Productivity Differences Between and Within Firms

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Abstract

We document how plants belonging to the same firm are heterogenous in their characteristics and then quantify a previously undocumented margin of aggregate labor productivity changes: within-firm across-plant reallocation of resources, Exploiting Mexican manufacturing plant-level panel data from 2003 to 2010, which allow us to identify which plants belong to which firms, we find that plants that have a bigger size within firm (i) are more productive, (ii) pay higher wages, (iii) are more likely to be export-oriented, and (iv) depend more on imported intermediate inputs. Reallocation of resources across plants within firms is a non-negligible part of aggregate labor productivity changes, especially for some important industries. We then explore the implication of within-firm across-plant heterogeneity, in particular non-exporting plants of exporting firms, on inferences from plant-level data and firm-level data. Within an exporting firm, non-exporting plants enjoy the same productivity levels as exporting plants, suggesting that the link between exporting and productivity arises at the firm level, but not additionally at the plant level. This induces plant-level data analysis to underestimate the exporter premium on productivity. On the other hand, non-exporting plants of exporting firms did not suffer at all during the trade crisis of 2008-09, which induces now firm-level data analysis to underestimate the impact of trade crisis. These findings together suggest that resource allocation within firms across plants is an important component of productivity changes and that conclusions drawn from the two types of data without considering this resource allocation may not be quantitatively comparable, and may also result in misleading inferences.

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1 Introduction

Heterogeneity in productivity at the level of producers has been the cornerstone of recent research in many fields, in particular international trade and economic growth.[1] Its implications for the effects of international trade on industry productivity, individual wages and aggregate welfare have been the most important developments in international trade since the seminal work by Melitz (2003).[2] The literature on misallocation of resources across heterogenous producers has also exploded since Restuccia and Rogerson (2008) and Hsieh and Klenow (2009).[3]

In most of the empirical applications, researchers have used two types of data: firm-level data and plant-level data. They use the word "firm" and "plant" interchangeably, and researchers compare the numbers across studies or statistics that come from firm-level data and plant-level data.[4] This is mostly due to data restrictions: most plant-level data do not recognize firm-plant structure.[5]

Recognizing firm-plant ownership structure could be important at least for two related reasons. First, we could observe what is happening within the firm. Specifically, the ability to look at plants within a firm allows us to investigate the re-allocation across plants within firms. This re-allocation within firms is something that is being emphasized in the emerging literature on multi-product firms - Bernard, Redding and Schott (2011) and Mayer, Melitz and Ottaviano (2011)) - though not directly with firm-plant linked data. Second, because of within-firm adjustment, failing to recognize firm-plant ownership structure and running regressions either at the plant level or at the firm level may lead to misleading conclusions. For example, what has been regarded as across-plant reallocation may really be within-firm reallocation. Also, response to a shock may be different at the plant level versus at the

[1]See Syverson (2011) for a survey on the literature on productivity.

[2]The number of surveys and introductions have also been already many. For example, see Melitz and Redding (2012) for a comprehensive survey and Melitz and Trefler (2012) for introduction of the topic.

[3]See Restuccia and Rogerson (2013) for an introduction of the topic and see other papers in the same volume of the *Review of Economic Dynamics*.

[4]For example, in Hsieh and Klenow (2009), the Chinese data are firm-level data, while the Indian and the U.S. data are plant-level data.

[5]There are studies that use data with firm-plant structure, but they do not exploit within-firm across-plant heterogeneity.

firm level.

We draw on newly constructed Mexican manufacturing plant-level panel data from 2003 to 2010, which allow us to identify which plants belong to which firms, and thus to compare across plants within firms. We document several facts that show the importance of multi-plant firms and within-firm across-plant heterogeneity. Then, we go on to explore the implication of the failure of recognizing firm-plant ownership structure in analyzing the impact of trade crisis on employment adjustment.

In terms of the facts, we document the following. First, multi-plant firms are not many but important in terms of the share of total sales and employment. Second, there is a substantial degree of systematic heterogeneity across plants within firms. We find that plants that have a bigger size within firm are (i) are more productive, (ii) pay higher wages, (iii) are more likely to be exporters, and (iv) depend more on imported intermediate goods. This pattern is remarkably similar across years. These linkages between productivity, size and exporting have been documented in the recent trade literature, but not across plants within firms. Third, we find that reallocation of resources across plants within firms contributes positively by eight percent to the aggregate labor productivity changes observed in our data from 2003 to 2008. While this may seem small, we see this as a lower bound since it is an estimate for all firms in the sample, a large majority of which are single plant firms. We also find that there is a substantial industry-level heterogeneity in the importance of this within firm reallocation of resources, and for some important industries the contribution is much larger than eight percent.

Recognizing the firm-plant structure has an important implication in studying the issue of exporter productivity premium - exporters tend to be more productive than non-exporters - , which is one of the main mechansims for selection of productive producers into export markets. When we compare the exporter premium based on plant-level data (ignoring the firm-plant structure) with that based on firm-level data, we find that the premium is much lower for plant-level data. Furthermore, once we recognize the firm-plant structure of our data, we find that the non-exporting plants of exporting firms enjoy the same productivity level as exporting plants of the same firm. The exporter productivity premium is vastly underestimated in plant-level regressions without recognizing the firm-plant structure because such plant-level regressions would not be able to distinguish between non-exporting plants of exporting firms and non-exporting plants of non-exporting firms.

These findings raise caution against using only plant-level data in estimating exporter productivity premium, and interpreting it to be coming from the usual mechanism that more productive plants select into export markets. What seems to be important is that the firm is an exporter.

