinwender (2019). "The Impact of Trade Liberalization on Firm Productivity and Innovation". In: *Innovation Policy and the Economy* 19, pp. 39–68. DOI: 10.1086/699932. eprint: https://doi.org/10.1086/699932.

Appendix A Gravity estimation

In the implementation of the gravity based approach, I follow Autor et al. (2013) closely. This section describes the approach.

Consider equation 6 which relates to a standard gravity specification as in e.g. Anderson and Wincoop (2003). Variables on the left hand side are country-sector specific export flows, i.e. X_{cz}^{East} are exports from the East to country c in sector z and accordingly X_{cz}^{Ger} are German exports to country c in sector z.

$$lnX_{cz}^{East} - lnX_{cz}^{Ger} = ln(z_z^{East}) - ln(z_z^{Ger}) - (\sigma_z - 1)[ln(\tau_{cz}^{East}) - ln(\tau_{cz}^{Ger})] \quad (6)$$

The first part on the right hand side of equation 6, $ln(z_z^{East}) - ln(z_z^{Ger})$ describes the East's export capacity in sector z relative to Germany's export capacity in sector z, i.e. the East's comparative advantage in industry z; for example driven by productivity differences. The second part on the r.h.s. of equation 6 - $[ln(\tau_{cz}^{East}) - ln(\tau_{cz}^{Ger})]$ - are export destination specific cost (note subscript c), for example costs determined by geography. Finally, σ_z is the elasticity of substitution for sector z.

To take the approach to the data, I estimate the following regression:

$$lnX_{czt}^{East} - lnX_{czt}^{Ger} = \alpha_z + \alpha_c + \epsilon_{zct} \quad (7)$$

Specifically, I project the difference between the East's exports and Germany's exports to country c in sector z (the East's relative exports) on sector and country/destination market fixed effects (α_z and α_c). I pool trade flows over the period 1995 to 2017 and export destination markets are primarily high income EU and OECD countries.

By equating the right hand sides of equations 6 and 7 and rearranging terms one gets the following expression for the residual:

$$\epsilon_{zct} = \underbrace{[ln(\frac{z_{zt}^{East}}{z_{zt}^{Ger}}) - \alpha_j]}_{Comparative\ advantage} + [-(\sigma - 1)\underbrace{ln(\frac{\tau_{cz}^{East}}{\tau_{cz}^{Ger}}) - \alpha_c}_{Trade\ cost\ advantage}] \quad (8)$$

The residual thus captures the East's comparative advantage in sector z and year t purged from structural differences due to the inclusion of the industry fixed effect α_z plus the trade cost advantage net of time invariant factors as the fixed effect α_c absorbs all such factors e.g. distance. Demand conditions in the importing country are differenced out by using the relative exports.

Hence, the four-year differences in the residual capture the change in the Easts' export capacity relative to Germany in sector z and country c. Averaging across export destination countries provides a measure of the relative rise of the East. From this, I construct the following alternative measure of a sector's import exposure from the East:

$$\Delta IPG_{zt}^{East} = \frac{\Delta\bar{\epsilon}_{zt} * Imp_{zt-4}^{East}}{Y_{z,1995} + Imp_{z,1995} - Exp_{z,1995}} \tag{9}$$

The hypothetical increase in imports in sector z is calculated from the mean change in the residual $\bar{\epsilon}_{zt}$ multiplied with the initial imports from the East in the respective industry. The predicted change depends on the change in the Easts comparative advantage and changes in trade costs. Note that domestic conditions in Germany are unrelated to the predicted changes in German imports from the East. Again I scale the change in imports with domestic absorption in the first period, i.e. in 1995.

Table A1: Import Competition and Prices

	ΔLog PPI		ΔLevels PPI	
	(1)	(2)	(3)	(4)
Import Share	-0.004***	-0.004***	-0.554***	-0.501***
	[0.001]	[0.001]	[0.192]	[0.144]
Observations	1530	1530	1530	1530
F-Stat	93.94	62.68	93.94	62.68
Year FE	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes

Notes: Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. All results are obtained from an IV estimation. The dependent variable is the four-year change of the (log) producer price index at the 3. digit sector level. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017. Standard errors were clustered at the 3. digit-industry level. The Kleibergen-Paap F-statistic is reported together with te num. of observations and fixed effects. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Table A2: Descriptive - trade data

Variable	Mean	Std. Dev	Min	Max	N
China level 1995 (in billion USD)	8	.	.	.	.
China level 2017 (in billion USD)	89	.	.	.	.
China share 1995	.02	.	.	.	.
China share 2017	.09	.	.	.	.
East level 1995 (in billion USD)	32	.	.	.	.
East level 2017 (in billion USD)	200	.	.	.	.
East share in 1995	.08	.	.	.	.
East share in 2017	.2	.	.	.	.
The East 1995 - sectoral shares	.10	.07	.01	.27	22
The East 2017 - sectoral shares	.33	.14	.11	.58	22

Notes: NOTES GO HERE, own calculations.

