Import Competition and Innovation at the Plant Level: Evidence from Mexico

Kensuke Teshima †

Job Market Paper

First Version: Nov. 2008. This Version: Feb. 2009.

Abstract

A key idea in the literature on trade and growth is that trade liberalization may affect plants' innovative activities through increased competition. Theoretical predictions remain ambiguous, however, and it has been difficult to investigate this relationship empirically because R&D expenditure data is rarely available at the plant level. This paper takes the advantage of a newly constructed combination of Mexican plant-level datasets to examine the extent to which tariff changes lead to changes in R&D through increased competition. The combined dataset has two unique features: it contains (1) the amount of R&D on product innovation and on process innovation, and (2) the trade-classification categories of plants' outputs and inputs, which allows me to construct plant-level tariff changes and to control for industry time effects. The degree of tariff reduction is not correlated with initial plant characteristics, suggesting that the tariff reduction is exogenous for plants. The key finding is that the reduction of tariffs of the goods produced by Mexican plants induced those plants to increase total R&D. This suggests that trade liberalization stimulates plants' innovative activities through increased competition. I also find that the pattern would not be discernable using the measures of plant behavior and trade exposure available in typical plant-level datasets – measured total factor productivity and industry-level average tariffs. Additional results using process R&D and product R&D expenditure information suggest that trade liberalization affects plants' capability through the effects of competition on plants' incentives to increase cost efficiency rather than through the effects on incentives to create new products or to upgrade quality.

---

†Columbia University, email: kt2123@columbia.edu. I am truly indebted to Eric Verhoogen and David Weinstein for continuous guidance and support at every stage of this project. I would like to thank Gerald Leyva, Abigail Duran, Adriana Ramirez, and Gabriel Romero of INEGI for assistance with establishment surveys. I also thank Alberto Zarco of Secretaría de Economía for his help on the SIEM data. I am grateful to Pierre-Andre Chiappori, Rajeev Cherukupalli, Donald Davis, Jan De Loecker, Ronald Findlay, Jessie Handbury, James Harrigan, Kate Ho, Takakazu Honryo, Amit Khandelwal, Ayako Kondo, Dilip Mookherjee, Christian Pop-Eleches, Michael Riordan, Prasana Sethupathy, Hitoshi Shigeoka, Yoichi Sugita, Mamiko Terasaki, Daniel Trefler and seminar participants at Columbia and the BREAD summer school for helpful conversations. I gratefully acknowledge the funding from the Institute of Latin American Studies and the Center for International Business Education Research at Columbia University. I am solely responsible for any errors.

1 Introduction

Economists have shown growing interest in whether international trade can generate dynamic gains through innovative activities. In contrast to traditional trade theories that predict static gains from trade from reallocation of resources across sectors, this recent literature emphasizes the idea that trade may increase growth. Beginning with the seminal work by Rivera-Batiz and Romer (1991) and Grossman and Helpman (1991a), a key idea in this literature has been that trade liberalization creates tougher market competition and that this increase in market competition may affect firms' incentive to innovate.

Identifying such effects empirically has been challenging, however, because of a scarcity of direct information on the innovative activities of plants. Many researchers have tried to identify the effects of trade liberalization on plants' productivity using total factor productivity (TFP).[1] However, measured TFP is known to suffer from many biases and may reflect a number of differences across plants apart from technical efficiency (Katayama, Lu and Tybout (2006)). In particular, measured TFP reflects mark-ups, which are also likely to be affected by trade liberalization.[2] As a consequence, changes in measured TFP due to trade liberalization may not reflect innovative activities.

This paper takes the advantage of a newly constructed combination of Mexican plant-level datasets to examine whether trade liberalization leads to changes in a direct measure of innovative activities – total R&D expenditures – at the plant level. The combined dataset has two unique features: it contains (1) the amount of total R&D as well as R&D on product innovation and process innovation, and (2) the trade-classification categories of plants' outputs and inputs, which allows me to construct plant-level tariff changes and therefore to control for industry-year effects. I use tariff changes of Mexico between 2000-2003 as a source of exogenous variation in market

[1] Plant-level studies on the effects of output tariff reduction on productivity include Harrison (1994), Tybout and Westbrook (1995), Krishna and Mitra (1998), Head and Ries (1999), Pavcnik (2002), Schor (2004), Topalova (2004), and Trefler (2004). See Tybout (2000) for a survey of literature on trade and productivity in developing countries and Tybout (2003) for a survey of literature on plant-level evidence on international trade theories.

[2] See Tybout (2000) for a further discussion of the issues arising when interpreting measured TFP and measured mark-ups. Klette and Griliches (1996) discuss the issues arising when estimating a production function or a cost function using revenue-based output measures.

competition. The tariff changes are an attractive source of variation because they are driven mainly by the reduction of tariffs due to free trade agreements (North American Free Trade Agreement (NAFTA) and the free trade agreement with the European Union (EU)), which are likely to be exogenous to Mexican plants.[3] This is the first paper to combine direct evidence on R&D expenditures at the plant level with credibly exogenous variation in exposure to international competition due to trade liberalization.

I find robust evidence that the reduction on the tariffs of goods produced by Mexican plants induced those plants to increase total R&D. This suggests that trade liberalization stimulates innovative activities through competition. I do not find any evidence that the same output tariff reduction affected TFP, which suggests that relying solely on TFP, as much of the literature has done, is likely to be misleading.

As an extension, this study separates total R&D expenditures into process R&D (i.e. R&D for improvement of the efficiency of production system) and product R&D (i.e. R&D for creation of new products or upgrading of the quality of existing products). Separating these types of innovative activities allows me to explore further the sources of gains from international trade. I find evidence that reductions in the output tariffs increased process R&D. I do not find evidence that the same output tariff reductions affected product R&D. These findings suggest that the effects of trade liberalization come primarily through cost-cutting and improvements in technical efficiency rather than product innovation.

All the results mentioned above are based on within-industry variation, from regressions that include industry-year effects. The same patterns are not discernable in regressions that do not control for such effects. Because typical plant-level datasets lack detailed product-level information,[4] tariffs can be constructed only at the industry level and the within-industry dimension cannot be explored.[5] The results of this paper thus underline the value of product-level information in

[3] Kowalczyk and Davis (1996) provide evidence that the Mexican tariff reductions through NAFTA were not driven by Mexican interests. I will further discuss endogeneity issues in Section 5.1.

[4] Exceptions include the Indonesian data used by Amiti and Konings (2007), the Colombian data used by Kugler and Verhoogen (2008) and the Canadian data used by Lileeva and Trefler (2007).

[5] See Levinsohn (1993) that noted the difficulty of capturing the effects of tariff changes on plant-level wages and employment.

analyzing the effects of tariff changes on plant-level innovative activities.

This paper is related to a number of strands of literature. Building on the early work of Grossman and Helpman (1991b, 1991c) and Rivera-Batiz and Romer (1991), recent studies incorporate innovation into the heterogeneous-firm model of Melitz (2003) to analyze the relation between international trade and innovation at the plant level (Baldwin and Robert-Nicoud (2008), Constantini and Melitz (2007) and Atkeson and Burstein (2007)). The effects of trade liberalization on innovation through increased competition depend on whether market competition increases innovation. Theoretical predictions on the effects of increased competition on innovation are ambiguous. On one hand, an increase in competition may hurt innovation through negative effects on the market share of firms (Grossman and Helpman (1991a) and Aghion and Howitt (1992)).[6] On the other hand, an influential set of recent papers suggest that competition may increase innovation: tougher competition increases the threat to rents of incumbent firms at or near the technology frontier; such firms maybe induced to innovate to preserve their rents (Aghion, Harris and Vickers (1997) and Aghion, Harris, Howitt and Vickers (2001)).[7] Competition may also reduce managerial slack or X-inefficiency among manufacturers, which may stimulate innovation.[8] Thus, it is an empirical question whether increased import competition encourages or discourages innovation.