Finally, for the trade crisis period of 2008-2009, firm-level regressions suggest that firms that were more export oriented as a whole did not suffer more, while plant-level regressions suggest that plants that were more export oriented within firms did suffer more than plants that were less. Thus, conclusions drawn on the impact of the trade crisis are starkly different between firm level data and firm-plant level data. This implies that a failure to account for firm-plant ownership structure may lead to a misleading conclusion in studies on the impact of aggregate shocks, such as the demand or credit collapse seen to be behind the trade collapse of 2008-09, on employment adjustment. Importantly, the results suggest that there is no risk sharing between export-market-oriented plants and domestic-market-oriented plants within firms. This is consistent with the story that export-market-oriented plants and domestic-market-oriented plants within firms produce very different products so that a shock to one of the plants cannot be mitigated through risk sharing within the firm.

This paper contributes to the emerging literature on multi-product firms. Most of this literature relies on data on export sales of a firm for different products, with highly disaggregated product classification (HS 8). For instance, Arkolakis and Muendler (2010), **?**, and Mayer, Melitz and Ottaviano (2011). Some papers combine the export sale by product datasets with production datasets at different levels of disaggregation. For instance, Bernard, Redding and Schott (2011), and **?**. Our data provide information on sales (domestic and export), employment, and inputs for plants within firms. While the information on specific products produced by the plants is not available, the data allow us to observe the industry a plant belongs at a level of disaggregation comparable to export sales datasets with multilpe products. We are, therefore, able to shed light on heterogeneity in labor productivity across plants within firms and analyze its implication on the firm-level and the aggregate labor productivity changes. All of the studies on multi-product firms, mentioned above, are silent on this issue. Change in firm productivity coming from a change in the product mix has beeb emphasized, theoretically, by Mayer, Melitz and Ottaviano (2011).

Within the class of models of multi-product firms, one class of models emphasizes differences across products with respect to costs - (Arkolakis and Muendler (2010), Mayer, Melitz and Ottaviano (2011)) - , while the other class of models emphasizes differences across products on the demand side - Bernard, Redding and Schott (2010) and Bernard, Redding and Schott (2010).[6] More generally speaking, models of multi-product firms in international trade feature firm- and product-specific components of firm profitability and the two classes of models differ with respect to the product-specific component. It is the product-specific component (low marginal costs or better demand attributes) that determines selection of a product into export markets. Our result that the exporter productivity premium of plants comes from the exporting status of the firm and not that of the plant within firm implies that the more productive plants within a firm do not self-select into export markets. In other words, the plant-specific attributes that lead to productivity differentials across plants do not influence the selection of plants into export markets. In order to pin down these attributes, and, consequently, differentiate between different theories of multi-product firms more analysis exploiting multi-product multi-plant firms and single-product multi-plant firms is necessary.

This paper is organized as follows. The next section describes the data, and presents descriptive statistics of plant-level variables and firm-level variables. Section 3 documents several facts about the importance of multi-plant firms. Section 4 provides evidence of the contribution of within-firm across-plant reallocation on aggregate labor productivity. Section 5 presents the results of the analysis of the exporter premium. Section 6 presents the results of the analysis on how firm-level data and plant-level data provide different answers

[6] There is a class of models that assumes that products are symmetric on both demand and cost dimensions - **?** and **?**.

for the analysis of the impact of the trade crisis 2008-2009 on employment adjustment. Section 7 concludes.

2 Data

The data come from the project Statistics of Exporting Firms by the Instituto Nacional de Estadísticas, Geografía (INEGI) [National Institute of Statistics and Geography] of Mexico. This project links plant survey data, namely the *Encuesta Industrial Anual* (EIA) [Annual Industrial Survey] with the custom transaction data in order for the INEGI to calculate various statistics of firms that trade and therefore the Mexican government to better understand the characteristics of firms that engage in international trade. The EIA is a longitudinal plant level dataset manufacturing industries, in which plants were then selected in decreasing order of value of output until the set of selected plants made up 85 % of the total value of output (not including maquiladoras, which we turn below) of each 6-digit industry covered. The custom transaction data are administrative records of the Mexican customs agency on every transaction crossing the Mexican border.[7] The former is at the plant level while the latter is at the firm (tax payer id) level. As a by-product, there is a concordance between firms and plants. The official data span from 2007 to 2010. We use test data that span from 2003 to 2010, excluding so-called maquiladora plants.[8]

The link between the custom transaction data and the establishment survey is constructed by the INEGI by the following procedure. First, the Economic Census of 2009 carried out by INEGI asks tax payer id. Therefore, for the establishments that existed in 2009 that provided a tax payer id in the 2009 Economic Census, the concordance between firm ID and plant ID exists. For the rest of the establishments, INEGI did the linking be-

[7]The custom transaction data part of the linked data include yearly export and import values for each 8-digit tariff classification code for each destination country (origin country in case of imports) for each firm, though the current version of this paper does not use the feature of the data yet.

[8]Maquiladora plants are assembly plants that participate in a Mexican government export-promotion program. They are typically selling the most, if not all, of their products to foreign countries, in particular to the U.S. The reason that the official data start from 2007 is that INEGI had separate surveying systems of non-Maquiladora plants and Maquiladora plants prior to 2007. Therefore, incorporating data on Maquiladora plants before 2006 in a consistent manner would not be easy. The reason that the test data start from 2003 is that the sampling scheme of the EIA was refreshed that year.

tween the two data using name, address and industry from the both data. The data cover plants that appeared at least once in the custom transaction data either as an exporter or an importer.

The data are not representative in many ways. First, by construction data are limited to firms that have exported or imported at least once in the data period. For big firms, however, not importing is almost impossible for firms that are more than medium size. Therefore the data end up covering most of firms with certain size. Second, the data may be missing for smaller plants of multi-plant firms. However, if anything, the importance of multi-plant firms and within-firm heterogeneity would be underestimated.[9] Third, Maquiladora plants are missing. However, they are very different in terms of their characteristics and of responses to trade shocks (Verhoogen, 2008), so we find it reasonable to focus on non-Maquiladora firms as a first analysis. To sum up, the current data are practically panel data of medium and large plants excluding Maquiladora plants.

