Are Exporters Mother Nature's Best Friends?

J. Scott Holladay*

July 15, 2010

Abstract

This paper documents a relationship between international trade and environmental performance at the establishment level. Using a panel of establishment-level data over the years 1990-2006, I estimate the relationship between export orientation, import competition and plant level characteristics. I find a robust relationship between international trade and plant level pollution emissions. Exporters emit 5.3% less than non-exporters after controlling for output and their emissions are significantly less toxic relative to non-exporters. Import competition is associated with the exit of the smallest, most pollution intensive plants. There is no evidence that this result is caused by polluting firms relocating to country's with low levels of environmental regulation and importing back into the U.S. This result provides an additional channel through which trade liberalization may impact pollution levels, which has implications for the previous trade-and-environment literature. Additionally, I explore the channels through which productivity, international trade and environmental performance may be related. I am able to rule out liability, but not establishment size and management quality. Even after controlling for these channels there remains an unexplained relationship between international trade and emissions. Finally, I develop a theoretical framework that is consistent with the empirical findings above. The empirical results are quite robust and suggest a strong relationship between international trade, environmental performance and plant-level productivity, but the direction of causality remains something of a mystery.

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

Acknowledgements: Thanks to Wolfgang Keller, James Markusen, M. Scott Taylor, Randy Walsh and seminar participants at the NBER Summer Institute, CU Environmental Workshop and Empirical Investigations in International Trade Workshop for helpful comments. The author gratefully acknowledges funding from the Ewing Kauffman Foundation to purchase data.

*NYU School of Law, james.holladay@nyu.edu

1 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 of this attention, surprisingly little is known about international trade's effect on individual polluting establishments. This paper focuses on the relationship between international trade orientation and environmental performance at the plant level.

The theoretical literature has produced conflicting results on 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) introduces 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 explain why only the most productive firms export. In addition to its role in determining international trade outcomes, productivity also plays an important role in determining an establishment's pollution profile. Cole et al. (2005) examine 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 (the ability to reduce or eliminate pollution) in the US chemical manufacturing industry.

In this paper I seek to empirically assess the relationship between international trade, environmental performance and productivity. The results should provide grounding for future theoretical work and context for existing country-level empirical analysis. I discover a strong relationship between productivity, international trade and environmental performance and establish several stylized facts using a unique dataset describing plant characteristics and pollution levels. The results show that exporters generate significantly less pollution emissions than non-exporters and that those emissions are less toxic than other establishments in the same industry. Import competition appears to drive less productive, pollution-intensive establishments out of business. This could provide an important channel through which international trade liberalization can lead to reductions in overall emissions levels. Additionally, I test several hypothesized channels through which productivity may impact environmental performance and trade behavior. I find some evidence that establishment size and management quality may play a role, but no evidence that liability concerns are driving plant behavior. After controlling for hypothesized channels there is still a significant relationship between productivity, trade and pollution that remains unexplained.

[1]See Bernard and Jensen (2004) and Bernard et al. (2003) among many others.

Although I cannot rule out the possibility that these statistical relationships are caused by other factors, the overall patterns appear generally robust. Finally, I develop a theoretical framework consistent with the stylized facts gleaned from the data that ties environmental performance and international trade orientation to underlying establishment productivity.

This paper proceeds as follows. Section 2 describes the establishment level dataset constructed from several different sources. Section 3 analyzes exporters' environmental performance relative to non-exporters in the same industry, section 4 analyzes the impact of import competition on polluters in the United States, including searching for a pollution haven effect. Section 5 seeks to establish the channels through which environmental performance, international trade orientation and productivity are related. Section 6 lays a out a theoretical framework consistent with the data and section 7 concludes.

2 Data

This paper employs a unique dataset to test for relationships between international trade and environmental outcomes at the establishment level. The data are constructed by merging the National Establishment Time Series (NETS) with the EPA's Risk-Screening Environmental Indicators (RSEI). The NETS is compiled from Dunn and Bradstreet data on creditworthiness by Walls and Associates. Dunn and Bradstreet collect 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. (2005) analyze the NETS data and compare 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 of comparable quality the CPS and CES. They also use a media search to find reports of 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 consists of annual observations from 1990-2006 with including the number of employees, value of sales, an indicator variable if a plant exports, information on corporate parents, 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 unique manufacturing establishments that have disposed of toxic chemicals during the study period.

The RSEI is an establishment-level record of toxic pollution emission collected by the EPA. Manufacturing establishments that release more than a threshold level of any of the approximately five-hundred toxic chemicals listed by the EPA must report details on how these chemicals are disposed. Specifically, establishments must report the quantity and disposal media (air, water, landfill, etc.) for each listed chemical. That information is used to build an annual report on emissions called the Toxic Release Inventory. Most empirical research on emissions rely on pounds of toxic emissions as reported in the Toxic Release Inventory available on the EPA website.

Pounds of emissions, however, are an imperfect measure of the environmental risk generated by pollution. The chemicals on the EPA list are extremely heterogenous with respect to toxicity and some establishments produce huge qualities of relatively benign waste while others produce very small quantities of extremely hazardous chemicals. To address this issue, the Risk Screening Environmental Indicators weights emissions quantities by toxicity level as measured in epidemiological studies. This generates a hazard score that encompasses both the quantity and toxicity of emissions and produces a clearer picture of the damages caused by pollution. The hazard score is then combined with reported disposal media and population characteristics (density and age structure) in the area around the establishment to create a measure of the risk of emissions to the nearby population.