In the empirical literature, this study is most closely related to papers by Sherer and Huh (1992), Bloom, Draca and Van Reenen (2008), and Gorodnichenko, Svejnar and Terrell (2008) which examine the relationship between import competition and plant-level R&D or information technology use.[9] Sherer and Huh (1992) find negative effects of high technology imports on U.S.

[6]See Schumpeter (1942) for the original work pushing the idea that monopoly rents stimulate innovation; in this view, competition is bad for innovation.

[7]This line of research is summarized in Aghion and Howitt (2005). See also Acemoglu, Aghion and Zilibotti (2002) for the implications of distance from technology frontier on the effects of openness on growth. See also Sutton (2007) for another analysis of the effects of global competition on innovation in developing countries.

[8]See Hicks (1932) and Corden (1974) for classical treatment. Schmidt (1997) builds a model in which competition induces more managerial efforts by increasing the risk of bankruptcy. Bertrand and Mullainathan (2003) provide evidence on managerial slack.

[9]There exist also papers analyzing the effects of competition without focusing on import competition. Early plant-level studies on domestic market competition and innovation have typically shown a positive correlation between the two (Nickell (1996), Blundell, Griffith and Van Reenen (1999)). See also Aghion, Bloom, Blundell, Griffith and Howitt (2005) that show empirically that the relation between competition and innovation is U-shaped as suggested by their models.

firms' R&D, Bloom, Draca and Van Reenen (2008) find positive effects of Chinese imports on European firms' technology use, and Gorodnichenko, Svejnar and Terrell (2008) find a negative correlation between firms' perception on the degree of competition and innovative activities in emerging countries. All the three studies are subject to concerns about omitted variables bias, however.[10] Since the degree of import competition could be affected by innovative activities or other factors that are related to them, exogenous variation in import competition is needed. In this study, tariff changes provide a more credibly exogenous source of variation with which to estimate the causal effects of import competition on R&D at the plant level.

This paper is also related to a number of papers highlighting alternative channels through which trade may affect innovation. Early empirical papers tried to estimate the effects of openness on growth using country-level data (Sachs and Werner (1995) and Frankel and Romer (1999)). Typical cross-country studies do not allow one to separate the mechanisms through which international trade could affect innovation and are subject to endogeneity concerns. Recently, several empirical papers have shown that indicators of plants' quality and technology choices respond positively to positive shocks to export market access (Verhoogen (2008), Bustos (2007), and Lileeva and Trefler (2007)). Another set of empirical papers investigate the effects of increased availability of imported intermediate inputs: Schor (2004) and Amiti and Konings (2007) analyze the effects of input tariff reduction on productivity and Broda, Greenfield and Weinstein (2007), and Goldberg, Khandelwal, Pavcnik and Topalova (2008) analyze the effects of availability of imported intermediate goods on variety expansion. Recent papers by Acharya and Keller (2007, 2008) also analyze the effects of imports on productivity in industries in developed countries stressing the role of imports in generating R&D spillovers. None of the papers above investigate empirically

[10]For example, growing industries may have more competition and more innovation at the same time, which would result in positive biases in the estimated effects of competition on innovation. This concern may apply to all cross-sectional studies. On the other hand, the plants that fail to do innovative activities might be more likely to lose from competition, which would result in negative biases in the estimated effects of competition on innovation. Gorodnichenko, Svejnar and Terrell (2008) are susceptible to this concern. Finally, in case of Chinese competition, China may have comparative advantage in industries with initially more scope for technology upgrading, and imports from China may be growing in such industries, which would result in positive biases in the estimated effects of Chinese competition on innovation. Identification strategies using current or initial imports from China as sources of variation, as in Bloom, Draca and Van Reenen (2008), are susceptible to this concern. (Bloom, Draca and Van Reenen (2008) mention other estimation strategies but do not report the results of those strategies.)

the effects of increased import competition on innovative activities at the plant level. I show that my findings are not driven by these other mechanisms.

The paper is organized as follows. The next section describes the new combination of datasets, and presents descriptive statistics of plant-level variables and tariff changes. Section 3 describes my econometric strategy. Section 4 presents the baseline results. Section 4.1 shows that the output tariff reduction decreased total sales, domestic sales, employment of the plants affected, but not export sales. Section 4.2 shows that the output tariff reduction did not affect TFP. Section 4.3 presents the key results on the effects of competition on R&D. In section 5, I present additional analysis to provide evidence that alternative hypothesis cannot fully explain the results of section 4. Section 5.1 deals with endogeneity concerns. Section 5.2 deals with an alternative hypothesis: export market access. Section 5.3 shows that the results are robust to the inclusion of region-year effects. Section 6 presents the additional results separating product and process innovation. Section 7 provides evidence that the results would be inconclusive without the availability of within-industry variation exposure to international competition. Section 8 concludes.

2 Data

This section describes the data. The first subsection describes the plant-level data and presents descriptive statistics of plant-level variables. The second subsection describes the imports and tariff data and presents descriptive statistics of tariff changes.

2.1 Plant-level Data

I combine three types of plant-level data for the analysis.[11] The first is a specialized survey on innovative activities. The second is a standard plant-level survey from which I draw basic variables such as sales and employment. The third is a registry of plants that includes information on the trade-classification category of plants' outputs and inputs from which I will construct measures of plant-level tariff changes.

[11] To the possible extent that the ownership information could be checked, a firm owns at most one plant in most of the cases. The results of the paper do not change if I aggregate the unit of analysis to the firm level.

2.1.1 ESIDET

The source of R&D information 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]. It has surveys for three sectors: manufacturing, education, and government. I will use the data for manufacturing. The survey contains information on several aspects of innovative activities: 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. I use the 2002 and 2004 surveys.[12] Each survey elicits information for the previous two years. This makes unbalanced panel data from 2000 to 2003.

The survey asks how much plants spend on (1) introduction of new products, (2) substantial quality upgrading of existing products, (3) routine quality upgrading existing products, (4) creation of new production process, (5) substantial improvement of existing production process and (6) routine improvement of existing production process. I classify (1) - (3) as product R&D and (4) - (6) as process R&D.[13]

2.1.2 EIA

In order to obtain various basic information such as domestic sales, export sales, capital stock, investment, and employment, I use 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, see Appendix II of Verhoogen (2008).

[12] Surveys were done in 1996, 1998, 2002, 2004 and 2006. The 1998 survey suffers from a number of data quality issues, and few plants can be linked between the 1996 and 2002 waves. In addition, the product-level information is available beginning 2001. The 2006 survey has become available too recently to be included in this version of the paper.

[13] I do not distinguish between creation of new products and quality upgrading because there is not a clear conceptual distinction between a new product and a substantially upgraded version of an existing product. Theoretically, the two types of innovation are often isomorphic (Grossman and Helpman (1991a)).

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, I 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 to the EIA and ESIDET using information on firm name, state, municipality, street address, and industry.

2.1.4 Descriptive Statistics of Plant-level Variables

Table 1a presents summary statistics for the EIA-SIEM panel. I report the mean and the standard deviation of each variable by export status. Consistent with patterns found for many countries, exporting plants have larger volumes of sales and employment.[14] Exporters are also more likely to be importers and to have larger volumes of imports than non-exporters.