In the following analysis, we regard three-digit Mexican industry code as the unit of industry and six-digit Mexican industry code as the unit of product.[10] Each plant in the data report one six-digit industry (product) code. One weakness of the data of the current paper compared to the standard in the multi-product firms literature is that we do not know what plants produce in detail. Therefore, we regard a firm as a multi-product firm if it contains more then one plant that report different six-digit industry (product) codes. Our definition of multi-product firms is more conservative than the standard in the literature in that multi-product firms by our definition would be also classified as multi-product firms by the standard in the literature while the opposite is not true as we cannot capture the cases a plant produces products other than what they report as their main product. We believe that the numbers we calculate give lower bounds for the importance of multi-product firms and the mechanism that are specific to them, such as reallocation

[9]For 2009, we cross-checked with the Economic Census and the importance of multi-plant firms is indeed bigger. The results are available upon request.

[10]Mexican industry code is based on Sistema de Clasificación Industrial de América del Norte (SCIAN), which is consistent with North American Industry Classification System (NAICS), which is a joint effort to harmonize industry classifications among the US, Canada and Mexico. A three-digit Mexican industry code is called a subsector (subsectro) and a six-digit Mexican industry code is called a clase de actividad (activity class) in the SCIAN system.

of resources with firms across plants that produce different products. Table 1 shows an example of how disaggregated each digit is.

Table 2 shows the summary statistics of key variables in 2003, the initial year of the data.[11] The variables shown are the number of workers, exporter dummy, export sales divided by total sales, importer dummy (1 if a plant reports non-zero imported intermediate cost), and imported material cost divided by total cost.[12] We sum up the values at the plant level to create variables at the firm level. The number of plants is 2629 while the number of firms is 2289, suggesting that the number of multi-plants firms is not large. In terms of the number of workers, the mean from the plant-level data is around 300 while that from firm-level data is around 350, implying that plants belonging to multi-plant firms are relatively large. The mean of the exporter dummy, the fraction of exporting plants or firms is 50 % for the plant-level data and 53% for the firm-level data, suggesting that there are instances in which a firm has at least non-exporting plants and exporting plants. The same is true for importers.

Table 3 shows the same summary statistics for plants single-plant firms and multi-plant firms separately. For the latter, the statistics both at the plant level and firm level are presented, allowing us to see the difference between the plant-level statistics and firm-level statistics for the subset of the sample that the difference could potentially arise. Comparing Columns (1) and (3), which is a comparison at the firm level, multi-plant firms hire more, and are more likely to export and import than single-plant firms. However, comparing Columns (1) and (2), which is a comparison at the plant level, the same is true only for the number of workers. Columns (2) and (3) show that the statistics from the plant level and at the firm level are very different, in particular for exporter and importer dummies. The fraction of exporting plants or firms is 43% for the plant-level data and 64% for the firm-level data, and the fraction of importing plants or firms is 57% for the plant-level data and 77% for the firm-level data. This implies that there are many non-exporting or non-importing plants belonging to firms with at least one exporting or importing plants.

[11]The pattern is similar across years except that the ratio of plants and firms that use imported intermediate is declining over years.

[12]In constructing the exporter and importer dummies, we used the EIA.

Related to this point, in Section 6, we present the results of the analysis on how firm-level data and plant-level data provide different answers for the analysis of the impact of the trade crisis 2008-2009 on employment adjustment.

Table 3 shows also that multi-plant firms are really large in size: the average number of workers at the firm level is 1911. In order to see the implication of this, Table 4 shows the share of top 5 plants and 5 firms in the industry-level employment. We can see that there is an important difference for some industries, in particular, the food industry (311), the paper industry (322), the chemical product industry (325), the fabricated metal product industry (332) and the transportation equipment industry (336). This raises caution against calculating concentration measures with plant-level data to use in the analysis.

3 Facts

Fact 1: Multi-plant firms are not many, but important.

Table 5 shows that multi-plant firms are not many-about 20 % total number of plants. However, they occupy 40 percent of total employment and 60 percent of total production in our data. This means that their behavior is important economically, and their within-firm across-plant adjustment behavior could potentially have important implications. This pattern is stable across years.

Table 6 shows the similar statistics within multi-plant firms, distinguishing between multi-plant single-product firms and multi-plant multi-product firms.[13] Among 40-50 % of the about 500 plants that belong to multi-plant firms are multi-industry firms. Among the multi-plant firms the share of multi-product firms in employment and production is about half. However, their share in exports is 75 percent to 85 percent, suggesting that multi-industry firms are concentrated in exporting industries.

Fact 2: Even for the case of Multi-plant firms, their main industry activity occupies a very high share.

[13]As is noted in the data section, we regard firms are multi-product firms if they contain at least two plants that report different products as their main products.

Table 7 shows that even for multi-plant multi-product firms, their main product (the 6-digit industry code that occupies the largest share in the firm-level total sales) occupies 75 percent to 80 percent of firm employment and firm sales and 90 percent of export sales. This suggests that on average and on aggregate their activities are concentrated to the most important activities. This is consistent with the idea of core competency in the multi-product models (Bernard, Redding and Schott (2011) and also Arkolakis and Muendler (2010)). Again, this pattern is stable across years.

Fact 3: Plants within Multi-plant firms exhibit substantial degree of heterogeneity in labor productivity both across and within industry.

Table 8 reports R^2 of the following regressions.

$$LogLaborProductivity_{ijst} = \lambda_{st} + \epsilon_{ijst} \quad (1)$$

$$LogLaborProductivity_{ijst} = \mu_{it} + \epsilon_{ijst} \quad (2)$$

where i, j, s and t denote firm, plant, sector (or product) and year, respectively. For the first regression, we use the three-digit-industry-code (what we call industry)- year fixed effects, four-digit-industry-code-year effects and six-digit-industry (what we call product)-code-year effects. The idea of these regressions is to know how much the variation in plant-level labor productivity can be explained by industry-level factors and firm-level factors. Columns (1) (2) and (3) report that three-digit industry, four-digit industry and six-digit-industry (product) effects explain 21 %, 31% and 50% of the variation in plant-level labor productivity. This means that more than half of the variation in plant-level labor productivity comes from plant-specific factors within industry or within product. Columns (4) reports that firm effects explain 78 % of the variation in plant-level labor productivity. This explanatory power is much better than any of industry or product fixed effects. However, this also means that 22 % of the variation in plant-level labor productivity cannot be explained by firm-level factors.

