DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 08-07

Are Exporters Mother Nature's Best Friends?

Scott Holladay

University of Colorado

October 2008

Center for Economic Analysis
Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

Are Exporters Mother Nature's Best Friends?

Scott Holladay *

This draft: August 2008

Abstract

This paper empirically analyzes the relationship between international trade and plant level pollution emissions for U.S. manufacturers. I develop a theoretical framework to study emissions in a heterogenous firm international trade model. The results suggest that exporters should pollute less per unit of output than non-exporters in the same industry. Industries that face import competition should have fewer plants that generate high levels of emissions per unit of output. Their average emissions per output level should also be lower than other industries that are sheltered from international competition. These implications are tested against a unique dataset built by combining plant level emissions data from the EPA and plant characteristic data from the National Establishment Time Series. The data set consists of 15,000 plants observed over 12 years and includes 8-digit SIC industry definitions. The empirical results confirm that exporters pollute around 8% less per unit of output than non-exporters. These results are consistent with a nearest-neighbor matching procedure used to address potential unobserved variable bias. I use this framework to examine the channels through which productivity impacts emissions. Industries that face import competition pollute 0.75% less than more sheltered industries. This difference is due to the exit of small firms with high levels of emissions per output. I find no evidence that this effect is related to polluting plants relocating in search of lower levels of environmental regulation.

Keywords: Trade and environment, Firm heterogeneity, Plant-level emissions
JEL Codes: F1, Q5

*Department of Economics, 256 UCB Boulder CO 80309-0256, E-mail: james.holladay@colorado.edu.

Introduction

Deepening cross border links have brought increased attention to the impacts of international trade on the environment. There are significant economic literatures analyzing the effect of trade liberalization on pollution, the pollution haven hypothesis, the Environmental Kuznet's Curve and the impact of environmental regulation on trade. Despite all this attention, surprisingly little is known about how international trade affects individual polluting plants. This work focuses on the impact of international trade on plant polluting behavior and the impact of this behavior on aggregate pollution emissions at the industry level.

The theoretical literature has produced conflicting results for the influence of international trade on pollution levels. For example, Copeland and Taylor (1995) find that trade liberalization can lead to an increase or decrease in pollution depending on how incomes differ across countries that liberalize. Cole and Elliott (2003) suggest that models which use differences in environmental policy to generate trade between countries find an increase in emissions after liberalization. Models that use differences in endowments to generate trade typically find a decrease in emissions post-liberalization. These conflicting results suggest the need for empirical studies of the impact of trade on pollution emissions.

Much of the empirical work analyzing the impact of globalization on the environment relies on cross-country variation in pollution levels and trade behavior. Antweiler *et al* (2001) compare levels of openness to pollution concentrations and find that greater openness is associated with small, but significant decreases in pollution. Frankel and Rose (2005) employ instruments to control for possible endogeneity in trade policy, environmental policy and income levels. They also find openness associated with decreases in pollution levels, though the results are not statistically significant for some pollutants. This literature separates the impact of trade liberalization on the environment into three parts: the impact generated by increased economic activity (the scale effect), the changing industry mix (the composition effect) and the impact of increased income on environmental regulation (the technique effect). Unfortunately these effects do not explain how polluting establishments or industries respond to changes in trade levels.

There is an extensive international trade literature examining firm level heterogeneity's impact on international trade behavior. This research has found that firms that serve foreign markets through exports tend to differ substantially from firms that only enter domestic markets. Exporters tend to be larger, more productive and pay workers more than their competitors[1]. Melitz (2003) introduce heterogenous firms to an international trade framework. Potential entrepreneurs draw a productivity at random then decide whether to set up business and enter foreign markets. Fixed costs to enter the market and additional fixed costs to export ensure that only the most productive firms export. In addition to its role in determining international trade outcomes, productivity also plays an important role in determining

[1] See Bernard and Jensen (2004) and Bernard, Eaton, Jensen and Kortum (2003) among many others.

an establishment's pollution profile. Cole *et al* (2005) examines the impact of firm level characteristics and environmental regulation on industry level emissions for manufacturing plants in the UK. They find emissions to be positively related to capital intensity and negatively related to firm size and productivity. Earnhart (2006) finds that better managed firms (measured by return on sales) have higher levels of environmental management in the US chemical manufacturing industry.

This study takes advantage of the relationship between international trade, environmental performance and productivity to analyze the impact of trade on individual polluting plants through productivity differences. The next section introduces heterogenous polluting firms to a trade model. The model generates several testable implications about the relationship between trade status and pollution levels. The third section describes the unique dataset that has been collected to test these implications and works through the empirical analysis of the relationship. The final section draws conclusions and suggests avenues for future research.

Theoretical Framework

This section develops a simple framework that adds pollution emissions as a by-product of production to a trade model developed in Melitz (2003). This framework is used to explore the behavior of polluting plants in conjunction with international trade status and policy. Plants differ in productivity, which is exogenously determined. Pollution emissions are a function of output and productivity. There are fixed costs to enter the market and additional fixed costs to serve foreign markets. These costs ensure that the entrepreneurs with the lowest productivity exit and only the most productive plants are able to serve foreign markets. The relationship between exporting behavior and productivity, coupled with the relationship between productivity and emissions generates a channel through which international trade can impact pollution level.

In the Melitz model there is only one factor (labor) that is used by a continuum of establishments to produce a unique variety. Potential entrants pay a fixed cost (f_e) and then draw a productivity level (φ) at random. Labor is a linear function of output q: $l = f_e + \frac{q}{\varphi}$. Higher productivity is modeled as a reduction in marginal cost. Entrants who receive a low productivity draw expect to earn negative profits and will choose to exit without producing. The remaining establishments compete in the domestic market and can choose to pay an additional fixed cost (f_x) to serve foreign markets by exporting. Because each plant receives the same market price, only those with the lowest marginal costs can afford to endure the additional fixed costs required to enter export markets. This framework produces two cut-off productivity levels: φ^*, the cutoff productivity for entry and φ_x^*, the cutoff productivity for exporting. Because preferences are C.E.S., prices are a constant markup above marginal cost and the ratio of establishments' sales and revenue simplify to the ratio of those plants' productivities. Taken together this shows that exporters enjoy higher productivity, sales and revenue than establishments that do not serve foreign markets.