Table 1b presents summary statistics for the ESIDET-SIEM panel. Exporters are more likely to be doing R&D and have higher expenditure on R&D. However, only 23% of these exporters report positive amount of total R&D expenditure. This ratio is 17% for all the plants and 9% for non-exporters. The intensity of R&D (R&D expenditure/ Total sales) is about 1% unconditionally, and about 4% conditional on spending a positive amount on R&D. On average, conditional on spending a positive amount of R&D expenditure, plants spend 24% of total R&D expenditure on creation of new products, 29% on quality upgrading of existing products, and 34% on improvement of production system.[15] The first two refer to product innovation and the last to

[14] For the U.S., see Bernard and Jensen (1999)

[15] These does not add up to 100% because there is uncategorized R&D expenditure in the data.

process innovation. The distribution of R&D is very different between exporter plants and non-exporter plants. Exporters are more likely to spend R&D for product innovation rather than process innovation.

2.2 Tariff Data

I 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.

2.2.1 Construction of Plant-level Tariff Measures

Because of free trade agreements, tariffs for one product differ depending on the country of origin. I 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 $Tariff_{gjt}$, I take the simple average of the tariffs of each plant's outputs to construct the output tariffs at the plant level.[16]

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

[16] I 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.

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.

Similarly, I 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 I 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. In Section 4, I report the results from two unbalanced panels: EIA-SIEM panel and ESIDET-panel. I used EIA-SIEM for the analysis of sales, employment and TFP, and I used ESIDET-SIEM for the analysis of R&D variables.[17]

2.2.2 Descriptive Statistics on Tariffs

Table 2a presents summary statistics for tariffs. I report 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. The purpose of the table is to show the sources of tariff changes during the period of the study. It shows that the tariff changes are largely coming from tariff changes scheduled in free trade agreements.

Table 2b presents summary statistics of plant-level tariffs for the ESIDET-SIEM panel. On average, both output and input tariffs at the plant-level are higher than the tariffs shown in Table 2b. Plant-level average output tariffs decreased from 7.9% in 2000 to 4.3% in 2003, while plant-level average input tariffs decreased from 6.3% to 3.4%.

[17] I also constructed another panel EIA-ESIDET-SIEM, and the results are qualitatively similar.

3 Specification

The baseline econometric model is the following:

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

where i, j, and t index plants, industries, and years, respectively; Y_{ijt} denotes the dependent variable: total sales, domestic sales, employment, and exports, TFP measures or Total R&D, process R&D, or product R&D; $\textit{Output Tariff}_{it}$ is output tariffs at the plant level constructed in the manner described in the previous 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 is β_1, which corresponds to the changes in the dependent variables in response to a one percent point change in the output tariff. 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 output 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*. If output tariff reduction affects plants' behavior through increase in competition, the coefficients of β_1 for the regressions with sales and employment as the dependent variables are expected to be positive. For TFP measures and R&D variables, there is no clear theoretical prediction on whether the coefficient should be positive or negative.

I also run regressions of the following form:

$$Y_{ijt} = \beta_1 \textit{Output Tariff}_{it} + \beta_2 \textit{Input Tariff}_{it} + \lambda_i + \mu_{jt} + \epsilon_{ijt} \tag{4}$$

This specification controls for the changes in input tariffs. It is important to control these input tariffs because the changes in output tariffs and those in input tariffs might be correlated. It is also important to note that most of the previous studies focusing on the effects of output tariff changes are not able to control for input tariff changes.[18] In Section 5.2, I further control for U.S. tariffs in order to control for the changes in export market access, and In section 5.3, I also control for state-year fixed effects to control for any shocks at the region level.

4 Results

This section reports the results from the regressions. There are three types of results. The first subsection reports the results for sales and employment as the dependent variables. The subsection 4.2 reports the results for various kinds of TFP measures as the dependent variables. The last subsection reports the key results of the paper: the regression results for R&D expenditure as the dependent variables.

4.1 Results on Plant-level Basic Variables

Before presenting the results for innovative activities, I report the results from the regressions using total sales, domestic sales, employment and exports as the dependent variables. The purpose is to show that the output tariff reduction did have an impact on basic plant behavior. Since output tariff reduction should affect plants' behavior through an increase in competition, it is important to confirm that the tariff reduction affected negatively the basic performance of the plants affected.

Table 3a shows the results. The regression results from EIA-SIEM panel confirm that output tariff reduction negatively affected the total sales, domestic sales, and total employment. I do not find significant effects of output tariff reduction on exports. There is no reason to believe the output tariff reductions affect the export behavior of the plants unless the output tariff reductions are correlated with tariff reductions of other countries. The fact that I do not find evidence of the effects of output tariff reduction on exports suggests that output tariff reductions affect plants'

[18] Schor (2004) and Amiti and Konings (2007) are exceptions.

behavior only through an increase in competition and are not correlated with the tariff reductions of other countries.[19]

Table 3b shows the results controlling for input tariff changes. The results are qualitatively similar in that the output tariff reduction decreased sales and employment, but not exports. This suggests that the effects of the output tariff changes found in Table 3a are not driven by changes in input tariffs that happens to be correlated with the changes in output tariffs.

4.2 Results on TFP

Next, I report the results from the regressions using TFP measures as the dependent variables. I estimated TFP using the estimation methods of production function by OLS, by the method developed by Olley and Pakes (1996) and by the method of Levinsohn and Petrin (2003).[20] The first three columns of Table 4 show the results from the basic specification. The coefficients are negative, which suggests that output tariff reductions positively affect productivity. But the effects are not significant for any of the TFP measures. One possibility is that increased competition due to the tariff reductions decreased mark-ups, which would reduce measured TFP.

The last three columns show the results from the regressions that control for input tariff changes. The results are qualitatively similar in that the coefficients are negative but not significant. This suggests that the effects of the output tariff changes found above are not driven by the changes in input tariffs correlated with the changes in output tariffs. From these results, one would be tempted to conclude that the trade liberalization had little effect on productivity, or, by extension, plants' innovative activities.

4.3 Results on R&D

Finally, I report the results from the regressions using R&D as the dependent variables. The first three columns show the results from the basic specification; equation (3). I find significant effects of output tariff reduction on R&D. I use three types of total R&D measures: Log Total R&D,

[19] In Section 5.2, I further control for U.S. tariffs in order to control for the changes in export market access.

[20] The methods by Olley and Pakes (1996) and Levinsohn and Petrin (2003) are standard methods to correct for endogeneity problems arising from the correlation between inputs and productivity.

R&D intensity, and R&D Dummy. They are defined in the following way. $Log\,Total\ R\&D_{it} = log(Total\ R\&D_{it} + 1)$, $R\&D\ Intensity_{it} = \frac{TotalR\&D_{it}}{TotalSales_{i0}}$, where 0 indicates the year I first observe the plants,[21] and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if total R&D is positive, and 0 otherwise. The intensity variable is likely to capture the intensive margin and the dummy will capture the extensive margin.

For all variables, the effect of output tariff on R&D is statistically significant. It seems that the effects are generated both through the intensive margin and the extensive margin. One percent reduction of the average tariffs of the goods that a plant produces increases total R&D by 8%, R&D intensity by 0.03% points, and the probability of undertaking R&D by 1% points. Given that the average R&D intensity is 1% in 2000, the increase in R&D intensity by 0.03% points is relatively small. Most of positive effect of increased competition on R&D seems to come from the extensive margin.

Columns (4)-(6) show the results controlling for input tariff changes, which is the specification in equation (4). The results are qualitatively similar in that estimated coefficients of the output tariffs are similar with and without controlling for the input tariffs. This suggests again that the effects of the output tariff changes found in the first three columns are not driven by the changes in input tariffs correlated with the changes in output tariffs.