In order to show further the degree of within-firm across-plant heterogeneity in labor productivity, Table 9 shows the ranking of the most productive and not most productive (in terms of labor productivity) plants, within firms, in the product distribution of several key variables. This comparison is done separately for single-product and multi-product multi-plant firms. We first construct percentile for each plant's variables within product, then compare them between the most labor productive plants within firm and not the most labor productive plants within firms. For single-product multi-plant firms, plants that are not the most productive plants within firms are at 55th percentile in terms of their production, which means that these plants' production is on average just slightly bigger than the median of the plants that produce the same product. Plants that are the most labor productive plants within firms are at 68th percentile, which means that these plants' production is on average close to top 30 percent of the industry. The most remarkable difference can be seen in labor productivity itself. For both single-product multi-plant firms and multi-product multi-plant firms, plants that not most labor productive within firms are just above the median of the plants producing the same product, while plants that are most labor productive within firms are on average close to top 20 percent labor productive plants within industry.

Fact 4: Bigger Plants within Multi-plant firms are more likely to be more productive, paying higher wages, being exporters and being importers.

Table 10 shows the results of the following regression:

$$Y_{ijt} = \beta CostShare_{ijt} + \lambda_{it} + \epsilon_{ijt} \tag{3}$$

where i, j and t denote firm, plant and year, respectively; Y_{ijt} is the log of the average wage per worker, export orientation (exports divided by total sales), imported material dependence (imported material cost divided by total material cost) and energy intensity (energy-related expenditure divided by total sales), which could arguably capture better machines or better technology.[14] For all multi-plant firms, we find strong evidence that plants that have a higher cost share are more productivity, pay higher wages, are more export oriented, are more dependent on imported materials, and are more energy efficient. For the first three variables, the results hold both for single-product multi-plant firms and multi-product multi-plant firms, though we do not have good explanations for the difference of coefficients between them. Table 10 suggests that plant or firm-level heterogeneity documented by the international trade literature holds also across plants within firms.

4 Importance of Between-Plant Within-Firm Reallocation

In this section, we decompose aggregate labor productivity changes into firm-level labor productivity changes and changes that are due reallocation of shares across firms. Furthermore, in addition to the standard practice, we decompose firm-level labor productivity changes into plant-level labor productivity changes weighted by plants' share in firm's total workforce and changes that are due reallocation of the labor shares across plants within firms. This will allow us to assess whether changes in labor productivity at firm level are driven by within-plant changes in productivity or across plant reallocation of workforce within firms. The quantitative magnitude of the latter reflects the quantitative importance of the new mechanism highlighted in recent theories of multi-product firms.[15]

Define the following variables. $L_t = \sum L_{it}$,$s_{it} = \frac{L_{it}}{L_t}$ and $y_{it} = \frac{Y_{it}}{L_{it}}$. This means that the aggregate labor in our data at time t is the sum across labor of individual firms at time t; s_{it} is the share of firm i in terms of labor; and y_{it} is labor productivity of firm i at time t. Then, the aggregate labor productivity is the weighted average of firm-level productivity.

[14]Gutierrez and Teshima (2011) relate this variable and other environmental performance measures to international trade.

[15]Some of the labor productivity changes within plants within firms could be really across-product within-firm changes. Therefore, our estimates would give the lower bound of the importance of the mechanism. We also further decomposed the between-plant within-firm component into the one coming from multi-product firms and and the one coming from single-product firms. The result is available upon request.

$$y_t = \sum s_{it} y_{it} \tag{4}$$

The changes in the aggregate labor productivity can be decomposed into the three components in the RHS of the following equation.

$$\triangle y = \underbrace{\sum_i (\triangle y_i s_{i0})}_{Within-Firm} + \overbrace{\underbrace{\sum_i (y_{i0} \triangle s_i)}_{Between-Firm} + \underbrace{\sum_i (\triangle y_i \triangle s_i)}_{Cross-Firm}}^{Reallocation} \tag{5}$$

where y_{i0} is the initial labor productivity of firm i, s_{i0} is the initial labor share of firm i, $\triangle y_i$ and $\triangle s_i$ are changes in firm i's labor productivity and labor share, respectively. The first term in the RHS is the within-firm component, because this component comes from labor productivity changes of each firm. The second term in the RHS is the between-firm component, the component coming from the changes in shares holding the initial productivity fixed. This term is positive if on the average labor goes to more productive firms. The third term in the RHS is the cross-firm component, the component coming from both the changes in shares and the changes in labor productivity. This term is positive if on the average labor goes to firms whose productivity is growing. We call the between-firm component and the cross-firm component together as reallocation component as both include the component coming from the share changes.

