Trade Policy Reform and Productivity:

The Colombian Manufacturing Sector from 1977 to 2001[♣]

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Abstract

This paper analyzes the effects on Colombian manufacturing productivity of foreign trade policy changes during the 1990s. Our results indicate that between 1978 and 1998, aggregate manufacturing productivity largely stagnates and even declines in some of the larger industries. Between 1999 and 2001, however, manufacturing productivity shows significant growth. Contraction of the economic activity in 1999 appears as a positive shock. There is little entry and exit of plants or reallocation of labor throughout the observed period. The productivity stagnation can be explained by this lack of liquidation of unproductive plants combined with slow technological advance. Dynamics vary significantly across sub-sectors, however, and our findings attribute this variation primarily to within-sector output reallocation. The importance of industrial policy is large. Sector-level productivity declines coincide with protectionist policies in the form of import tariffs, while rising productivity is correlated with sectors' increasing exposure to foreign markets.

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I. Introduction

The 1990s have seen the liberalization of foreign trade in a large number of countries, including most Latin American countries. These liberalization programs provide ideal settings for assessing the impact of foreign policy on industry productivity to answer the question of whether – and if so why – openness to trade leads to productivity growth.[1] The theoretical literature suggests several avenues through which trade liberalization may affect productivity. Increased access to imported materials and equipment may allow firms to raise efficiency through technological improvements. The removal of barriers to trade may furthermore increase product market competition due to the market interaction of domestic products with foreign imports. Increased competition could affect firms' productivity in two ways. On the one hand, competition may spur firm innovation to enable domestic producers to compete on equal grounds with potentially higher-quality or cheaper imports. Increased competition could also lead to a reallocation of output from less to more productive firms by forcing the least productive firms to exit the industry.

The first two channels lead to productivity growth by affecting technological change, in the form of technological progress, learning by doing, or product and process innovation. Technological progress raises firm productivity indiscriminately and, consequently, industry-level productivity increases. The last channel leads to industry-level productivity increases without intra-firm efficiency increases, but through a selection effect that allows more productive firms to survive and grow in open markets, while the less productive firms contract. Regardless of channel, though, not only is industry productivity affected, there are also potentially serious implications for factor markets. Industry productivity growth due to technological improvements across firms may lead to the partial displacement of labor within firms, in particular if growth arises from skill-biased or labor-augmenting technological progress. Productivity growth through exit of less productive firms entails the displacement of the entire workforce of the exiting plants. Isolating

[1] Work that studies the link between trade liberalization and productivity growth includes cross-country comparisons (Sachs and Warner 1995), sector-level studies such as Keller (2000) and Kim (2000), and plant-level analyses that will be discussed in greater detail below. For a review of the latter branch of the literature, see Tybout (2001).

the sources of productivity growth is therefore also of importance in assessing the broader welfare effects of trade reforms.

This paper analyzes the role of policy reforms in shaping industry productivity using the case of the Colombian manufacturing industry over the time period from 1977 to 2001. We estimate plant-level total factor productivity for 10 three-digit manufacturing industries using the estimation framework suggested by Olley and Pakes (1996) and Levinsohn and Petrin (2003).[2] We then provide empirical evidence about the role of industrial policy in contributing to the characterization of productivity growth in the Colombian manufacturing sector.

The sample period covers various policy regimes, including a tightening of foreign trade policies in the mid 1980s, followed by extensive trade liberalization in the early 1990s, which was partially reversed beginning in 1995. The data thus allows us to not only study the immediate effect of trade liberalization, but also the extent to which productivity effects are sustained in the face of reform reversal.

The empirical evidence on the importance of the various trade policy channels is mixed. A number of studies have pointed to the importance of foreign competition in generating intra-firm efficiency gains. In looking at the trade liberalization measures put in place in Chile during the late 1970s, Pavcnik (2002) finds significant productivity improvements in import-competing sectors by up to 10.4% in response to liberalized trade. Furthermore, these productivity differentials become more pronounced over time, suggesting persistent consequences for liberalization programs. Tybout and Westbrook (1995) and Muendler (2004) find similarly strong effects of foreign competition on productivity for Mexico during 1986 to 1990 and Brazil from 1986 to 1998. Only Muendler finds that firm turnover significantly contributes to industry productivity gains in the long run through an increased likelihood of exit by less efficient plants. Lopez-Cordova (2003), a study of the productivity effects of NAFTA on Mexican manufacturing from 1993 to 2000, is a second example where plant turnover is found to significantly contribute

[2] Olley and Pakes (1996) examine productivity dynamics in the U.S. telecommunications equipment industry and analyze the effect of deregulation and technological change on productivity. Based on Chilean data, Levinsohn and Petrin (2003) investigate the role in Chilean productivity dynamics of intra-firm productivity improvements relative to productivity gains caused by firm turnover.

to productivity gains. He presents evidence that suggests that increased investment exposure and reduced barriers to trade with the United States channel these productivity gains.
The Colombian manufacturing sector is the subject of several studies using earlier waves of the plant-level database employed in this paper. Lui and Tybout (1996) examine Colombian plant-level productivity during 1981 to 1989 and find that exiting plants are, on average, significantly less productive than incumbents. The productivity of an exiting plant furthermore deteriorates several years before the plant actually exits.

