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Import Competition and Environmental Performance: Evidence from Mexican Plant-level and Satellite Imagery Data

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Import Competition and Environmental Performance: Evidence from Mexican Plant-level and Satellite Imagery Data

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Abstract

We investigate the impact of international trade, in particular import competition, on the environment. We tackle this question from a new perspective, i.e., whether trade liberalization affects production plants' environmental performance by changing incentives of firms to undertake two types of investment: investment in the environment and in efficient energy use, and investment in technology in general. Identifying such effects empirically has been challenging. Not only is it unusual to obtain direct information on plants' environmental performance as well as plants' effort towards environmental protection; it is also difficult to find an exogenous source of variation in tariffs on goods produced by plants. We overcome these difficulties by constructing a unique combination of Mexican plant-level data and satellite imagery data, thus providing evidence of the effects of import competition on three direct measures: energy efficiency in terms of electricity use; investment at the plant level in efficient energy and the environment; and measures of pollution around plants' geographic location. We use tariff changes due to free trade agreements as shocks to import competition, which are arguably less endogenous than unilateral tariff reduction and have been shown to have no systematic correlation with initial plant-level characteristics. The key finding is that the reduction of tariffs on goods produced by Mexican plants induced them to increase efficiency in energy use, thus allowing them to reduce pollution and in turn also *reduce* direct investment in efficient energy and environmental protection. The results suggest that even when detailed data on environmental *effort* at the plant level are available, caution should be taken when trying to measure the effects of openness to trade on environmental *performance*, as trade is also likely to change the firms' incentive to invest in technology in general, which may indirectly be more environmentally friendly.

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1 Introduction

Economists have shown growing interest in whether international trade affects the environment, and thus have proposed several mechanisms linking them. Traditionally, international trade economists have focused on the effects of a change in the location of production induced by international trade: trade can affect the location (country) of production, and therefore can affect the global environment, because different countries have different levels of pollution intensity (Grossman and Krueger (1992), Copeland and Taylor (1994), and Antweiler et al. (2001)).[1] Some recent papers propose different channels. For instance, international trade can also affect the location of consumption International trade can also affect the location of consumption (Davis and Kahn (2008)). Furthermore, it can also alter emission levels at the industry level when, depending on their productivity level, firms are heterogeneous in their emission intensity, and trade induces resource reallocation from low-productivity plants to high-productivity plants(Holladay (2008)).

All of these studies, however, are static in the sense that energy efficiency or environmental efficiency of individual plants is constant before and after trade liberalization; i.e., the change in the environmental outcome is driven only by the reallocation of resources induced by international trade. However, plants may adjust their energy efficiency after facing tougher competition induced by international trade, either by engaging in more or less environmental investment or by engaging in more or less general technology investment that embodies more environmentally efficient technology. Identifying such effects empirically and separately is challenging because of the scarcity of direct information on environmental investment at the plant level.

This paper takes advantage of a newly constructed combination of Mexican plant-level datasets and satellite imagery data on air pollution concentrations to examine whether import competition induced by trade liberalization leads to changes in (1) plants' investment in environmental protection and/or efficient energy use; (2) plants' actual energy efficiency measured as electricity and fuel expenditures over sales; and (3) the measure of pollution concentrations around plants' locations. The combined dataset contains three unique features: (1) the amount of investment in

[1] Copeland and Taylor (2003) summarize nicely the literature of this line.

efficient energy use and environmental protection; (2) the measures of air pollution concentration in plants' zip codes; and (3) the trade-classification categories of plants' outputs and inputs, which allows us to construct plant-level tariff changes and therefore to control for industry-year effects.[2]

We use tariff changes in Mexico between 2000 and 2003 as a source of exogenous variation in market competition. These tariff changes are an attractive source of variation because they are driven mainly by tariff reductions due to free trade agreements such as the North American Free Trade Agreement (NAFTA) and the free trade agreement with the European Union (EU). The reduction in tariffs resulting from free trade agreements is likely to have increased the degree of competition for Mexican plants producing the liberalized goods. Furthermore, it can be argued that this multilateral tariff reductions are more likely to be exogenous than unilateral tariff reduction because the reduction are likely to be driven by the interests of the other bigger parties.[3] This is the first paper to combine direct evidence on investment in energy efficiency and environmental protection at the plant level as well as pollution concentrations around plants' locations, with trade liberalization providing credible exogenous variation in the plant's exposure to import competition.

We find evidence of an increase in energy efficiency in response to an increase in import competition through tariff reduction. We find modest evidence that competition also led to a decrease the concentration of air pollution around the plant's location. Perhaps surprisingly, the same tariff reduction *decreased* specific investment in environmental protection and energy efficiency. Why might this happen? One of the authors of this paper has shown that the same plants, when facing the same increase in competition during this period, increased investment in improving production processes (Teshima, 2008). In light of the aforementioned results, our interpretation is that this improvement in plants' production processes was possibly achieved through the adoption of technology in general, including more energy efficient technology which directly improved their

[2]International trade can affect firms' incentive to adopt technology also by increased access to imported intermediate products and by increased access to the external market. We control these other channels in the robustness check section.

[3]See Kowalczyk and Davis (1996) provide evidence that the Mexican tariff reductions through NAFTA were not driven by Mexican interests. Teshima (2008) shows that plant-level characteristics in 2000 were not systematically correlated with the degree of reduction of tariffs of goods they produced.

environmental performance, allowing firms to spend less on specific environmental technologies.