Now, due to the advantage of our current data, we can further decompose $\triangle y_i$, using a similar argument above.

$$\triangle y_i = \underbrace{\sum_{j \in i} (\triangle y_{ij} s_{ij0})}_{Within-Plant} + \overbrace{\underbrace{\sum_{j \in i} (y_{ij0} \triangle s_{ij})}_{Between-Plant} + \underbrace{\sum_{j \in i} (\triangle y_{ij} \triangle s_{ij})}_{Cross-Plant}}^{Reallocation} \tag{6}$$

Putting the two equations, above, together, we can decompose the aggregate labor productivity changes into the following five components.

$$
\begin{aligned}
\triangle y \quad = \quad & \underbrace{\sum_i [\sum_{j \in i} (\triangle y_{ij} s_{ij0})] s_{i0}}_{Within-Firm-Within-plant} + \underbrace{\sum_i [\sum_{j \in i} (y_{ij0} \triangle s_{ij}) + \sum (\triangle y_{ij} \triangle s_{ij})] s_{i0}}_{Within-Firm-Reallocation} \\
+ \quad & \underbrace{\sum (y_{i0} \triangle s_i)}_{Between-Firm} \\
+ \quad & \underbrace{\sum_i [\sum_{j \in i} (\triangle y_{ij} s_{ij0})] \triangle s_i}_{Cross-Firm-Within-plant} + \underbrace{\sum_i [\sum_{j \in i} (y_{ij0} \triangle s_{ij}) + \sum (\triangle y_{ij} \triangle s_{ij})] \triangle s_i}_{Cross-Firm-Reallocation}
\end{aligned}
$$

Table 11 shows the results of the above decomposition for the three types of periods separately: (1) from 2003 to 2008, which we call the normal period, (2) from 2008 to 2009, which we call the crisis period and (3) from 2009 to 2010, which we call the recovery period.[16] Column (1) of Table 11 suggests that the most of productivity changes is explained by the within-firm component of which the within-firm reallocation component explains eight percent. Eight percent may not sound large, but note that this is the contribution to the aggregate labor productivity changes in our data, of which single-plant firms for which the within-firm across-plant reallocation component cannot operate occupies around 60 percent of employment and 40 percent of production. Therefore this suggests that the magnitude is much larger for firms for which this mechanism is relevant. The signs of Between-firm and Cross-firm components are both negative, indicating that the reallocation across firms contributed negatively in aggregate labor productivity changes.[17] The term Residual captures the residual component that comes from entry and exit of firms.[18] The fact that this term is positive means that on average plants that are more labor productive than the average entered or plants that are less labor productive than the average exited, though we would not want to emphasize this result as the data are not well suited to capture

[16]The margin of adjustment in terms of Mexican exports for the three periods is analyzed in detail in Giri, Seira and Teshima (2012).

[17]This is typical in the literature. See Pages, Pierre and Scarpetta (2009) for the cases of Latin American countries.

[18]This term is not expressed in the above equation.

this component. Column (2) of Table 11 suggests that within-firm reallocation component contributes negatively to the aggregate labor productivity growth by 25 %. This suggests that more labor-productive plants within firms lost their employment share during the trade crisis. This may be because that the trade crisis made exporting plants suffer more than non-exporting plants within firms and the former is more labor-productive than the latter, as is suggested by Table 10. Column (3) of Table 11 suggests that within-firm reallocation component is not important at all in the recovery period. The asymmetry between the crisis period and the recover period will be analyzed in our future work.

We did the same exercise separately for each 3-digit industry, and Table 12 shows the list of five industries in which the within-firm reallocation component occupies more than 10 % in the absolute term. We can see that the steel product industry and the food industry experience negative contributions of the within-firm reallocation component, while the transportation equipment industry, the chemical product industry and the paper industry experience substantially positive contributions of the within-firm reallocation component. Again, note that this is the contribution to the aggregate labor productivity changes in our data as a whole; the magnitude could be much larger for firms for which this mechanism is relevant. These five industries are also the industries in which we documented the difference between the share of top 5 plants and that of top 5 firms in industry-level employment in Table 4, suggesting that within-firm across-plant reallocation in important for the industries in which this mechanism is relevant. How is the importance of within-firm reallocation systematically correlated with industry characteristics and changes in trade exposure is left for future work.

5 Exporter Premium

In this section, we investigate the implication of firm-plant structure on the exporter wage and productivity premia. We estimate the following equation.

$$
\begin{aligned}
Y_{ijpt} &= \beta_1 FirmExporterDummy_{it} + \beta_2 PlantExporterDummy_{ijt} &(7)\\
&+ \beta_3 MultiPlantFirmDummy_{it} + \lambda_{pt} + \epsilon_{ijpt} &(8)
\end{aligned}
$$

where i, j, p and t denote firm, plant, product and year, respectively; Y_{ijt} is the average wage per worker, employment, or labor productivity (all in logs). The key in this equation that there are two exporter dummies, one at the firm level, and the other at the plant level, which allows us to analyze whether exporting plants within exporting firms perform better than non-exporting plants within exporting firms. By construction, the plant-level exporter dummy is necessarily zero if the firm-level exporter dummy is zero, and the two dummies are necessarily the same for single-plant firms. For this analysis, we use all the data, not restricting to multi-plant firms, to make the analysis closer to the typical empirical setting. Therefore, we control the multi-plant firm dummy.

Table 13 shows the results. Column (1) shows that plant-level employment is higher if the firm a plant belongs to is an exporter, and is also *even much* higher if the plant itself is an exporter. Column (2) shows that the plant-level average wage per worker is higher if the firm a plant belongs to is an exporter, and is also *additionally* higher if the plant itself is an exporter, though this additional impact is only marginally statistically significant. Column (3) shows that the plant-level productivity is higher if the firm a plant belongs to is an exporter, but *not* additionally higher if the plant itself is an exporter. The point estimate of the coefficient on the plant exporter dummy is also very small (0.013), compare to that on firm exporter dummy (0.220). The results together suggest that the correlation between labor productivity and exports is determined at the firm level, the correlation between employment and exports determined at the plant level, and the correlation between wages and exports is in between.[19] This results suggest that the productivity is first determined at the firm level and firms decide how to allocate resources across different plants.

[19] Exporting plants may be willing to pay high wages than non-exporting plants of the same firm even if their productivity are same if exporters produce higher-quality products than non-exporters and the former need to pay higher wage to solicit workers' effort. See Verhoogen (2008) for such a model.

