EU air pollution regulation: A breath of air for East-European polluting industries?

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Abstract

In this paper we test whether tighter EU environmental regulation fosters pollution havens in ECA countries. By making an assumption on which sectors are more affected by environmental regulation, we provide robust evidence that ECA polluting industries benefit from EU environmental stringency. Moreover, we propose an original and relevant variable that evaluates environmental regulation stringency and limits simultaneity issues, based on the EU Air Quality Framework Directive. Finally, we use a wide range of fixed effects and instrumental variable approach to control for potential bias due to omitted variables and reverse causality.

JEL: F18, F14, Q53, Q56

1 Introduction

Global climate warming and pollution related human health depletion put air pollution at the heart of policy decision-making. This issue is increasingly important for emerging and developing countries of Europe and Central Asia (ECA). Today's environmental challenges,

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originated from historic legacy of centrally planned economy, are accentuated by a current low energy efficiency and weak environmental legislation. Many of the region's countries are indeed among the most carbon-intensive exporters in the world (Davis and Caldeira, 2010).[1]

The European Union (EU) is the main trading partner of these countries. Over the last decade increasing efforts have been undertaken to protect the environment in EU Member States. As a result, air quality has considerably improved in the EU, whereas it has at best stagnated or even strongly deteriorated in ECA countries, Despite a small 8 percent share of European GDP (including Central Asia), carbon dioxide emissions (CO2) of ECA countries account today for some 40 percent of total emissions in this region.[2] The contribution of ECA countries in European emissions has also greatly increased since the mid-1990s. For sulphur dioxide (SO2), another major pollutant, this share reaches more than 50% in 2008 (see Figure 1). This begs an important question: Does environmental regulation in the EU affect the activity of polluting industries in Eastern Europe? In other words, does EU environmental regulatory stringency foster pollution havens in ECA countries? Indeed, a stricter regulation may raise the relative cost of pollution-intensive activity inside the EU, thus affecting relative competitiveness of polluting sectors outside the EU.

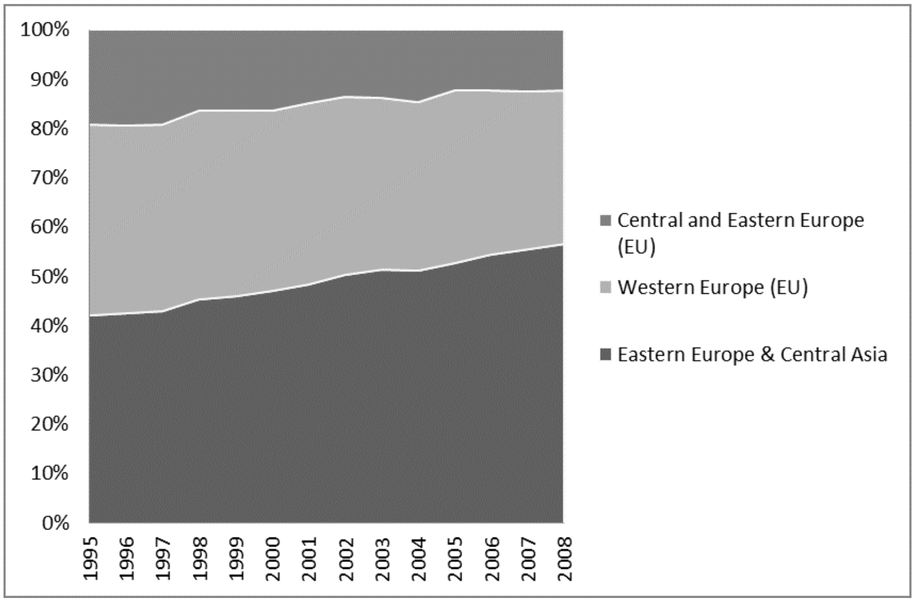
The related literature on the pollution haven hypothesis (PHH) or pollution haven effect (PHE) posits that countries (or regions) with weak environmental regulations attract polluting industries from countries (regions) with more stringent regulations. However, despite the general opinion, econometric studies that test for a PHH have typically found no effect or a small effect of environmental regulations on firm location or on trade flows.

It is now generally admitted that these empirical studies face several conceptual and methodological problems (e.g. Ederington et al., 2005, Levinson and Taylor, 2008, Brunel and Levinson, 2013). First, it is very difficult to find an appropriate measure of regulatory stringency. Authors generally use either private sector abatement costs, or some indices based on surveys, or a measure of pollution, or public environmental expenditures. How-

[1]Ukraine, Russia and Kazakhstan are respectively first, third and fourth worldwide leading carbon-intensive exporters.

[2]Data for 2010 come from World Development Indicators (WDI) (World Bank, 2014).

Figure 1: Sulphur dioxide (SO2) emissions in Europe and Central Asia (%)



Source: Emissions Database for Global Atmospheric Research (EDGAR).

ever, none of these measures are totally satisfactory, notably because they capture only partially the multidimensional aspect of environmental regulation (Brunel and Levinson, 2013). Second, economic activity and environmental regulation may be determined simultaneously. The location of firms or international trade may influence regulators and lead them to establish more or less stringent rules. Third, omitted factors could influence both regulatory stringency and economic activity. Simultaneity and omitted variables lead to an endogeneity bias in the relation between environmental regulation and international trade or foreign direct investments.

More recent studies trying to tackle these methodological problems using panels of data and controlling for unobserved industry and country characteristics have demonstrated small but statistically significant pollution haven effects (e.g. Becker and Henderson, 2000; Greenstone, 2002; Broner et al., 2012).

In this paper, we focus on the impact of EU regulation on EU-ECA trade. Most papers in the PHH literature focus on the United States (see Jug and Mirza, 2005 for an exception on Europe). Our approach also tempers several methodological issues. First, we propose an original variable that evaluates environmental regulation stringency. This variable is based on the Air Quality Framework implemented by the EU. In this framework, the 1996 directive and successive 'daughter' directives set numerical limits and thresholds for different types of pollutants and force countries to implement environmental measures in case of exceedance. We construct an original variable that identifies for every country, year and pollutant, exceedance of air quality limit values and use this variable as a proxy for stringent environmental regulation. This variable partially solves the simultaneity problem because limit values are the same for all Member States and are based on the World Health Organization (WHO) guidelines to protect human health. Therefore, they are not responding to the level of trade.[3] A similar quasi natural experiment approach has been used in the case of the United States.[4] For instance, Becker and Henderson (2000) use the county non-attainment status as a proxy for stricter regulation and find that regulation reduces the creation of new firms in polluting industries, inducing a reallocation of stock of plants within the US from non-attainment areas toward attainment areas (see also Greenstone, 2002). Using a similar approach, Hanna (2010) shows that US multinationals also relocate outside the US because of more stringent regulation. Moreover, considering the Air Quality Framework also allows to account for the multidimensions of environmental regulation because countries might implement any policies and measures in case of exceedance of air quality limit values.

Second, we test for a pollution haven effect by examining the underlying mechanism: whether pollution intensive goods are imported disproportionately more in countries with more stringent environmental regulation. Focusing on this conditional effect of environmental policy allows to include a wide range of fixed effects to control for omitted variables. Third, we implement an instrumental variable approach to account for reverse causality. Our instrumentation strategy based on Broner et al. (2012) consists in using exogenous variation in exceedances of limit values (our proxy for environmental regulation) related to the climate and meteorological characteristics. More explicitly, we compute for every EU

[3] Furthermore, because ECA countries represent only a small share of EU total trade, we can think that the EU authorities will not enact a regulation depending on the level of trade with ECA countries.

[4] The US Clean Air Act establishes air quality standards that apply to every county in the US. Each year, every county is classified as being in or out of attainment (i.e. meet or not these standards) and non-attainment counties are required to submit a plan imposing more stringent regulation.

country an annual ventilation coefficient measuring the speed at which pollutants disperse in the air, and we use this variable as an instrument for exceedances of limit values.