In particular, our results show that even when detailed data at the plant level are available, caution should be taken when trying to measure the effects of openness to trade on environmental performance. In our setting, one would have been tempted to conclude that import competition affects the environment negatively if the plant-level environmental investment measure had been the only available variable. Firms often make direct investments in reducing emissions to comply with environmental regulation that caps these emissions. However, since trade has effects not only on the incentives to pollute but also on the adoption of different technologies (which are already more efficient and less polluting), the direct investment in reducing emissions can decrease. It is then necessary to obtain data both on plants' direct investment in pollution abatement and on environmental performance in general, in order to better understand the relationship between trade openness, technology adoption, and the aggregate effect of both on pollution emissions. This message generally applies to any evaluation of the determinants of environmental performance.

This paper is related to several strands of literature. First, there is the literature concerning the effect of trade on the environment.[4] For example, trade can increase or decrease environmental quality by affecting the location of production. In related literature, Antweiler et al. (2001) disentangle the effects of trade into scale, composition and technology effects.[5] The scale effect is the negative consequence on the environment that results from scalar increases in economic activity. The composition effect is concerned with how the changes in the composition of output affect pollution concentrations.[6] The technology effect occurs when a rise in income increases pressure for cleaner production methods that have a positive environmental effect. Our paper highlights a particular different channel through which trade could affect the environment through its effect on technology, although there are other channels which exceed the scope of this paper.

Recently, trade economists have been interested in how firms in the same industry are different in terms of pollution intensity, and thus how international trade can affect aggregate environmental

[4]See Grossman and Krueger (1992), Copeland and Taylor (1994) Copeland and Taylor (1995).

[5]See also Frankel and Rose (2005)for more recent extension.

[6]This mechanism is closely connected to the so-called pollution haven hypothesis. See Low and Yeats (1992),Lucas and Hettige (1992), Mani and Wheeler (1997), Tobey (1990) for empirical studies on the pollution heaven hypothesis.

outcomes by inducing resource reallocations within an industry. Extending the heterogeneous-firm model of Melitz (2003), Holladay (2008) theorizes that exporters pollute less per unit of output than non-exporters in the same industry, and finds supporting empirical evidence. Liscomb (2008) also extends Melitz's heterogeneous-firm model to analyze how environmental regulation affects the production decisions of multi-product plants, and how the reallocation of resources resulting from these decisions affects industry-level environmental outcomes. In contrast to these studies, which analyze the effects of trade through reallocation of resources, we study a plant's dynamic incentive to change its environmental efficiency.

Mechanisms that explain positive effects of import competition on energy efficiency can be found in literature on competition and innovation. Recent theoretical papers proposing mechanisms through which competition has a positive effect on technological progress have been written in response to growing empirical evidence suggesting this relationship.[7] They introduce either a type of product innovation whose value increases with the threat of competition, or a type of cost-reducing innovation with switching costs (switchover disruptions). Product innovation whose value increases with the threat of competition allows a firm to have a monopoly by avoiding competition (Aghion et al. (1997), Aghion et al. (2001)). Cost-reducing innovation with switching costs lowers the opportunity cost of innovation when tougher competition causes sales to fall (Holmes et al. (2008)).

Our study is also related to study of firm-level environmental performance and its determinant in general. Earnhart (2006) and Earnhart and Lizal (2006) use U.S. and Czech firm-level data respectively to test whether financial performance affect firms' air pollutant emissions. They find that successful financial performance is related to lower emissions, theorizing that this happens because better financial performance reflects cost-effective technology. This is consistent with our results. We should note, however, that our results suggest that the positive correlation between financial and environmental performance exists only to the extent that the former is correlated with technological efficiency. Competition may hurt financial performance but could still improve

[7]For early empirical studies that motivate the recent theories, see for example Nickell (1996) and Blundell et al. (1999)).

the environment through its effect on technology.

Continuing with the effects on direct environmental investment, an alternative hypothesis may be found in managerial incentives literature. In this line of research, competition is argued to reduce managerial slack.[8] Therefore, if environmental investment is some form of luxury for managers, competition may reduce environmental investment by reducing managerial slack. In the robustness check section, we did not find an effect of import competition on firms' investment in workers' health, which may be another type of luxury for managers. Therefore, to the extent that investment in workers' health and investment in pollution abatement are comparable "social" investments, our results suggest that the decrease in direct environmental investment cannot be explained by the reduction of managerial slack due to more competition.

The discussions in the last two paragraphs reinforce our claim that it is important to look not only at environmental *effort* but also at environmental *performance*. If we had limited our analysis to the effects of trade on direct environmental investment (and assumed a positive correlation between this variable and environmental performance), we could have reached different conclusions, all of which would have found theoretical support in some strands of literature.

This paper is organized as follows. The next section (Section 2) describes the new combination of datasets, and presents descriptive statistics of plant-level variables as well as the air pollution measures. Section 3 describes our econometric strategy. Section 4 presents the key results of the effects of competition on plants' energy efficiency, environmental investment, and the pollution level at the plants' locations. Section 5.1 discusses endogeneity concerns. Section 5.2 shows that the results are robust to the inclusion of other tariffs. Section 5.3 provides evidence against the alternative hypothesis that luxury behavior of plant managers explains environmental investment by showing that, although that hypothesis might explain some of our findings, it cannot explain other results, such as the effects of trade on other types of investment. Section 6 concludes.

[8]Schmidt (1997) builds a model in which competition induces more managerial efforts by increasing the risk of bankruptcy. Bertrand and Mullainathan (2003) (2003) provide evidence of managerial slack.

