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Globalization and Emissions in Europe

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Abstract

This paper examines the impact of five globalization variables on sulfur dioxide and nitrogen oxides emissions in Europe from 1980-2000 in the framework of one empirical model. The spatial autoregressive regression model is estimated using 2SLS. The five variables of interest are trade, foreign direct investment, neighboring countries wealth, cross-border pollution and participation in international environmental treaties. I then omit each of the globalization effects one at a time and find that omitted variable bias would be significant for four of the globalization variables, the exception being neighbors' wealth.

JEL Classifications: F18, Q53, Q58

Keywords: Globalization, environment, spatial econometrics

1. Introduction

Disagreement about the relationship between globalization and the environment remains an unresolved issue. Theoretical predictions of the effects of globalization are often ambiguous.[2] Therefore, empirical work must provide evidence of the actual impact on the environment. This study looks at five globalization effects predicted to affect the environment. Three aspects of globalization – trade, foreign direct investment (FDI) and international environmental treaty participation – have received a fair share of attention. Even so, Antweiler et al. (2001) is the only study to include all three of these effects. Less attention has been given to cross-border pollution and nearby countries' wealth effects. Maddison (2006) is the only study to consider these spatial variables, but he excludes the other three globalization variables. I estimate European sulfur dioxide (SO_2) and nitrogen oxides (NO_X) emissions between 1980 and 2000 within one empirical model including five different globalization variables.

Increased globalization allows countries to strategically affect each other. For example, countries can use trade relations to persuade their polluting neighbors to lower emissions or join international environmental treaties. FDI can contribute to a country's emissions via technology transfer or by responding to lax environmental regulation, but it is also closely related to a country's trade. Countries that are poor relative to their neighbors may serve as pollution havens and thus have higher emission levels. These same countries also trade more because of large markets nearby. While the links between emissions and these globalization variables have separately been studied before,

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[2] Sources of these ambiguities for trade's effect on the environment, for example, are discussed by Copeland and Taylor (2003).

the correlations between the globalization variables must be considered as well. I do that by estimating models while omitting relevant globalization variables.

Many previous studies relating trade to environment use international air quality data, but the theoretical link between trade and the environment emerges through emissions, not air quality.[3] Using air quality rather than emissions data may be problematic because air quality does not only depend on local emissions but is also a function of many geo-spatial factors and cross-border pollution. Aggregating air quality data across cities to form an air quality index for a country may also not be appropriate.[4]

Figure 1 plots sulfur dioxide (SO_2) emissions against mean SO_2 concentrations in 1995 for 28 countries. The correlation between these two variables is only 0.048, suggesting that air quality data may not be an appropriate proxy for emissions. In Figure 2 nitrogen oxides (NO_X) emissions are plotted against nitrogen dioxide (NO_2) concentrations for 26 countries in 1995. [5] Again, there is only a 0.098 correlation between emissions and air quality. While controlling for monitoring-site specific characteristics alleviates some of the problems with air quality data, emissions data provide a better test of the existing theories. Therefore, I use data on SO_2 and NO_X emissions.[6]

[3] See for example Antweiler et al. (2001), Harbaugh et al. (2002) and Frankel and Rose (2005).

[4] For example, the average standard deviation in SO_2 concentrations (for the sixteen countries that report concentrations for more than one monitoring station) is 57 percent of the mean SO_2 concentrations. That for NO_X concentration levels (for the twelve countries with more than one reporting monitoring stations) is 32 percent. The 1995 data used in this footnote are reported by World Bank's 1998 World Development Index available online at http://www.worldbank.int/nipr/wdi98/index.htm.

[5] Dropping the two outliers in these figures from correlation calculation does not increase the correlation significantly.

[6] This study does not explicitly consider the social damage of emissions. In order to get at the social damage of pollution emissions, not only the toxicity level but also exposure to these emissions would need to be known. I estimate separate models for SO_2 and NO_X to allow for different toxicity of these pollutants. While that is important in getting at the social damage of these emissions, the theoretical relationship considered in this study is between the globalization variables and emissions. Nevertheless, it is important to note that most environmental policies are to limit emissions of a particular pollutant and do not account for the toxicity of those emissions. This is potentially due to the greater ease in observing emissions.