In sum, I find significant negative effects of output tariff reduction on total and domestic sales and employment. I find the significant positive effects of output tariff reduction on R&D. However, I do not find evidence that TFP has responded. It suggests that the effects that I have been finding are thanks to the data that allows me to observe direct information on the innovative activities that are not contaminated by mark-ups.

[21] I already showed that the output tariff reduction affected total sales negatively. The reduction of total sales would automatically increase the R&D intensity. I fixed the period of denominator at the initial period in order to avoid this.

5 Robustness Checks

I perform two kinds of analysis to provide evidence that alternative hypotheses cannot fully explain the results of Section 4. Section 5.1 deals with endogeneity concerns. Section 5.2 deals with an alternative hypothesis: export market access. Section 5.3 show the additional results from the regressions that control for region-year fixed effects.

5.1 Endogeneity Check

Tariff reductions could be endogenous because the government could have set the tariffs to favor some firms over others. Since I have been relying on within-industry variation of tariff changes, correlation between tariffs and omitted industry characteristics would not invalidate my results. However, the government could have set trade policies to favor some particular plants even within industries, which would invalidate my assumption that the tariff changes are exogenous at least within industry. One way to investigate this story is to check whether the degree of tariff reduction was correlated with plants' initial characteristics within industry.

To do so, I run regressions of the following form:

$$Y_{ij2000} = \beta_1 \triangle Output\ Tariff_{ij} + \mu_j + \epsilon_{ij} \quad (5)$$

where Y_{ij2000} is either total sales, domestic sales, exporter dummies, exports, total employment or TFP[22] of plant i in 2000; $\triangle Output\ Tariff_{ij}$ is a change in tariff of plant i from 2000 to 2003; μ_j is a industry fixed effect. A significant coefficient β_1 tells that smaller or larger plants were more likely to face tougher import competition induced by tariff reduction, even within industry, which would imply that the governments might have set the tariffs to favor plants with particular characteristics over other plants.

Table 6a shows the results. It shows that there is no correlation between plant characteristics and subsequent output tariff reduction within an industry. None of the dependent variables in the

[22] I report the results for TFP estimated using Olley-Pakes method, but the results are qualitatively similar if I use other TFP measures.

initial year, initial total sales -domestic sales, export status, exports or employment- are correlated with the degree of the output tariff reduction between 2000 and 2003.

I also run regressions of the following form to see whether this conclusion is robust to the inclusion of the degree of input tariff reduction:

$$Y_{ij2000} = \beta_1 \triangle Output\ Tariff_{ij} + \beta_2 \triangle Input\ Tariff_{ij} + \mu_j + \epsilon_{ij} \tag{6}$$

Table 6b shows the results. The conclusion above is robust to the inclusion of the changes in input tariffs as controls: none of the initial total sales, domestic sales, export status, exports, employment are correlated with the degree of the output tariff reduction between 2000 and 2003. However, 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,[23] which had a higher degree of tariff reduction.[24]

The fact that the degree of input tariff reduction is correlated with the initial plant size may be consistent with the findings of the previous sections that there seem to be no significant effects of the input tariff reductions on sales, employment or R&D. The period between 2000 and 2003 is a period in which the performance of Mexican exports was relatively sluggish. Exporting plants, which are likely to be bigger in size, might have been relatively more likely to reduce sales, employment and R&D. If this is the case, it would produce positive biases in the estimated coefficients (negative biases in the effects of input tariff reductions) and it might have prevented me from finding the positive effects of the input tariff reductions.

5.2 Other Hypothesis: Export Market Access

All the results reported so far are from the specifications with plant fixed effects and industry-year fixed effects. Therefore, the results are robust to any changes in domestic or external demand

[23]This story is consistent with Kugler and Verhoogen (2008) who show that more productive plants are more likely to produce higher quality products and to therefore need higher quality inputs.

[24]In 2002, Mexico ratified Information Technology Agreement (ITA)-plus, which reduced the tariffs of many high-technology inputs.

at the industry level. A potential confounding factor is the tariff changes of other countries.[25] This is especially relevant in the context of my study, because the Mexican tariff changes that I am focusing on are due to free trade agreements. The other countries that have a free trade agreement with Mexico must have also decreased their tariffs. If the degree of Mexican tariff reduction and the tariff reduction of the other countries are correlated, then the results might not be due to the effects of increased competition but due to the effects of export market access. As Table 4a and 4b show, however, output tariffs did not cause any changes in exports; therefore it is not likely that the results are driven by the changes in export market access.

In order to further examine this alternative hypothesis, I run regressions of the following form for the main R&D variables:

$$Y_{ijt} = \beta_1 Output\ Tariff_{it} + \beta_2 Input\ Tariff_{it} + \beta_3 US\ Tariff_{it} + \lambda_i + \mu_{jt} + \epsilon_{ijt} \quad (7)$$

This is the basic specification with U.S. tariffs as a further control variable. The trade classifications of U.S. and those of Mexico are harmonized up to 6 digits, therefore I aggregated U.S. tariffs to 6 digits, and calculated plant-level US tariffs in the manner described in Section 2.2.1. The US tariffs are the tariffs that Mexican producer would face. Therefore higher US tariffs mean less export market access. Since approximately 90% of Mexican exports over the study period are to the U.S., I treat U.S. market access as equivalent to export market access.

Table 7 shows the results. The first three columns are the results with U.S. tariffs as an only control, and the next three columns are the results with both U.S tariffs and input tariffs. The magnitude of the coefficients for the output tariffs are similar to the results in Table 5: one percent reduction of the average tariffs of the goods that a plant produces increases total R&D by 8%, R&D intensity by 0.03% points, and the probability of undertaking R&D by 1% point. The results confirm that the effects of output reduction are not driven by the effects of export

[25] Another potential confounding factor may be tax incentives for R&D investment. To the extent I know, however, there are no such incentives that are correlated with output tariffs.

market access.

In some specifications, the U.S tariff reductions significantly increased Log of $R\&D$ and $R\&D$ dummy. The results are consistent with other papers that investigate the effects of export market access on innovative activities at the plant level (Verhoogen (2008), Bustos (2007) and Lileeva and Trefler (2007)).

5.3 Regional Factors

I also run regressions of the form (3) and (4) with state-year effects to control any regional growth factors and changes in policies at the state level. Table 8 shows the results. The qualitative conclusions are very similar to the previous subsection. Moreover, the extensive margin effects (the effect of output reduction on the R&D dummy) are now stronger and have stronger statistical significance.

6 Extension: Product vs Process R&D

One of the unique features of the dataset is that it has separate information on product R&D and process R&D. I run regressions of the form (3) and (4) to examine whether competition affects innovative activity mainly through product innovation or through process innovation, or both. Tables 9a and 9b show the results. For all specification of the R&D variables, product R&D is not significantly affected by the output tariff reduction. However, process R&D responded significantly to the output tariff reduction. The findings suggest that trade liberalization affects plants' capability primary through increases in cost efficiency rather than through the creation of new products or quality upgrading. This is somewhat surprising because most of the papers on trade and growth model innovation as occurring either through variety expansion or through quality upgrading. Recent models of industrial organization that try to predict a positive correlation between the market competition and innovation also focus on product innovation. The results are consistent, however, with Lawrence (2000) and Lawrence and Weinstein (2001), which stress the positive effects of competition on plants' incentive to be more cost efficient. Building a formal model to explain the findings is left to future research.[26]

7 The Results without Industry-year Effects

All the regressions mentioned up to the previous section controlled for industry-year fixed effects. To show the importance of controlling for industry-year fixed effects, I run all the regressions without them. Table 10a shows the results for the basic plant-level variables such as sales and employment, and table 10b shows the results for R&D variables. None of the coefficients are significant. These results for both the basic plant-level variables and R&D variables share a common feature that the effects of competition are smaller. One explanation may be that the industries with a higher degree of tariff reduction faced some offsetting forces. Note that the table 2a shows that the tariff reduction for the period of analysis is due to the NAFTA and the free trade agreement with the EU. However, during this period occurred a surge of Chinese imports, which do not experience tariff reduction.[27] Since Chinese imports are likely to have a negative correlation with plants' performances as well as with the degree of the tariff reduction, it may be difficult to capture the effects of the tariff reductions with typical plant-level datasets. This is because typical plant-level data have information only on the industry classification of plants' main products but not on detailed product-level information. The results of this paper suggest caution when relying on typical plant-level data in analyzing the effects of tariff changes when external factors are changing greatly.