2 Data

2.1 Plant-level Data

The plant-level data are the same as in Teshima (2008). We combine three types of plant-level data for the analysis. The first is a specialized survey on innovative activities from which we draw investment on environmental technology. The second is a standard plant-level survey from which we draw information on energy efficiency, measured as expenditure on fuel and electricity divided by total sales. The third is a registry of plants that includes information on the trade-classification category of plants' outputs and inputs from which we construct measures of plant-level tariff changes.

2.1.1 ESIDET

The source for the information on the environmental and energy investment is the *Encuesta Sobre Investigación y Desarrollo de Tecnología* (ESIDET) [Survey on Research and Development of Technology]. This is a confidential survey carried out by the Instituto Nacional de Estadísticas, Geografía (INEGI) [National Institute of Statistics and Geography] of Mexico for the Consejo Nacional de Ciencia y Tecnología (CONACYT) [National Council of Science and Technology].

The survey contains information on several aspects of innovative activities of manufacturing plants: expenditures, human resources and collaborating firms and institutions. It includes information on expenditures for each type of R&D: product R&D and process R&D. We use the 2002 and 2004 surveys.[9] Each survey elicits information for the previous two years. This makes unbalanced panel data from 2000 to 2003. In addition to the standard technology-related variables, the survey asks how much plants spend on socio-economic activities. Specifically, the survey asks how much plants spend on (1) care and control of the environment (cuidado y control del medio ambiente), which includes prevention, detection and improvement of contamination of land, water, and air, (2) rational production and use of energey (Producción y uso racional de la energía), and

[9] Surveys were done in 1996, 1998, 2002, 2004, 2006 and 2008. We focus on 2002 and 2004 because the satellite data starts in 2000. The 2006 survey has become available too recently to be included in this version of the paper.

(3) health except pollution reduction (salud (Se excluye contaminación)). We use (1) and (2) for the main analysis and (3) in the robustness check section. We call (1) environmental investment, (2) energy investment and (3) health investment.[10]

2.1.2 EIA

In order to obtain energy-related expenditure and sales, and thus energy efficiency, we draw the *Encuesta Industrial Anual* (EIA) [Annual Industrial Survey]. The EIA is a longitudinal plant level dataset in 205 of the 305 6-digit industries in manufacturing. The EIA is also compiled by INEGI. For further details of the EIA, see Appendix II in Verhoogen (2008).

2.1.3 SIEM

For information on the output and input categories of the firms to calculate output and input tariffs at the plant level, we use the *Sistema de Información Empresarial Mexicano* (SIEM) [Mexican Company Information System] compiled by Mexico's Secretaría de Economía [Ministry of Economy]. It is a directory of firms in Mexico to facilitate business contacts between firms in Mexico and foreign firms. SIEM lists firms' inputs and outputs at the 6-digit or 8-digit trade-classification level regardless of whether the firms export or import. It does not have information on the volumes of each output or input, or on whether the plants export or import. The SIEM starts in 1997, but detailed information about firms' inputs and outputs are available only from 2001. Firms are legally obliged to report; therefore in principle the SIEM can be regarded as a census of firms in the formal economy. The SIEM has been linked by INEGI personnel to the EIA and ESIDET using information on firm name, state, municipality, street address, and industry.

2.2 Descriptive Statistics of Plant-level Variables

Table 1 presents summary statistics of environmental and energy investment for the ESIDET-EIA-SIEM panel. Consistent with the trade lietrature on exporting firms, exporters are larger in

[10] Energy investment and health investment maybe noisier because the former may include investment on production of energy and the latter may include production of medical products.

terms of employment. Exporters not only spend more on fuel and electricty but also have a higher share of these expenditures on total sales, though this may be reflecting the industry composition of exporters and non-exporters. Similarly to the summary statistics for R&D expenditures in Teshima (2008), exporters are more likely to be engaging environmental and energy investment and have higher expenditure. However, only 6% of these exporters report positive amount of environmental investment. This ratio is 4% for all the plants and 2% for non-exporters.

2.3 Satellite Imagery Data

In order to assess the overall impact of the changes in tariffs on plants' environmental performance, we constructed a zip-code level dataset, which assigns, along with measures of weighted tariff changes in each zip-code, measures of pollution concentrations in the atmosphere around them. For this, we obtained daily measures of Aerosol Optical Depth (AOD) at a 5km spatial resolution for cloud-free images for the entire land area of Mexico over the 2000-2003 time period. For the Mexican context, these AOD measures have already made it possible to evaluate pollution abatement policies (Foster and Gutierrez (2008)), and their potential relationship with health outcomes (Gutierrez (2010) and Foster et al. (2009)). The data were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS onboard the Terra Satellite), of NASA's Goddard Space Flight Center Earth Sciences Distributed Active Archive Center (DAAC). Aerosols are liquid and solid particles suspended in the air, and AOD can be described as the extinction of beam power caused by the presence of these particles in the atmosphere. Existing literature suggests a strong relationship between AOD and other measures of particulate matter concentrations in the atmosphere (Chu et al. (2003) and Gupta et al. (2006)). Kumar et al. (2007) show that linear regression estimates suggest that a 10 percent change in AOD explains a 0.52 percent change in their ground measure of particulate matter (PM2.5,) with an R-squared of 0.71. However, while AOD is a good predictor of general levels of suspended particles in the atmosphere, it is worth mentioning that it does not allow to make any distinction between pollutants and comparisons across regions with different climate and geographic conditions are hard to make. Our analysis will then focus on changes in AOD levels within zip codes. As the information at the plant level is available yearly in our analysis, we constructed a measure of the average yearly AOD level for each zip code in our data set. Using GIS, the observed measures of AOD from the satellite images were overlapped with each zip-code's exact geographic locations. The estimated AOD daily value for each zip-code was averaged for each month in the sample. The yearly average is the mean of all monthly averages.