Figure 1 SO_2 Emissions and Mean SO_2 Concentrations, 1995

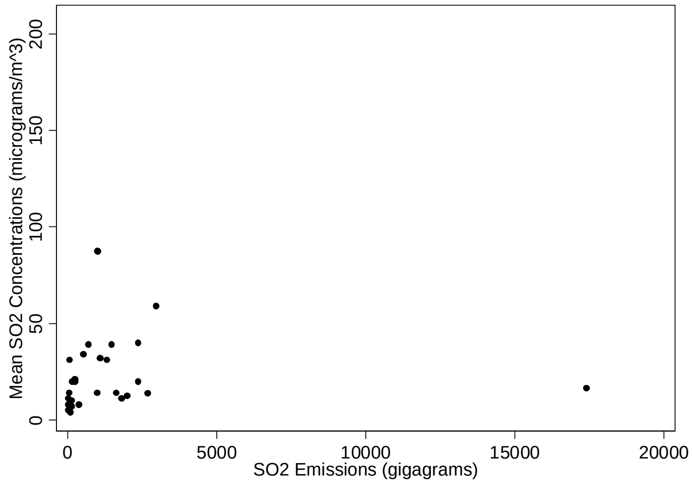
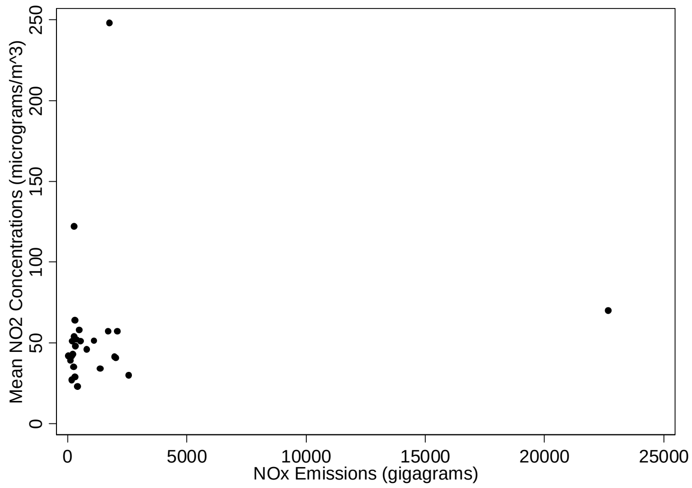


Figure 2 NOX Emissions and Mean NO2 Concentrations, 1995



Sources: Emissions from EMEP (2005) and concentrations from World Bank (1998)

An important aspect of these emissions is that they themselves introduce an international interaction. Nitrogen oxides and sulfur dioxide are both production byproducts that pollute the air. Once in the air, these pollutants may travel great distances resulting in acid rain and worsened air quality not only in the country of origin but in other countries as well. Three international environmental agreements are in effect to control their emissions. The Helsinki Protocol required a 30 percent reduction of the 1980 sulfur emissions by 1990. In contrast, the Oslo Protocol on sulfur emissions provides individual sulfur reduction targets for each country and a longer timeline—target dates extend from 2000 to 2010. The Sofia Protocol concerning nitrogen oxides calls on the participating nations to reduce their emissions to 1987 levels by 1994 and provides other guidelines for controlling NO_X emissions. While these agreements are written and signed at international meetings, nations are not bound by an agreement until they ratify it. Therefore, to capture treaty effects I use the ratification date, not the signature date.

Much of the literature on interactions between globalization and the environment focuses on the effect of environmental regulations on trade. The pollution haven effect (PHE) predicts that more stringent environmental regulation in a country would decrease domestic production and increase imports in the regulated markets. Levinson and Taylor (2008) and Ederington and Minier (2003) are two examples of studies that focus on the PHE. The goal of my paper is the flip side of the PHE and determines how trade affects the environment. Ederington and Minier (2003) control for the effect of trade on the environment by endogenizing environmental regulation in the trade equation. I make this point more explicit by estimating the equations for emissions.

Central to the literature on trade's effect on the environment is the pollution haven hypothesis (PHH) that predicts that removal of trade barriers results in flow of dirty industries to countries with lax environmental regulations. Taylor (2004) discusses the challenges of empirical research in pinning down evidence related to this hypothesis. The PHH provides reason to believe that trade affects the environment, as modeled in this paper.

My sample includes European countries alone because I use emissions transport matrix only available for Europe and the results should be viewed with this in mind. Focusing on a group of geographically small countries packed in relatively close quarters provides a good sample to test for cross-border pollution effects. While the estimated coefficients may not be the same outside of Europe, the omission of relevant globalization variables would most likely cause similar problems in an analysis that includes all countries.