Table A3: Single plant firms - Log of emission intensity

	IV			OLS
	(1)	(2)	(3)	(7)
Panel A. Baseline Results				
Coefficient	-0.0052***	-0.0051***	-0.0040***	-0.0033***
Standard Error	0.0008	0.0008	0.0008	0.0005
P-Value	0.0000	0.0000	0.0000	0.0000
Kleibergen-Paap F-statistic	182.7	183.1	174.9	
Panel B. Control for Industry Trends				
Coefficient	-0.0030***	-0.0028***	-0.0026***	-0.0005
Standard Error	0.0009	0.0009	0.0009	0.0005
P-Value	0.0011	0.0019	0.0031	0.3545
Kleibergen-Paap F-statistic	127.9	128.1	128.8	
CO_2 intensity-decile-year-dummy	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	Yes	No	Yes
Export share-decile-year-dummy	No	No	Yes	Yes
Observations	328172	328172	328172	328172

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (3) show results from 2SLS estimations and column (4) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions per sales. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All multi-plant firms were dropped. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification I report the Kleibergen-Paap F-statistic. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Table A4: Baseline results - Log of total emissions

	IV						OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline Results							
Coefficient	-0.0019***	-0.0043***	-0.0045***	-0.0046***	-0.0049***	-0.0047***	-0.0030***
Standard Error	0.0006	0.0008	0.0008	0.0008	0.0009	0.0010	0.0010
P-Value	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021
First-stage coefficient	0.309	0.307	0.307	0.301	0.301	0.301	
Standard Error	0.0314	0.0318	0.0318	0.0320	0.0318	0.0320	
Kleibergen-Paap F-statistic	96.82	93.18	93.10	88.73	89.62	88.76	
Panel B. Control for Industry Trends							
Coefficient	-0.0004	-0.0011**	-0.0013**	-0.0014**	-0.0016***	-0.0014**	0.0010***
Standard Error	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	0.0004
P-Value	0.4407	0.0418	0.0238	0.0165	0.0062	0.0339	0.0097
First-stage coefficient	0.309	0.275	0.275	0.274	0.274	0.274	
Standard Error	0.0314	0.339	0.0339	0.0339	0.0338	0.0338	
Kleibergen-Paap F-statistic	65.43	65.89	65.85	65.15	65.95	65.43	
Year dummy	Yes	No	No	No	No	No	No
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	No	Yes	Yes	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	No	Yes	Yes	Yes	Yes
Region-year-dummy	No	No	No	No	Yes	No	No
Start-off-period values	No	No	No	No	No	Yes	No
Observations	345772	345772	345772	345772	345772	345772	345772

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (6) show results from 2SLS estimations and column (7) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification first-stage coefficients, corresponding standard errors and the Kleibergen-Paap F-statistic is reported. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Table A5: Main results - Log of sales

	IV						OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline Results							
Coefficient	0.0017	0.0022**	0.0018*	0.0011	0.0007	0.0007	0.0028**
Standard Error	0.0011	0.0011	0.0011	0.0011	0.0010	0.0010	0.0012
P-Value	0.1281	0.0482	0.0914	0.3046	0.4964	0.4744	0.0175
First-stage coefficient	0.309	0.307	0.307	0.301	0.301	0.301	
Standard Error	0.0314	0.0318	0.0318	0.0320	0.0318	0.0319	
Kleibergen-Paap F-statistic	96.82	93.18	93.10	88.73	89.62	89.18	
Panel B. Control for Industry Trends							
Coefficient	0.0026**	0.0030**	0.0028**	0.0026**	0.0026**	0.0022**	0.0023*
Standard Error	0.0012	0.0012	0.0012	0.0012	0.0012	0.0011	0.0012
P-Value	0.0280	0.0151	0.0206	0.0279	0.0279	0.0468	0.0663
First-stage coefficient	0.309	0.275	0.275	0.274	0.274	0.274	
Standard Error	0.0314	0.339	0.0339	0.0339	0.0338	0.0338	
Kleibergen-Paap F-statistic	65.43	65.89	65.85	65.15	65.95	65.84	
Year dummy	Yes	No	No	No	No	No	No
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	No	Yes	Yes	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	No	Yes	Yes	Yes	Yes
Region-year-dummy	No	No	No	No	Yes	No	No
Start-off-period values	No	No	No	No	No	Yes	No
Observations	345870	345870	345870	345870	345610	345870	345870