2.4 Descriptive Statistics of the Pollution Measure

Figure 1 shows a map with the calculated AOD level for the year 2000 in all Mexican zip codes for which we have precise geographic coordinates and for which AOD measures are available. The lighter dots represent zip codes with lower AOD levels. Although, as stated, differences in AOD levels across regions can be due to geographic and climatic conditions unrelated to concentrations of particulate matter, AOD measures do appear higher around metropolitan areas and along the Gulf Coast (possibly due to the importance of the oil industry in this region). Figure 2, in contrast, maps the changes in our AOD measure within zip codes between 2000 and 2003. Darker dots represent the zip codes that experienced higher increases in AOD during this period. Clear geographic patterns on the increase or reduction of our AOD measures during the period are not evident.

Table 2 shows statistics for both AOD levels in 2000 and changes in AOD between 2000 and 2003 for all 378 zip codes matched with our firm-level dataset. The mean AOD level in our sample in the year 2000 was 0.42, ranging from 0.02 to 0.93 and with a standard deviation of 0.24. As our regression estimates difference out variations in AOD levels across zip codes with the zip code fixed effects, the relevant variation exploited in this paper corresponds to changes in this variable. Between 2000 and 2003, for all zip-codes in our sample, the change in AOD (on average close to zero) ranges from -0.32 to 0.38 with a standard deviation of 0.09 (more than 20% of the average AOD level in 2000). To put this variation in context, it is perhaps useful to mention that Foster et al. (2009), exploiting variation in AOD and infant mortality within municipalities, found that the elasticity of infant mortality with respect to AOD in Mexico is approximately 4.

2.5 Tariff Data

We construct tariff data using (1) Mexican import statistics published in trade statistics yearbooks and (2) tariff information from the tariff law of Mexico and from the documents of the free trade agreements between Mexico and other countries. The first subsection describes the method to calculate plant-level tariffs. The second subsection describes the summary statistics for the tariff data.

2.5.1 Construction of Plant-level Tariff Measures

Because of free trade agreements, tariffs for one product differ depending on the country of origin. We first aggregate the country-good specific tariffs to good-level tariffs by taking the weighted average with the initial volume of imports used as weights. $Imports_{gjct}$ is imports of good g in industry j from country c at time t. $Tariff_{gjct}$is tariff of good g in industry j from country c at time t.

$$Tariff_{gjt} = \sum_{c} \alpha_c Tariff_{gjct} \tag{1}$$

where $\alpha_c = \frac{Imports_{gjc2000}}{\sum_c Imports_{gjc2000}}$.

Next, using this good-level tariff data $Tariff_{gjt}$, we take the simple average of the tariffs of each plant's outputs to construct the output tariffs at the plant level.[11]

$$Output\ Tariff_{igt} = \frac{\sum_{g \in G_i} Tariff_{gjt}}{N_i} \tag{2}$$

where G_i is the set of products that plant i produces, and N_i is the number of products of plant i produces, respectively.

[11] We have to use the simple average because SIEM data does not allow one to obtain the information on the volumes of each product by plant.

Similarly, we take the simple average of the tariffs of each plant's inputs in the initial period to construct the input tariffs at the plant level. Note that we always use the outputs and inputs information from year 2001 to compute the output and input tariffs for each year. Thus all the variation of the tariff of a good is coming from the changes in the tariff of the good but not from the changes in the volume of the imports of the good. This is to avoid bias due to the changes in output mix or in input mix in response to the tariff reduction.

When we calculate the weighted average tariffs for imports from all the countries as well as from four groups of sets of countries: NAFTA, EU, countries to which most favored nations (MFN) tariffs are applied, and other countries that are not in NAFTA or in EU and that have a free trade agreement with Mexico, we see that the tariff changes are largely coming from tariff changes scheduled, late NAFTA liberalization and the free trade agreement with EU. In terms of plant-level tariffs, average output tariffs decreased from 7.7% in 2000 to 4.1% in 2003.

3 Specification

3.1 Plant-level Analysis

The baseline econometric model is the following:

$$Y_{ijt} = \beta_1 Output\ Tariff_{it} + \lambda_i + \mu_{jt} + \epsilon_{ijt} \tag{3}$$

where i, j, and t index plants, industries, and years, respectively; Y_{ijt} denotes the dependent variable: Energy efficiency measured as the share of expenditures on fuel or/and electricity over total sales, environmental effort measured as the sum of environmental investment and energy investment; $Output\ Tariff_{it}$ is output tariffs at the plant level constructed in the manner described in the tariff data section; λ_i is a plant fixed effect; μ_{jt} is an industry-year fixed effect; ϵ_{ijt} is an error term.

The coefficient of interest in these regressions are β_1. β_1 corresponds to the changes in the dependent variables in response to a one percent point change in the output tariff, which captures (the inverse of) the effect of competition. The plant fixed effects capture all observed or unobserved time-invariant heterogeneity across plants. The industry-year fixed effects capture all observed or unobserved shocks at the industry level. Thus, the coefficient of interest is identified on the basis of within-plant changes in the three types of tariffs and within-plant changes in the dependent variables controlling for industry-level idiosyncratic shocks. The identification assumption of this econometric model is that no unobservable factors are correlated with the output tariffs after controlling for time-invariant plant-level heterogeneity and industry-level idiosyncratic shocks.

Note that a positive value of the coefficient means that output tariff reduction affects the dependent variable *negatively*. A priori, there is no clear theoretical prediction on whether the coefficients should be positive or negative. In some specifications, we also control for state-year fixed effects to control for any shocks at the region level.