Using bilateral trade data for 27 EU importing countries and 11 Eastern European exporting countries over the period 1999-2012, we find that environmental regulation in EU countries increases their imports from ECA countries relatively more in sectors with high pollution intensity. This result is robust to the omitted variable bias and reverse causality issues. Overall, we provide evidence that EU air quality regulation fosters pollution havens in ECA countries.

The paper is structured as follows. In Section 2, we present the EU air quality framework. In Section 3, we describe our empirical strategy and data. In Section 4, we present our empirical results and in Section 5, we discuss endogeneity issues. In Section 6 we add some conclusions.

2 EU Air Quality Framework

Air quality is a major issue in Europe since the early 1970s. In 1996 the EU adopted a series of ambitious actions to further decrease pollutant emissions throughout the continent. The most important was the setting of air quality binding targets for Member States and the implementation of harmonised structure for monitoring, reporting and managing air quality across the EU through the 1996 Air Quality Framework Directive (AQFD) and its daughter directives. These daughter directives set limit values and alert thresholds for the most prevalent air pollutants in order to better protect human health. For example, in the first daughter directive (1999/30/EC), limits values were established for sulphur dioxide (SO2), nitrogen oxides (NOx), lead and particulates (PM) (further pollutants, such as carbon monoxide, benzene or ozone have been appended in subsequent daughter directives) (see Table 2.6 in Appendix).

For the purpose of air quality assessment and monitoring, Member States have to define geographical areas within their territory. These zones include all agglomerations with a population of 250,000 inhabitants or more. Member States have full competence to define geographical limits of other zones on the basis of air quality management considerations, but they generally use administrative boundaries (EEA, 2005).

The AQFD requires Member States to draw up detailed plans and programs for zones where at least one pollutant exceeds its limit value plus the margin of tolerance, in order to fall below the limit value.[5] The AQFD planning requirements – in addition to information related to the nature and origins of not-attainment and its location – include the description of measures and programs implemented to improve air quality in these zones.

Two types of programs can be identified. Article 8(3) of the AQFD requires Member States to develop plans and programs in potential non-attainment zones, setting specific measures for attaining limit values within a time limit.[6] These measures may be identified as medium or long term measures, because they often require private long-standing investments, law regulations, urban transport facilities programs or long-term public investments. According to article 7, short run measures must be implemented as well in case of exceedance of alert thresholds or limit values, or when exceedance is anticipated for any given pollutant. Such measures include suspensions or restrictions of polluting activities contributing to the limit value non-attainment or any other responsive actions able to be implemented quickly by the local competent authorities. For instance, the French annual reporting on air quality limit values plans in 2005[7] provides some short term actions such as traffic restrictions, requirements concerning industrial dedusting facilities, prescription to use high pollutant fuels in industry, restrictions or interruption of high emitting production processes, etc.[8]

[5]The first daughter directive entered into force in 1999 but, for each pollutant, there is a specific date by which limit values have to be met (for example 2005 for SO2). In the run up to the attainment date, if concentration of that pollutant is above the limit value plus a defined margin of tolerance, Member States have to draw up plans "to demonstrate which measures they are going to take to achieve the limit values by the attainment date" (EC, 2005). The margin of tolerance decreases over time and is equal to zero by the attainment date.

[6]"In the zones and agglomerations referred to in paragraph 1 [i.e. in which the levels of one or more pollutants are higher than the limit value plus the margin of tolerance], Member States shall take measures to ensure that a plan or programme is prepared or implemented for attaining the limit value within the specific time limit. The said plan or programme [...] must be made available to the public" (Article 8.3 of the Directive 96/62).

[7]The French report for 2005 is accessible on http://cdr.eionet.europa.eu/fr/eu/aqpp/envr2ss9q/. When available, reports for other EU countries may be found through the Central Data Repository website, at http://cdr.eionet.europa.eu/.

[8]More recently, in March 2014, France, and to a lower extent, Belgium and Germany experienced an

According to article 9, there are no particular requirements for Member States in zones where the levels of pollutant concentration are lower than the limit values or within the margin of tolerance.

An important characteristic of the AQFD is that limit values are legally binding, meaning that judicial actions may be undertaken if a Member State fails to comply with limit values. Moreover, the European Commission oversees the implementation of EU legislation, and can launch legal proceedings including enforcement measures against Member States that do not comply with the AQFD requirements.[9] From 2006 to 2012, the European Commission has brought 420 environmental infringements concerning air quality issues to the European Court of Justice.[10] Measures to encourage or enforce compliance also rely on peer pressure and pressure from citizens and environmental organisations because the directives require Member States to inform the public about the assessment and management of air quality.

The AQFD is considered as relatively effective in comparison with other environmental measures. According to a questionnaire sent to 90 stakeholders, air quality limit values have had a significant impact on improving air quality and reduce emissions and are viewed as one of the most cost-effective measures compared to other directives that focus more specifically on large combustion plans or large industrial plants (European Commission Report, 2004).

Measures that have to be implemented in order to meet limit values are different depending on the pollutant. In particular, they may be more or less expensive for the private sector or more or less constraining for the industrial activity. According to a report addressed to the European Commission (EEA, 2006), the highest share of expenses implied by the EU environmental law in 2000 came from SO2 controls. Indeed, the main sources of sulphur oxides (SOx) emissions[11] are the energy sector and the industrial sector (accounting

extended episode of high air pollution due to a calm weather. The French Ministry of Ecology announced immediately a series of measures to reduce short term pollution levels, such as free public transport in Paris, the reduction of tariff speed limits in some areas, controls of fertilizer spreading, etc.

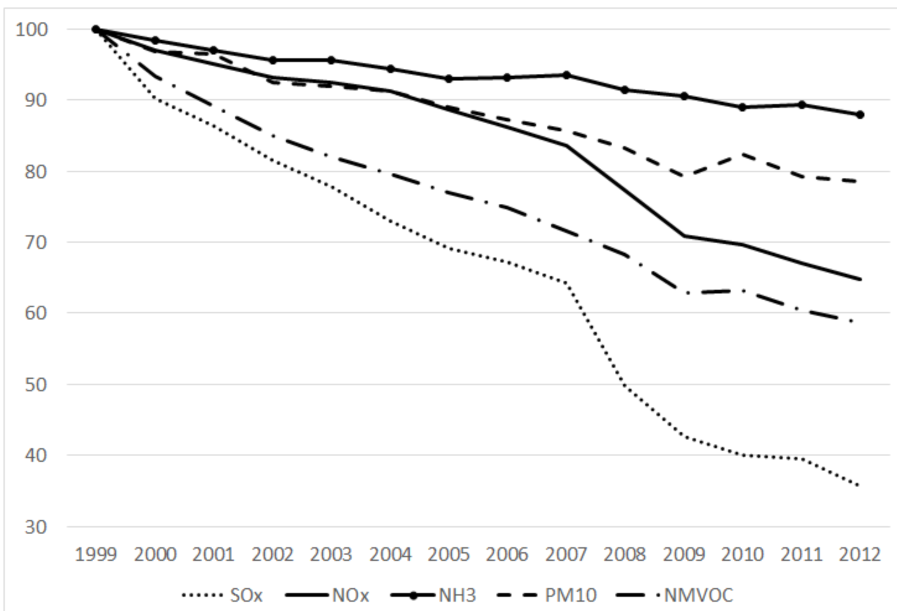
[9] This power of enforcement is not specific to air quality regulation but applies to all areas of EU law.

[10] Over these 420 infringements, less than 15% fail to comply with the judgment of the Court. Therefore, in 85% of all cases, Member States have fulfilled their obligations to comply with the EU air quality law.