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (6) show results from 2SLS estimations and column (7) from a OLS estimation. The dependent variable is the four-year change in log of firms' sales. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification first-stage coefficients, corresponding standard errors and the Kleibergen-Paap F-statistic is reported. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Table A6: Results robustness - Log of emission intensity

	IV						OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline specifications							
Coefficient	-0.0013*	-0.0052***	-0.0050***	-0.0040***	-0.0040***	-0.0040***	-0.0011
Standard Error	0.0007	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009
P-Value	0.0577	0.0000	0.0000	0.0000	0.0000	0.0000	0.2021
First-stage coefficient	0.369	0.365	0.365	0.358	0.357	0.358	
Standard Error	0.0265	0.0265	0.0265	0.0266	0.0264	0.0266	
Kleibergen-Paap F-statistic	193.7	188.9	189.3	180.8	182.7	180.8	
Panel B. Control for industry trends							
Coefficient	-0.0011	-0.0030***	-0.0028***	-0.0026***	-0.0025***	-0.0026***	-0.0005
Standard Error	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0005
P-Value	0.2021	0.0011	0.0018	0.0028	0.0033	0.0032	0.3562
First-stage coefficient	0.369	0.338	0.338	0.337	0.337	0.337	
Standard Error	0.0265	0.0294	0.0294	0.0291	0.0289	0.0291	
Kleibergen-Paap F-statistic	129.1	132.7	132.8	133.6	135.4	133.6	
Year dummy	Yes	No	No	No	No	No	No
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	No	Yes	Yes	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	No	Yes	Yes	Yes	Yes
Region-year-dummy	No	No	No	No	Yes	No	No
Start-off-period values	No	No	No	No	No	Yes	No
Observations	341998	341998	341998	341998	341998	341998	341998

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (6) show results from 2SLS estimations and column (7) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions scaled with firms' sales (emission intensity). The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification first-stage coefficients, corresponding standard errors and the Kleibergen-Paap F-statistic is reported. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Table A7: Results robustness - Log of total emissions

	IV						OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline specifications							
Coefficient	-0.0032***	-0.0065***	-0.0068***	-0.0069***	-0.0074***	-0.0070***	-0.0011**
Standard Error	0.0008	0.0010	0.0010	0.0010	0.0011	0.0010	0.0005
P-Value	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0294
First-stage coefficient	0.369	0.365	0.365	0.358	0.357	0.358	
Standard Error	0.0265	0.0265	0.0265	0.0266	0.0264	0.0266	
Kleibergen-Paap F-statistic	193.7	188.9	189.3	180.8	182.7	180.8	
Panel B. Control for industry trends							
Coefficient	-0.0004	-0.0019**	-0.0022***	-0.0023***	-0.0025***	-0.0024***	0.0014***
Standard Error	0.0007	0.0008	0.0008	0.0008	0.0008	0.0008	0.0004
P-Value	0.5836	0.0210	0.0089	0.0056	0.0032	0.0043	0.0016
First-stage coefficient	0.369	0.338	0.338	0.337	0.337	0.337	
Standard Error	0.0265	0.0294	0.0294	0.0291	0.0289	0.0291	
Kleibergen-Paap F-statistic	129.1	132.7	132.8	133.6	135.4	133.6	
Year dummy	Yes	No	No	No	No	No	No
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	No	Yes	Yes	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	No	Yes	Yes	Yes	Yes
Region-year-dummy	No	No	No	No	Yes	No	No
Start-off-period values	No	No	No	No	No	Yes	No
Observations	341998	341998	341998	341998	341998	341998	341998

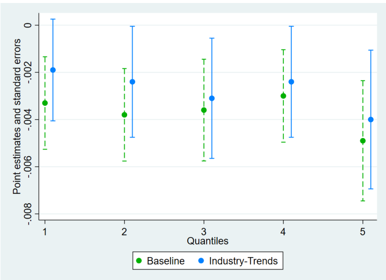
Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (6) show results from 2SLS estimations and column (7) from a OLS estimation. The dependent variable is the four-year change in log of firms' CO_2 emissions. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector "manufacturing of radio, television and communication equipment and apparatus" (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification first-stage coefficients, corresponding standard errors and the Kleibergen-Paap F-statistic is reported. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