Pollution emissions are modeled as a by-product of production. Emissions are a function of productivity, output (which itself is a function of productivity) and an industry specific emissions intensity (z_j): $E_i j = f(q(\varphi_i), \varphi_i, z_j)$, where j is an industry subscript. Emissions increase with output, but it is not clear what impact productivity has on emissions holding output constant. Investment in recycling and other waste treatment programs is nonproductive, and may make it appear that lower productivity is associated with decreased emissions. On the other hand, more productive plants are able to produce more output from the same quantity of input. That may mean they can generate their output with fewer toxic inputs that must later be emitted. This issue has been addressed empirically by a number of studies of the determinants of firm level emissions. These studies consistently find that high levels of productivity are associated with lower levels of emissions after controlling for output level[2]. For this reason, emissions are modeled as a decreasing function of productivity. Possible explanations for this relationship are explored in the empirical section below.

This study seeks to explain the impact of international trade on both polluting establishments and industries. The most straightforward implication of this analysis is that exporters pollute less than non-exporters after controlling for output[3] and industry differences. Exporters are more productive than non-exporters, but they also have greater output so the relationship between export status and total emissions depends on the relative strength

[2]These results tend to be a by-product of the literature that analyzes the productivity impacts of environmental regulation. See Gray and Shadbegian (2003), Shadbegian and Gray (2005), Earnhart (2006) and Cole *et al* (2005) for examples.

[3]In this framework output is completely determined by productivity so it is impossible to compare two firms (in the same industry) with the same output and different productivity levels

of these effects. If the productivity effect outweighs the output effect then exporters should pollute strictly less than non-exporters despite differences in output. On the other hand, if the output effect is strong, exporters will pollute more than non-exporters.

Perhaps more interesting is the impact of increased imports on emissions. While most countries strongly encourage exports, imports tend to be less popular politically. The impact of import competition on job growth and wages has been studied extensively, but there has been comparably little focus on the impact of imports on individual polluting establishments. Melitz (2003) has shown that trade liberalization leads to a smaller number of firms and increase in the average productivity compared to autarky. The least productive firms exit and those firms that export are able to take advantage of the resources freed up by this exit to increase total sales. The change in total output is not clear. Less productive firms that do not exit see a decrease in output while the more productive exporting firms experience an increase in output. This makes predicting the total change in emissions after a trade liberalization difficult. There are several straightforward implications for the distribution of establishment level emissions within an industry. Import competition should force the least productive firms to exit the market. Those plants will tend to pollute more per unit of output than their more productive competitors. Industries facing import competition should have the left side of their emissions per unit of output distribution truncated by the exit of less productive firms. The variance of emissions per unit of output within industries that face import competition should be smaller than industries that do not face international competition. The relationship between productivity and sales suggest that similar distributional results should hold for sales as well.

This framework can also be used to analyze concerns about the pollution haven hypothesis, which argues that countries will attempt to attract polluting firms and industries by lowering environmental regulation. This appears to be at odds with the prediction of the model described above. If polluting firms were leaving countries with strict environmental regulation for more enticing locales, the firms that pollute the most (without regard for output) would be the ones that would be most likely to move. Those establishments would have the most to gain from reduced environmental compliance cost. If environmental regulation were driving location decisions for polluting plants the distribution of plant emissions would likely be truncated on the right as large polluters moved abroad and served the local market through exports.

Empirical Analysis

The model described in the previous section generated several straightforward implications for the relationship between international trade and pollution emissions. The first is that exporters within an industry should pollute less than non-exporters after controlling for differences in output. The second set of implications involve the impact of import competition on polluting firms and industries. Industries facing foreign competition should produce less emissions after controlling for output. These industries should also have a smaller variance in emissions than non-import competing industries. The smaller variance should come from a truncated right side of the emissions per unit of output distribution as a result of the exit of the most polluting firms. This section will seek to test these implications against the data, which requires measures of pollution emissions, total output, industry and exporting status.

Data

This paper relies on a unique dataset to test implications of the model outlined in the previous section. The data are constructed by merging the National Establishment Time Series (NETS) with the EPA's Risk-Screening Environmental Indicators (RSEI). The NETS is complied from Dunn and Bradstreet data on creditworthiness by Walls and Associates. Dunn and Bradstreet collects establishment level information that is used to generate credit scores. These scores are required to receive government contracts and are used to make decisions about accepting payment, leasing equipment or office space and setting financing terms. The data is collected by surveying establishments, tracking payment histories with other establishments and through research in trade publications and news archives. Neumark *et al* (2004) analyzed the NETS data and compared it to data collected by the Current Population Survey and the Current Employment Statistics Payroll Survey. They find that the NETS data on employment is comparable to that reported in the CPS and CES. They also use a media search to find stories about plant relocation. The NETS reflected around three-quarters of the moves that crossed a county or city line. That rate is similar to the rates found in Lexis-Nexis and Hoovers.com company location datasets. The data is annual from 1988-2006 with observations on the number of employees, value of sales, exporter status, information on corporate parents, children, siblings, SIC codes at the 8-digit level and credit rating among many other variables. The NETS contains no information on capital making estimating productivity using a production function approach impossible. The data set acquired for this study contains about 35,000 manufacturing establishments that have been listed in the RSEI at one time.

The RSEI is an establishment level record of toxic pollution emission collected by the EPA. Manufacturing establishments that release more than a thresh-hold level of toxic chemicals must report how those chemicals are disposed of to the EPA. That information is used to build an annual report on emissions called the Toxic Release Inventory. This data is cross referenced with measures of the toxicity of each pollutant to build a measure of the hazard from pollution generated by each polluting establishment. That data is then combined with information on population density and age structure to create a measure of the risk of emissions to the nearby population. These measures, along with the total quantity of emissions, are reported annually for each establishment from 1988-2002. The data also contains a DUNS number field, which is the identifier used by Dunn and Bradstreet to index establishments, along with a variety of location information. This makes it possible to match NETS data to the emissions data in RSEI.