To further corroborate this point, we run the following equation separately at the plant level and at the firm level.

$$LogLaborProductivity_{ipt} = \beta_1 ExporterDummy_{it} + (\beta_2 MultiPlantFirmDummy_{it}) + \lambda_{pt} + \epsilon_{ipt} \quad (9)$$

where i, p and t denote firm or plant, plant, product and year, respectively.[20] We run the regressions both with and without the dummy for multi-plant firms because the regressions with it are consistent with the previous table while the regressions without it are consistent with the typical empirical setting in which the plant-firm structure information is not available.

Table 14 shows the results. With or without the the dummy for multi-plant firms, the exporter premium on labor productivity is substantially higher for the firm-level regressions than for the plant-level regressions. This is consistent with the argument above that the productivity is first determined at the firm level and that therefore non-exporting plants of exporting firms enjoy the same productivity level as exporting plants of the same firm. This is correctly captured in the firm-level regressions, but not in the plant-level regressions, therefore, the exporter productivity premium is vastly underestimated in the plant-level regressions. This raises caution against using only plant-level data in estimating exporter productivity premium.[21]

6 Impact of the Crisis on Employment

Finally, we investigate the impact of the trade crisis 2008-2009 on employment changes using both firm-level data and plant-level data to compare how the two data could lead to different conclusions. For the firm-level data, we run the following regression for multi-plant

[20]Note that subscript i could denote plant in this analysis.

[21]This also suggests that the substantial heterogeneity in labor productivity within firms across plants documented earlier in this paper may not be due to the co-existence of exporter plants and non-exporting plants within same firms. More analysis exploiting multi-product multi-plant firms and single-product multi-plant firms needs to be done, however, to link the results of this section to theories of multi-product firms.

firms.

$$\triangle Employment_{i2009-2008} = \beta ExporterDummy_{i2008} + \epsilon_{it} \tag{10}$$

$ExporterDummy_{i2008}$ is one for a firm if at least one plant belonging to the firm was exporting in 2008. Column (1) of Table 15 shows the result of this regression, and we find a statistically insignificant and small β. This suggests that exporting firms were no less worse off than non-exporting firms. However, doing the same regression at the plant level shows a very different picture. For the plant-level data, we run the following regression.

$$\triangle Employment_{ij2009-2008} = \beta ExporterDummy_{ij2008} + (\lambda_i) + \epsilon_{ijt} \tag{11}$$

Columns (2) (3) (4) of Table 15 show the results of this regression. Columns (2) shows that exporting plants suffered much more than non-exporting plants and the impact is statistically and economically significant: Exporting plants reduced more than 200 workers than non-exporting plants. Columns (3) shows the results of the regression replacing the plant-exporter dummy with the firm-exporter dummy and shows that the analysis with the firm-exporter dummy fails to capture this effect. Columns (4) shows the results of the regression using plant-exporter again and with firm fixed effects. Thus, the effect of the crisis on employment is significant and starkly different between exporting and non-exporting plants within a firm; but the effect is absent when the unit of analysis is the firm.[22]

To sum up, for the trade crisis period of 2008-2009, firm-level regressions suggest that firms that were more export oriented as a whole did not suffer more, while plant-level regressions suggest that plants that were more export oriented within firms did suffer more than plants that were less. This implies that a failure to account for firm-plant ownership

[22]This is consistent with the negative contribution of the within-firm reallocation components in the crisis period shown in the previous section.

structure may lead to a misleading conclusion in studies on the impact of trade and financial crisis on employment adjustment using the firm-level data. Specifically, it would be wrong to conclude that exporter did not suffer from the trade crisis in term of employment based on the result of the firm-level regression in our context. Also, this suggests that there is no risk sharing between export-market-oriented plants and domestic-market-oriented plants within firms and that this finding is consistent with the story that export-oriented plants and domestic-market-oriented plants within firms produce very different products so a demand shock to one of them cannot be coped at the level of firms.[23]

7 Conclusion

We document how plants belonging to the same firm are heterogenous in their characteristics and illustrate how the patterns are consistent with leading models of multi-product firms advanced by a recent strand of the international trade literature. We draw on newly constructed Mexican manufacturing plant-level panel data from 2003 to 2010, which allow us to identify which plants belong to which firms, and thus to compare across plants within firm. We find that plants that have a bigger size within firm are (i) more productive (ii) paying higher wages (iii) more likely to be export-oriented and (iv) depending more on imported intermediate inputs, implying that plant-level heterogeneity documented in the trade literature also holds *within firms*. We also find evidence that reallocation of resources across plants within firms is a non-negligible part of firm-level labor productivity changes, at least for some important industries. We also illustrate how failing to recognize plant-firm ownership structure could lead to a misleading conclusion in the analysis of the impact of trade crisis. Our analysis on within-firm across-plant heterogeneity and its implications on overall labor productivity changes gives support to claims that the mechanism of productivity changes highlighted by recent theories of multi-product firms is quantitatively important.

[23] See Verhoogen (2008) for a model in which exporting plants and non-exporting plants end up producing goods with different quality within industry. Our results suggest that this type of heterogeneity exists even within firms across plants.

Additionally, we show that plant-level and rm-level analysis could give different results to the analysis of the exporter productivity premium and the impact of trade crisis, suggesting that failing to recognize plant-rm ownership structure could lead to misleading conclusions in some important questions in international economics.

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Table 1: Example of Industry and Product List: Case of Lather and Shoe Industries.

Industry Code	Industry Name
316	Leather Industries
-3161	
...	...
-3162	Shoes
–316211	Leather shoes
–316212	Textile shoes
–316213	Plastic shoes
–316214	Leather shoes
–316219	Shoes made in other materials
-3169	Other leather products
...	...

Notes: This table shows an example of the level of aggregation of 3-digit, 4-digit and 6-digit industry code of the data, taking the leather and shoe industry as an example.

Table 2: Summary Statistics of Key Variables at the Plant Level and at the Firm Level in 2003.