The RSEI contains annual data on these three measures of emissions (pounds, hazard and risk) for each establishment that exceeds the quantity threshold from 1988-2006. 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. I have used those fields 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 matched are larger as measured by pounds of emissions and hazard score, but there are no significant differences in the risk generated by those emissions. Unmatched establishments could not be assigned plant characteristic data from the NETS so I cannot compare the matched and unmatched establishments along those dimensions. 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.[2]

The merged dataset is an unbalanced panel of between 12,000 and 14,000 annual establishment level observations between 1990-2006. Approximately 7,500 of these establishments survive throughout the study period. To control for the price inflation the values of sales was divided by the manufacturing PPI deflator provided by the BLS.[3] The matched data set is summarized in Table 1.

3 Exporters' Environmental Performance

This section describes the differences in environmental performance between exporters and non-exporters. Table 2 summarizes the differences between exporters and non-exporters across several establishment characteristics. Exporters are larger as measured by both sales and employees. This result is consistent with the voluminous international trade literature on the importance of firm heterogeneity. 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 other firms in the same industry.[4] Despite extensive documentation of the differences between exporters and non-exporters and the sources of these differences, the differences in environmental performance between exporters and non-exporters have not been analyzed.

[2]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.

[3]See Levinson (2009) for a nice summary of the tradeoff between using industry specific and economy wide deflators.

[4]See Bernard and Jensen (2004) and Bernard et al. (2003) among many others.

Exporters produce around 23,600 fewer pounds of toxic emissions than non-exporters, for a difference of more than 7%. This emissions measure does not capture differences in the toxicity of the chemicals released by establishments. Exporters have marginally higher hazard scores than non-exporters and their emissions produce significantly more risk than non-exporters. Because the risk measure is a function of location it is difficult to assess the differences. Exporters produce somewhat more hazardous emissions than non-exporters, but they also may systematically locate in locations with dense populations (such as near the coasts) for reasons that have nothing to do with environmental performance. For that reason I will focus primarily on the pounds and hazard measures of emissions. The final line of table 2 compares the pounds of emissions per dollar of sales at exporting to domestic-only establishments. Exporters generate far more pollution per dollar of sales than non-exporters on average, but the huge variance of both groups makes this difference insignificant at conventional levels.

Following the firm heterogeneity literature I seek to analyze the difference in environmental performance between exporters and non-exporters within industries. I conduct a series of fixed-effect regressions to analyze the emissions conditional on establishment characteristics and industry. The estimation equation takes the form:

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

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 mean 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 (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. The β coefficient is 0.11 suggesting that exporters generate around 11% more emissions (measured in pounds) than their competitors in the same industry. Exporters tend to be larger than non-exporters so this difference could be attributable to establishment size or pollution intensity. In regression 2 I control for establishment-level output to separate the impact of plant size and pollution intensity. The β coefficient shifts to negative and significant at the 1% level. Exporters pollute around 5.3% less than non-exporters after controlling for size differences.

Differences in environmental regulations over space and time may significantly impact establishment environmental performance and be related to exporting status. For example coastal states, with relatively high per capita incomes, might have stricter environmental regulations and may also be more likely to be home to exporters seeking access to foreign distribution channels. Similarly, environmental regulations have been strengthening over time so if newer plants are more likely than average to be exporters, this may bias the exporter coefficient downward. To address these issues I include state and year fixed effects in regression 3. [5] The β coefficient remains negative and significant, but drops in magnitude to 0.036.

In the fourth regression I include 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

[5] 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.

produce a given amount of output the more capital the plant likely possesses. By including 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, again the β coefficient drops in magnitude, but remains significant at 1% level.

Regressions 1-4 confirm that, after controlling for output, exporters generated fewer emissions than non-exporters. The elasticity of emissions intensity is estimated to be between 0.57 and 0.50 depending on the specification. This could be due to significant fixed emissions required for manufacturing production or economies of scale in emissions. Perhaps large establishments are more likely to invest in abatement technology to reduce emissions or larger scale manufacturing allows for more efficient and less polluting production techniques. With existing data it is difficult to determine the source of this low elasticity.

4 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 might also be important. Melitz and Ottaviano (2008) finds that import competition will force the least productive firms to exit in a given industry.[6] The empirical results above suggest a relationship between productivity and emissions. This section further analyzes that relationship by estimating the impact of import competition and the environmental performance of polluting establishments. Following Pavcnik (2002) I create a variable using the ratio of imports(m_j) in a given industry to that industry's total output (y_j):

[6] Melitz (2003) finds that trade liberalization leads to exit of the least productive establishments due to factor market competition from the expanding exporters. Melitz and Ottaviano (2008) relies on a different channel to produce the same effect. In that model import competition leads to reduced markups in domestic markets which leads to exit of the least productive firms. While both channels may be leading to this effect I will concentrate on the expansion of import competition making the latter model more appropriate.

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

where T is a threshold level of import competition that serves as 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 Peter Schott's collection of trade data as described in Schott (2008).[7] The trade and productivity data are reported annually at the four-digit SIC level for the years 1990-2005.