8 Conclusion

This paper has found evidence that the reduction of tariffs on the goods produced by Mexican plants induced those plants to increase total R&D. This suggests that trade liberalization stimulates innovative activities through competition. I do not find any evidence that the same

[26]Models with both product and process innovation have been proposed by Cohen and Klepper (1996), Lin and Saggi (2002) and Rosenkranz (2003).

[27]See López Córdova (2004) and Shigeoka, Verhoogen and Wai-Poi (2006) for analysis on the effects of Chinese competition on manufacturing performance of Mexico.

output tariff reduction affects measured TFP, which suggests that relying on measured TFP — which includes mark-ups — might lead to wrong conclusions on the effects of trade liberalization on innovative activities. Additional results using process R&D and product R&D expenditure information suggest that trade liberalization affects plants' capability through increases in cost efficiency rather than through the creation of new products quality upgrading.

These results suggest that competitive pressure stimulates plants to be more efficient. The results are evidence against the infant-industry argument that assumes that competition from abroad will hurt the capacity and the incentive of plants' to innovate. The proponents of infant-industry protection might argue that the government could have selectively reduced tariffs on plants that were in the position to innovate. However, this does not appear to be the case. Initial plant characteristics are not correlated with the degree of the output tariff changes.

The overall analysis demonstrates the value of using direct measures of innovative activities. The effects of competition on innovation would not be discernable using standard TFP measures. The effects overall would not be discernable without the data that allows me to control for industry-specific shocks. This suggests caution in using typical plant-level datasets to analyze the effects of trade liberalization on plant-level outcomes, especially in situations where the degree of tariff reduction is modest and the global business environment is rapidly changing.

References

Acemoglu, D, Aghion, P, and F. Zilibotti. 2002. "Distance to Frontier, Selection, and Economic Growth."NBER Working Paper No. 9066.

Aghion, Phillipe, Christopher Harris, Peter Howitt and John Vickers. 2001. "Competition, Imitation and Growth with Step-by-Step Innovation." *Review of Economic Studies*, 68: 467-492.

Aghion, Phillipe, Nicholas Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt. 2005. "Competition and Innovation: An Inverted-U Relationship." *Quarterly Journal of Economics*, 120(2): 701-728.

Aghion, Philippe, Christopher Harris and John Vickers. 1997. "Competition and Growth with Step-by-Step Innovation: An Example."*European Economic Review, Papers and Proceedings*: 771-782.

Aghion, Philippe and Peter Howitt. 1992. "A Model of Growth through Creative Destruction."*Econometrica*, 60(2): 323-51.

Aghion, Philippe and Peter Howitt. 2005. "Growth with Quality-Improving Innovations: An Integrated Framework."in: Philippe Aghion and Steven Durlauf (ed.), *Handbook of Economic Growth*, edition 1, volume 1, chapter 2, 67-110. Elsevier.

Amiti, Mary and Joseph Konings. 2007. "Trade Liberalization, Intermediate Inputs and Productivity."*American Economic Review*, 97: 1611-1638.

Acharya, C. Ram, and Wolfgang Keller. 2007. "Technology Transfer Through Imports."NBER Working Paper No. 13086.

Acharya, C. Ram, and Wolfgang Keller. 2008. "Estimating the Productivity Selection and Technology Spillover Effects from Imports."mimeo.

Baldwin, Richard and Frédéric Robert-Nicoud. 2008. "Trade and Growth with Heterogenous Firms."*Journal of International Economics*. 74(1): 21-34.

Bernard, Andrew B., and J. B. Jensen. 1999. "Exceptional Exporter Performance: Cause, Effect, or Both?."*Journal of International Economics*, 47: 1-25.

Bertrand, Marianne and Sendhil Mullainathan. 2003. "Enjoying the Quiet Life? Corporate Governance and Managerial Preferences."*Journal of Political Economy*, 111(5): 1043-1075.

Bloom, Nicholas, Mirko Draca and John Van Reenen. 2008. "Trade induced technical change? The impact of Chinese imports on IT and innovation."mimeo.

Blundell, Richard, Rachel Griffith and Jon Van Reenen. 1999. "Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms." *Review of Economic Studies*, 66: 529-554.

Broda, Cristian, Joshua Greenfield and David Weinstein. 2006. "From Groundnuts to Globalization: A Structural Estimate of Trade and Growth." NBER Working Paper No. 12512.

Bustos. Paula. 2007. "Multilateral Trade Liberalization, Exports and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinean Firms." CREI and Universitat Pompeu Fabra.

Cohen, Wesley and Steven Klepper. 1996. "Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D." *Review of Economics and Statistics*, 78(2): 232-43.

Constantini, James A., and Marc J. Melitz. 2007. "The Dynamics of Firm-Level Adjustment to Trade Liberalization." forthcoming in Helpman, E., D. Marin, and T. Verdier. *The Organization of Firms in a Global Economy.* Harvard University Press, 2008

Corden, W. Max. 1974. *Trade Policy and Economic Welfare.* Oxford: Clarendon Press.

Frankel, Jeffery and David Romer. 1999. "Does Trade Cause Growth?." *American Economic Review*, 89: 379-399.

Goldberg, P, Amit Khandelwal, Nina Pavcnik and Petia Topalova. 2008. "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India." mimeo.

Gorodnichenko, Yuriy, Jan Svejnar, and Katherine Terrell. 2008. "Globalization and Innovation in Emerging Markets." NBER Working Paper No. 14481.

Grossman, Gene M., and Elhanan Helpman. 1991a. "Innovation and Growth in the Global Economy." Cambridge, MA: MIT Press.

Grossman, Gene M., and Elhanan Helpman. 1991b. "Quality Ladders in the Theory of Growth." *Review of Economic Studies*, 58: 43-61.

Grossman, Gene M., and Elhanan Helpman. 1991c. "Endogenous Product Cycles." *The Economic Journal*, 101: 1229-1241.

Harrison, Ann E. 1994. "Productivity, Imperfect Competition and Trade Reform: Theory and Evidence." *Journal of International Economics*, 36(1-2): 53-73.

Head, C. Keith, and John Ries. 1999. "Rationalization Effects of Tariff Reductions." *Journal of International Economics*, 47(2): 295-320.

Hicks, John R. 1935. "Annual Survey of Economic Theory: The Theory of Monopoly." *Econometrica*, 3: 1-20.

Katayama, Hajime, Lu, Shihua., and Tybout, James R. 2006. "Firm-level Productivity Studies: Illusions and a Solution."forthcoming in *International Journal of Industrial Organization.*

Klette, Tor and Zvi Griliches . 1996. "The Inconsistency of Common Scale Estimators When Output Prices Are Unobserved and Endogenous " *Journal of Applied Econometrics*, 11(4): 343-61.