[11] SOx is a family of gases that includes SO2 and SO3. Note that the major part of emissions of sulphur

respectively for 60% and 24% of EU-28 emissions in 2012) (EEA, 2014). Therefore, when emissions exceed the SO2 limit values, stringency measures included in the national plans or programs target mostly the industrial sector.[12] Besides, emissions of this pollutant have experienced the largest decrease over the past fifteen years in the EU (see Figure 2). Total SOx emissions in 2012 were 64% less than in 1999. This may suggest that appropriate measures have been implemented in EU countries to reduce emissions of this pollutant. For all these reasons, we will focus primarily on the non-attainment of SO2 limit values as a measure of changes in environmental stringency affecting the industrial sector.

Figure 2: Variation in EU 28 emissions of SOx, NOx, NH3, PM10, and NMVOC (index, % 1999)



Source: EEA (Air Pollutant Emissions Data Viewer - LRTAP Convention).

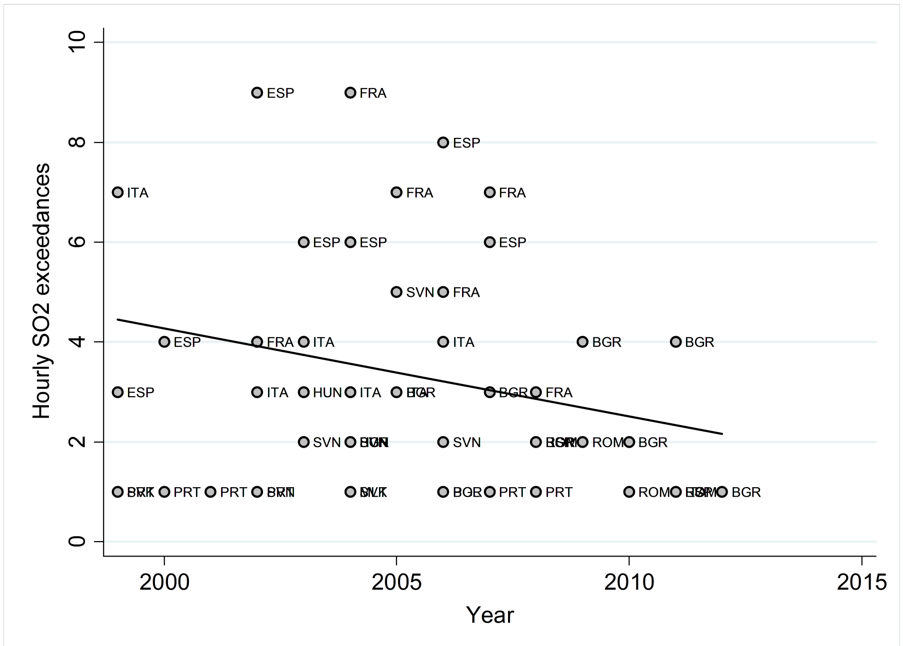
More precisely, we construct an original variable (RegAQ) that measures, with a dummy variable, exceedances of SO2 hourly limit values, whenever the number of exceedances is larger than twenty four (which is the number allowed each year) and zero otherwise. In our

oxides to the atmosphere is in the form of SO2.

[12]For other pollutants, stringency measures target uniformly all activities, or more specifically the agricultural sector, households or road traffic. For example, non-attainment of the limit value of nitrogen dioxide (NO2) might entail measures mainly targeting the primary NO2 emitter, i.e. road transport responsible for about 50 percent of total emissions (EEA, 2006).

empirical estimations, we also use another variable that counts for every country and year the number of exceedances whenever this number is larger than twenty four (see Tables 2.6 and 2.7 in Appendix).

Figure 3: Number of exceedances (strictly positive) of SO2 hourly limit value by country



Sources: AirBase database (EEA) and authors' calculations.

On our period of investigation (1999-2012), 12 countries have at least one exceedance of SO2 hourly limit value (including both old and new EU member countries) and the average number of exceedances is 1,38.[13] The number of exceedances decreases over time (see Figure 3).

In the next section we present the empirical strategy used to investigate the effect of the Air Quality Framework on EU imports from ECA countries.

[13]Note that we exclude four country-year observations where the number of exceedances is larger than ten. These observations are clear outliers and concern Spain (2001 and 2005) and France (2001 and 2003).

3 Empirical model and data

3.1 Empirical strategy

We use a gravity model to investigate the role of environmental regulation on bilateral trade. The gravity model relates bilateral trade M_{ijst}, (e.g. imports) between country i and country j in sector s at time t, to their economic sizes (Y_{it} and Y_{jt}), bilateral trade costs (τ_{ijt}) and multilateral trade resistances (P_{it} and P_{jt}) (Anderson and van Wincoop, 2003). The gravity equation can be written as:

$$M_{ijst} = \frac{Y_{it}Y_{jt}}{Y_{wt}}(\frac{\tau_{ijt}}{P_{it}P_{jt}})^{1-\sigma} \quad (1)$$

where Y_{wt} is the nominal world income and $\sigma > 1$ the elasticity of substitution between all goods. Trade costs (τ_{ijt}) are generally modelled as a function of some observable factors, including bilateral distance between trade partners, the existence of a common border, a common language, and regional trade agreements (RTA).

Multilateral resistance indices account for the fact that "the more resistant to trade with all others a region is, the more it is pushed to trade with a given bilateral partner" (Anderson and van Wincoop, 2003). A standard way to control for time-varying unobservable multilateral resistance terms is to use country-year (or country-sector-year) fixed effects (e.g. Baldwin and Taglioni, 2006). In our specification, country-sector-year fixed effects capture multilateral resistance indices as well as all other determinants of trade specific to a country, sector and year (such as economic size and all aspects of comparative advantages not related to environmental regulation).

In this general model of trade, we introduce environmental regulation in the importing country i. More precisely, we add in the estimated equation an interaction term between an industry characteristic (sector pollution intensity) and a country characteristic (environmental regulation) ($RegAQ_{it} \times Ener_{js}$). We expect that environmental regulation in the importing country will favour imports relatively more in sectors with high pollution intensity. This kind of interaction between an industry and a country characteristic has been first used by Rajan and Zingales (1998) who show that industrial sectors that are more dependent on external finance grow faster in countries with a high level of financial development (see also Beck, 2003; or Nunn, 2007 for another application of a similar approach). This approach provides a strong test of causality (Rajan and Zingales, 1998) and allows to introduce a wide range of fixed effect controls. Our estimated equation is as follows:

$$\begin{aligned} \ln M_{ijst} &= \beta_0 + \beta_1 \ln Dist_{ij} + \beta_2 Contig_{ij} + \beta_3 RegAQ_{it} \times Ener_{js} \\ &+ \alpha_{ist} + \alpha_{jst} + \epsilon_{ijst} \end{aligned} \quad (2)$$

where M_{ijst} are imports of country i from country j in sector s at time t, $Dist_{ij}$ is bilateral distance between countries i and j, $Contig_{ij}$ is a dummy variable indicating that i and j share a border, $RegAQ_{it}$ is our environmental regulation proxy (see above) and $Ener_{js}$ is a proxy for sector pollution intensity (see subsection 3.3). α_{ist} and α_{jst} are country-sector-year fixed effects and ϵ_{ijst} is the usual error term. Our coefficient of interest is β_3 and we expect $\beta_3 > 0$ if a stricter regulation in European countries disproportionately increase their imports from ECA countries in sectors with high pollution intensity. This implies for instance that European countries with strong environmental regulations would import relatively more in pollution intensive sectors (chemicals as compared to wood products for example).

We consider bilateral imports of 27 EU countries from 11 countries of Europe and Central Asia over the period 1999-2012.[14] All variables and data sources are described in Appendix (Table 2.7).