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. It is identified from differences in emissions levels between plants in the same two-digit industry in the same year, whose four digit industries differ in exposure to import competition. Identification of λ comes from differences in environmental performance between establishments in the same two-digit SIC code that face differing levels of import competition as measured at the four-digit SIC level.

The results of this specification are described in table 4. Regressions 5-9 test the various definitions of import competition. Regression 5 uses a 0.25 ratio of imports to output. In 1990, 147 of the 455 four-digit SIC industries in the dataset faced that level of import penetration, but by 2005 over half of the industries have import penetration over 0.25. The impact of import competition on establishment emissions is positive and significant at the 1% level. Plants that face this level

[7] The import penetration data is only available through 2005 slightly cutting one year off the dataset and slightly reducing the sample size for regressions including import competition data.

of import penetration pollute around 16.7% more than those who do not. Regression 6 introduces an indicator variable for import penetration over 0.5. The indicator coefficient is negative and statistically significant at the 1% level. Establishments facing this high level of import penetration pollute nearly 12% less than their competitors in the same two-digit SIC industry who do not face such a high level of import competition. Additional regressions assessing different indicator thresholds suggest that as import competition increases the average level of plant level emissions decrease.

Regression 7 examines the impact of import competition using measures of import penetration directly rather than indicator variables for import competition. Import penetration enters the estimating equation in a non-linear fashion. The linear term is positive and the square term negative; each are significant at the 1% level implying that the import competition is associated with an increase in emissions at low levels of import penetration, but at higher levels the effect of increased import penetration is negative. A scatter plot shows that the variance of level of emissions per unit of output drops as the level of import penetration increases. The variance of emissions per dollar of output is 105.6 for plants facing import penetration levels between 0 and 0.25, but that variance drops to just 4.5 for establishments facing import penetration levels between 0.25 and 0.5. This reduction in variance comes from the reduction in establishments with extremely high levels of emissions per dollar of sales at higher levels of import competition. Figure 1 shows a scatter plot with import penetration on the horizontal axis and the pounds of toxic emissions divided by the dollar value of establishment sales on the vertical without controlling for industry. The dispersion of emissions per dollar of output drops off quickly as import penetration increases. This reduced variance explanation is consistent with the difference between the 0.25 and 0.5 indicator variables observed in regressions 5 and 6.

Regressions 8 and 9 examine the impact of import competition on hazard scores. Establishments facing import penetration levels of at least 0.25 actually have higher hazard scores than those facing slightly lower levels of foreign competition. When looking at higher levels of import competition the effect becomes negative. Establishments in industries with at least 0.5 import penetration have hazard scores 11.6% less than establishments in competing industries. Throughout each of these regressions the export coefficient remains negative and statically significant at the 1% level. Even after controlling for the impact of import competition into the U.S., exporters still pollute less than non-exporters as measured both in pounds and toxicity. Figure 2 illustrates the dispersion of plant hazard divided by plant sales as import penetration increases. The dispersion at low levels of import penetration is greater than the dispersion of pounds per sales, but the variance falls even more quickly, and at extremely high levels of import penetration there are no high hazard per dollar of output establishments.

The impact of import competition on polluters has implications for the trade and environment literature. The literature has separated the impact of trade liberalization on pollution emissions into three categories: the scale, technique and composition effects. These channels were first hypothesized by Grossman and Krueger (1993) and modeled explicitly by Copeland and Taylor (1994). The scale effect is the increase in pollution due to increased economic activity generated by a trade liberalization. The technique effect is a reduction in pollution due to increased demand for environmental quality (a normal good) after a trade liberalization. The composition effect is the change in pollution due to the changes in the production (or consumption) bundle generated by a trade liberalization. This effect may generate either increases or decreases in pollution.

The technique effect is typically modeled as consumers demand for environmental quality encouraging government to increase pollution taxes to reduce emissions. This channel is certainly a possibility, but it requires government to act in response to citizens' preferences in a way that may or may not be realistic. The results of this section suggest a possible alternative channel through which trade liberalization may lead to reduction in emissions. A trade liberalization may lead to increases in import competition which drives out the smallest, least productive and most pollution-intensive establishments. Empirical analysis comparing ambient pollution levels or aggregate emissions to trade volumes would identify this reduction in emissions, but it may be operating through industry dynamics instead of (or in addition to) the standard policy response modeled by papers in this literature.

Source of Imports

The results in the previous section have described the impact of import competition on pollution emissions. 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 the issue, I analyze the relationship between imports and the pollution haven hypothesis. To do this I consider the impact of the source country of imports into the U.S. on plant-level emissions. If the pollution haven hypothesis is driving this result then imports from countries with low levels of environmental regulation will be associated with the exit of pollution-intensive manufacturers, while imports from high regulation jurisdictions should have no effect. This can be tested by taking advantage of the bilateral trade data described above. The source of imports were matched with their per capita GDP and measures of their environmental stringency from the Environmental Performance Index (EPI) complied by Yale University. 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 where the weights are the fraction of total imports from each source country. 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 big decreases in pollution. Controlling for the sources of imports should also eliminate the statistical relationship between import competition and establishment environmental performance. In fact, the results suggest that the source of import competition has little if any effect on establishment emissions profiles and the relationship between emissions and imports is robust to controlling for import source. Table 5 reports the regressions describing the relationship between the source of the imports and plant-level environmental performance. Regression 10 is similar to regression 5 above, but includes the environmental competition and income competition measures. Competition from countries with high levels of environmental regulation is associated with a small increase in emissions. The coefficients are difficult to interpret directly because they are generated from a weighted average, but a one standard deviation increase in the environmental competition score (in the average industry this would be equivalent to ten percent imports coming from Denmark instead of Vietnam) is associated with a 6.7% increase in plant-level emissions. A one standard deviation increase in income competition (in the average industry this would be equivalent to ten percent imports coming from Hungary instead of Malaysia) is associated with a 3.4% decrease in establishment emissions. Most importantly the impact of high levels of import competition remains consistent. Establishments in industries facing import penetration rates above 0.5 pollute around 15.6% less than their competitors in less competitive industries even after controlling for the source of emissions.