Cole and Elliott (2003) were the first to use international emissions data when estimating the impact of trade on the environment. They found mixed results with respect to trade's effect on emissions. Some recent studies, Grether et al. (2010), Grether et al. (2009), and Kellenberg (2008), find that trade has decreased emissions. In contrast, Managi and Kumar (2009) find a positive effect of trade on emissions and Cole (2006) find that trade liberalization increases national energy use.[7] Furthermore, Managi et al. (2009) find that trade lowers emissions in OECD countries but that trade increases emissions in non-OECD countries, at least for some pollutants. Lamla (2008) finds little evidence of trade affecting emissions. Therefore, evidence of trade's effect on emissions is mixed. I believe part of the reason for the mixed results could be driven by omitted globalization variables. Most of the previous studies include just trade, and none include more than three globalization variables. I find robust evidence that trade lowers emissions.

Unlike previous studies that include no more than three globalization effects, my study includes five. In addition to trade, I include cross-border pollution, foreign direct investment, neighbors' wealth and treaty effects in a unified empirical model, and explore the potential omitted variable biases caused by inclusion of a subset of these

[7] In another study, Cole (2004) uses trade variables to explain the prevalence of the Environmental Kuznets Curve. He does not provide the net effect of trade on emissions.

effects. Omission of the globalization variables typically changes the included coefficients significantly.

The following section outlines the empirical methodology. Section 3 presents the results and Section 4 concludes.

2. Empirical Model

Following Frankel and Rose (2005), pollution emissions are estimated as a function of trade, income, and other country characteristics:

$$E_{it} = \beta_0 + \beta_1 (Trade / GDP)_{it} + \beta_2 Ln(Inc_{it}) + \beta_3 [Ln(Inc_{it})]^2 + \beta_4 X_{it} + \kappa_t + \gamma_i + \varepsilon_{it}, \; i = 1,\ldots,n \quad (1)$$

where E_{it} is either log of per capita SO_2 or NO_X emissions in country *i* at time *t*; *Trade/GDP* is trade intensity (or openness) measured by imports plus exports over GDP; *Inc* is national income measured by GDP per capita; X_{it} captures other country specific characteristics; κ_t are year fixed effects; γ_i are country fixed effects and ε_{it} is the i.i.d. error term. I estimate this equation using spatial 2SLS, where I instrument for trade intensity, income, income squared and the spatial lag.

Previous literature decomposes the trade effect on emissions into scale, composition and technique effects (Grossman and Krueger, 1993; Copeland and Taylor, 1994, 1995, 2003; and Antweiler et al., 2001). The positive scale effect arises because trade tends to increase GDP, which in turn increases industrial production and emissions. The composition effect accounts for the changes in emissions due to changes in the composition of national output (shifts of production from clean to dirty or from dirty to clean industries), which may increase or decrease emissions depending on the industries in which a country has a comparative advantage. Finally, the negative technique effect is due to increased income resulting in higher demand for cleaner production techniques. Because of these opposing effects, the theoretical relationship between trade and emissions is ambiguous and remains an empirical question.

To allow for the inverse-U shaped environmental Kuznets curve (EKC), I include the log of income and the square of the log of income. The EKC hypothesis implies that as poorer countries' incomes grow their emissions rise, while an increase in wealthier countries' incomes decrease emissions. The EKC would be supported if the linear term of income has a positive coefficient and the quadratic term has a negative coefficient. See Grossman and Krueger (1993) for a discussion of the EKC.

Following Frankel and Rose's (2005) methodology, I instrument for openness to trade, income and income squared due to a potential simultaneity problem. There is a two-way link between each of the three variables. First, trade impacts the environment through scale, composition and technique effects. On the other hand, the pollution haven hypothesis implies that countries with lower environmental regulations export dirty goods. Second, the effect of income on environmental quality can be presented as the environmental Kuznets curve. However, environmental regulation may also impact income through productivity—either by dampening it or by stimulating it.[8] Finally, the gains-from-trade hypothesis implies a positive effect of trade on income while the gravity models of trade predict that higher income increases trade.

Country characteristics are captured by the matrix X_{it} which includes the other four globalization variables, a corruption index, a repression index, and population density. The globalization effects include cross-border pollution, FDI, neighbors' wealth and treaty effects. These, along with the trade intensity variable, are the variables of interest in this study. All of these country-specific characteristics are described in detail below.