3.2 Estimation issues

The measurement of environmental regulatory stringency is a fundamental issue in the empirical literature dealing with pollution havens. As highlighted by Levinson and Taylor

[14]These countries are Albania, Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, FYR Macedonia, Moldova, Russian Federation, Tajikistan and Ukraine.

(2008) and Brunel and Levinson (2013), empirical studies assessing the impact of environmental regulation face several conceptual obstacles. Our proxy variable for environmental regulation based on exceedances of air quality limit values allows to tackle two major problems, i.e. simultaneity and multidimensionality.

The choice of our environmental regulation proxy attempts to address the simultaneity problem. Ambient air quality limits that we consider are equally and uniformly imposed to all the Member States, and based on considerations related to the protection of human health. Thus, all Member States face the same limits of air quality pollutants, which are exogenous to their own economic activity or preferences (lobbying from citizens or industrial sectors). As detailed in Section 2, exceedance of these thresholds imposes Member States to implement short-term and mid-term measures to meet the limit values. The main advantage of the AQFD is that it can be viewed as a natural experiment. Indeed, this directive requires countries to set up further measures or regulations to meet the limit values in zones where pollutant levels are not attained (the 'treatment' group). Whereas countries are exempt of enforcing new environmental stringency measures when zones are below the limit values (the 'control' group). Accordingly, the changes in countries' regulatory stringency imposed by the AQFD can arguably be interpreted as exogenous.

The second obstacle in identifying the impact of environmental regulation is related to multidimensionality because it is difficult to capture this regulation with one single variable (Brunel and Levinson, 2013). In this paper, we do not focus on one particular measure, such as lead content of gasoline or eco-taxation. Indeed, Member States have high flexibility to implement adequate measures to reduce emissions below the limits imposed by the directives. They generally use multiple measures: setting up control devices to restrict polluting activities (for example traffic restrictions or temporary shutdowns of polluting production processes) or impose obligations to use less polluting inputs or technologies (see Section 2).

3.3 Proxy for sector pollution intensity

For the purpose of our empirical strategy, we need information about structural air pollution intensity varying over countries and sectors ($Ener_{js}$ in equation 2). The empirical literature dealing with the pollution haven effect generally uses proxies that vary only across sectors and that identify dirty industries. Typically based on U.S. sector data, industries are ranked according to their toxicity (emission intensity for one or all pollutants) and then classified as "dirty" or "clean" using a dummy variable (Copeland and Taylor, 2004). But our empirical strategy needs a pollution intensity indicator with sufficiently high variability to ensure that the interaction term $RegAQ_{it} \times Ener_{js}$ will not be captured by the set of fixed effects included in equation (2.2). Moreover, allowing the pollution intensity proxy to vary across sectors and *countries* should better capture the differences in comparative advantages in polluting industries.

We use *exporter* (ECA) country pollution intensity because it is exogenous to importer's environmental policy and it should be related to the dependent variable only through the pollution haven effect mechanism. In contrast, *importer* (EU) country pollution intensity may be endogenous to trade, via intra-industry imports of pollution-intensive inputs (upward bias). Instead, if pollution-intensive imports substitute to local production, share of polluting sub-sectors in importer country should decrease, thus decreasing sector pollution intensity (downward bias). This composition effect has been pointed out by Copeland and Taylor (2004) and Levinson and Taylor (2008). To avoid this endogeneity and composition biases we use pollution intensity proxy reported by *exporter* (ECA) country.

Data on industry pollution intensity is typically not available for most of the ECA countries. One way to address the problem is to find a proxy for air pollution at the industry level. Energy consumption data provided by the International Energy Agency seems a good candidate. There is a strong statistical relationship between firm or industry level energy use and air pollution in developed countries (see Eskeland and Harrison, 2003, Cole et al., 2005). We expect an even stronger correlation in our sample, as emission control equipment are likely to be less constraining and air pollutant content of fuels higher than in developed countries.

Energy combustion processes are the main anthropogenic emitters of SO2: combustion in manufacturing and energy industries, as well as production processes account for about four fifth of SO2 emissions (EEA, 2014). Therefore, energy-intensive industrial sectors are likely to be the most affected by measures involved by non-attainment of SO2 limit values. Focusing on the interaction of SO2 non-attainments with sector energy intensity should provide an accurate identification strategy to test our empirical question.

We match data on energy use (in kilotons of oil equivalent) from the International Energy Agency (IEA) with sector value added (in constant 2000 USD) from the United Nations Industrial Development Organization (UNIDO). We are thus able to define energy intensities at 2-digit industrial level for 11 ECA countries.[15] As we only need the technological content of energy use by industry and country, we compute country-industry energy intensities for the year 2007 which provides the highest data accuracy.[16] Moreover, keeping constant the energy intensity prevents our variable to be affected by sub-sector activity shifts and efficiency improvements.[17]

Because of missing or inaccurate data, we have 85 sector-country energy intensities out of a total of 110 possible cases (10 manufacturing sectors in 11 exporting countries). Table 1 displays summary statistics and the ranking of energy-intensive industries across exporting countries. An important feature is that leading energy-intensive sectors (iron and steel, non-metallic minerals, non-ferrous metals, chemicals and paper, pulp and print) are the same as those defined as dirty industries in the pollution haven literature (see for example Mani and Wheeler, 1998). The ranking of high energy-intensive sectors is particularly close to the main conventional air pollutant emitters (Greenstone, 2002, Cole et al., 2005). Moreover, as shown in Cole et al. (2005), the correlation between energy use and air pollution is the highest for SO2 emissions.

[15]IEA energy consumption data and UNIDO value added data are not displayed in the same classification, respectively 2-digit ISIC rev.4 and 3-digit ISIC rev.3. We match both data using correspondence table from the UNIDO website. When matching was imperfect or unclear, we consider data as missing for the corresponding sectors. Manufacture of rubber and plastics products is missing in our data for this reason.

[16]We use the year 2008 to compute energy intensity for Belarus because of data unavailability for 2007.

[17]Changing the reference year, or allowing energy intensities to vary over time, would not fundamentally alter our results, but would affect the size of our sample.

Table 1: Energy intensity in ECA countries by sector, 2007:

2-digit industrial sectors	Rank	Mean	Std. Dev.
Iron and steel	1	0.20	0.22
Non-metallic minerals	2	0.13	0.05
Non-ferrous metals	3	0.11	0.14
Chemicals	4	0.08	0.08
Paper, pulp and print	5	0.04	0.05
Wood and wood products	6	0.04	0.02
Food and Tobacco	7	0.02	0.01
Textile and leather	8	0.02	0.01
Transport equipment	9	0.02	0.02
Machinery	10	0.01	0.01

Notes: Energy intensity is defined as energy consumption in kilotonnes of oil equivalent per output in PPP 2011 dollars. Sources: IEA, UNIDO, authors' calculations.