Due to incomplete data on location (and DUNS numbers) in the RSEI dataset, matching every polluting establishment is impossible. 74.7% of the establishments identified by the EPA match with observations in the

NETS each year. The RSEI observations that were not matched produce more pounds of emissions and have a higher hazard score, but there is no significant differences in the risk generated by those emissions. While there are differences in the level of emissions between the two groups, there are no differences in the ratios of any measure of emissions[4]. The merged dataset is an unbalanced panel of between 14,000 and 16,000 annual establishment level observations between 1990-2002. The matched variables are summarized in Table 1. To control for the price inflation the values of sales was divided by the manufacturing PPI deflator provided by the BLS[5].

Exporters' Environmental Performance

The model described in the previous section predicts that firms that draw productivity levels above the export cutoff should pollute less per unit of output than those who do not export. The merged NETS and TRI data will be used to compare the emissions of exporting and non-exporting firms after controlling for output and industry. Table 2 summarizes the differences between exporters and non-exporters across the observable variables. Exporters are larger as measured by both sales and employees, and the differences are significant at the 5% and 1% levels respectively. The exporters average nearly 21,000 fewer pounds of toxic emissions than their non-exporting competitors, but they do not fare as well in the broader mea-

[4]The difference between the matched and unmatched groups in pounds and hazard are significant at the 1% level. The differences between the groups risk scores and the ratio of pounds to hazard, pounds to risk and risk to hazard are not significant at the 10% level

[5]See Levinson 2007 for a description of the trade off between using industry specific and economy wide deflators.

sures of the damages from emissions. Exporters have significantly higher hazard and risk scores. The hazard score suggests that while exporters generate a smaller quantity of emissions those pollutants are more toxic. The final line compares the emissions per unit of output for each industry. Exporters generate far less pollution per dollar of sales than non-exporters on average, but the huge variance of both groups makes this difference insignificant at conventional levels. These results are generally consistent with the theoretical framework described above, but they do not control for difference in industry emissions intensity. If the United States has a comparative advantage in the production of less polluting goods, or the pollution haven effect has driven polluters to foreign countries the same pattern would emerge. The estimation equation is:

$$E_{ijt} = \alpha + \pi_W W_{ijt} + \beta X_{ijt} + \gamma_j + \delta_t + \epsilon_{ijt},$$

where i references a plant, j indicates an industry and t indexes years. The outcome variable, E_{ijt} is a plant-level measure of pollution from the RSEI such as pounds of emissions, hazard score or risk level. γ_j is a set of industry fixed effects that control for the differing levels of emissions intensity of production across industries and δ_t are year fixed effects. ϵ_{ijt} is the stochastic error term. W is a vector of plant-level characteristics such as sales, employees and credit ratings. X is an indicator variable that equals 1 if the plant exported any amount of its production and β is the parameter of interest. It measures the difference in plant level emissions between exporters and non-exporters conditional on all the plant-level characteristics and indicator variables. The combination of fixed-effects guarantee that β is identified from variation between exporters and non-exporters in the same industry during the same year. The model does not include establishment fixed effects because there is such a high degree of persistence in exporting. Fewer than 1% of establishments in the sample switch their export status during the sample period. This is consistent with Bernard and Jensen's (2004)findings on export behavior over time.

The regression results are described in Table 3. They examine the relationship between exporting status and pollution emissions after controlling for industry type. Pollution emissions are measured in pounds of emissions as reported by the RSEI. Industry classifications are at the 6-digit SIC level as reported in the NETS and confirmed (at the four-digit level) in the RSEI. In regression 1 the impact of exporter status is measured without controlling for sales. This tests the relative size of the productivity effect on emissions (negative) and the output effect (positive). The regression includes industry fixed effects at the SIC 6-digit level to control for the industry specific emissions intensity (z_i) which is not observed. The results indicate that an exporter pollutes around 7% more than a non-exporter in the same industry. This implies that output effect outweighs the productivity effect. It also implies that the United States has a comparative advantage in polluting goods.

The stronger implication of the theoretical framework was that an exporter should pollute less than a non-exporter in the same industry after controlling for output. This is accomplished by including establishment sales as reported in the NETS in regression 2. The results suggest that exporters pollute around 8% less than non-exporters after controlling for output. This regression also makes it possible to estimate the magnitude of the output effect. A 1% increase in sales is associated with a 0.6% increase in emissions. Environmental regulations have been strengthening with time so if newer plants are more likely than average to be exporters, this may bias the exporter coefficient downward. To address this problem year fixed effects are included. A similar issue arises with plant location. Certain states have stricter environmental regulations. If establishments in those states are more likely to export, the export coefficient may be biased downward. To address this concern state fixed effects have been added to the regression[6]. The results of the regression including these fixed effects have been included in regression 3. In this specification β is identified from variation between exporters and non-exporters in the same industry, during the same year that are located in the same state. The additional controls cause a small change in both the sales and export coefficients and the significance of the export coefficient drops from the 5% to 10% level. The additional controls do not change the conclusion that exporters pollute less than non-exporters after controlling for output.

The final regression includes additional controls that may be related to export status and emissions. The number of employees can be thought of as proxying for the capital intensity of production, which is closely related to pollution emissions. The more employees it takes to produce a given amount of output the more capital the plant likely possesses. By including

[6]These regressions have also been calculated using county fixed effects and two-digit SIC fixed effects and the results were similar. Due to computational restrictions six-digit SIC fixed effects and county fixed effects cannot be run at the same time

the number of employees and controlling for output, the issue of capital intensity is partially addressed. Establishments that relocate often may be moving to take advantage of changes in environmental regulation and/or exporting infrastructure. To control for that possibility the number of times a firm has changed location during the time period is included as a control in this regression. The additional controls reduce the output effect of sales on emissions slightly, but it has no impact on the export indicator variable.