Table A8: Results robustness - Log of sales

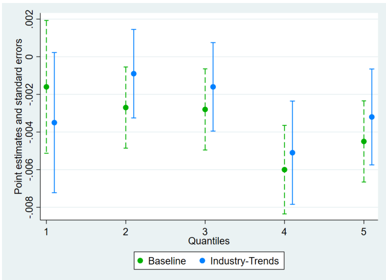
	IV						OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline specifications							
Coefficient	-0.0019**	-0.0014	-0.0017	-0.0029***	-0.0034***	-0.0029***	0.0021***
Standard Error	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0006
P-Value	0.0991	0.2040	0.1105	0.0079	0.0022	0.0073	0.0008
First-stage coefficient	0.369	0.365	0.365	0.358	0.357	0.358	
Standard Error	0.0265	0.0265	0.0265	0.0266	0.0264	0.0266	
Kleibergen-Paap F-statistic	193.7	188.9	189.3	180.8	182.7	180.9	
Panel B. Control for industry trends							
Coefficient	0.0007	0.0011	0.0006	0.0003	0.0001	0.0002	0.0019***
Standard Error	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0007
P-Value	0.5230	0.3455	0.5648	0.0056	0.0032	0.0043	0.0063
First-stage coefficient	0.369	0.338	0.338	0.337	0.337	0.336	
Standard Error	0.0265	0.0294	0.0294	0.0291	0.0289	0.0291	
Kleibergen-Paap F-statistic	129.1	132.7	132.8	133.6	135.4	133.5	
Year dummy	Yes	No	No	No	No	No	No
CO_2 intensity-decile-year-dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Sales-decile-year-dummy	No	No	Yes	Yes	Yes	Yes	Yes
Export share-decile-year-dummy	No	No	No	Yes	Yes	Yes	Yes
Region-year-dummy	No	No	No	No	Yes	No	No
Start-off-period values	No	No	No	No	No	Yes	No
Observations	342096	342096	342096	342096	342096	342096	342096

Notes: *** denotes 1% significance; ** denotes 5% significance; and * denotes 10% significance. Column (1) to (6) show results from 2SLS estimations and column (7) from a OLS estimation. The dependent variable is the four-year change in log of sales. The explanatory variable is the four-year change in imports from China and eastern Europe scaled with domestic absorption in 1995 in each three-digit industry. The instrument is the four-year change of exports from China and eastern Europe to other countries in each three-digit industry. Sample period is 1995 until 2017 but the years 2003 - 2007 were excluded due to a break in the reporting of energy variables in 2003. All firms from sector ”manufacturing of radio, television and communication equipment and apparatus” (WZ-32 from German classification of economic activity) were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. Panel A shows baseline results and panel B includes trends within 12 broadly defined industries. For each specification first-stage coefficients, corresponding standard errors and the Kleibergen-Paap F-statistic is reported. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.

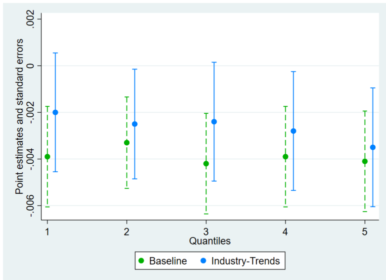
Figure A1: Effect heterogeneity - splits by within sector quantiles



(a) Emission intensity



(b) Export shares



(c) Size (num.employees)

Notes: The dependent variable is emission intensity in log. All specifications include year by decile fixed effects for emission intensity, sales and export shares. Point estimates in blue further include industry trends. The lines demarcate 95% confidence intervals. Firms are assigned to a quantile based on the first observation available for each firm. All firms from sector ”manufacturing of radio, television and communication equipment and apparatus” were omitted. Standard errors were clustered both, at the firm and at the three-digit-industry-year level. The number of observations by quantile of emission intensity are 71288, 73260, 71367, 66412 and 59669; by quantile of export share 16783, 79966, 64591, 95648, 85108 and by number of employees 65977, 76279, 72335, 68548 and 58953. Source: Research Data Centres of the Federal Statistical Office and the Statistical Offices of the Länder: AFiD-Panel Industriebetriebe, 1995-2017, own calculations.