3.2 Zip-code level analysis

As stated, in order to assess the aggregate effect that the changes in plant-level outcomes translate into changes in pollution emissions, we present a set of results relating the changes in tariffs to changes in environmental performance by directly looking at measures of pollution concentrations around plants' location. If a measure of environmental performance at the plant level were available, we would run the same specification as in the previous sub-section, using this measure as our outcome variable. However, AOD measures pollution concentrations in the atmosphere at the zip-code level, and more than one plant can be located in the same zip-code. We then assume that the pollution concentrations in each zip-code are a weighted average of the pollution emissions by each plant in that zip-code. We calculated a weighted average of the tariff variable in the main regression equation for each zip-code, using the total number of employees reported by each plant divided by the total number of employees in each zip code (the sum of the employees of all plants in the SIEM database in each zip code) as the weight for each of the plant-level observations, and run regressions, with each of these variables as regressors, at the zip-code level. Spedicifally, we run the following regression:

$$AOD_{zjt} = \beta_1 Output\ Tariff_{zt} + \lambda_z + \mu_{jt} + \epsilon_{zjt} \tag{4}$$

where z denotes zip-code. λ_z captures the indiosyncratic effect of each zip-code. μ_{jt} indicates a dummy variable indicating whether the zipcode has any plants in industry j.

4 Results

4.1 Results on the Plant-level Measures

4.1.1 Results on Electricity Use Intensity

We run regressions of electricity and fuel use on the output tariff. Column (1) suggests that we find an significant effect for the sum of the two energy-related expenditures, electricity and fuel, suggesting that an increase in competition *increases* energy efficiency in general. One percent point decrease in output tariff implies that energy-related expenditure over sales by about 0.05 percent.[12] Column (2) shows that the result is robust to the inclusion of state-year fixed effects, suggesting that the results are not driven by the changes in geographic conditions or state-level policies.

When we disaggregate the expenditure into fuel and electricity, Column (3) of Table 3 shows that there is significant positive effects of output tariffs on electricity use over sales, suggesting that an increase in competition *increases* energy efficiency in terms of electricity. One percent point decrease in output tariff implies that electricity expenditure over sales by about 0.02 percent.[13] The result is again robust to the inclusion of state-year effects (Column (4)). In terms of fuel, Column (5) and (6) suggest that there is no significant effect, though the sign is same as electricity use and the magnitude is quantitatively larger, which makes it difficult for us to conclude that

[12] The mean of the energy-related expenditure over total sales is 2 percent.

[13] The mean of electricity expenditure over total sales is 1 percent.

from which type of expenditure the effect is coming.

Overall, we find in this analysis that the increase in import competition induced by output tariff reduction led to an increase in energy efficiency of the affected plants. Our interpretation is that this is due to the general technology improvement documented in the same context as ours. Specifically, Teshima (2008) finds that increased competition increased total R&D and process R&D. These increases might have brought new technology which reduces the need for plants to spend resources on the environmental and energy investment.

4.1.2 Results on Environmental and Energy Investment

Next, we report the results from the regressions using the sum of environmental and energy Investment as the dependent variables. Here we use three types of investment measures: intensity over total sales. log investment, and investment dummy.

Table 4 shows the regression results. Column (1) and (2) suggest that one percent point decrease in output tariff implies a decrease in the environmental and energy investment over sales by about 0.02 percent. Column (3) and (4) suggest that the same decrease in output tariff leads to 0.7 percent decrease in the likelihood of engaging environmental and energy investment. Column (5) and (6) suggest that the same one percent point decrease in output tariff leads to 5-6 percent decrease in the amount spent on such types of investment. Column (2)(4)(6) are the results after also controlling for the state-year effects, which suggests the all the results are not driven by state specific economic fluctuations.[14] Overall the increase in import competition induced by output tariff reduction led to a decrease in environmental and energy investment of the affected plants.

4.2 Zip-Code level Results on the Pollution Measure

The results on energy efficiency and environmental investment go in opposite directions: While tariff reductions (increased competition) imply higher energy efficiency, it is also related to lower environmental investment at the plant level. The overall effect of the tariff change on environ-

[14] We also get statistically significant results when we run environmental investment and energy investment separately.

mental performance is then uncertain.

In order to shed light into the aggregate effect of changes in tariffs on environmental performance, Table 4 presents the results for our zip-code level regressions, with our measure of pollution concentrations (AOD) as the dependent variable. As can be seen in Column (1), the coefficient on output tariffs implies an increase in pollution concentrations around plants' location. An increase of 1% in tariffs implies an increase in AOD of 0.0015 points (around 0.4% points). The coefficient seems robust to the inclusion of controls such as total sales within the zipcode (Column (2)).

However, the effect of the output tariff is not robust to the inclusion of state-year effects. The coefficient on the output becomes insignificant in Columns (3) and (4). Since geography influences our AOD measure, there may be little variation left after taking out the variation induced by zip-code specific time invariant factors and by state level fluctuations in climate. However, the coefficient still remains positive. This modest result could also be due to the fact that the effects of tariff reductions on energy efficiency are split between electricity and fuel use. The effects on overall air pollution at the plantLs location are likely to not be as strong as the overall effect on energy efficiency, as they are likely to be mainly driven by changes in fuel use.