Regression 11 is parallel to regression 6 above with the addition of the income and environmental competition variables. The the linear term is positive and the quadratic term is negative, implying an upside-down U shape relationship between import competition and plant level emissions. Regressions 12 and 13 shift the focus to hazard score from pounds of toxic emissions. Again controlling for the sources of imports has no impact on the previous conclusions. In this case the income and environmental competition variables are insignificant and small in magnitude. While the source of imports seems to have some impact on the quantity of emissions, it appears to have little or no impact on the toxicity of those emissions. The results of the analysis of the sources of imports suggest that the relationship between import competition and establishment environmental performance is not a function of a pollution haven hypothesis. Import competing establishments tend to pollute less per unit of output whether those imports are coming from high or low regulation jurisdictions. This is not consistent with pollution-intensive U.S. establishments relocating to countries with low levels of environmental protection and then importing their production back to the United States.[8]

[8] Note that these results are not evidence that the pollution haven effect does not exist, but that the environmental performance differences noted described above are not caused by the pollution haven hypothesis. See Levinsont and Taylor (2008) for a theory of the pollution haven hypothesis and an empirical assessment of its magnitude.

5 Channels through which Trade and Pollution are Related

There are several hypothesized channels through which productivity may affect emissions. The correlation between environmental performance and export orientation could operate through firm size. Large firms have a high public profile and therefore may 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 (summarized in table 6) describe the environmental performance of exporters across different measures of pollution intensity. Regression 5 is directly comparable to regression 2 in the previous table. Exporters pollute around 5.3% as measured in pounds, but nearly 13% less when measured in total hazard. Not only do exporters pollute less than other establishments in the same industry, but those emissions tend to be less toxic than those of their domestic-only competitors. Exporters tend to have a higher risk score than non-exporters. The RSEI risk score weights the hazard score by the population near the emissions. The relatively high risk scores of exporters may be due to the benefits of locating near ports, railroads and other transport hubs. These locations tend to have relatively low transport costs, access to high-skill labor and have high population density. If high productivity establishments like exporters determine their emissions performance based primarily on their long term-liability concerns, then they would be more motivated to reduce their risk score, which is the best proxy for liability from the RSEI data. Instead other factors seem to be more important in driving the plant location decision than the potential long-term liability of emitting pollutants in densely populated areas. It is unlikely that long-term liability concerns are dictating establishment-level environmental performance.

Arora and Cason (1996) argue that large firms have higher public profiles and therefore have a stronger incentive to reduce emissions 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[9] 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 7 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 a monotonic relationship as predicted by the proponents of the high-profile polluter explanation.

A final hypothesized channel through which productivity, international trade orientation and environmental performance could be related is by management quality. The debate over the relationship between environmental performance and management quality is summarized in Klassen and McLaughlin (1996). The authors suggest that high quality management may produce better environmental performance, perhaps by limiting waste. To test this channel I proxy for plant management quality using establishment credit rating from the NETS data.[10] The results are sum-

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

[10]Ashbaugh-Skaife et al. (2006) describe a strong positive correlation between measures of management quality

marized in table 8. Regression 16 introduces the credit rating variable to the baseline regression. Establishments with better credit ratings tend to pollute less all else equal, but the magnitude is fairly small. The average credit rating in the dataset is 74.7 and the standard deviation is 6.6. A one standard deviation increase in credit ratings is associated with a 2.8% decrease in the quantity of toxic releases all else equal. Controlling for credit rating has little impact on the exporter coefficient; even after controlling for management quality (by proxy) exporters generate around 5% fewer pounds of emissions than non-exporters.

Introducing management quality into the hazard regression also does not affect the conclusion that exporters pollute less than their domestic-only competitors. In fact, the magnitude of the exporter coefficient increases slightly when controlling for credit rating. Again establishments with higher quality management pollute less and the magnitude of the coefficient is much larger than in regression 16. In regression 17 I examine the impact of management quality on total risk from pollution emissions. Including credit rating in this regression reduces the statistical significance and magnitude of the exporter coefficient. This suggests that more productive, well managed establishments may be better at controlling their long-term lability than their competitors, but this effect may come more through location decisions than process innovations.

It is clear that exporters pollute less than non-exporters in the same industry after controlling for output. There are a variety of possible channels through which this relationship could operate. Several pathways appear to transmit the effect, but no single channel or combination of the channels explored here can fully explain the relationship. Unfortunately with this dataset the channel cannot be completely identified. The exact nature of the relationship among international trade orientation, environmental performance and productivity must remain something of a mystery.