Cross-border pollution effects are captured with a spatial lag. The spatial lag is calculated as the weighted sum of other countries' emissions, $\sum_{i \neq j} \omega_{ij} E_{jt}$. The weight, ω_{ij}, is the percent of country *j*'s emissions, E_{jt}, that cross over to country *i*. These weights are calculated for European countries by the Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP) using atmospheric chemistry models of source and receptor relationships that take into account the geography, prevailing winds, and forest cover of both the emitting and receiving countries. These emissions-based weights are only available for European countries, which is why my sample only includes Europe. The geo-spatial factors contributing to cross-border pollution have not changed greatly over the last couple of decades, so I use the same weights for all years. The Moran's I statistic for per capita SO_2 is 0.312 and the related p-value is 0.001. Similarly, the Moran's I statistic for per capita NO_X is 0.293 and the related p-value is 0.001. These statistics provide strong evidence of spatial autocorrelation in the dependent variable that I correct for by using the spatial lag model.

Using E_{jt} in estimation of E_{it} and E_{it} in the estimation of E_{jt} introduces an endogeneity problem. Therefore, I instrument for cross-border pollution using standard instruments for this type of problem, the weighted sums of other exogenous variables. The weights used in construction of instruments are the same as the ones used in the spatial lag. A similar approach was used by Murdoch et al. (1997) and Murdoch et al. (2003) to determine the effect of cross-border pollution on emission-reductions and treaty participation. Both of these studies omit trade, FDI and neighbors' wealth. Using a similar method but a different weighting scheme, Maddison (2006) also estimates a spatial lag in emissions. His weights are based on a negative function of distance rather than pollutant-specific transport matrices used in this study.

A positive coefficient on the spatial lag could be driven by coordination in environmental regulation across countries. For example, Davies and Naughton (2007) develop a model that illustrates how cross-border pollution intensifies competition in emissions taxes and increases gains from cooperation for nearby countries. If environmental regulations tend to move in the same direction in both countries, then emissions should also move in the same direction. On the other hand, a country with high levels of cross-border pollution will have a higher marginal cost of polluting. This effect, also captured by the spatial lag, would decrease domestic pollution. Because I am

[8] Porter and Linde (1995) argue that environmental regulation may stimulate productivity.

unable to distinguish between these two interactions, the estimated spatial lag coefficient will provide the net effect of the two.

Even though the vast majority of FDI takes place between relatively rich countries for market access purposes, some FDI flows from relatively rich countries to poorer countries. To the extent that this latter pattern of FDI movement is present in Europe, cleaner technology transferred from the richer source country would reduce emissions intensity, all else constant.[9] On the other hand, if multinational firms are responding to weak environmental regulation in the host country, then FDI could increase emissions. The coefficient on FDI will estimate the net effect as in Antweiler et al. (2001).

Neighboring countries' wealth is calculated as a weighted average of other countries' GDP, where the weights are declining in distance. While there is no theory to guide me in the choice of this weight function, I chose the weight of 100 divided by distance.[10] The expected sign on neighbors' wealth is positive and driven by the hypothesis that poorer countries near rich countries may serve as pollution havens.

Similar to Ringquist and Kostadinova (2005), I include the Helsinki and Oslo Protocol ratification and participation effects in the SO_2 equations and the Sofia Protocol effects in the NO_X equations. Protocol ratification effects are introduced as dummy variables to capture the intercept shifts caused by ratifying the protocols. Protocol participation is a variable indicating the number of years since ratification. The participation effect captures the Protocol's effects on emissions trends. The expected signs for all treaty effects are negative.

To control for differences in environmental regulations across countries, I construct a repression index from the civil liberties and political rights indices provided by Freedom House. This index proxies for citizens' ability to assert their preferences about environmental policy. Civil liberties and political rights take on values between one and seven, where lower numbers are associated with higher civil liberties and political rights. The repression index I use is the sum of the two divided by fourteen and the expected sign is positive—more repression is expected to increase emissions. [11] While it is difficult to obtain environmental regulation enforcement data for different countries, I use corruption as a proxy for enforcement. Higher corruption should imply lower enforcement and higher emissions. Therefore the expected sign on corruption is positive. Finally, a standard control included in the model is the log of population density. More densely populated countries have higher energy and production needs and hence are expected to have higher emissions. The data sources are described in

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[9] This effect could also be driven by FDI occurring in cleaner industries.