Regressions 1-4 confirm that, after controlling for output, exporters generated fewer emissions than non-exporters. While, to my knowledge, this fact has never been documented, it is related to a debate in the environmental economics literature about the determinants of firm level emissions. There are several hypothesized channels through which productivity may affect emissions. Larger firms tend to be the most productive and have a higher public profile and therefore seek to limit pollution. It is also possible that productive firms are better able to control the long-term liability of emitting pollution. Less productive firms may be more worried about the company's survival than minimizing a potential liability which may not appear for many years. Some authors have argued that the most productive firms locate in the regions with the strictest environmental regulations and are therefore compelled to pollute less. A final hypothesis suggests that the same management skills that generate frequent innovation and high productivity can be applied to preventing pollution emissions. While there has been research indicating that highly productive firms pollute less, there is no consensus on why this may be the case.

Konar and Cohen (1997) argue that more productive establishments may pollute less because they are more concerned with the long term liability that toxic emissions may generate. More productive firms have a larger incentive to reduce their long term liability, since they are more likely to survive to see claims made against them. Less productive firms are concerned with the day-to-day struggle of staying in business and do not worry about the long term liability that toxic emissions will bring. If this were, the case we would expect the most productive firms to reduce their liability by reducing the level of emissions and the toxicity of their emissions. This suggests exporters should have hazard and risk scores substantially lower than non-exporters. Regressions 5-7 show that this is not the case. In each regression the dependent variable is a different measure of plant level emissions. Regression 5 is similar to regression 2 above, except the dependent variable has not been logged to make it comparable to the other regressions in this table[7]. Exporters produce around 62,300 pounds fewer emissions than a non-exporter in the same industry after controlling for sales. That point estimate is 21% of the average plant's emissions. Recall that hazard is a measure of the toxicity of an establishment's emissions. Exporters have higher hazard scores than non-exporters despite their productivity advantage, however the coefficient is insignificant. Risk measures the toxicity of emissions weighted by location. Again exporters have insignificantly higher scores than non-exporters. Liability is a function of the toxicity and the location of emissions more than the quantity. Hazard and risk scores are a better proxy for liability than pounds. Taken together they suggest that exporters actually emit pollutants

[7]Hazard and risk scores may be zero for small quantities of relatively non-toxic pollutants.

that are more toxic than their competitors in the same industry. They do produce fewer of those emissions.

Arora and Cason (1996) argue that large firms have higher public profiles and therefore must pollute less than their smaller competitors. Larger firms may receive more attention from regulators, watchdog groups and environmentally conscious consumers. In this framework exporters are larger than their competitors due to their productivity advantages. To test the impact of plant size on emissions the sample was stratified into 5 quintiles based on establishment sales[8] and regression 2 was run on each quintile. If firm size is the primary channel through which productivity impacts emissions, then export status (and the increased productivity it signals) should not have a negative impact on emissions among the smallest firms. Table 5 lists the coefficients and t-statistics for the log sales and the export indicator variables for each of the 5 regressions. In four of the five regressions the exporter coefficient is negative, in three of the regressions its is negative and significant. In no case was the exporter coefficient positive and significant. Among the smallest plants exporters may pollute more than non-exporters, but there is not the monotonic relationship predicted by the proponents of the high-profile polluter explanation. Figure 1 illustrates the same point. The left vertical axis shows the fraction of firms that are exporters (represented by the bars) and the right vertical axis represents the exporter coefficients. The bars are display the 95% confidence intervals and the squares represent the point estimates. The horizontal line is at 0 on the exporter coefficient axis,

[8]The results are robust to dividing the sample into quintiles by employees and using 10 and 20 groups.

so for the percentile groups' whose coefficient confidence interval entirely below the line exporters pollute significantly less than non-exporters after controlling for output. Among the 20-40 and 40-60 percentile groupings exporters pollute significantly less than non-exporters. This effect would not be predicted if firm size was the main driver of pollution behavior. The elasticity of sales on pollution emissions is between 0.6 and 1.0 for every group, with the exception of the smallest (for which the point estimate is -0.07). Firm size does not appear to have much impact on polluting behavior within different percentiles. These results are robust to defining size by the number of plant employees.

It is clear that exporters pollute less than non-exporters in the same industry after controlling for output. This is consistent with the model described in the previous section. It appears that this phenomena is a function of plant productivity and not firm size or liability concerns as proposed by previous authors. These results seem to support the view that more productive firms generate fewer emissions because they are better able to manage their production process to minimize waste of all sorts. This management expertise explanation was advanced by Earnhart (2007). The exact channel through which productivity impacts emissions is a subject for future research.

Matching Estimators

The previous section attempted to control for differences between exporters and non-exporters using available data. There are still some variables which may impact both emissions level and export status that remain unobserved. In an effort to control for these unobserved variables this paper implements a nearest neighbor matching estimator to examine the impact of exporting on measures of emissions after controlling for differences between the two types of establishments. Matching estimators are used to examine the impact of treatment on an outcome variable of interest. They work by matching two observations that are similar across the observable variables, but differ in the exposure to treatment. The different values of the outcome variable for those observations are used to identify the impact of treatment[9]. The export indicator is the treatment variable and the pounds of emissions is the outcome variable of interest. The other explanatory variables in the NETS serve as controls for exporting status.

The matching estimator is consistent if two conditions are met. First the level of pollution must be independent of export status after controlling for differences in observable establishment characteristics. Secondly there must be some overlap in observable variables between those that export and those that do not. If the observable variables do not share similar values, then it will be impossible to find similar establishments to compare for estimates of treatment effect. Nearest neighbor matching is extremely computationally intensive. The distance from each observation to every other observation must be calculated based on the matching variables. The procedure finds two observations that are nearest neighbors to each observation in the data set. The nearest neighbors are required to match exactly on industry (at the 6 digit level) and state. Groups with different exposure to the treatment

[9]See Abadie *et al* for a full description of matching estimators

variable (export status) were used to identify the impact of exporting on the pounds of emissions variable.