6 Theoretical Framework

This section develops a simple framework that adds pollution emissions as a by-product of production to a heterogenous firm trade model similar to that developed in Melitz and Ottaviano (2008). This framework is consistent with the empirical relationship among international trade, environ-

and credit rating using information on German firms.

mental performance and plant-level productivity. In this framework 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.

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):

$l = f_e + \frac{q}{\varphi} + \eta,$

where η is an independent and identically distributed (i.i.d.) plant-level shock and $E(\eta)=0$. 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 participate in a monopolistically competitive 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. Preferences are standard constant elasticity of substitution over the endogenous measure of goods. It is straightforward to find the optimal consumption and expenditure share over varieties. Because preferences are C.E.S., prices are a constant markup above marginal cost and the ratio of two 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[11] (z_j): E_{ij}=f(q(φ_i), φ_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.[12] This is consistent with the empirical evidence on the relationship between environmental performance, international trade orientation and productivity described above. 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 framework 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 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 of these effects. If the productivity effect (the direct effect of reduced emissions through increased productivity) outweighs the output effect (the indirect effect of increased emissions due to increased output associated with an increase in productivity), 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.

This framework can be used to predict the impact of increased imports on emissions. Melitz (2003) has shown that in this model, trade liberalization leads to a smaller number of firms and

[11]The Melitz and Ottaviano (2008) model is a single industry model, but this extends the within sector treatment across industries. This framework cannot be used to make predictions on plant polluting behavior across industries. The within industry margin is more important for environmental and trade policy.

[12]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.

increase in the average productivity compared to autarky.[13] 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 after a trade liberalization is indeterminate in this model. 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 the total change in emissions after a trade liberalization ambiguous. The model does produce 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 lower end 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. These implications are consistent with the empirical facts described above.

In this framework productivity is exogenous and determines export orientation, environmental performance and response to import competition. While this is consistent with the data, the causality could run in another direction. For example, establishments in jurisdictions with strong local environmental regulations may be forced to pollute less, but may also have higher productivity through a Porter hypothesis effect,[14] in which regulation induces cost saving innovations which both reduce emissions and increase productivity. Yet another possible explanation is that exporters enjoy increased productivity through contacts with consumers in other markets.[15] This increased productivity could lead to improved environmental performance and generate the relationship observed in the data. Unfortunately this data set is not rich enough to distinguish between these hypotheses and the true nature of the relationship between international trade, pollution emissions and productivity remains an open question.

[13]This result holds in the long run when trade liberalization is multilateral.

[14]See Porter and van der Linde (1995) for a full description of the Porter Hypothesis. It should be noted that empirical evidence of such an effect is decidedly mixed.

[15]See Biesebroeck (2005) for an empirical estimation of productivity increases from entering export markets.

7 Conclusion

Despite a considerable economic literature on the relationship between international trade and pollution there has been little or no research on how individual polluting establishments respond to international trade. The importance of firm heterogeneity in international trade behavior suggests that considering the environmental performance of individual establishments may provide additional insights. In fact firm heterogeneity in environmental performance is significant and systematically related to international trade orientation. Exporters tend to pollute significantly less than non-exporters in the same industry. Further, import competition is associated with the exit of the most pollution-intensive establishments. This exit occurs regardless of the source of the imports suggesting that it is not an artifact of pollution-intensive plants relocating to areas of with lower environmental regulation and importing back into the United States.

The import competition result is particularly important in light of the empirical results on the relationship between international trade liberalization and pollution. Previous work has associated reductions in pollution levels after a trade liberalization with either increased environmental regulation (the technique effect) or trade induced changes in the relative size of different industries (the composition effect). If import competition leads to the exit of pollution-intensive establishments, it would be an additional channel through which trade liberalization could impact pollution. Comparing the relative importance of environmental regulation, changes in industry structure and within industry is left an important unresolved question.

I attempt to assess the channel that relates environmental performance to international trade and nominate establishment productivity as a likely causal factor. By analyzing several factors correlated with productivity, international trade orientation and environmental performance I am able to eliminate liability laws as an important channel, but both establishment size and management quality, which are higher in more productive plants, are associated with reduced emissions. Still after controlling for these channels a productivity effect on emissions remains unexplained. The exact nature of this relationship requires additional work.

The results lead to several important 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. Any trade policy behavior that protects low productivity plants is likely to have negative environmental consequences.

References

Antweiler, W., Copeland, B. and Taylor, M. S.: 2001, Is free trade good for the environment?, *American Economic Review* **91**, 877–908.

Arora, S. and Cason, T. N.: 1996, Why do firms volunteer to exceed environmental regulations? understanding participation in EPA's 33/50 program, *Land Economics* **72**, 413–432.

Ashbaugh-Skaife, H., Collins, D. W. and LaFond, R.: 2006, The effects of corporate governance on firms' credit ratings, *Journal of Accounting and Economics* **42**(1-2), 203 – 243. Conference Issue on Implications of Changing Financial Reporting Standards.

Bernard, A. B., Eaton, J., Jensen, J. B. and Kortum, S.: 2003, Plants, productivity and international trade, *American Economic Review* **93**, 1268–1290.

Bernard, A. B. and Jensen, J. B.: 2004, Why do some firms export, *Review of Economics and Statistics* **86**, 561–569.