4 Empirical results

4.1 Overall results

We start by reporting OLS estimates of the conditional impact of environmental stringency on EU imports from ECA countries. Table 2 provides results of the estimation of our basic specification (equation 2). Conventional gravity variables (distance and contiguity) are significant and display the expected signs.[18] A larger distance deters bilateral trade, while countries sharing a border trade more, all other things being equal. The specification controls for country-sector-year fixed effects that take into account potential omitted factors and sources of comparative advantage that are not related to environmental regulation. To capture environmental regulation, we first introduce a dummy variable indicating whether SO2 emissions exceed the limit value in a given country and a given year (see Section 2 and Table 6 in Appendix). The coefficient of our variable of interest, the interaction between

[18] We do not include a dummy variable for common language as in traditional gravity equations because of its low variation related to our specific dataset. For the same reason we omit the dummy for former colonial ties.

this dummy variable and energy intensity at the sector level, is positive and significantly different from zero at 5 percent level (Column 1). This result strongly supports our testing assumption. The positive and significant sign of the interaction term indicates that more regulated EU countries import from ECA countries relatively more in sectors with high pollution intensity. To get a sense of the magnitude of the coefficient, compare two around median sectors in terms of energy intensity (chemicals and wood). Our estimation results imply that in regulated countries (countries reporting exceedances) the average increase of imports of chemicals is 25% higher than in the wood sector as compared to less regulated countries [=0.247*100*(1-0)].[19]

Table 2: OLS estimations

	(1)	(2)
$RegAQ\ SO2h_{it}$ (dummy)$\times \ln Ener_{js}$	0.247**	
	(0.114)	
$RegAQ\ SO2h_{it}$ (number)$\times \ln Ener_{js}$		0.0518**
		(0.0230)
Distance$_{ij}$ (ln)	-2.267***	-2.265***
	(0.282)	(0.283)
Contiguity$_{ij}$	0.738***	0.737***
	(0.273)	(0.274)
Constant	25.97***	25.96***
	(2.162)	(2.167)
Importer-sector-year fixed effects$_{ist}$	Yes	Yes
Exporter-sector-year fixed effects$_{jst}$	Yes	Yes
Observations	20,223	19,900
Adjusted R^2	0.732	0.732

Notes: The dependent variable is the logarithm of bilateral imports. The variable *RegAQ SO2h* (dummy) is a dummy variable equal to one if SO2 hourly emissions exceed the AQFD limit value. The variable *RegAQ SO2h* (number) indicates the number of exceedances of SO2 hourly limit value. $\ln Ener$ is sector energy intensity expressed as the logarithm of energy consumption over value added. Robust standard errors clustered by bilateral country-pair in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In Column 2, we measure environmental regulation by the number of exceedances of SO2 hourly limit value in every country and year.[20] Here again, we find a positive and significant

[19] According to Table 1, energy intensity in the chemicals sector (0.08) is 100% higher than in the wood and wood products sector (0.04).

[20] In this estimation, we exclude four country-year observations for which the number of exceedances is

coefficient for the interaction variable.

4.2 Sensitivity analysis

We further perform a sensitivity analysis. First, we test the robustness of our energy intensity variable by excluding electricity consumption from total energy consumption. This leaves fossil energy which is more likely to contribute to SO2 emissions. As previously, we interact this fossil energy intensity variable with the dummy equal to one in case of exceedance of limit values (Table 3, Column 1) or the number of exceedances (Column 2).[21] The positive and significant coefficients for the interaction variables show that more regulated EU countries import relatively more in sectors that are more intensive in fossil energy. This estimation also indicates that our results are not driven by the electricity consumption. Thereafter, we will present only our estimation results with the interaction on the dummy variable. Results obtained with the number of exceedances (instead of the dummy) provide the same general conclusions and are available upon request.

Second, we add as an additional control variable the level of SOx emissions interacted with energy intensity (Table 3, Column 3). This allows to test whether our variable measuring exceedances of limit values is a good proxy for environmental regulation and does not only capture the level of emissions.[22] We find that the level of emissions does not affect imports *per se* and that our interaction variable for environmental regulation is still large and significant at the 10% level.[23]

Third, we drop one specific sector, iron and steel, from the dataset. This sector is the most energy-intensive industry (see Table 1) and it uses a lot of pollution intensive inputs. In particular, EU steel industry imports a large share of its iron and low quality steel inputs

larger than ten. We obtain very similar results when we include these outliers and a dummy variable that captures their specific behavior. Results are available upon request.

[21] Note that the sample is smaller as compared to the benchmark results (Columns 1 and 2 of Table 2) because of more missing observations in the fossil energy intensity variable.

[22] The level of emissions is captured by country-sector-year fixed effects. That is why, in Column 3, we only add the interaction between the level of emission and our energy intensity variable. See Table 7 in Appendix for the definition and source of this variable.

[23] The less significant impact of our interaction variable is probably due to multicollinearity (a high correlation between the level of emissions and exceedances of limit values).

Table 3: Sensitivity analysis

	(1)	(2)	(3)	w/o Iron & Steel (4)	EU15 (5)	EU+12 (6)	≥2005 (7)	<2005 (8)
$RegAQ\ SO2h_{it}$ (dummy)×ln $Fossil\ Ener_{js}$	0.179*							
	(0.098)							
$RegAQ\ SO2h_{it}$ (number)×ln $Fossil\ Ener_{js}$		0.0486***						
		(0.0180)						
$RegAQ\ SO2h_{it}$ (dummy)×ln $Ener_{js}$			0.235*	0.258**	0.262**	0.174	0.296**	0.169
			(0.132)	(0.122)	(0.130)	(0.164)	(0.141)	(0.130)
SOx Emissions$_{it}$ (ln)×ln $Ener_{js}$			0.008					
			(0.041)					
Distance$_{ij}$ (ln)	-2.308***	-2.296***	-2.257***	-2.251***	-2.341***	-2.354***	-2.351***	-2.085***
	(0.324)	(0.326)	(0.298)	(0.290)	(0.390)	(0.340)	(0.284)	(0.332)
Contiguity$_{ij}$	0.834***	0.837***	0.742***	0.795***	1.217***	0.294	0.726***	0.759**
	(0.296)	(0.296)	(0.276)	(0.281)	(0.348)	(0.299)	(0.277)	(0.315)
Constant	25.76***	25.66***	25.96***	25.86***	26.42***	32.20***	24.80***	24.74***
	(2.457)	(2.464)	(2.360)	(2.210)	(2.902)	(2.542)	(2.257)	(2.492)
Importer-sector-year fixed effects$_{ist}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-sector-year fixed effects$_{jst}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,181	14,982	18,922	18,645	12,209	8,014	13,015	7,208
Adjusted R^2	0.740	0.740	0.733	0.732	0.746	0.741	0.730	0.738

Notes: The dependent variable is the logarithm of bilateral imports. The variable *RegAQ SO2h* (dummy) is a dummy variable equal to one if SO2 hourly emissions exceed the AQFD limit value. The variable *RegAQ SO2h* (number) indicates the number of exceedances of SO2 hourly limit value. ln $Fossil\ Ener_{js}$ is sector fossil fuel energy intensity expressed as the logarithm of non-electric energy consumption over value added. ln $Ener$ is sector energy intensity expressed as the logarithm of energy consumption over value added. Robust standard errors clustered by bilateral country-pair in parentheses. *** p<0.01, ** p<0.05, * p<0.1

from ECA countries. This could be a source of an upward bias in the OLS estimates if imports of pollution intensive goods increase the production of pollution intensive goods and thus contribute to non-attainment of SO2 limit value. It could also produce a downward bias because of omitted variables if increasing environmental stringency limits the activity of the iron and steel industry and decreases the need of importing highly pollution intensive intermediate inputs from ECA region. When we exclude iron and steel from the analysis (Column 4) the environmental regulation interaction variable is still positive and significant. The magnitude of the coefficient is similar to the benchmark coefficient (Column 1 of Table 2), indicating that the bias is not so large or that we have both an upward and a downward bias.[24]

In Columns 5 and 6, we estimate our basic model on two sub-samples. In Column 5, we restrict the sample to the EU-15 countries and in Column 6, we restrict the sample to new EU-comers (the ten Eastern European countries, Cyprus and Malta, EU+12).[25] Interestingly, our variable of interest is positive and significant only in the case of the EU-15 sub-sample. This indicates that the pollution haven effect seems to affect only imports of richer EU countries. This result is consistent with our expectations. Measures to comply with the EU air quality regulation are likely to be implemented more stringently in 'old' member states. Moreover, inter-sectoral factor mobility is probably larger in EU-15 countries, so that an increase in the relative cost in pollution-intensive sectors may lead to a greater reallocation of production in these countries.