While this evidence is not strong enough to conclude that tariff reductions imply a reduction in pollution concentrations, we do believe this that the consistently positive coefficient suggests that the overall impact of tariff changes on pollution emissions are driven by the changes in energy efficiency and not by the changes in environmental investment. This suggests that trade liberalization can have distinct effects on environmental effort through competition, and that, even when direct measures of investment in environmental protection are available, empirical studies should be careful interpreting the results found. In particular, our results show that that even when detailed data at the plant level are available, caution should be taken when trying to measure the effects of openness to trade on environmental performance. Regulation is usually based on limiting emissions, and trade has effects not only on the incentives to pollute but also on the adoption of different technologies. If this is the case, when adopting new, more efficient and less polluting technologies, the direct investment in reducing emissions (which was possibly used to comply with environmental regulation while not upgrading the technology) can decrease. It is then necessary to obtain data both on plantLs direct investment in pollution abatement and on environmental performance in order to better understand the relationship between trade openness, technology adoption, and the aggregate effect of both on pollution emissions.

5 Robustness Checks

5.1 Discussions on Endogeneity

Teshima (2008) ran regressions of the following form to see whether tariffs are endogenous in a sense that plants with some particular characteristics received higher tariff reduction.

$$Y_{ij2000} = \beta_1 \triangle Output\ Tariff_{ij} + \beta_2 \triangle Input\ Tariff_{ij} + \mu_j + \epsilon_{ij} \tag{5}$$

where Y_{ij2000} is either total sales, domestic sales, exporter dummies, exports, total employment or TFP of plant i in 2000; $\triangle Output\ Tariff_{ij}$ is a change in output tariff of plant i from 2000 to 2003; $\triangle Input\ Tariff_{ij}$ is a change in input tariff of plant i from 2000 to 2003; μ_j is a industry fixed effect.

A significant coefficient β_1 or β_2 would tell that smaller or larger plants were more likely to face tougher import competition induced by tariff reduction or to face lower cost of imported intermediate products, even within industry, which would imply that the governments might have set the tariffs to favor plants with particular characteristics over other plants.

He did not find any evidence that there is a correlation between plant characteristics and subsequent output tariff reduction within an industry.[15] The result is consistent with the study by Kowalczyk and Davis (1996) which show that the Mexican tariff reductions through NAFTA were not driven by Mexican interests, but more by U.S. interests.

[15] On the other hand, he found that there is a significant positive correlation between the size of the plants and the degree of the subsequent input tariff reduction. One possibility is that larger and more productive plants use high-technology inputs, which had a higher degree of tariff reduction

5.2 Other Types of Tariffs

In this section, we present the results of the main regressions with the other two types of tariffs as controls: the input tariff and the U.S. tariff on Mexican exporters. Since competition is not the only channel through which trade could affect plants' investment, it is important to investigate the effects we have been finding so far are not driven by the changes in other type of tariffs. Specifically, we run the following regression:

$$Y_{ijt} = \beta_1 Output\ Tariff_{it} + \beta_2 Input\ Tariff_{it} + \beta_3 US\ Tariff_{it} \lambda_i + \mu_{jt} + \epsilon_{ijt} \tag{6}$$

, where $Input\ Tariff_{it}$ is input tariffs constructed similarly and $US\ Tariff_{it}$ is US tariffs.

In addition to β_1, which corresponds to the changes in the dependent variables in response to a one percent point change in the output tariff, which captures (the inverse of) the effect of competition, β_2 corresponds to those in the input tariff, which captures (the inverse of) the effect of access to imported intermediate product. β_3 corresponds to those in the US tariff that plants would face if they export, which captures (the inverse of)the effect of export market access.

Table 5 shows the results of the regression of the three types of measures we have used, i.e. energy efficiency, environmental and energy investment and pollution outcome. Table 5 shows that the magnitude of the coefficients for output tariff stays roughly the same and significant. Therefore, the results we have been putting forth do not appear to be driven by other mechanisms possibly happening at the same time such as increased access to imported intermediate products and increased access to export market.

5.3 Investment on Worker's Health

One of the possible alternative explanation on the negative effects of increased competition on environmental and energy investment is that those types of investment are luxury for managers of firms, and competitive pressure reduces the room for these types of activity. This alternative hypothesis have difficulty in wholly explaining why then the energy efficiency and pollution measures could improve. We provide one more piece evidence against this alternative explanation. We run regressions of investment on health on the three types of tariffs. Our idea is that if the environmental investment decreased after an increase in competition and thus after there is less room for luxury behavior of plant managers, then we should also see the negative effect of competition on other types of social investment. Table 7 shows that there is no significant effects of any tariffs on investment on health for any form and that the signs of the coefficients on output tariffs are opposite from the one for environmental and energy investment. This is evidence against the luxury-hypothesis, because we should expect similar effects of competition if environmental and energy investment and health investment are similar luxurious goods for the managers.[16]

6 Conclusion

We have found evidence that the reduction of tariffs on the goods produced by Mexican plants induced those plants to improve energy efficiency of them and pollution near the plants' location but at the same time to reduce environment and energy investment. This suggests that import competition induced by trade liberalization improve the environment through the plants' incentive to change their energy efficiency through general technological investment. The findings illustrate the importance of analyzing the three related measures at the same time, as relying solely on the environment and energy investment would have tempted researchers to conclude that import competition damages the environment.

[16]We acknowledge the possibility, however, that investment for the workers' health may have different nature in that it could affect workers' productivity directly.