[10] Head and Mayer (2004) introduce a measure of market potential (or what I call neighbors' wealth) with an inverse distance function. Previous studies using market potential find that the choice of the functional form for the weights has little effect on their results. See for example Blonigen et al. (2007), Blonigen et al. (2007), and Davies and Naughton (2007).

[11] The correlation between the civil liberties and political rights indices is very high (0.8). Combining the two into one index allows for both to impact emissions without introducing multicollinearity problems. Including either index on its own instead of the repression index does not qualitatively change the results.

Appendix A and the descriptive statistics are summarized in Table 1. Also, Table 2 provides the list of countries and the minimum and the maximum year for each country.

Table 1 Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Ln(SO_2/Pop)	-10.57	0.84	-12.83	-8.93
Ln(NO_X/Pop)	-10.34	0.41	-11.55	-9.20
Trade/GDP*	0.69	0.26	0.30	1.82
Ln(Inbound FDI Stock)	10.01	1.48	4.06	12.99
Ln(Neighbors Wealth)	7.00	0.30	6.36	7.67
Helsinki Ratification	0.50	0.50	0.00	1.00
Helsinki Participation	3.42	4.53	0.00	14.00
Oslo Ratification	0.17	0.37	0.00	1.00
Oslo Participation	0.28	0.88	0.00	5.00
Sofia Ratification	0.47	0.50	0.00	1.00
Sofia Participation	2.31	3.27	0.00	11.00
Ln(GDP per capita)	9.84	0.68	7.34	10.75
GDP per capita	22,316	10,449	1,538	46,815
Square of Ln(GDP per capita)	97.38	12.65	53.85	115.65
Corruption	2.62	1.75	0.00	8.37
Repression Index	0.20	0.11	0.14	0.71
Ln(Density)	4.44	1.00	1.01	6.15

Sources: Outlined in Appendix A

Table 2 List of Countries

Country	**Frequency**	**Min(year)**	**Max(year)**
Austria	21	1980	2000
Denmark	21	1980	2000
Finland	21	1980	2000
France	21	1980	2000
Germany	9	1991	1999
Hungary	16	1985	2000
Ireland	21	1980	2000
Italy	20	1980	1999
Netherlands	21	1980	2000
Norway	21	1980	2000
Portugal	15	1980	1998
Spain	21	1980	2000
Sweden	21	1980	2000
Switzerland	21	1980	2000
Turkey	13	1988	2000
United Kingdom	21	1980	2000
Number of observations	**304**		

2.1 Construction of Instruments

As discussed above, there is simultaneity between openness to trade, income and emissions. Therefore, following Frankel and Rose's (2005) methodology, I construct instruments for the trade and income variables in that order. First, I estimate equation (2) of bilateral trade using the gravity model of trade.

$$\begin{aligned} Ln(Trade_{ijt} / GDP_{it}) &= \alpha_0 + \alpha_1 Ln(Dist_{ij}) + \alpha_2 Ln(GDP_{jt}) + \alpha_3 Ln(Pop_{it}) + \alpha_4 Ln(Pop_{jt}) \\ &+ \alpha_5 Lang_{ij} + \alpha_6 Border_{ij} + \alpha_7 Ln(Area_i) + \alpha_8 Ln(Area_j) + \alpha_9 Landlocked_{ij} \\ &+ \alpha_{10} X_i + \alpha_{11} X_j + \nu_t + \varepsilon_{ijt} \end{aligned} \quad (2)$$

Log of trade as a share of GDP from country *i* to country *j* is estimated as a function of log of distance between the two countries, log of country *j*'s GDP, log of each of the countries' population, dummies for common language and land border, log of each of the countries' areas, and a variable indicating whether neither country, one country or both countries are landlocked. Equation (2) is a modified version of Frankel and Rose's (2005) specification—I have added country *j*'s GDP and country *i*'s population. In addition, I have included all the exogenous variables from equation (1) for each country (X_i and X_j). The latter modification moves this method closer to netting out the effects of X from the instrument for Trade/GDP in equation (1). Furthermore, I do not restrict the coefficients on the two countries' areas to be the same as Frankel and Rose's original specification does.