In the theoretical framework described above, there can be no exact matching of establishments that are exporters with those that are non-exporters in the same industry. Exporters are larger by definition. The nearest neighbor procedure will find close matches between the smallest exporters and the largest non-exporters giving this procedure a regression-discontinuity-type estimate. Unfortunately, even at the 6 digit SIC level, industry definitions are not specific enough to allow for true regression discontinuity estimation. These industry definitions produce the overlap necessary for the matching estimator to be consistent. Table 6 describes the average effect of export status on two plants that are the same across the matched variables. The results consistently show that exporters pollute less than similar non-exporters though the difference is not statistically significant. Each establishment was matched over its sales, number of employees, relocations and credit rating. In the first matching procedure establishments almost be in the same SIC 6-level industry. Plants that export had a sample average treatment effect (SATE) of 37,269 fewer pounds of emissions though this difference is not significant at standard levels. That amounts to around 12.6% of the average establishment emissions. This estimate is broadly similar to the one produced by the regression estimations above. Restricting matches by forcing establishments to be in the same state and from the same year reduced the significance of this impact. Estimating the impact on logged sales improves the significance of the estimated impact.

The matching was conducted separately for each year to study the impact of exporting status over time. The annual SATE's appear in table 7. Nine of the twelve yearly coefficients are negative. The Z-scores vary between insignificant and marginally significant. Splitting the sample size into twelve groups reduces the significance somewhat, but exporting appears to have a negative impact on emissions overall. The impact of exporting on emissions appears to be growing over time. The last three years of data (1999-2001) show the strongest treatment effect. This generates further evidence that exporters pollute less than non-exporters, which is consistent with the theoretical framework described above.

Import Competition's Impact on Emissions

The previous empirical analysis has examined the relationship between export status and pollution. Import competition's impact on plant and industry pollution dynamics is likely to be more interesting. Melitz (2003) finds that import competition will force the least productive firms to exit in a given industry. The model described above suggests that those plants should generate the most emissions per unit of output. Their exit should result in a truncated distribution of emissions per unit of output and a cleaner industry on average after controlling for output. Following Pavcnik (2002) a variable is created using the ratio of imports(m_j) in a given industry to that industry's total output (y_j):

$$ImportCompetition_j = \begin{cases} 1 & \text{if } \frac{m_j}{y_j} > 0.1, \\ 0 & \text{otherwise,} \end{cases}$$

which is an indicator for industries that face stiff import competition. Several different thresholds for exposure to import competition are tested.This variable is created using data from the NBER's collection of bilateral international trade date described in Feenstra *et al* (2002) and the productivity and output data described in Bartelsman and Gray (1996). The trade and productivity data are reported annually at the four-digit SIC level. Data for 1990 was used to construct this variable.

This effect is estimated using the following equation:

$$E_{ijt} = \alpha + \pi_W W_{ijt} + \lambda M_{jt} + \gamma_j + \delta_t + \epsilon_{ijt},$$

where, as above, E_{ijt} is a plant level measure of of emissions, W_{ijt} is a vector of plant characteristics that serve as controls and δ_t is set of year fixed effects. M_{jt} is an industry level indicator variable that takes a value of 1 if the industry faces import competition and a value of 0 if the industry does not. This variable is calculated at the four-digit SIC industry level, for this reason γ is a set of industry fixed effects at the two-digit SIC level in this specification. λ is the parameter of interest in this set of regressions. It is identified from differences in emissions levels between plants in the same two-digit industry, whose four digit industries differ in exposure to import competition.

The results of this specification are described in table 8. Regressions 8-11 test the various thresholds for defining import competition. Regression 8 uses a 15% ratio of imports to output, which is the same level used in Pavcnik (2002). At this level the impact of import competition is negative, but it is not statistically significant. Regression 9 reports a 25% threshold and regression 11 reports a 10% threshold. As the threshold increases the impact of import competition increases and becomes more statistically significant. Industries with imports greater than 25% of output pollute nearly 77% less per unit of output than other industries that do not face this high level of competition. The import competition variables are defined at the four-digit SIC level meaning that the industry fixed effects for these regressions must be at the two-digit SIC level. Regressions 12 and 13 examine the impact of exporting on regressions taking import competition into account. Regression 12 indicates that exporters pollute around 10% less than non-exporters in the same industry. The impact for exports in an import competing industry is even lager. Regression 13 uses an import competition-exporter fixed effect to estimate the impact of export status on plant level emissions in industries classified as import competing. The indicator takes the value 1 if firm is an exporter and in an import competing industry and 0 otherwise. Those firms pollute 57% less than other firms after controlling for output and the difference is significant at the 1% level. This suggests that the productivity effect described in the theoretical framework outweighs any output effect.

The theoretical framework also suggests that the establishments that exit an import competing industry should be the smallest, least productive ones with the highest level of emissions per unit of output. A straightforward test of this implication is to compare the size and emissions per unit of output level for firms facing import competition to those that are not. Table 9 compares the first percentile of firms that face import competition compared to those that do not for a few example two-digit SIC industries. These industries have the highest concentrations of firms in four-digit industries that face high levels of import competition. Import competition 15 equals to 1 indicates the size measures for establishments that face imports equal to at least 15% of total domestic output. In each case the smallest establishments that are subject to import competition are larger than those that are not. This is consistent with the smallest firms exiting the market due to import competition.

The theoretical framework further suggested that import competing industries should have a smaller variance of emissions per unit of output. Table 10 reports a series of industry level regressions to test these implications. In each regression the independent variable is the level of import competition for the four-digit SIC level industry. Regression 13 tests the impact of import competition on average industry pollution. As expected there is a small negative impact, but the coefficient is not significant. The average industry emissions drop when import competition is stiff. The results are similar if industry output is included as an explanatory variable. Regression 14 and 15 test the impact of import competition on the variance of industry sales and emissions. In both cases import competition reduces the variance, but the coefficients are not significant. Regressions 16 and 17 test the impact of import competition on the size of the smallest firms in an industry by using the 1^{st} percentile of the distribution as the dependent variable. Industries that face import competition have larger smallest firms, suggesting that the smallest firms have been forced exit (or never enter) the market. The fact that the smallest firms that face import competition pollute more than the smallest firms that do not suggests that the output effect outweighs the productivity effect.