	Plant	Firm
Number of Workers	303.03	348.04
Exporter Dummy	0.50	0.53
Exports/Total Sales	0.15	0.16
Importer Dummy	0.60	0.62
Imported Material Cost/Total Cost	0.15	0.16
Importer or Exporter Dummy	0.78	0.80
N	2629	2289

Notes: This table shows summary statistics of key variables in 2003 both at the plant level and at the firm level.

Table 3: Summary Statistics of Key Variables at the Plant Level and at the Firm Level in 2003, Separated by Type of Plants

	(1)	(2)	(3)
	Single-plant Firms	Multi-plant Firms	
	Firm=Plant	Plant	Firm
Number of Workers	238	583	1911
Exporter Dummy	0.52	0.43	0.64
Export/Total Sales	0.16	0.12	0.15
Importer Dummy	0.61	0.57	0.77
Imported Material Cost/Total Cost	0.16	0.15	0.16
Exporter or Importer Dummy	0.74	0.68	0.86
N	2139	492	150

Notes: This table shows summary statistics of key variables in 2003 both by the type of plants, namely plants belonging to single-plant firms or plants belonging to multi-plant firms. For the latter, the summary statistics at the plant level and at the firm level are also shown.

Table 4: Share of the top 5 Plants or Firms in the Total Industry-level Employment, by Industry. Average of 2003-2010.

Industry Code	Description	Plant	Firm
312	Beverage and Tobacco	0.29	0.37
313	Textile Mills	0.32	0.37
314	Textile Product Mills	0.39	0.39
315	Apparel	0.21	0.22
316	Leather and Shoes	0.22	0.23
321	Wood Product	0.40	0.40
322	Paper	0.17	0.37
323	Printing Related	0.26	0.26
325	Chemical Manufacturing	0.18	0.29
326	Plastics and Rubber Products	0.10	0.12
327	Nonmetallic Mineral Product	0.27	0.30
331	Primary Metal	0.39	0.47
332	Fabricated Metal Product	0.18	0.25
333	Machinery	0.25	0.25
334	Computer and Electronics	0.66	0.66
335	Electrical Equipment	0.29	0.40
336	Transportation Equipment	0.23	0.34
337	Furniture and Related	0.27	0.29
339	Miscellaneous	0.27	0.27

Notes: This table shows the share of top 5 plants or firms in the total industry-level employment, for each 3-digit industry. The table excludes the Petroleum industry because of the high concentration of the industry.

Table 5: Number of Multi-plant Firms and Its Shares in Employment and Sales. 2003-2010.

Year	Type of Firm		Share of Multi-plant Firms		
	Single-plant	Multi-plant	N Plant	Employment	Production
2003	2137	492	0.19	0.36	0.62
2004	2195	443	0.17	0.33	0.60
2005	2299	499	0.18	0.33	0.61
2006	2340	498	0.18	0.32	0.61
2007	2369	521	0.18	0.33	0.62
2008	2454	473	0.16	0.31	0.62
2009	2243	460	0.17	0.32	0.62
2010	2126	502	0.19	0.34	0.67

Notes: This table shows the number of plants owned by single-plant firms and by multi-plant firms, and share of employment and production accounted for by multi-plant firms, for each year from 2003 to 2010.

Table 6: Number of Multi-Product Firms and Its Shares in Employment and Sales within Multi-Plant Firms. 2003-2010.

Year	Type of Firm		Share of Multi-product Firms			
	Single-product	Multi-product	N Plant	Employment	Production	Exports
2003	248	244	0.50	0.54	0.51	0.84
2004	229	214	0.48	0.56	0.48	0.83
2005	263	236	0.47	0.56	0.45	0.79
2006	253	245	0.49	0.56	0.47	0.82
2007	277	244	0.47	0.54	0.50	0.86
2008	273	200	0.42	0.49	0.41	0.77
2009	263	197	0.43	0.50	0.42	0.84
2010	288	214	0.43	0.53	0.43	0.87

Notes: This table shows the number of plants owned by single-product multi-plant firms and by multi-product multi-plant firms, and share of employment, production and exports accounted for by multi-product multi-plant firms on the sum of the respective variables of the two types of firms, for each year from 2003 to 2010.

Table 7: Importance of the Most Important Industry for Multi-product Firms.. 2003-2010.

Year	Type of Product		Share of the Top Product: Aggregate			
	Non Top Ind	Top Ind	N Plant	Employment	Production	Exports
2003	102	142	0.58	0.75	0.80	0.88
2004	84	130	0.61	0.75	0.78	0.87
2005	88	148	0.63	0.77	0.78	0.87
2006	86	159	0.65	0.78	0.81	0.90
2007	90	154	0.63	0.77	0.79	0.87
2008	75	125	0.63	0.76	0.77	0.82
2009	70	127	0.64	0.80	0.81	0.87
2010	84	130	0.61	0.77	0.81	0.86

Notes: This table shows the number of plants belonging to multi-product multi-plant firms that produce the top product within the firm and the non-top product within the firm, for each year from 2003 to 2010. This table also shows the fraction of total employment, production and exports that are explained by the top products of each firm, for each year from 2003 to 2010.

Table 8: Labor productivity (1) across and within industry and (2) across and within firm. 2003-2010.

	(1)	(2)	(3)	(4)
	Industry Effects (3 digit)	Industry Effects (4 digit)	Product Effects	Firm Effects
R2	0.21	0.31	0.50	0.78

Notes: This table reports the value of R^2 from the regressions of plant-level labor productivity at time t on (1) subsector (3-digit)-year effects, (2) 4-digit-industry-year effects, (3) product(6-digit)-year effects and (4) firm-year effects. Each number shows the variation of labor productivity explained by sector-level, or product-level or firm-level factors.

Table 9: Heterogeneity between the most labor productive plants and other plants within firms. 2003-2010.