Equation (2) is estimated for 1980-2000 with year fixed effects. Each trade flow is only included once in the estimation equation. That is, if $Trade_{ijt} / GDP_{it}$ is included in the estimation, then $Trade_{jit} / GDP_{jt}$ is excluded from the analysis. When constructing the instrument each observation is used twice—once for estimation of total trade flows of each country. The instrument for openness in country *i* is constructed by taking the exponent of the estimated log of trade flows to each country *j* and summing over all *j* countries as presented in equation (3)[12]:

$$(\overset{Estimated}{Trade / GDP})_{it} = \sum_{j \neq i} \exp[\overset{Estimated}{Ln(Trade_{ijt}} / GDP_{it})] \tag{3}$$

The second step involves constructing an instrument for income and income squared. I instrument for openness in the income equation below because of the potentially endogenous relationship between trade and income. Log of income is estimated using IV estimation as a function of openness to trade, log of population, log of income lagged twenty years, investment rate, population growth rate, log of education and the set of exogenous variables from equation (1), X:

$$\begin{aligned} Ln(Inc_{it}) = {} & \delta_1 (Trade / GDP)_{it} + \delta_2 Ln(Pop_{it}) + \delta_3 Ln(Inc_{i,t-20}) + \\ & \delta_4 Inv_{it} + \delta_5 PopGR_{it} + \delta_6 Ln(Educ_{it}) + \delta_6 X_{it} + \gamma_t + \varepsilon_{it} \end{aligned} \tag{4}$$

Equation (4) is also estimated for 1980-2000 and includes year fixed effects. The major modification from Frankel and Rose (2005) is again the addition of the exogenous variables from the final equation of interest. As before, this gets me closer to netting out the effects of X from the instruments for the income variables in equation (1). The predicted values from equation (4) are used to instrument for log of income and the square of these predicted values are used to instrument for square of log of income.[13]

[12] Taking the exponents provide the median not the mean of $Trade_{ijt} / GDP_{it}$. For comparability of methods across studies I use this method of constructing the instrument.

[13] See Frankel and Rose (2002) for further discussion of developing these instruments.

3. Results

This section presents the fixed effects model results for logged per capita SO_2 and NO_X emissions. Therefore, time-series variation drives the results. The preferred specification is presented in column (1) of Tables 3 and 4 and includes all five globalization variables. I then examine the omitted variable bias by sequentially removing one of the five globalization variables from the model. The section concludes with discussion of additional findings and robustness checks.

3.1 Baseline Results

In each of the baseline models, four of the five globalization effects are statistically significant. For both types of emissions, I find that increase in trade intensity reduces per capita emissions with a larger effect for SO_2. Spatial lag is positive for both emissions but statistically significant for just SO_2. This result is consistent with the hypothesis that countries may be coordinating their environmental regulations with nearby countries. For 1980-2000, inbound FDI stock in Europe increase per capita emissions on average, consistent with the idea that FDI might be locating in areas with less stringent environmental regulations. Neighbors' wealth affects SO_2 negatively and NO_X positively. The unexpected negative effect in the SO_2 equation matches the coefficient found by Maddison (2006) and appears with the inclusion of fixed effects. This unexpected negative sign on neighbors' wealth may be explained by the SO_2 has larger regional effects through acid rain while NO_X cause more problems at a local level (Burtraw and Szambelan 2009). Therefore, a country that is surrounded by wealthier countries could be used for production of goods with local emissions (more of a feature of NO_X) but per haps is pressured to produce less of goods with regional effects (SO_2). Treaty ratification and participation variables in the SO_2 model are statistically insignificant in the SO_2 equations but are statistically significant for the Sofia Protocol in the NO_X models. The income and income-squared variables have the expected signs. Repression index and corruption are statistically insignificant in the baseline regressions and density decreases per capita NO_X emissions.