Biesebroeck, J. V.: 2005, Exporting raises productivity in sub-Saharan African manufacturing firms, *Journal of International Economics* **67**(2), 373 – 391.

Cole, M. and Elliott, R.: 2003, Determining the trade-environment composition effect: The role of capital, labour and environmental regulations, *Journal of Environmental Economics and Management* **46**, 363–383.

Cole, M., Elliott, R. and Shimamoto, K.: 2005, Industrial characteristics, environmental regulations and air pollution: an analysis of the UK manufacturing sector, *Journal of Environmental Economics and Management* **50**, 121–143.

Copeland, B. and Taylor, M. S.: 1994, North-south trade and the environment, *Quarterly Journal of Economics* **109**, 755–787.

Copeland, B. and Taylor, M. S.: 1995, Trade and transboundary pollution, *American Economic Review* **85**, 716–737.

Earnhart, D.: 2006, The effects of financial status on corporate environmental performance: Liquidity, solvency and bottom line success, *University of Kansas Working Paper* .

Frankel, J. and Rose, A.: 2005, Is trade good or bad for the environment? sorting out the causality, *The Review of Economics and Statistics* **85**, 85–91.

Gray, W. and Shadbegian, R.: 2003, Plant vintage, technology, and environmental regulation, *Journal of Environmental Economics and Management* **46**, 384–402.

Grossman, G. M. and Krueger, A.: 1993, *Environmental Impacts of a North American Free Trade Agreement*, Vol. The U.S.-Mexico Free Trade Agreement, MIT Press, Cambridge, MA, pp. 131–184.

Klassen, R. D. and McLaughlin, C. P.: 1996, The impact of environmental management on firm performance, *Management Science* **42**(8), 1199–1214.

Konar, S. and Cohen, M. A.: 1997, Information as regulation: The effect of community right to know laws on toxic emissions, *Journal of Environmental Economics and Management* **32**, 109–124.

Levinson, A.: 2009, Technology, international trade and pollution from U.S. manufacturing, *American Economic Review* **99**.

Levinsont, A. and Taylor, M. S.: 2008, Unmasking the pollution haven effect, *International Economic Review* **49**, 223–254.

Melitz, M. J.: 2003, The impact of trade on intra-industry reallocations and aggregate industry productivity, *Econometrica* **71**, 1695–1725.

Melitz, M. and Ottaviano, G.: 2008, Market size, trade, and productivity, *Review of Economic studies* **75**(1), 295–316.

Neumark, D., Zhang, J. and Wall, B.: 2005, Employment dynamics and business relocation: New evidence from the national establishment time series, *Public Policy Institute of California Working Paper* .

Pavcnik, N.: 2002, Trade liberalization, exit, and productivity improvements: Evidence from chilean plants, *The Review of Economic Studies* **69**, 245–276.

Porter, M. E. and van der Linde, C.: 1995, Toward a new conception of the environment-competitiveness relationship, *Journal of Economic Perspectives* **9**.

Schott, P. K.: 2008, The relative sophistication of chinese exports, *Economic Policy* **23**, 5–49.

Shadbegian, R. and Gray, W.: 2005, Pollution abatement expenditures and plant-level productivity: A production function approach, *Ecological Economics* **54**, 196–208.

Table 1: Summary Statistics

Variable	N	Mean	Std Dev	Min	Max
Sales	$198,318	$38,400,000	$117,000,000	$1	$9,650,000,000
Employees	198,318	282	646	1	27,000
Pounds	198,318	318,387	2,004,250	0.00002	250,000,000
Hazard	198,318	2,230,000,000	25,300,000,000	0	3,480,000,000,000
Risk	198,318	1,772	46,148	0	7,934,812

Table 2: Comparing Exporters to Non-exporters

Variable	Exporter	Non-exporter	Difference	T-Stat
Sales	$39,800,000	$37,600,000	$2,200,000	4.01 ***
Employees	302.4	270.8	31.6	10.44 ***
Pounds	303,293	326,893	-23,601	-2.52 ***
Hazard	2,370,000,000	2,150,000,000	220,000,000	1.88*
Risk	2,317.3	1,464.1	853.2	3.95 ***
Emissions per Sale	0.4148	0.0469	0.3679	0.97

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.

Table 3: Exporters' Pollution Emissions

Regression Num	1	2	3	4
Dep Var	Log Pounds	Log Pounds	Log Pounds	Log Pounds
Log Sales		0.566***	0.558***	0.499***
		(116.77)	(115.40)	(90.66)
Employees				0.000264***
				(22.48)
Relocations				0.0226
				(1.52)
Export	0.107***	-0.0528***	-0.0361***	-0.0288**
	(7.86)	(-3.98)	(-2.73)	(-2.18)
Intercept	9.731***	0.494***	3.079***	3.944***
	(1251.58)	(6.21)	(6.53)	(8.34)
r2	0.000314	0.0651	0.0862	0.0885
N	198,318	198,318	198,318	198,318
FE	SIC 6	SIC 6	SIC 6, State, Year	SIC 6, State, Year