The results described in this section are consistent with the theoretical framework described in the previous section. Taken together they suggest that import competition leads to the exit of the smallest firms. Those establishments tend to pollute more per unit of output than their competitors. Their departure reduces the industry output per unit of emissions. These results are not consistent with the pollution haven hypothesis, but further evidence is considered below.

Source of Imports

The results in the previous section have described the impact of import competition on pollution emissions. The results are consistent with the model described at the beginning of this study. The distribution of emissions per unit of output does not appear to be consistent with the pollution haven hypothesis, but because of the policy import of this issue, this study will further analyze the relationship between imports and the pollution haven hypothesis by considering the source of those imports and its impact on plant level emissions. This can be done taking advantage of the bilateral trade data described above. This data was used to pinpoint the source of imports. Those sources were then matched with their per capita GDP and measures of their environmental stringency from the Environmental Performance Index (EPI). The EPI compares countries across more than 20 measures of environmental outcomes and policies. This data was used to create a weighted average of environmental measures and income for each industry's imports. The higher the measure the better the environmental performance of the countries that import this sector's goods to the U.S. The measures of environmental performance and income embodied in U.S. imports are highly correlated, which reflects the strong relationship between environmental regulation and income.

If the reduction in emissions in import competing industries is due to pollution-haven-type effects then industries which receive the majority of their imports from countries with the lowest EPI scores should see the the biggest drops. This would be consistent with establishments relocating to take advantage of the lower levels of regulation. In fact, the results suggest that the source of imports has little impact on the reductions in emissions. Table 11 reports the regressions describing the relationship between the source of the imports and plant-level environmental performance. The EPI competition variable is the average of the environmental performance score for each country that exports goods to the U.S. weighted by the quantity of exports. The GDP competition variable is a similar variable measured for the GDP of the exporting country and the environmental competition variable uses a subset of EPI data to calculate a pollution score[10]. Regression 18 reports the impact of the EPI competition score. The higher the level of EPI competition embodied in imports the higher the level of emissions produced by plants in that industry. This relationship is neither particularly strong, nor statistically significant. Per capita GDP is highly correlated with environmental regulation levels. For that reason regressions 20 reports the

[10]In addition to pollution measures the EPI includes measure of ecosystem health. There is a high degree of correlation between ecosystem, pollution and aggregate EPI scores. The results described here are robust to the inclusion of other measures.

impact of the per capita GDP embodied in imports. Again the relationship is positive, but statistically insignificant. The final measure of environmental competition is the EPI's pollution prevention specific score, reported in regression 21. Again the relationship with establishment emissions is positive and statistically insignificant. Regression 19 tests the impact of the source of imports on the import competition variable described earlier. Introducing a measure of the environmental competition embodied in imports does not effect the conclusion that import competition drives down plant emissions. The final regression confirms that exporting plants pollute less than their competitors even after import competition and import source are taken into account. Further analysis of the relationship between import sources and plant level emissions is ongoing.

Conclusion

This study has sought to analyze the relationship between international trade and plant level environmental performance. The empirical results are largely consistent with a model of heterogenous plants that vary in productivity. The relationship between productivity and output per unit of emissions is strong and consistent. Exporters consistently pollute less than non-exporters after controlling for a laundry-list of other variables. Industries that face import competition tend to pollute less on average than those who do not. The higher the level of import competition the further the reduction in average emissions. The reduction in average emissions is a result of the exit of the smallest, least productive plants. These plants tend to generated more emissions per unit of output than their more productive competitors. This is inconsistent with plants relocating to take advantage of lax environmental regulation in other countries. To confirm that this result is not a function of the pollution haven hypothesis, this study takes advantage of the variation in sources of imports across industries. There source of imports seems to have little impact on the behavior of plant level emissions.

This study bring up a host of interesting questions about the impact of trade policy on pollution emissions. Most countries actively promote exporters. To the extent that exporting increases productivity, this should lead to a reduction in firm level emissions per unit of output and likely a reduction in overall emissions. Import competition is more sensitive politically, but the results of this study suggest that improvements in productivity generated by import competition should reduce plant level emissions in addition to broader economic efficiency gains. This leaves a host of interesting questions about the impact of trade policy (tariff rates, non-tariff barriers and antidumping cases to name a few) on plant emissions unanswered. Any trade policy behavior that protects low productivity plants is likely to have negative environmental consequences.

Citations

Abadie, Alberto, David Drukker, Jane Leber Herr and Guido W. Imbens "Implementing Matching Estimators for Average Treatment Effects in Stata." *Stata Journal.* Janurary, 2001. 1(1):1-18.

Antweiler, Werner, Brian Copeland and M. Scott Taylor, “Is free trade good for the environment?” *American Economic Review.* 91 (2001) 877-908.

Arora, Seema and Timothy N. Cason. “Why Do Firms Volunteer to Exceed Environmental Regulations? Understanding Participation in EPA’s 33/50 Program.” *Land Economics.* November, 1996 72(4):413-432.

Bartelsman, Eric and Wayne Gray. “The NBER Manufacturing Productivity Database.” NBER Technical Working Paper 205. October, 2006.

Bernard, Andrew B and J Bradford Jensen. ”Why do Some Firms Export?” *Review of Economics and Statistics.* May 2004, 86(2):561-569.

Bernard, Andrew B, Jonathan Eaton, J Bradford Jensen and Samuel Kortum. ”Plants, Productivity and International Trade.” *American Economic Review.* November 2003, 93(4):1268-1290.

Cole, Matthew A, Robert J R Elliott and Kenichi Shimamoto. ”Industrial Characteristics, Environmental Regulations and Air Pollution: An Analysis of the UK Manufacturing Sector.” *Journal of Environmental Economics and Management.* July 2005, 50(1):121-143.

Collins, Alan and Richard I. D. Harris. ”Does Plant Ownership Affect the Level of Pollution Abatement Expenditure?” *Land Economics.* May 2002, 78(2):171-189.

Copeland, Brian and M. Scott Taylor, “Trade and Transboundary Pollution.” American Economic Review. 85 (1995) 716-737.