Kowalczyk, Castern, and Donald Davis. 1996. "Tariff Phase-outs: Theory and Evidence from GATT and NAFTA. "NBER Working Paper No. 5421.

Krishna, Pravin, and Devashish Mitra. 1998. "Trade Liberalization, Market Discipline and Productivity Growth: New Evidence from India." *Journal of Development Economics*, 56(2): 447-462.

Kugler, Maurice and Eric. A. Verhoogen. 2008. "The Quality-complementarity Hypothesis: Theory and Evidence from Colombia." Columbia University.

Lawrence, Robert. 2000. "Does a Kick in the Pants Get You Going or Does It Just Hurt? The Impact of International Competition on Technological Change in U.S. Manufacturing."In

Robert C. Feenstra ed. *The Impact of International Trade on Wages.* NBER.

Lawrence, Robert and David Weinstein. 2001. "Trade and Growth: Import Led or Export Led? Evidence from Japan and Korea."In Stiglitz and Yusuf eds. *Rethinking the East Asian Miracle*. New York: Oxford University Press.

Levinsohn, James. 1993. "Testing the Imports-as-Market-Discipline Hypothesis." *Journal of International Economics*, 35(1-2): 1-22.

Levinsohn, James and Amil Petrin, A. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables."*Review of Economic Studies*, 70: 317-341.

Lileeva, Alla and Daniel Trefler. 2007. "Improved Access to Foreign Markets Raises Plant-Level Productivity ... for Some Plants."NBER Working Paper No. 13297.

Lin, Ping and Kamal Saggi. 2002. "Product Differentiation, Process R&D, and the Nature of Market Competition."*European Economic Review*, 46: 201-211.

López Córdova, J. Ernesto. 2004. "Economic Integration and Manufacturing Performance in Mexico: Is Chinese Competition to Blame?"Latin America/Caribbean and Asia/Pacific Economics and Business Association Working Paper No. 23.

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

Nickell, Stephen. 1996. "Competition and Corporate Performance."*Journal of Political Economy*, 104: 724-746.

Olley, G. Steven, and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry."*Econometrica*, 64(6): 1263-1297.

Pavcnik, Nina. 2002. "Trade liberalization, Exit and Productivity Improvements: Evidence from Chilean Plants."*Review of Economic Studies*, 69: 245-276.

Rivera-Batiz, Luis, and Paul Romer. 1991. "Economic Integration and Endogenous Growth." *Quarterly Journal of Economics*, 106: 531-555.

Rosenkranz, Stephanie. 2003. "Simultaneous Choice of Process and Product Innovation when Consumers Have a Preference for Product Variety." *Journal of Economic Behavior and Organization*, 50:183-201.

Sachs, Jeffery, and Andrew M. Warner. 1995. "Economic Reform and the Process of Global Integration." *Brookings Papers on Economic Activity*, 1:1-118.

Shoar, Adriana. 2004. "Heterogeneous Productivity Response to Tariff Reduction. Evidence from Brazilian Manufacturing Firms." *Journal of Development Economics*, 75(2): 373-396.

Schmidt, Klaus. 1997. "Managerial Incentives and Product Market Competition." *Review of Economic Studies*, 64(2): 191-213.

Schumpeter, Joseph. A. 1942. *Capitalism, Socialism and Democracy.* New York. Harper and Row.

Sherer, M. Frederic, and Keun Huh. 1992. "R&D Reactions to High-Technology Import Competition." *Review of Economics and Statistics*, 72(2): 202-212.

Shigeoka, Hitoshi, Eric. A. Verhoogen, and Matthew. G. Wai-Poi. 2006. "Chinese Competition and Mexican Manufacturers: Plant-Level Evidence and Policy Implications." Unpub. paper, Columbia University.

Sutton, John. 2007. "Quality, Trade and the Moving Window: The Globalization Process." forthcoming in *Economic Journal.*

Topalova, Petia. 2004. "Trade Liberalization and Firm Productivity: The Case of India." IMF Working Paper 04/28.

Trefler, Daniel.2004. "The Long and The Short of the Canada-U.S. Free Trade Agreement." *American Economic Review*, 94(4): 870-895.

Tybout, James. 2000. "Manufacturing Firms in Developing Countries: How Well Do They Do, and Why?" *Journal of Economic Literature*, 38: 11-44.

Tybout, James. 2003. "Plant and Firm-Level Evidence on 'New' Trade Theories." In *Handbook of International Trade*, ed. James Harrigan and Kwan Choi, 388-415. New York: Blackwell Publishing Ltd.

Tybout, James, Jaime de Melo, and Vittorio Corbo. 1991. "The Effects of Trade Reforms on Scale and Technical Efficiency." *Journal of International Economics*, 31(3-4): 231-250.

Tybout, James, and M. Daniel Westbrook. 1995. "Trade Liberalization and the Dimensions of Efficiency Change in Mexican Manufacturing Industries." *Journal of International Economics*, 39(1-2): 53-78.

Verhoogen, Eric A. 2008. "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector." *Quarterly Journal of Economics*, 123(2): 489-530.

Table 1a: Summary statistics of basic plant variables in 2000 (EIA-SIEM panel)

	Non-Exporter	Exporter	Total
Total Sales	168.6***	607.9***	394.4
(millions of pesos)	(13.8)	(116.7)	(60.7)
Exports	0.00**	241.0**	130.1
(millions of pesos)	(0.00)	(9.5)	(3.7)
Exports Share	0.00***	0.21***	0.11
	(0.00)	(0.01)	(0.01)
Importer Dummy	0.45***	0.78***	0.62
	(0.02)	(0.02)	(0.01)
Use of Imported Materials	19.1***	161.7***	93.23
(millions of pesos)	(3.2)	(51.1)	(26.5)
Employment	236.18***	489.36***	366.33
	(16.26)	(34.95)	(19.94)
N	606	641	1247

Notes: The table reports summary statistics of basic plant 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. Sales and exports are in nominal 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.

Table 1b: Summary statistics of R&D variables in 2000 (ESIDET-SIEM panel)

	Non-Exporter	Exporter	Total
R&D Expenditure (thousands of pesos)	614.51**	4267.34**	2686.91
	(294.81)	(1550.14)	(892.68)
R&D Dummy (1 if $R\&D > 0$)	0.09***	0.23***	0.17
	(0.02)	(0.02)	(0.02)
R&D/Total Sales	0.00	0.01	0.01
	(0.00)	(0.01)	(0.005)
R&D/Total Sales (if $R\&D > 0$)	0.01	0.05	0.04
	(0.005)	(0.03)	(0.02)
Share of R&D for creation of new products	0.16	0.26	0.24
(if $R\&D > 0$)	(0.06)	(0.04)	(0.03)
Share of R&D for quality improvement of products	0.16*	0.32*	0.29
(if $R\&D > 0$)	(0.05)	(0.04)	(0.04)
Share of R&D for improvement of production process	0.66***	0.34***	0.41
(if $R\&D > 0$)	(0.07)	(0.05)	(0.04)
N	257	337	592

Notes: The table reports summary statistics of R&D 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. R&D expenditure is in nominal 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.

Table 2a: Weighted average tariffs by type of country. Goods level data.