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

Table 4: Import Competition

	5	6	7	8	9
	Log Pounds	Log Pounds	Log Pounds	Log Hazard	Log Hazard
Log Sales	0.550***	0.552***	0.550***	0.778***	0.784***
	(92.56)	(92.80)	(92.38)	(91.78)	(92.18)
Emp	0.000221***	0.000220***	0.000221***	0.000165***	0.000162***
	(18.19)	(18.14)	(18.21)	(9.52)	(9.35)
Export	-0.0775***	-0.0773***	-0.0790***	-0.217***	-0.218***
	(-5.21)	(-5.20)	(-5.31)	(-10.22)	(-10.25)
Import Comp25	0.167***			0.748***	
	(9.13)			(28.77)	
Import Comp50		-0.117***			-0.116***
		(-3.73)			(-2.60)
Import Penetration			0.214***		
			(7.77)		
Import Penetration^2			-0.0105***		
			(-3.76)		
Intercept	0.640***	0.668***	0.660***	2.102***	2.230***
	(6.63)	(6.93)	(6.84)	(15.29)	(16.18)
FE	SIC 2	SIC 2	SIC 2	SIC 2	SIC 2
r2	0.0842	0.0838	0.0841	0.0799	0.0751
N	158,790	158,790	158,790	158,790	158,790

Note: Import Competition variables are four digit SIC level dummies that indicate if more than X% of the sales in a particular industry come from imports. *** significant at the 1% level, ** significant at the 5% level, * significant at the 1% level

Table 5: Sources of Import Competition

Regression Num	10	11	12	13
Dep Var	Log Pounds	Log Pounds	Log Hazard	Log Hazard
Log Sales	0.522***	0.522***	0.785***	0.782***
	(76.21)	(76.09)	(81.79)	(81.53)
Emp	0.000205***	0.000207***	0.000121***	0.000127***
	(15.31)	(15.43)	(6.44)	(6.77)
Export	-0.0527***	-0.0538***	-0.208***	-0.211***
	(-3.06)	(-3.13)	(-8.64)	(-8.79)
Import Comp50	-0.156***		-0.256***	
	(-4.51)		(-5.27)	
Enviro Comp	14.4***	14.0***	1.14	0.0113
	(16.91)	(16.50)	(0.96)	(-0.01)
Income Comp	-27.0***	-26.7***	1.70	2.06
	(-8.67)	(-8.57)	(0.39)	(0.47)
Import Penetration		0.103***		0.505***
		(3.26)		(11.49)
Import Penetration^2		-0.00494		-0.0212***
		(-1.53)		(-4.69)
Intercept	1.313***	1.296***	2.646***	2.582***
	(11.74)	(11.58)	(16.91)	(16.50)
FE	SIC 2	SIC 2	SIC 2	SIC 2
r2	0.0843	0.0843	0.0790	0.0798
N	158,790	158,790	158,790	158,790

Note: Import Competition variables defined as above. Enviro and Income competition weight imports by the level of environmental protection or average per capita income in the source country. *** significant at the 1% level, ** significant at the 5% level, * significant at the 1% level

Table 6: Exporters' Emissions Measures

Regression Num	10	11	12
Dep Var	Log Pounds	Log Hazard	Log Risk
Log Sales	0.566***	0.764***	0.502***
	(116.77)	(112.93)	(80.85)
Export	-0.0528***	-0.129***	0.0337**
	(-3.98)	(-6.94)	(1.97)
Intercept	0.494***	2.657***	-5.418***
	(6.21)	(23.95)	(-53.16)
r2	0.0651	0.0611	0.0367
N	198,318	198,318	198,318

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.

Table 7: Regression Coefficients From Firm Size Regressions

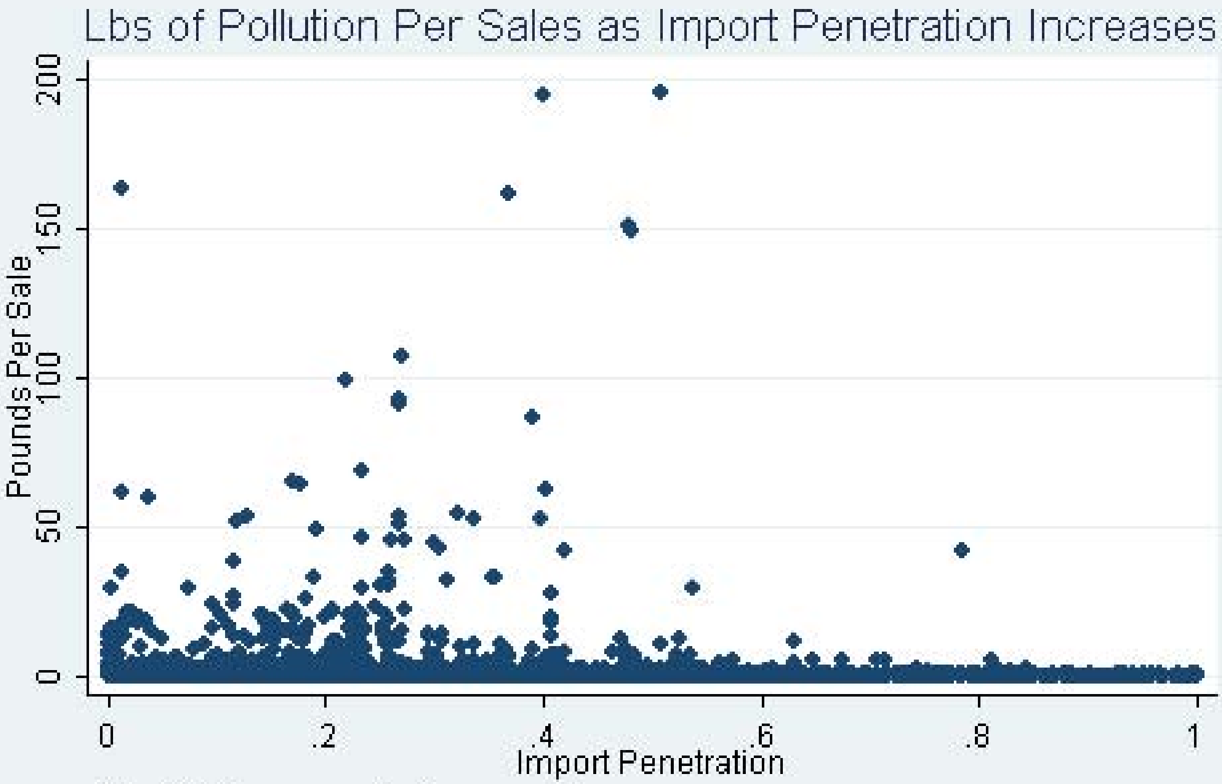
Percentile	Fraction Export	Exporter Coefficient	Exporter T-stat
0-20	24.2%	0.0374	1.10
20-40	35.5%	-0.121	-4.05
40-60	39.9%	-0.132	-4.41
60-80	40.8%	0.0330	1.12
80-100	39.2%	-0.156	-5.52