Earnhart, Dietrich. ”The Effects of Financial Status on Corporate Environmental Performance: Liquidity, Solvency and ”Bottom Line Success.” *University of Kansas Working Paper.* August 2006.

Feenstra, Robert, John Romalis and Peter Schott. “U.S. Imports, Exports and Tariff Data 1989-2001.” NBER Working Paper w9387. December, 2002.

Frankel, Jeffery and Andrew Rose. “Is Trade Good or Bad for the Environment? Sorting Out the Causality.” *The Review of Economics and Statistics.* February, 2005. 85(1) 85-91.

Gray, Wayne and Ronald Shadbegian. “Plant vintage, technology, and environmental regulation.” *Journal of Environmental Economics and Management.* November, 2003. 46: 384-402.

Konar, Shameek and Mark A Cohen. ”Information as Regulation: The Effect of Community Right to Know Laws on Toxic Emissions.” *Journal of Environmental Economics and Management.* January 1997, 32(1):109-124.

Levinson, Arik. Technology, International Trade and Pollution from U.S. Manufacturing. *NBER Working Paper 13616.* November 2007.

Melitz, Marc J. ”The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity.” *Econometrica.* November 2003. 71(6):1695-1725.

Neumark, David, Junfu Zhang, and Brandon Wall. ”Employment Dynamics and Business Relocation: New Evidence from the National Establishment Time Series.” *Public Policy Institute of California Working Paper.* November 2005.

Pavcnik, Nina. “Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants.” *The Review of Economic Studies.* January, 2002 69:245-276.

Shadbegian, Ronald and Wayne Gray. “Pollution Abatement Expenditures and Plant-Level Productivity: A Production Function Approach.” *Ecological Economics.* August, 2005. 54 196-208.

Variable	N	Mean	Std. Dev.	Min	Max
Sales	148,085	307,931	885,846	0.0374532	72,200,000
Employees	148,085	294	692	1	27,000
Pounds	148,085	294,091	1,976,998	0.000172	250,000,000
Hazard	148,085	2,007	23,836	0	2,730,232
Risk	148,085	2,790	61,115	0	8,273,306

Table 1: Summary Statistics

Variable	Exporter	Non-exporter	Difference	T-stat
Sales	313,006	304,934	8,071	1.69 **
Employees	307	286	21	5.53 ***
Pounds of Emissions	280,841	301,745	-20,904	-1.96 **
Hazard Score	2,194	1,899	295	2.30 **
Risk Score	3,434	2,415	1,019	3.09 ***
Emissions Per Sale	4.3	67.1	-62.8	-0.93

Table 2: Comparing Exporters to Non-exporters

Note: Difference in means between exporters and non-exporters for selected variables. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Regression Num	1	2	3	4
Dep Var	Log Pounds	Log Pounds	Log Pounds	Log Pounds
Log Sales	.	0.60	0.58	0.54
		(43.77)***	(42.57)***	(33.90)***
Employees	.	.	.	0.02
(in 100's)				(5.60)***
Relocations	.	.	.	0.12
				(2.95)***
Export	0.07	-0.08	-0.06	-0.06
	(1.96)*	(-2.26)**	(-1.79)*	(-1.76)*
Constant	9.84	0.08	3.25	3.92
	(477.32)***	(0.34)	(2.41)**	(2.91)***
R^2	0.0006	0.08	0.09	0.10
N	148,085	148,085	148,085	148,085
FE	SIC6	SIC6	SIC6, State, Year	SIC6, State, Year

Table 3: Exporters' Pollution Emissions

Note: All standard errors clustered at the establishment level. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Regression Num	5	6	7
Dep Var	Pounds	Hazard	Risk
Log Sales	176,100	913.92	1,268.88
	(11.65)***	(5.52)***	(4.81)***
Export	-62,285	122.43	526.75
	(-2.08)**	(0.36)	(0.77)
Constant	-2,574,420	-1,3043.38	-18237.54
	(-10.73)***	(-4.83)***	(-4.28)***
R^2	0.01	0.004	0.006
N	148,085	148,085	148,085
Dep var avg	294,060	2007.17	2789.32
Fixed Effects	SIC 6	SIC 6	SIC 6

Table 4: Exporters' Emissions Measures

Note: Pounds are the quantity of emissions, hazard is a score that measures the quantity and toxicity of emissions and risk measures the quantity, toxicity and location of emissions. All standard errors clustered at the establishment level. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Percentile	Fraction Exporters	Export Coeff.	Export T-stat
0-20	25%	0.015	0.41
20-40	37%	-0.134	-4.24
40-60	41%	-0.134	-4.29
60-80	39%	-0.013	-0.42
80-100	41%	-0.197	-6.45

Table 5: Regression Coefficients From Firm Size Regressions

Note: The export coefficient and t-statistic are taken from the baseline regression with year and state fixed effects.