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Table 1: Summary statistics of Energy Efficiency and Environment and Energy Investment variables in 2000 (EIA-ESIDET-SIEM panel)

	Non-Exporter	Exporter	Total
Employment	420***	799***	593
	(30.77)	(77.94)	(40.22)
Electricity and fuel	10665.11**	19543.73**	14726.42
	(1703.69)	(2632.52)	(1529.22)
Electricity and fuel	3.58	5.95	5.11
/Total sales (percent)	(0.36)	(2.26)	(1.46)
Investment for	36.85	125.05	93.69
Energy and Environment	(20.01)	(50.27)	(33.21)
Dummy (1 if *Either Investment* > 0)	0.02***	0.06***	0.04
	(0.01)	(0.02)	(0.01)
Energy and Environment Investment	0.00*	0.04*	0.02
/Total sales (percent)	(0.00)	(0.01)	(0.01)
Number	233	278	511

Notes: The table reports summary statistics of energy-related expenditure and environmental and energy investment variables. The first column is the statistics for non-exporter plants, while the second for exporter plants, and the third for all plants pooled together. Standard deviation of the means in parentheses. Expenditure is in nominal thousand pesos (A dollar was 9.5 pesos in the beginning of 2000). Significance of the test of the equality of the mean of the two groups: * 10 percent, ** 5 percent, *** 1 percent.

Figure 1: AOD Measure in 2000.

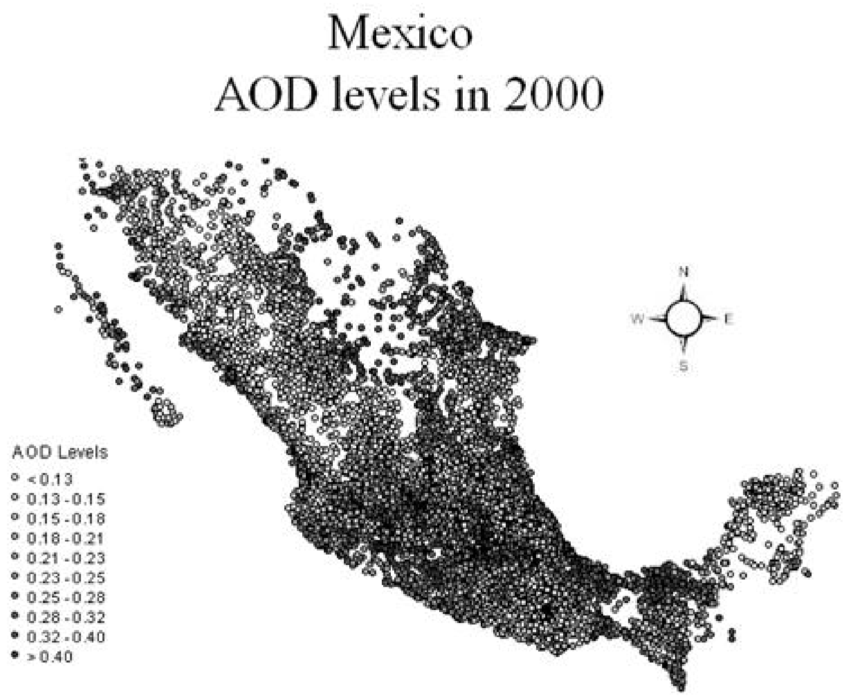

Figure 2: Changes in AOD measure.

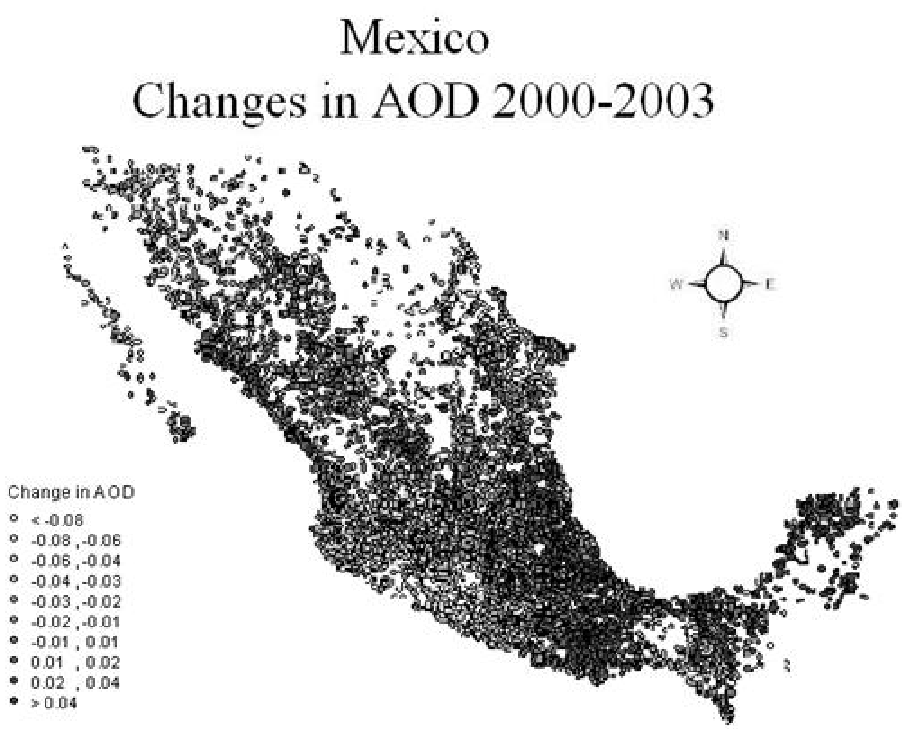

Table 2: Summary statistics of AOD measures.

	Mean	Standard deviation	Min	Max
AOD in 2000	0.39	0.22	0.02	0.98
AOD change 2000-2003	-0.03	0.09	-0.32	0.38
Number	378			

Notes: The table reports summary statistics of AOD measures in 2000 and its changes between 2000 and 2003.