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

Table 8: The Impact of Management Quality

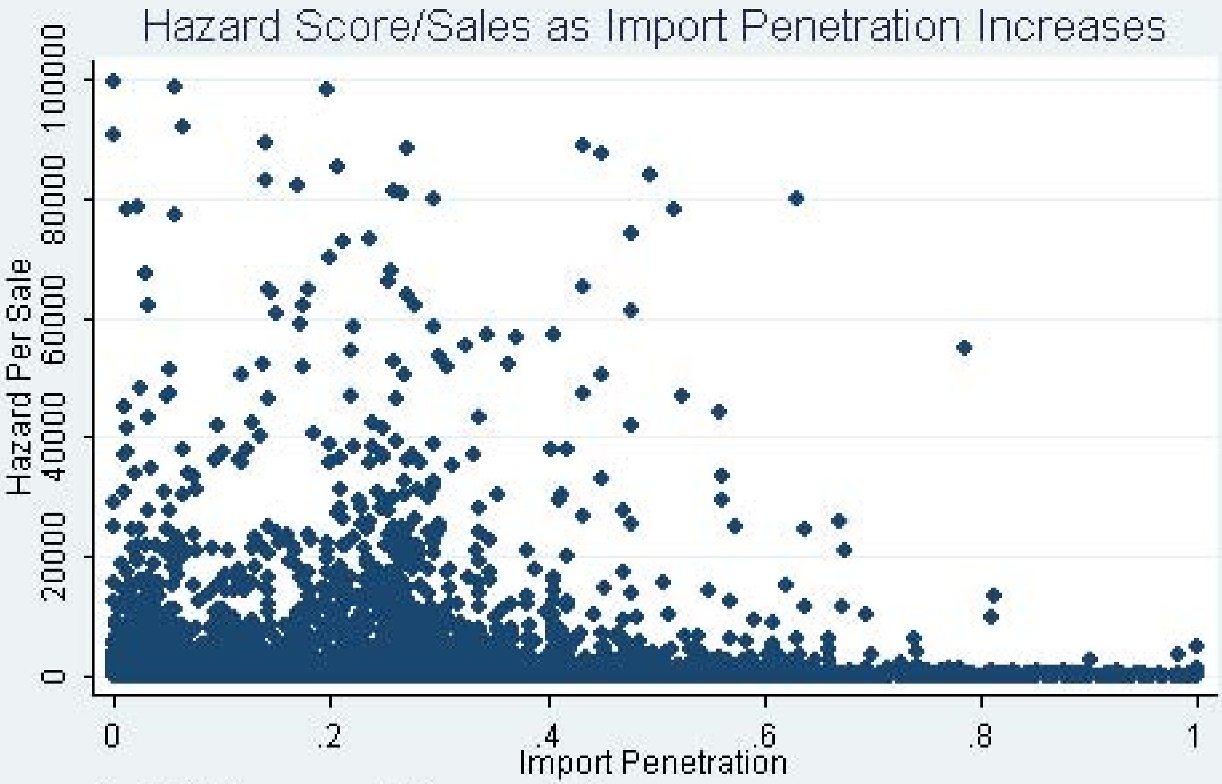
Reg Num	13	14	15
Dep Var	Log Pounds	Log Hazard	Log Risk
Log Sales	0.598***	0.811***	0.527***
	(115.63)	(112.47)	(79.43)
Credit Rating	-0.00429***	-0.0124***	-0.00279**
	(-4.46)	(-9.25)	(-2.25)
Export	-0.0547***	-0.137***	0.0164
	(-4.02)	(-7.25)	(0.93)
Intercept	0.274**	2.801***	-5.624***
	(2.42)	(17.71)	(-38.64)
r2	0.0684	0.0654	0.0379
N	198,318	198,318	198,318

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



Note: Outliers removed to improve scaling.

Figure 1



Note: Outliers removed to improve scaling.

Figure 2