In Columns 7 and 8, we estimate our model on two sub-periods (before and after 2005). We expect a larger effect of environmental regulation on the later period. Indeed, the SO2 limit value (without any margin of tolerance) fully applies since 2005, and the overall constraint to implement measures in order to meet the limit values should be more intense for all countries from that date. Column 7 shows the results of our baseline specification restricting the sample to the sub-period 2005-2012. As expected, the magnitude of the

[24] In unreported regressions, we also estimated our model by dropping successively each of the other nine sectors and found in all cases a positive and significant coefficient for our variable of interest (comprehensive results are available upon request).

[25] Eight Eastern European countries, Cyprus and Malta joined the EU in 2004 and Romania and Bulgaria joined in 2007.

interaction term coefficient is larger as compared to Column 1 of Table 2, and remains highly significant. Conversely, we do not find any impact of the Air Quality framework before 2005, which is reassuring (Column 8).

Overall, these results support evidence that EU air quality regulation fosters pollution havens in ECA countries.

Finally, we test the robustness of our results with respect to the method of estimation. Instead of the OLS estimator we use a Poisson Pseudo-Maximum Likelihood (PPML) estimator. As highlighted in the recent literature, the PPML estimator has several advantages: it incorporates the zero trade values and it is robust to different patterns of heteroskedasticity (e.g. Santos Silva and Tenreyro, 2006). We report these new estimation results in Appendix (Table 8). Note that in this table we restrict the number of fixed effects because the PPML estimator has trouble to converge in case of a very large number of fixed effects. We first report the simple OLS estimator which drops the zero trade observations (Column 1). We then turn to the PPML estimator without and with the zero trade values (resp. Columns 2 and 3).[26] Results are consistent with our previous findings.

4.3 Other pollutants

Table 4 presents regression results using five alternative proxies for environmental regulation related to exceedances of the limit values for SO2 (daily), PM10 and NO2. In the first column of Table 4, our measure of environmental stringency is captured by a dummy equal to one when a country exceeds the SO2 *daily* limit value (over 3 occurrences per year) allowed by the air quality directive. The impact of the interaction term is positive, significant and almost unchanged compared to our baseline estimation (Column 1, Table 2). This result confirms that the effect of environmental regulation due to non-attainment of SO2 limit values is not sensitive to the change of our proxy variable (hourly or daily).

[26] Note that the UN Comtrade database only reports strictly positive trade flows. Therefore to distinguish between zero and missing trade values, we follow the usual assumption: we consider that a mising value is a zero when a country reports at least one positive trade flow for a given year in a given sector.

Table 4: Other pollutants

	(1)	(2)	(3)	(4)	(5)
$RegAQ\ SO2d_{it}$ (dummy)$\times \ln Ener_{js}$	0.228**				
	(0.105)				
$RegAQ\ PM10d_{it}$ (dummy)$\times \ln Ener_{js}$		0.0960			
		(0.119)			
$RegAQ\ PM10y_{it}$ (dummy)$\times \ln Ener_{js}$			0.198*		
			(0.101)		
$RegAQ\ NO2h_{it}$ (dummy)$\times \ln Ener_{js}$				0.0848	
				(0.0963)	
$RegAQ\ NO2y_{it}$ (dummy)$\times \ln Ener_{js}$					0.0593
					(0.142)
Distance$_{ij}$ (ln)	-2.253***	-2.249***	-2.253***	-2.276***	-2.247***
	(0.279)	(0.287)	(0.285)	(0.281)	(0.281)
Contiguity$_{ij}$	0.695**	0.720***	0.721***	0.707***	0.698***
	(0.273)	(0.275)	(0.274)	(0.271)	(0.272)
Constant	25.83***	25.24***	25.25***	25.81***	25.79***
	(2.139)	(2.224)	(2.216)	(2.152)	(2.245)
Importer-sector-year fixed effects$_{ist}$	Yes	Yes	Yes	Yes	Yes
Exporter-sector-year fixed effects$_{jst}$	Yes	Yes	Yes	Yes	Yes
Observations	20,897	20,197	20,197	20,673	20,897
Adjusted R^2	0.732	0.732	0.732	0.732	0.731

Notes: The dependent variable is the logarithm of bilateral imports. The variable $RegAQ\ SO2d_{it}$ (dummy) is a dummy variable equal to one if SO2 daily emissions exceed the AQFD limit value. The variables $RegAQ\ PM10d_{it}$ (dummy) and $RegAQ\ PM10y_{it}$ (dummy) capture exceedances of PM10 daily and yearly limit values. The variables $RegAQ\ NO2h_{it}$ (dummy) and $RegAQ\ NO2y_{it}$ (dummy) capture exceedances of NO2 hourly and yearly limit values. $\ln Ener$ is sector energy intensity expressed as the logarithm of energy consumption over value added. Robust standard errors clustered by bilateral country-pair in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Aside from SO2 limit values, we further investigate the trade effect of exceedances in two other main air pollutants, i.e. particulates (PM10) and nitrogen dioxide (NO2). For this purpose, we use three new dummies capturing exceedances in the daily PM10, yearly PM10, hourly NO2 and yearly NO2 concentrations. We compute these four dummy variables using air quality thresholds given in the first daughter directive (1999/30/EC) (see Table 6 in Appendix). In Columns 2 and 3, we focus on daily and yearly limit values for PM10. Because polluting industries, captured by sector energy intensity, are also important emitters of PM10, we expect to find a positive relationship between exceedances of PM10 limit values and imports in polluting sectors from ECA countries. The conditional effect related to exceedances of PM10 daily limit values is not significant (Column 2), which is probably due to the low variability of this dummy variable. The corresponding variable for the PM10 yearly threshold is positive and significant at the 10% level (Column 3).[27] The size of the impact is slightly smaller than our basic estimate (Column 1 of Table 2), indicating that the conditional effect of environmental regulation is larger in the case of S02 exceedances than for PM10 exceedances. This is consistent with the fact that measures implemented to meet PM10 limit values do not only focus on polluting industries, but concern automotive traffic, dedusting facilities and the construction sector.[28] Another explanation may be related to our proxy for sector pollution generation (i.e. energy consumption) which could be much closely related to SO2 pollution (see subsection 3.3).

Similarly, in the last two columns of Table 4 we look at the trade effect of environmental regulation related to the non-attainment of (hourly and yearly) NO2 limit values. We do not find any significant effect for the interaction terms in these cases, indicating that measures to meet NO2 air concentration thresholds do not increase imports relatively more in pollution intensive sectors. Here again, this is probably due to the specific measures implemented to comply with NO2 limit values. These measures are mainly related to the largest anthropogenic emitter of NO2 – road traffic (traffic restrictions, transport sector regulations, etc.) – and thus should affect manufacturing sectors independently of their

[27]Exceedances of the PM10 daily limit value are very frequent. Over our period of investigation, countries do not meet limit values in almost 90% of all cases. The dummy variable identifying exceedances of the PM10 yearly limit value has a more normal distribution, with approximately 70% of non-attainment.

[28]Trade flows in the construction sector are not available in our database. See Table 1 for the list of industrial sectors included in this paper.

pollution intensity.

Overall, results of Table 4 are consistent with expectations and show that EU air quality standards impact imports of pollution (energy) -intensive sectors mainly through measures implemented to meet SO2 limit values, and to a lesser extent through measures related to exceedances of the PM10 thresholds.

5 Endogeneity and instrumental variable results

In the previous section, we show that environmental regulation in EU countries increases their imports from ECA countries relatively more in sectors with high pollution intensity. Despite our effort to limit endogeneity issues using country-sector-year fixed effects and an interaction variable, our results could still be affected by reverse causality. Reverse causality may introduce both a positive and a negative bias. In countries importing a lot of inputs in sectors with high pollution intensity (e.g. iron and steel or chemicals), the production of pollution intensive goods may increase, leading to an increase in the number of exceedances (our proxy for environmental regulation). In this case, OLS estimates will be overestimated. Conversely, it is also possible that countries importing a lot of pollution intensive goods produce less of these goods, leading to a decrease in the number of exceedances. Moreover, polluting industry lobbying in strong domestic sectors may influence the type of measures chosen by national authorities to meet the limit values, preventing to implement measures constraining polluting industrial activity. In both cases OLS estimates will be underestimated. An endogeneity bias may also be due to measurement error in the environmental regulation proxy variable.