Table 3 Ln(SO_2/Pop) Equations

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**All**	**No Trade**	**No Lag**	**No FDI**	**No Wealth**	**No Treaties**
Trade/GDP	-1.797***		0.433	-0.848**	-1.797***	-1.192***
	(0.536)		(1.059)	(0.383)	(0.550)	(0.396)
Spatial Lag (*W*E$_{it}$*)	0.180***	0.141***		0.131**	0.238***	0.139**
	(0.064)	(0.054)		(0.055)	(0.062)	(0.056)
Ln(Inbound FDI Stock)	0.175**	0.027	-0.055		0.196***	0.082
	(0.072)	(0.048)	(0.105)		(0.073)	(0.054)
Ln(Neighbors Wealth)	-5.496***	-5.097***	-6.088***	-5.690***		-5.396***
(W*GDP)	(1.454)	(1.243)	(1.325)	(1.316)		(1.288)
Helsinki Ratification	0.049	0.015	0.067	0.056	-0.036	
	(0.084)	(0.072)	(0.078)	(0.078)	(0.082)	
Oslo Ratification	0.023	-0.014	-0.022	0.005	0.021	
	(0.017)	(0.011)	(0.023)	(0.015)	(0.017)	
Helsinki Participation	-0.042	-0.030	0.041	-0.020	-0.058	
	(0.087)	(0.076)	(0.088)	(0.079)	(0.088)	
Oslo Participation	-0.021	0.038	0.074	0.022	-0.024	
	(0.039)	(0.030)	(0.055)	(0.032)	(0.040)	
Ln(GDP per capita)	43.566***	30.006***	34.069***	39.327***	40.287***	40.160***
	(6.727)	(5.027)	(8.054)	(6.227)	(6.763)	(3.409)
Square of Ln (GDP per capita)	-2.067***	-1.473***	-1.720***	-1.914***	-1.895***	-1.956***
	(0.331)	(0.261)	(0.374)	(0.308)	(0.332)	(0.177)
Repression Index	-0.582	-0.914**	-1.393***	-1.357***	-0.106	-0.908**
	(0.460)	(0.385)	(0.468)	(0.319)	(0.447)	(0.377)
Corruption	0.044	0.034	0.027	0.048*	0.052*	0.041
	(0.029)	(0.025)	(0.027)	(0.026)	(0.029)	(0.026)
Ln(Density)	0.836	1.527*	1.412	0.784	0.801	0.947
	(0.972)	(0.819)	(0.943)	(0.883)	(0.983)	(0.875)
Observations	304	304	304	304	304	304
R-Squared (within)	0.840	0.882	0.863	0.868	0.836	0.864
F-test for fixed effects	57.49	85.78	69.52	78.39	62.57	85
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

All equations include a constant, year fixed effects and country fixed effects.

3.2 Omission of One Relevant Variable

In columns (2)-(6) of Table 3 and Table 4 I sequentially remove one of the five globalization effects from the model. Removing trade from the model turns FDI stock insignificant in the model. Removing the spatial lag from the SO_2 model biases the trade and the FDI stock variables and removing the spatial lag from the NO_X model removes the statistically significant Sofia treaty effects. Removing FDI stock from the model biases the trade coefficient for each of the emissions. Omitting neighbor's wealth variable does not significantly affect other variables' coefficients but is statistically significant in the baseline equation. Excluding treaty effects from the SO_2 equation makes FDI stock insignificant but omitting the statistically significant treaty effects from the NO_X equation leaves the rest of the coefficients qualitatively unchanged.

Table 4 Ln(NO_X/Pop) Equations

VARIABLES	(1) All	(2) No Trade	(3) No Lag	(4) No FDI	(5) No Wealth	(6) No Treaties
Trade/GDP	-0.691***		-0.937***	-0.312*	-0.652***	-0.835***
	(0.202)		(0.295)	(0.187)	(0.200)	(0.225)
Spatial Lag (*W*Eit*)	0.029	0.024		0.007	0.021	0.031
	(0.026)	(0.024)		(0.026)	(0.025)	(0.027)
Ln(Inbound FDI Stock)	0.099***	0.039	0.140***		0.092***	0.109***
	(0.035)	(0.029)	(0.046)		(0.035)	(0.040)
Ln(Neighbors Wealth)	1.319*	0.851	1.626*	1.454*		1.626**
(W*GDP)	(0.758)	(0.716)	(0.858)	(0.798)		(0.801)
Sofia Ratification	-0.110**	-0.189***	-0.081	-0.101**	-0.112***	
	(0.043)	(0.038)	(0.052)	(0.045)	(0.043)	
Sofia Participation	-0.020**	-0.034***	-0.009	-0.008	-0.023**	
	(0.010)	(0.009)	(0.012)	(0.011)	(0.009)	
Ln(GDP per capita)	12.327***	6.506***	14.907***	14.089***	11.705***	16.657***
	(2.299)	(2.084)	(2.896)	(2.457)	(2.275)	(1.994)
Square of Ln (GDP per capita)	-0.513***	-0.254**	-0.616***	-0.609***	-0.485***	-0.723***
	(0.117)	(0.110)	(0.144)	(0.124)	(0.117)	(0.109)
Repression Index	0.031	-0.011	0.086	-0.497***	-0.066	0.039
	(0.219)	(0.208)	(0.248)	(0.187)	(0.207)	(0.238)
Corruption	-0.008	0.001	-0.022	-0.016	-0.009	-0.023
	(0.016)	(0.015)	(0.018)	(0.017)	(0.016)	(0.016)
Ln(Density)	-1.300**	-1.428***	-0.979	-1.269**	-1.270**	-1.191**
	(0.517)	(0.492)	(0.598)	(0.538)	(0.516)	(0.565)
Observations	304	304	304	304	304	304
R-Squared (within)	0.619	0.653	0.515	0.574	0.624	0.559
F-test for fixed effects	57.37	69.63	45.63	51.09	65.00	53.34
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All equations include a constant, year fixed effects and country fixed effects.*