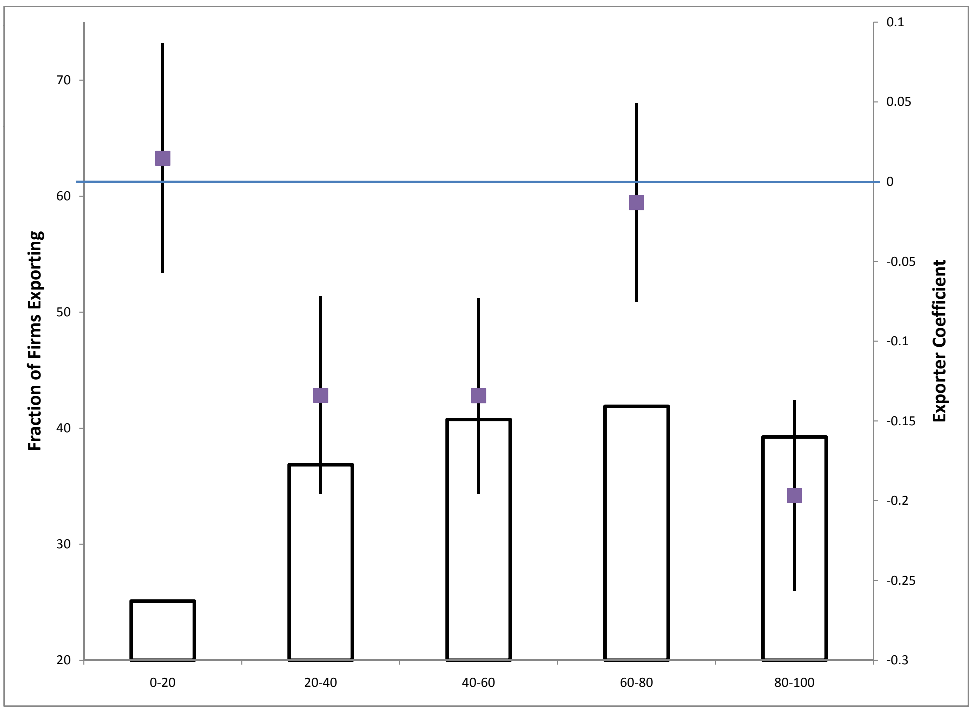

Figure 1: Firm size regressions and confidence intervals
Note: The bar indicates the fraction of firms in a given quintile (read off the left axis). The line is the 95% confidence interval for the exporter coefficient in the baseline regression (read off the right axis). The square represents the point estimate.

Dep Var	SATE	Z Score	P-value	Exact Match
Pounds	-37269	-1.24	0.215	SIC 6
Pounds	-44559	-1.44	0.151	SIC 6 State
Pounds	615	0	0.997	SIC 6 State Year
Log Pounds	-0.10798	-1.69	0.092	SIC 6

Table 6: Nearest Neighbor Matching Estimators
Note: The Sample Average Treatment Effect (SATE) measures the impact of treatment (in this case exporting) on emissions by comparing matched treated and untreated establishments that are similar across observable variables. Matching variables were sales, employees, relocations and credit ratings for each match.

Year	SATE	Z-score
90	23,321	0.39
91	-10,212	-0.15
92	-61,882	-0.83
93	38,174	0.46
94	-42,659	-1.54
95	-30,836	-1.12
96	-28,579	-1.01
97	-69,647	-1.66
98	13,375	0.18
99	-47,641	-1.28
00	-26,004	-1.60
01	-69,996	-1.67

Table 7: Average Treatment Effect By Year
Note: The Sample Average Treatment Effect (SATE) measures the impact of treatment (in this case exporting) on emissions by comparing matched treated and untreated establishments that are similar across observable variables. The SATE is measured in pounds of emissions.

Dep Var	8 Log Pounds	9 Log Pounds	10 Log Pounds	11 Log Pounds	12 Log Pounds
Log Sales	0.64	0.64	0.64	0.64	0.64
	131.08***	131.05***	131.07***	131.16***	131.18***
Import Comp 15	-0.11	.	.	.	.
	-1.1				
Import Comp 25	.	-0.77	.	-0.78	-0.56
		-3.91***		-3.94***	-2.73***
Import Comp 10	.		0.03	.	.
			0.44		
Export	.	.	.	-0.1	-0.1
				-7.17***	-6.93***
Ex-Im Interact	.	.	.	.	-0.57
					-3.70***
Constant	-0.59	-0.58	-0.59	-0.6	-0.6
	-7.34***	-7.31***	-7.35***	-7.52***	-7.54***
R^2	0.1	0.1	0.1	0.1	0.1
N	148,133	148,133	148,133	148,133	148,133
FE	SIC 2	SIC 2	SIC 2	SIC 2	SIC 2

Table 8: Import Competition

Note: Import Competition variables are industry-level dummies that indicate if more than X% of the sales in a particular industry come from imports. Those industries are defined as import competing. *** significant at the 1% level, ** significant at the 5% level, * significant at the 1% level

SIC Code	Sales	Employees	Import Comp 15
25	$2,968	8	0
25	$20,810	41	1
30	$2,646	3	0
30	$1,569	3	1
36	$2,244	3	0
36	$6,999	6	1
39	$966	2	0
39	$4,280	8	1

Table 9: Smallest Firms in Selected Industries

Note: This table displays the 1 percentile of firms by their exposure to import competition. Import competition 15=1 implies that more than 15% of industry sales occur through imports.

Dep Var	13 Avg Pounds	14 Var Pounds	15 Var Sales	16 Small Pounds	17 Small Sales
Import Comp	-131,808	-437,020	-466,358	23,737	61,083
	-0.2	-0.3	-0.91	4.75***	1
Constant	241749	586610	436647	458	23564
	6.10***	6.49***	13.93***	1.5	6.30***
R^2	0	0	0	0.05	0
N	442	441	441	442	442

Table 10: Import Competition's Effects

Note: These regressions test the impact of import competition on moments of the distribution of establishment sales and pollution emissions. *** significant at the 1% level, ** significant at the 5% level, * significant at the 1% level.

	18 Log Pounds	19 Log Pounds	20 Log Pounds	21 Log Pounds	22 Log Pounds
Log Sales	0.62	0.62	0.62	0.62	0.62
	113.77***	113.71***	115.18***	113.74***	113.78***
EPI Competition	1.69	1.54			1.04
	0.60	0.68			0.51
GDP Competition			1.25		
			0.59		
Pollution Competition				0.89	
				0.60	
Import Competition 25		-0.82	-0.82	-0.82	-0.82
		-4.13***	-4.14***	-4.13***	-4.15***
Export					-0.08
					-4.95***
Constant	-0.33	-0.32	-0.39	-0.32	-0.32
	-3.63***	-3.57***	-4.41***	-3.58***	-3.59***
R^2	0.1	0.1	0.1	0.1	0.1
N	122397	122397	122397	122397	122397
FE	SIC 2	SIC 2	SIC 2	SIC 2	SIC 2

Table 11: The pollution haven hypothesis and Environmental Competition
Note: The EPI, GDP and Pollution competition variables measure the average of EPI, GDP and Pollution Prevention Index across countries that send imports to the United States. The average is weighted by the value of imports. The import competition variable is an indicator that equals one if more than 25% of an industry's sales are from imports. *** significant at the 1% level, ** significant at the 5% level, * significant at the 1% level.