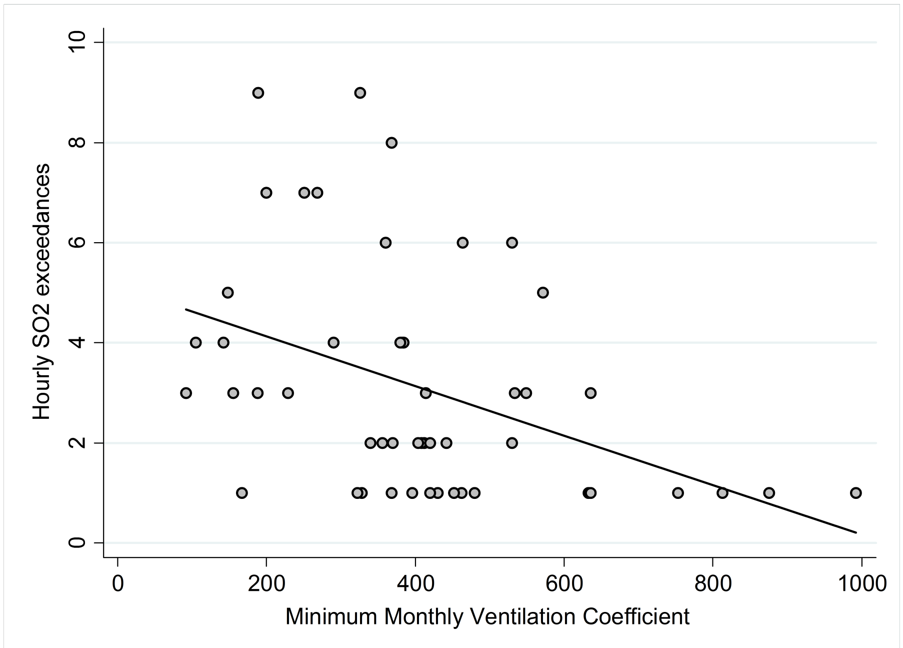
To overcome this endogeneity bias, we implement an instrumental variable (IV) methodology. Our instrumentation strategy relies on Broner et al. (2012). To instrument environmental regulation, we compute for every country and year a ventilation coefficient measuring the speed at which pollutants disperse in the air. Then, we interact this ventilation coefficient with our variable measuring sector pollution intensity.

The ventilation coefficient is based on two meteorological processes: wind and the depth of the atmospheric mixed layer. Wind and mixing height are the main sources of air motion and largely contribute to the dispersion of air pollution in the atmosphere. By multiplying these two variables we obtain a very simple ventilation coefficient for a given area. This information is commonly used in meteorological studies to assess and anticipate levels of pollution concentration in a given region. Monthly ERA-Interim data from the European Centre for Medium-Term Weather Forecasting (ECMWF), give ventilation coefficients for the whole European continent grid of 0.25° x 0.25° cells (representing on average less than 10 square kilometres). We merge data on ventilation coefficient with geographical coordinates of all monitored stations using to assess air quality levels in each EU Member State. For every EU country and year we use the minimum monthly ventilation coefficient to get country-annual observations.

There are fundamental differences between the IV strategy in Broner et al. (2012) and our strategy. Because they want to determine the countries' long-term comparative advantage in polluting activities, they average monthly ventilation coefficients over the period 1980-2010 for capital cities throughout the world. In comparison, our aim is to capture the trade effect of environmental regulation in EU countries. Because stringency measures implied by the AQFD rely on short-term (hourly, daily and yearly) air pollutant concentrations, we need air ventilation coefficients that vary across time. Therefore, we compute a monthly series of ventilation coefficients for areas where are located all the stations used to identify compliance with air pollution limit values and then calculate the minimum monthly ventilation coefficient for each country and year.

Our ventilation coefficient satisfies the two conditions to be a good instrument: (i) it explains exceedances of air quality limit values set by the European directive which is our proxy for environmental regulation and (ii) it is exogenous because it is determined by the weather and geographical characteristics (see Broner et al., 2012). This instrumentation strategy allows to solve the endogeneity problem because it uses exogenous variation in exceedances not related to economic activity (including trade) but related to the weather and geographical characteristics.

Figure 4: Number of SO2 exceedances to hourly limit value and ventilation coefficient



Sources: AirBase database (EEA), ERA-Interim data (ECMWF) and authors' calculations.

Estimation results using the IV approach are displayed in Table 5. The bottom row of the table corresponds to the first-stage estimation and shows that our instrumental variable, the interaction between the ventilation coefficient and sector energy intensity, has a highly significant effect on the exceedance of the SO2 limit value (interacted with energy intensity). As expected, the effect is negative. This supports the simple correlation illustrated in Figure 4. An increase in the minimum monthly average of the ventilation coefficient decreases exceedances of SO2 limit values, whenever we consider the non-attainment dummy (Column 1) or the number of exceedances (Column 2). Thus, favourable weather conditions (a higher ventilation coefficient) imply a higher ability in a given country to disperse air pollutant concentration.

At the top of Table 5, we present the second stage results. Control variables are significant and have the expected sign. Our coefficient of interest is positive and significant at the 5% level (Column 1). It indicates that highly regulated EU countries import relatively more in pollution intensive sectors. In Column 2, we redo the estimation but using the number of exceedances instead of the dummy variable. We find that the effect of the environmental regulation is basically unchanged and remains significant at the 5% level.

Note that IV estimates are generally larger than OLS estimates. This downward bias in OLS estimation is consistent with previous evidence (e.g. Broner et al., 2012). It seems to indicate that the endogeneity problem relates either to measurement errors, or to two potential sources of reverse causality. First, countries importing a lot of pollution intensive goods may generate less pollution, thus leading to a decrease in the number of exceedances. Second, industry lobbying may prevent countries with larger industrial polluting sectors to implement environmental measures constraining these sectors. Take into account the endogeneity issue strengthens the evidence that EU air pollution regulation increases imports of polluting goods from the ECA region.

Results of the instrumental variable estimations strongly support our testing assumption. The increase in the EU's environmental stringency, as reflected by the Air Quality Framework, sharply affects the structure of imports from ECA countries towards (energy) - pollution intensive industries.

6 Conclusion

Air pollution is a major issue for emerging and developing countries of Europe and Central Asia, whereas their main trading partner - the EU - has undertaken increasing efforts to protect the environment by adopting stricter environmental regulations. This paper investigates whether tighter EU environmental regulation fosters pollution havens in ECA countries.