Overall, I find that removal of just one globalization effect, even if insignificant in the baseline equation, can severely bias included globalization coefficients. This then suggests that previous studies may have results that are biased since no previous study on emissions includes more than three of these globalization effects.

3.3 Additional Findings and Robustness Checks

The models discussed so far employ time-series variation. A previous version of this paper focused on regressions without country fixed effects and found similar results that omitting any of the five globalization effects biased the included coefficients. I also estimated the models for logged values of emissions/GDP, emissions/area and total emissions. The patterns of omitted variable biases for these additional equations are similar and sometimes more severe than in the reported results. These results are available by request.

4. Conclusion

Empirical work is always a balancing act between choosing a simple model that answers the question of interest and ensuring that all the relevant variables are included in the model. This study brings together different strands of literature that estimate the impacts of globalization on emissions. The central focus in the past has been on the effect of trade on the environment. When I include four additional globalization variables in the model I find robust results of trade intensity reducing emissions.

The globalization effects included in the preferred model are openness to trade, cross-border pollution, FDI, neighboring countries' wealth and treaty effects. Previous studies usually include these effects on their own and no one has included more than three of these in one model. My results suggest that excluding any of the globalization variables one at a time or in groups significantly biases some of the included coefficients. This can explain the mixed results of previous studies.

Appendix A: Data Sources

The emissions data come from the EMEP (2005) and are country level sulfur dioxide (SO_2) and nitrogen oxides (NO_X) emissions for nineteen European countries for 1980-2000 measured in gigagrams. The spatial lag is constructed using emissions transport matrices, or blame matrices, for SO_2 and NO_X as reported by the Meteorological Synthesizing Centre—West (MSC-W, 2002). When calculating the dependent variables, the logarithmic versions always use emissions in gigagrams, population in thousands, GDP in dollars and area in km^2. The linear versions of the variables were scaled so that the coefficients would be easier to read. Total emissions were scaled down by 1000. Per capita emissions were scaled up by 10^5.

Trade as a fraction of GDP, GDP per capita, population and density come from 2004 World Development Indicators compiled by World Bank. All money values used in this analysis are in 1995 US dollars. FDI is measured as inbound FDI stock and is obtained from the United Nations Conference on Trade and Development online at http://stats.unctad.org/fdi. Corruption is measured by 10-CPI, where CPI is the Corruption Perceptions Index decreasing in corruption provided by Transparency International online at http://www.transparency.org. The civil liberties and political rights indices that I use in construction of the repression index are reported by Freedom House online at http://www.freedomhouse.org/ratings/index.htm. The treaty-related data come from the United Nations' Treaty Database. Table 1 reports the descriptive statistics.

Bilateral trade data are reported by Feenstra et al. (2005) online at http://cid.econ.ucdavis.edu. To convert the trade data into constant 1995 US dollars I use the US GDP deflator as reported by the Economic Report of the President. Data for distances between countries, common language, common border, area and whether or not a country is landlocked come from Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) available online at http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

Investment as a share of GDP is reported by Penn World Tables 6.1 and is averaged over all available years. Population growth rate for a given year in a country is calculated based on the preceding twenty years. Education measured as average years of schooling for people aged over 25 come from the Barro and Lee (2001) dataset available online at http://www.nber.org/pub/barro.lee/. These data are reported every five years between 1960 and 2000. I interpolate the data for intermittent years.

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