	All	NAFTA	EU	MFN	Others
Tariff in 2000	5.1	2.7	13.5	12.5	7.2
Tariff in 2001	3.9	1.9	5.8	12.4	5.4
Tariff in 2002	3.3	1.2	4.7	12.6	3.1
Tariff in 2003	2.7	0.5	4.0	12.5	3.2

Notes: The table reports the weighted average of tariffs by type of country. The second column shows the tariffs for each year for the imports from the NAFTA countries (US and Canada). The third column shows the tariffs for each year for the imports from the EU countries. The fourth column shows MFN tariffs. The fifth column shows the tariffs for the imports from other countries with free trade agreements or with Mexico during the period of this study. They are Colombia (1995), Venezuela (1995), Costa Rica (1995), Bolivia (1995), Nicaragua (1995), Chile (1999), Israel (2000), Guatemala, El Salvador (2001), Honduras (2001), Iceland (2001), Liechtenstein (2001), Norway (2001), and Switzerland (2001).

Table 2b: Plant-level output and input tariffs (ESIDET-SIEM Panel).

Variable	**Mean**	**Std. Dev.**	**N**
Output tariff 2000	7.87	7.63	527
Output tariff 2001	5.60	5.82	527
Output tariff 2002	5.05	5.87	602
Output tariff 2003	4.26	5.74	602
Input tariff 2000	6.28	8.46	559
Input tariff 2001	4.69	7.03	559
Input tariff 2002	4.12	7.20	629
Input tariff 2003	3.41	6.31	629

Notes: The table reports summary statistics of output tariffs and input tariffs at the plant level. The method of construction of plant-level output tariffs and input tariffs are in section 2.2. Briefly, the 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.

Table 3a: Regressions of sales and employment on output tariffs, EIA-SIEM panel 2000-2003.

	(1) Log Total Sales	(2) Log Domestic Sales	(3) Exporter Dummy	(4) Log Exports	(5) Log Employment
Output Tariff	0.0088**	0.0115**	-0.0012	0.0025	0.0067*
	(0.0047)	(0.0056)	(0.00203)	(0.0033)	(0.0038)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes
Observation	4105	4105	4105	2753	4105
R^2	0.0522	0.0410	0.0731	0.0813	0.0868

Notes: The table reports coefficients on the output tariffs from plant-level regressions of sales, employment or export-related variables on the output tariffs, plant fixed effects and industry-year fixed effects. All dependent variables are in logs except the exporter dummy. 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. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 3b: Regression of sales and employment on output tariffs, EIA-SIEM panel 2000-2003 (with input tariffs as control variables).

	(1) Log Total Sales	(2) Log Domestic Sales	(3) Exporter Dummy	(4) Log Exports	(5) Log Employment
Output Tariff	0.0132*	0.0155**	-0.0013	0.0032	0.0048*
	(0.0065)	(0.0081)	(0.0013)	(0.0043)	(0.0029)
Input Tariff	-0.0083	-0.0055	-0.0025	0.0022	0.0001
	(0.0089)	(0.0093)	(0.0018)	(0.0042)	(0.0019)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes
Observation	4105	4105	4105	2753	4105
R^2	0.0538	0.0422	0.0745	0.0865	0.0941

Notes: The table reports coefficients on the output tariffs from plant-level regressions of sales, employment or export-related variables on the output tariffs, plant fixed effects and industry-year fixed effects. All dependent variables are in logs except the exporter dummy. 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. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 4: Regressions of TFP measures on output tariffs, EIA-SIEM panel 2000-2003.

	(1) Log TFP OLS	(2) Log TFP Levinson-Petrin	(3) Log TFP Olley-Pakes	(4) Log TFP OLS	(5) Log TFP Levinsohn-Petrin	(6) Log TFP Olley-Pakes
Output Tariff	-0.0103	-0.0066	-0.0128	-0.0083	-0.0069	-0.0059
	(0.0119)	(0.0113)	(0.0122)	(0.0121)	(0.0122)	(0.0118)
Input Tariff				0.0058	0.0014	0.0056
				(0.0070)	(0.0066)	(0.0067)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2612	2612	2612	2612	2612	2612
R^2	0.121	0.116	0.121	0.135	0.121	0.125

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the TFP on the output tariffs, plant fixed effects and industry-year fixed effects. All dependent variables are in logs. TFP is estimated using OLS, the method by Olley and Pakes (1996), and the method by Levinsohn and Petrin (2003). 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. Robust standard errors in parentheses. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 5: Regressions of total R&D on output tariffs, ESIDET-SIEM panel 2000-2003.

	(1) Log R&D	(2) R&D Intensity	(3) R&D dummy	(4) Log R&D	(5) R&D Intensity	(6) R&D dummy
Output Tariff	-0.0833**	-0.0345*	-0.0102*	-0.0814**	-0.0364*	-0.0116*
	(0.0421)	(0.0182)	(0.0057)	(0.041)	(0.0196)	(0.0068)
Input Tariff				-0.0090	-0.0043	0.0006
				(0.0269)	(0.0122)	(0.0034)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2178	2178	2178	2178	2178	2178
R^2	0.13	0.70	0.22	0.12	0.71	0.21

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the total R&D on the output tariffs, plant fixed effects and industry-year fixed effects. Robust standard errors in parentheses. $Log\ R\&D_{it} = log(R\&D_{it} + 1)$, $R\&D\ Intensity_{it} = \frac{R\&D_{it}}{Total\ Sales_{i0}} * 100$, where 0 is the time first I observe the plants, and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if $R\&D$ is positive, and 0 otherwise. 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. Robust standard errors in parentheses. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 6a: Regressions of initial sales and employment on the changes in output tariffs, EIA-SIEM panel 2000-2003.

	(1) Log Total Sales	(2) Log Domestic Sales	(3) Exporter Dummy	(4) Log Exports	(5) Log Employment	(6) Log TFP
Output Tariff Changes	0.0113	0.0096	-0.00541	0.0278	0.0133	-0.0062
	(0.0157)	(0.0153)	(0.00569)	(0.0322)	(0.0118)	(0.0112)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	649	649	649	433	649	649
R^2	0.316	0.318	0.231	0.253	0.305	0.133

Notes: The table reports coefficients on the changes in output tariffs from plant-level regressions of the initial plant characteristics on the changes in output tariffs and industry fixed effects. Robust standard errors in parentheses. All dependent variables are in logs except the exporter dummy. TFP is estimated using Olley-Pakes method. 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. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 6b: Regressions of initial sales and employment on the changes in output tariffs, EIA-SIEM panel 2000-2003 (with input tariffs).

	(1) Log Total Sales	(2) Log Domestic Sales	(3) Exporter Dummy	(4) Log Exports	(5) Log Employment	(6) Log TFP
Output Tariff Changes	0.0205	0.0189	0.0028	0.0296	0.0186	-0.0022
	(0.0164)	(0.0158)	(0.0054)	(0.0319)	(0.0133)	(0.0122)
Input Tariff Changes	-0.0268**	-0.0254**	-0.0183***	-0.0461	-0.0117	-0.0108
	(0.0128)	(0.0125)	(0.0040)	(0.0353)	(0.00857)	(0.0079)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	649	649	649	427	649	649
R^2	0.335	0.336	0.242	0.259	0.318	0.143

Notes: The table reports coefficients on the changes in output tariffs from plant-level regressions of the initial plant characteristics on the changes in output tariffs and industry effects. Robust standard errors in parentheses. All dependent variables are in logs except the exporter dummy. TFP is estimated using Olley-Pakes method. 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. Robust standard errors in parentheses. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 7: Regressions of total R&D on output tariffs, ESIDET-SIEM panel 2000-2003 (with US tariffs and input tariffs as control variables).