Table 3: Regressions of the intensity of electricity and fuel over sales on output tariffs, ESIDET-EIA-SIEM panel 2000-2003.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Sum	Sum	Electricity	Electricity	Fuel	Fuel
Output Tariff	0.0481**	0.0551**	0.0262*	0.0223*	0.0262	0.0258
	(0.0235)	(0.0274)	(0.0149)	(0.0133)	(0.0344)	(0.0315)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Region-year effects	No	Yes	No	Yes	No	Yes
Observations	1776	1776	1776	1776	1776	1776
R^2	0.17	0.22	0.18	0.22	0.19	0.23

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the intensity of expenditures on electricity and fuel over total sales on these the output tariffs, plant fixed effects, industry-year fixed effects and in some cases state-year fixed effects. Plant-level output tariff for a plant is the simple averages of the product-level tariffs of the products that the plants produce. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 4: Regressions of the environmental and energy investment on output tariffs, ESIDET-EIA-SIEM panel 2000-2003.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Sum of Environmental and Energy Investment					
	Intensity		Dummy		Log	
Output Tariff	0.0023*	0.0026*	0.0072**	0.0074**	0.059***	0.066***
	(0.0014)	(0.0014)	(0.0028)	(0.0029)	(0.21)	(0.021)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
State-year effects	No	Yes	No	Yes	No	Yes
Observations	1776	1776	1776	1776	1776	1776
R^2	0.23	0.27	0.24	0.27	0.22	0.27

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the intensity, dummy and the log of the sum of environmental and energy investment on the output tariffs, plant fixed effects and industry-year fixed effects. Plant-level output tariff for a plant is the simple averages of the product-level tariffs of the products that the plants produce. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 5: Regressions of the AOD measure on output tariffs:2000-2003.

	(1)	(2)	(3)	(4)
Dependent Variable		AOD		
Output Tariff	0.0017*	0.0016*	0.0008	0.0008
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Total Sales		0.0000		0.0000
		(0.0000)		(0.0000)
Zip-code fixed effects	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes
Region-year effects	No	No	Yes	Yes
Observations	1512	1512	1512	1512
R^2	0.95	0.95	0.96	0.96

Notes: The table reports coefficients on the output tariffs from zip-code level regressions of the AOD measure on the output tariffs, zip-code fixed effects and industry-year fixed effects. Zip-code-level output tariff is the weighted averages of the plant-level tariffs of the products that the plants in the zip-code produce. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 6: Regressions with output tariffs, input tariffs and the U.S. tariffs, ESIDET-EIA-SIEM panel 2000-2003.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Energy Efficiency		Environmental Investment		Pollution Measures	
Output Tariff	0.0533**	0.0574**	0.0023**	0.0024**	0.0015*	0.0004
	(0.0255)	(0.0244)	(0.0011)	(0.0011)	(0.0009)	(0.0009)
Input Tariff	0.0444	0.0491	-0.0011	-0.0012	-0.0006	0.0001
	(0.0416)	(0.0518)	(0.0009)	(0.0009)	(0.0007)	(0.0010)
US Tariff	-0.0562	-0.0684	-0.0006	-0.0007	0.0005	0.0006
	(0.168)	(0.189)	(0.0008)	(0.0008)	(0.0010)	(0.0009)
Plant/Zip code Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Region-year effects	No	Yes	No	Yes	No	Yes
Observations	1776	1776	1776	1776	1437	1437
R^2	0.22	0.23	0.17	0.19	0.95	0.96

Notes: The table reports coefficients on the output tariffs, the input tariffs, and the U.S. tariffs from plant-level regressions of the energy efficiency (energy-related expenditure divided by total sales), environmental investment (intensity of environmental and energy investment over total sales) and the AOD measure on these three tariffs, plant fixed effects and industry-year fixed effects. Plant-level output tariff for a plant is the simple averages of the product-level tariffs of the products that the plants produce. Similarly, the plant-level input tariff for a plant is the simple averages of the product-level tariffs of the products that the plant uses as intermediate products. Similarly, the plant-level U.S. tariff for a plant is the simple averages of the product-level tariffs of the products that the plant would face if they export to the U.S.. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 7: Regressions of the log of health investment on tariffs, ESIDET-EIA-SIEM panel 2000-2003.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable			Health Investment			
	Intensity		Dummy		Log	
Output Tariff	-0.0022	-0.0023	-0.0055	-0.0065	-0.0228	-0.0256
	(0.0032)	(0.0033)	(0.0044)	(0.0052)	(0.0214)	(0.0220)
Input Tariff		0.0035		0.0079		0.0100
		(0.0027)		(0.0082)		(0.0132)
US Tariff		-0.0033		-0.010		-0.012
		(0.0029)		(0.010)		(0.015)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Region-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1776	1776	1776	1776	1776	1776
R^2	0.16	0.14	0.14	0.14	0.13	0.13

Notes: The table reports coefficients on the output tariffs, the input tariffs, and the U.S. tariffs from plant-level regressions of the intensity (over sales), the dummy for and the log of health investment on these three tariffs, plant fixed effects, industry-year fixed effects and state-year fixed effects. $Log\, HealthInvestment_{it} = log(Health\, Investment_{it} + 1)$. Plant-level output tariff for a plant is the simple averages of the product-level tariffs of the products that the plants produce. Similarly, the plant-level input tariff for a plant is the simple averages of the product-level tariffs of the products that the plant uses as intermediate products. Similarly, the plant-level U.S. tariff for a plant is the simple averages of the product-level tariffs of the products that the plant would face if they export to the U.S.. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.