	Percentile within industry							
Type of firm	Production		Employment		Export		Labor Productivity	
	Non Top	Top	Non Top	Top	Non Top	Top	Non Top	Top
Single Industry	56.0	67.8	55.4	57.6	53.6	59.1	52.6	77.2
Multi Industry	64.8	71.4	63.2	57.4	56.0	59.9	60.8	79.6

Notes: This table shows the ranking of the most productive and not-most productive (in terms of labor productivity) plants, within firms, in the industry distribution of several key variables. This comparison is done separately for single-product and multi-product multi-plant firms. We first construct percentile for each plant's variables within industry, then compare them between the most labor productive plants within firm and not the most labor productive plants within firms. For example, for single-product multi-plant firms, plants that are not the most productive plants within firms are at 55th percentile in terms of their production, which means that these plants' production is on average just slightly bigger than the industry-average. Plants that are the most productive plants within firms are at 68th percentile, which means that these plants' production is on average close to top 30 percent of the industry.

Table 10: Heterogeneity between bigger plants and other plants within firms. 2003-2010.

	Log Labor Productivity	Average Wage	Export /Sales	Imported Materials Cost /Total Material Cost	Energy Cost /Sales
			All Multi-plant Firms		
Cost share	0.472***	0.159***	0.108***	0.068***	-0.018***
	(0.080)	(0.037)	(0.020)	(0.019)	(0.006)
Firm-year Effects	Yes	Yes	Yes	Yes	Yes
N	3888	3888	3888	3888	3888
			Single-Industry Multi-plant Firms		
Cost share	0.507***	0.154***	0.119***	0.075***	-0.013
	(0.093)	(0.036)	(0.021)	(0.011)	(0.008)
Firm-year Effects	Yes	Yes	Yes	Yes	Yes
N	2094	2094	2094	2094	2094
			Multi-Industry Multi-plant Firms		
Cost share	0.418***	0.168**	0.091***	0.056**	-0.026***
	(0.145)	(0.037)	(0.022)	(0.023)	(0.003)
Firm-year Effects	Yes	Yes	Yes	Yes	Yes
N	1794	1794	1794	1794	1794

Notes: This table shows the results from the regression of dependent variable (average wage, export orientation, imported intermediate products dependence or the share of energy cost) on the cost share of plants within their firms controlling for firm-year effects. The standard errors are clustered at the firm-year level. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 11: Decomposition of Aggregate Labor Productivity Changes. Normal, Crisis and Recovery Periods.

	(1) 2003-2008 Normal Period	(2) 2008-2009 Crisis	(3) 2009-2010 Recovery
Within-Within	101 %	150%	113%
Within-Reallocation	8 %	-25 %	0%
Between	-10 %	266 %	11 %
Cross-within	-13%	-7%	-12%
Cross-reallocation	1%	-8 %	3%
Residual	13%	-376%	-15%

Notes: This table shows the result of the decomposition analysis of the aggregate labor productivity changes for the three types of period: the normal period from 2003 to 2008, the crisis period from 2008 to 2009, and the recovery period from 2009 to 2010.

Table 12: Decomposition of Aggregate Labor Productivity Changes By Industry. 2003-2008.

Industry Code	Industry Name	2003-2008 Within-Firm Across Plant Reallocation
332	Fabricated Metal Product	-58 %
311	Food	-28 %
336	Transportation Equipment	18 %
325	Chemical Products	26 %
322	Paper	32 %

Notes: This table shows the contribution of within-firm reallocation components from the decomposition analysis of the aggregate labor productivity changes separately for each industry from 2003 to 2008, for five industries for which this component is important.

Table 13: Exporter Premium with both Firm Exporter dummy and Plant Exporter Dummy. 2003-2008.

	(1) Employment	(2) Average Wage	(3) Labor Productivity
Firm Export Dummy	0.188***	0.152***	0.220***
	(0.059)	(0.029)	(0.069)
Plant Export Dummy	0.318***	0.054*	0.013
	(0.058)	(0.028)	(0.066)
Multi-Plant Firm Dummy	0.292***	0.257***	0.558***
	(0.037)	(0.019)	(0.034)
R2	0.466	0.373	0.459
N	16720	16720	16720

Notes: This table shows the results from the regression of total employment, average wages and labor productivity on firm exporter dummy, plant exporter dummy, multi-plant firm dummy and product-year fixed effects. The data are from 2003 to 2008. The standard errors are clustered at the product-year level. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 14: Exporter Productivity Premium. Firm-level and Plant-level Analysis Separately. 2003-2008.

	(1)	(2)	(3)	(4)
Type of Unit	Plant	Plant	Firm	Firm
Exporter Dummy	0.207***	0.215***	0.754***	0.698***
	(0.017)	(0.016)	(0.028)	(0.027)
Multi-Plant Firm Dummy		0.598***		1.792***
		(0.033)		(0.050)
r2	0.429	0.458	0.508	0.557
N	16720	16720	14714	14714

Notes: This table shows the results from the regression of log labor productivity on exporter dummy and product-year fixed effects. The regressions have been run both at the plant-level and at the firm-level. The data are from 2003 to 2008. The standard errors are clustered at the product-year level. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 15: Employment Adjustment during the 2008-2009 crisis. Firm-level and plant-level analysis.

	(1)	(2)	(3)	(4)
Type of Unit	Firm		Plant	
	$\triangle Emp_i$		$\triangle Emp_i$	
Firm Export Dummy (t-1)	-38.571		-17.814	
	(52.034)		(57.902)	
Plant Export Dummy (t-1)		-195.535**		-477.037**
		(75.921)		(206.463)
Firm Fixed Effects	No	No	No	Yes
N	144	458	458	458

Notes: This table shows the results from the regression of the employment change from 2008 to 2009 on a dummy variable indicating whether a firm (or a plant) is an exporter, run both at the level of firm and at the level of plant. Column (1) shows the result of the firm-level regression, while columns (2)(3)(4) shows the results of the plant-level regressions.