	(1) Log R&D	(2) R&D Intensity	(3) R&D dummy	(4) Log R&D	(5) R&D Intensity	(6) R&D dummy
Output Tariff	-0.0862**	-0.0391*	-0.0123*	-0.0854**	-0.0406*	-0.0121*
	(0.0423)	(0.0213)	(0.0068)	(0.043)	(0.0221)	(0.0069)
US Tariff	-0.0920**	0.0160	-0.0134*	-0.0870*	0.0014	-0.0122
	(0.0442)	(0.231)	(0.0076)	(0.0474)	(0.239)	(0.0078)
Input Tariff				-0.0070	-0.0036	-0.0007
				(0.0272)	(0.0123)	(0.0035)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2137	2137	2137	2137	2137	2137
R^2	0.23	0.71	0.23	0.22	0.70	0.22

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the total R&D on the output tariffs, plant fixed effects and industry-year fixed effects with U.S. tariffs and input tariffs as control variables. Robust standard errors in parentheses. $Log\ R\&D_{it} = log(R\&D_{it} + 1) * 100$, $R\&D\ Intensity_{it} = \frac{R\&D_{it}}{Total\ Sales_{i0}}$, where 0 is the time first I observe the plants, and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if $R\&D$ is positive, and 0 otherwise. The plant-level output tariff for a plant is the simple averages of the product-level tariffs of the products that the plants produce. The plant-level U.S. tariff for a plant is the simple averages of the U.S. tariffs for U.S imports from Mexico 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. Robust standard errors in parentheses. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 8: Regressions of total R&D on output tariffs, ESIDET-SIEM panel 2000-2003 (with US tariffs, input tariffs and region-year effects as control variables).

	(1) Log R&D	(2) R&D Intensity	(3) R&D dummy	(4) Log R&D	(5) R&D Intensity	(6) R&D dummy
Output Tariff	-0.1087**	-0.0409*	-0.0133**	-0.1123**	-0.0406*	-0.0143**
	(0.0512)	(0.0222)	(0.0064)	(0.0532)	(0.0223)	(0.0069)
US Tariff	-0.102**	0.0404	-0.0150*	-0.101*	0.0361	-0.0145
	(0.0447)	(0.379)	(0.0083)	(0.0496)	(0.339)	(0.0089)
Input Tariff				-0.0102	-0.0046	-0.0008
				(0.0272)	(0.0123)	(0.0035)
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
Observation	2137	2137	2137	2137	2137	2137
R^2	0.29	0.73	0.29	0.28	0.70	0.30

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the total R&D on the output tariffs, plant fixed effects, industry-year fixed effects and region-year effects with US tariffs and input tariffs as control variables. Robust standard errors in parentheses. $Log\, R\&D_{it} = log(R\&D_{it}+1)*100$, $R\&D\, Intensity_{it} = \frac{R\&D_{it}}{Total\ Sales_{i0}}$, where 0 is the time first I observe the plants, and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if $R\&D$ is positive, and 0 otherwise. The plant-level output tariff for a plant is the simple averages of the product-level tariffs of the products that the plants produce. The plant-level U.S. tariff for a plant is the simple averages of the U.S. tariffs for U.S imports from Mexico 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. Robust standard errors in parentheses. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 9a: Regressions of product and process R&D on output tariffs, ESIDET-SIEM panel 2000-2003.

	(1) Log Product R&D	(2) Product R&D Intensity	(3) Product R&D dummy	(4) Log Process R&D	(5) Process R&D Intensity	(6) Process R&D dummy
Output Tariff	-0.0288	-0.0133	-0.0045	-0.0735*	-0.0250*	-0.106*
	(0.0532)	(0.0148)	(0.0061)	(0.041)	(0.0138)	(0.0064)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	2178	2178	2178	2178	2178	2178
R^2	0.21	0.13	0.17	0.19	0.15	0.19

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the product R&D or process R&D on the output tariffs, plant fixed effects and industry-year fixed effects. Robust standard errors in parentheses. $Log\, R\&D_{it} = log(R\&D_{it}+1)$, $R\&D\ Intensity_{it} = \frac{R\&D_{it}}{Total\ Sales_{i0}} * 100$, where 0 is the time first I observe the plants, and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if $R\&D$ is positive, and 0 otherwise. The 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 9b: Regressions of product and process R&D on output tariffs, ESIDET-SIEM panel 2000-2003. With input tariffs.

	(1) Log Product R&D	(2) Product R&D Intensity	(3) Product R&D dummy	(4) Log Process R&D	(5) Process R&D Intensity	(6) Process R&D dummy
Output Tariff	-0.0314	-0.0135	-0.0054	-0.0715*	-0.0224*	-0.0107*
	(0.056)	(0.0158)	(0.0068)	(0.036)	(0.0133)	(0.0066)
Input Tariff	-0.0245	-0.0064	-0.0025	-0.009	0.021	0.0007
	(0.018)	(0.0078)	(0.0023)	(0.026)	(0.0082)	(0.0034)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	2178	2178	2178	2178	2178	2178
R^2	0.22	0.14	0.18	0.21	0.16	0.20

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the product R&D or process R&D on the output tariffs, plant fixed effects and industry-year fixed effects. Robust standard errors in parentheses. $Log\, R\&D_{it} = log(R\&D_{it}+1)$, $R\&D\ Intensity_{it} = \frac{R\&D_{it}}{Total\ Sales_{i0}} * 100$, where 0 is the time first I observe the plants, and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if $R\&D$ is positive, and 0 otherwise. Robust standard errors in parentheses. The 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. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 10a: Regressions of sales and employment on output tariffs, EIA-SIEM panel 2000-2003 (*without* controlling for industry-year effects).

	(1) Log Total Sales	(2) Log Domestic Sales	(3) Exporter Dummy	(4) Log Exports	(5) Log Employment
Output Tariff	0.0062	0.0071	-0.0004	0.0024	0.0008
	(0.0084)	(0.0088)	(0.0019)	(0.0023)	(0.0034)
Input Tariff	-0.0032	-0.0041	-0.0016	-0.0017	0.0007
	(0.0076)	(0.0077)	(0.0021)	(0.0027)	(0.0019)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes
Industry-year effects	No	No	No	No	No
Observation	4105	4105	4105	2753	4105
R^2	0.0040	0.0025	0.0115	0.0265	0.0499

Notes: The table reports coefficients on the output tariffs and the input tariffs from plant-level regressions of sales, employment or export-related variables on the output tariffs, plant fixed effects *without* controlling for industry-year fixed effects. All dependent variables are in logs except the exporter dummy. The 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. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 10b: Regressions of total R&D on output tariffs, ESIDET-SIEM panel 2000-2003 (*without* controlling for industry-year effects).

	(1) Log R&D	(2) R&D Intensity	(3) R&D dummy	(4) Log R&D	(5) R&D Intensity	(6) R&D dummy
Output Tariff	0.0316	0.0102	0.0056	0.0218	0.0040	0.030
	(0.352)	(0.0183)	(0.0053)	(0.0371)	(0.0192)	(0.0046)
Input Tariff				0.0158	0.0103	0.0028
				(0.0162)	(0.0116)	(0.0020)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	No	No	No	No	No	No
Observation	2178	2178	2178	2178	2178	2178
R^2	0.11	0.69	0.19	0.12	0.71	0.21

Notes: The table reports coefficients on the output tariffs from plant-level regressions of the total R&D on the output tariffs, plant fixed effects *without* controlling for industry-year fixed effects. Robust standard errors in parentheses. $Log\ R\&D_{it} = log(R\&D_{it} + 1)$, $R\&D\ Intensity_{it} = \frac{R\&D_{it}}{Total\ Sales_{i0}} * 100$, where 0 is the time first I observe the plants, and $R\&D\ Dummy_{it}$ is a dummy variable taking value 1 if $R\&D$ is positive, and 0 otherwise. The 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. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.