A large body of empirical literature found it difficult to provide convincing support for the pollution haven effect. But, a growing evidence suggests the likely conceptual and methodological issues faced by the existing empirical papers. In particular, the existence of omitted factors and simultaneity bias have been stressed. The empirical strategy developed in this paper aims at adressing these problems by examining one rationale for the pollution haven

Table 5: 2SLS estimations

2nd stage		
Instrument: Minimum Monthly Ventilation Coefficient$_{it}$ (ln)$\times$ln $Ener_{js}$	(1)	(2)
$RegAQ\ SO2h_{it}$ (dummy)$\times$ln $Ener_{js}$	0.724**	
	(0.317)	
$RegAQ\ SO2h_{it}$ (number)$\times$ln $Ener_{js}$		0.147**
		(0.060)
Distance$_{ij}$ (ln)	-2.261***	-2.260***
	(0.279)	(0.247)
Contiguity$_{ij}$	0.759***	0.754***
	(0.273)	(0.240)
Constant	25.88***	25.87***
	(2.150)	(1.891)
Importer-sector-year fixed effects$_{ist}$	Yes	Yes
Exporter-sector-year fixed effects$_{jst}$	Yes	Yes
1st stage		
Dependent variable	$RegAQ$ $SO2h_{it}$ (dummy)$\times$ ln $Ener_{js}$ (1)	$RegAQ$ $SO2h_{it}$ (number)$\times$ ln $Ener_{js}$ (2)
Min. Monthly Ventilation Coeff.$_{it}$ (ln)$\times$ln $Ener_{js}$	-0.250***	-1.229***
	(0.004)	(0.061)
Distance$_{ij}$ (ln)	-0.007	-0.041
	(0.009)	(0.045)
Contiguity$_{ij}$	-0.035***	-0.136***
	(0.010)	(0.037)
Constant	25.97***	25.87***
	(2.162)	(1.891)
Importer-sector-year fixed effects$_{ist}$	Yes	Yes
Exporter-sector-year fixed effects$_{jst}$	Yes	Yes
Observations	20,223	20,223
Partial R^2	0.1489	0. 1495
F test of excluded instrument	54.61***	273,05***

Notes: The dependent variable in the 2nd stage estimation is the logarithm of bilateral imports. The variable *RegAQ SO2h* (dummy) is a dummy variable equal to one if SO2 hourly emissions exceed the AQFD limit value. The variable *RegAQ SO2h* (number) indicates the number of exceedances of SO2 hourly limit value. ln *Ener* is sector energy intensity expressed as the logarithm of energy consumption over value added. Robust standard errors clustered by bilateral country-pair in parentheses. *** p<0.01, ** p<0.05, * p<0.1

hypothesis: that pollution intensive goods should be imported disproportionately more in countries with more stringent environmental regulation. Focusing on this conditional effect of environmental policy allows to include an extensive set of fixed effects. This enables to isolate the specific effect of regulation from any omitted factor influence.

Furthermore, this paper provides an original and unexplored variable that evaluates environmental regulation stringency and limits simultaneity issues, based on the EU Air Quality Framework Directive. Our findings thus exhibit that tighter environmental regulation lead to a significantly higher increase of EU imports in pollution intensive sectors.

Finally, we acknowledge a causal link between environmental regulation and trade by adopting a reliable instrumentation strategy. We use the climate variability impact on short term air pollution concentration, to compute an exogenous component of environmental stringency implied by the EU Air Quality Framework. This provides further evidence about the causal impact of EU environmental regulation on pollution haven development in ECA countries.

Our results suggest a number of directions for future research. Our strategy can be further extended to the case of foreign direct investment. A large literature has examined the potential effect of environmental regulation on outsourcing of polluting activity. But, the evidence so far has shown only limited effects. The AQFD provides an interesting framework to study the effect of environmental stringency on EU outward - and inward - investments. In addition, the evidence of a pollution haven mechanism in ECA countries also calls into question the economic consequences of deeper energy and pollution intensive specialization in this region. The high industrial 'endowments' in energy-intensive sectors in East European countries is a direct legacy of the distorsions implied by the Soviet-type economic system. This rises concerns about the growth consequences of maintaining a high reliance on energy and pollution intensive industries.

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7 Appendix

Table 6: Pollutant limit values from the first Daughter Directive (1999/30/EC)

Pollutant	Concentration	Averaging period	Limit value enters into force	Allowed exceedances each year
Sulphur dioxide (SO_2)	350 μg/m3	1 hour	1.1.2005	24
	125 μg/m3	24 hours	1.1.2005	3
Nitrogen dioxide (NO_2)	200 μg/m3	1 hour	1.1.2010	18
	40 μg/m3	1 year	1.1.2010	None
Oxides of nitrogen (NOx)	30 μg/m3	1 year	19.07.2001	None
PM10	50 μg/m3	24 hours	1.1.2005	35
	40 μg/m3	1 year	1.1.2005	None
Lead (Pb)	0.5 μg/m3	1 year	1.1.2005 (or 1.1.2010 in specific cases)	n/a

Notes: Lead limit value enters into force in 1.1.2010 in the immediate vicinity of some specific industrial sources. The second Daughter Directive (2000/69/EC) introduces limit values for Benzene and Carbon Monoxid. The third Daughter Directive (2002/3/EC) establishes target values for Ozone. The fourth Daughter Directive (2004/107/EC) completes the list of pollutants and imposes limit values for arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons.

Table 7: Data description and sources

Variables	Description and sources
M_{ijst}	Bilateral imports of EU 27 countries from 11 Eastern European countries at the sector level (2 digits). Data come from the UN Comtrade database.
$Distance_{ij}$, $Contiguity_{ij}$	Bilateral distance and contiguity dummy variables come from the CEPII database.
$Ener_{js}$	Sector (2 digits) energy intensity. Defined as energy consumption (in kg of oil equivalent) over output (in constant 2005 dollars). Data on energy consumption is provided by the International Energy Agency and sector value added data come from UN Industrial Development Organization (UNIDO).
Fossil $Ener_{js}$	Sector (2 digits) fossil fuel energy intensity. Defined as non-electric energy consumption (in kg of oil equivalent) over output (in constant 2005 dollars). This variable encompasses oil, gas and coal sources of energy. Data on energy consumption is provided by the International Energy Agency and sector value added data come from UN Industrial Development Organization (UNIDO).
$RegAQ\ SO2h_{it}$	Environmental regulation proxy. This variable is a dummy that takes the value 1 if SO2 emissions exceed the SO2 hourly limit value more than twenty four times a year (which is the number of exceedances allowed each year). As an alternative proxy, we use a variable that counts for every country and year the number of exceedances of SO2 hourly limit value, whenever this number exceeds twenty four. In other cases, this variable equals to zero. Data on the number of exceedances come from the AirBase database (European Environment Agency, EEA).
SOx $Emissions_{it}$	Annual national total emissions of sulphur oxides SOx (SO2 and SO3) reported by EU countries to the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP Convention). Source: European Environment Agency (EEA).
Minimum Monthly Ventilation $Coefficient_{it}$	This variable is the minimum ventilation coefficient for each EU country and year. Ventilation coefficient is computed by multiplying wind and mixing height of the geographic grid where are located air quality monitoring stations. Wind and mixing height information is provided by the ERA-Interim data from the European Centre for Medium-Term Weather Forecasting (ECMWF). Geographic coordinates of monitoring stations of EU countries are obtained from the AirBase database (EEA).

Table 8: PPML estimations

	OLS (1)	PPML (2)	PPML (3)
$RegAQ\ SO2h_{it}$ (dummy)$\times \ln Ener_{js}$	0.173**	0.125**	0.126**
	(0.0672)	(0.0574)	(0.0579)
Distance (ln)	-2.269***	-1.869***	-1.890***
	(0.256)	(0.283)	(0.280)
Contiguity	0.751***	0.0125	0.0213
	(0.247)	(0.280)	(0.282)
Constant	24.92***	9.368***	9.388***
	(1.889)	(1.823)	(1.811)
Importer-sector fixed effects$_{is}$	Yes	Yes	Yes
Exporter-sector fixed effects$_{js}$	Yes	Yes	Yes
Importer-year fixed effects$_{it}$	Yes	Yes	Yes
Exporter-year fixed effects$_{jt}$	Yes	Yes	Yes
Observations	20,223	20,223	29,179

Notes: The dependent variable is the logarithm (Column 1) or the absolute value (Columns 2 and 3) of bilateral imports. The variable *RegAQ SO2h* (dummy) is a dummy variable equal to one if SO2 hourly emissions exceed the AQFD limit value. $\ln Ener$ is sector energy intensity expressed as the logarithm of energy consumption over value added. Robust standard errors clustered by bilateral country-pair in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$