Fernandes (2003) explores whether increased exposure to foreign competition generates gains in Colombian plant-level productivity for the period 1977 to 1991. She finds a strong, negative relationship between lagged nominal tariff rates and plant productivity that is more pronounced for larger plants or those in more concentrated industries. Most of the important labor market, financial, tax, and trade reforms that were undertaken by Colombia in recent years are unfortunately not covered by her data.

The impact of the wide-ranging policy reforms of the 1990s on firm productivity and reallocation of output and inputs has, so far, received less attention. A series of papers by Kugler (1999), Kugler and Kugler (2002), and Eslava, Haltiwanger, Kugler, and Kugler (2004) present a notable exception. Based on a rich panel data set for the period 1982-‘96, the first two papers investigate the effect of both gradual and sudden increases in pay-roll taxation during the sample period on the composition of firms’ labor forces and wages. Their findings indicate that payroll taxes are only partially shifted to workers in the form of lower wages. Eslava et al. (2004) extend this research to more directly address the question of whether such reallocation is productivity enhancing. Using a plant-level longitudinal dataset for the period 1982-‘98, the paper examines the interaction between labor market allocation, productivity and plant profitability. Their findings indicate that reforms of, for example, labor and financial markets are associated with rising overall productivity due to a shift in economic activity from low- toward high-productivity businesses. This improved allocation of activity across firms contributes more to the post-reform sustained aggregate productivity than demand factors. We complement their work by focusing on the impact of foreign trade reforms on firm-level and aggregate productivity.

A variety of frameworks have been developed to infer a firm's total factor productivity level from observable input and output data, as the residual of the production function. Since firms' input choices are likely to be correlated with unobserved productivity, OLS or panel fixed effects techniques are subject to a simultaneity bias that can be addressed by using an instrumental variables estimator. In the case of plant-level data, however, valid instruments are scarce. As an alternative to instrumental variables estimation, we use semi-parametric estimation techniques that the recent literature (Olley and Pakes (1996) and Levinsohn and Petrin (2003), henceforth LP) has put forth, relying directly on the dynamic nature of the underlying plant decision problem that drives revealed input and output outcomes. We employ this framework in estimating production function coefficients and subsequently deriving estimates of the underlying TFP series. As a comparison, we also present results from alternative estimation procedures.

Section II introduces the data, while section III summarizes the production function estimation results. Section IV relates the estimated productivity measures to trade reforms that went into effect during the sample period. Lastly, section V concludes. Appendix A contains a summary of the data used in the study, whereas Appendix B contains the supporting tables.

II. Data Sources and Summary Statistics

Our primary data source is the Annual Manufacturing Survey of Colombia ("*Encuesta Annual Manufacturera*," henceforth EAM) collected by the Colombian Statistical Office DANE.[3] The available data from the Annual Manufacturing Survey extends from 1977 to 2001. The survey represents a complete Census of the manufacturing sector, which accounts for approximately 15% of Colombian GDP. According to the EAM, the largest sectors, Textiles and Food Processing, together comprise 45% of manufacturing plants and employment. From 1977 to 2001, the manufacturing sector overall doubled its real output; however, as measured in terms of either plant count or employment, it has grown in size only by approximately 15% and 8%

[3] DANE granted access to the data under an Inter-Institutional Cooperation Agreement between DANE and Fedesarrollo.

respectively, implying significantly rising labor productivity. The later analysis investigates the sources of this output growth to determine whether it is driven by rising (total factor) productivity or simply by a reallocation of resources away from labor towards other inputs into production.

The EAM has several limitations for empirical analyses. First, not all surveyed plants enter DANE's official database. To be included in the official database, a manufacturing plant must report either an employment level at or above 10 employees or a production level that exceeds a cutoff value set by DANE.[4] This selection procedure entails difficulties in defining plant entry and exit since the (dis-) appearance of a plant in the official database does not necessarily correspond to the formation (liquidation) of a plant. For plants with close to 10 employees, entry and exit rates are thus likely to be overestimated. To correct for this possible overstatement of plant turnover, we use only those plants with a workforce of 15 or more employees in at least one of two adjacent years, either at time *t* or time *t*-1.

A second shortcoming of the data for panel analyses is a difficulty in uniquely identifying plants across survey years due to the introduction of a new plant identification method in 1992.[5] A large fraction of plants have been traced manually across years. Table 1 illustrates, however, that the data continues to exhibit unnaturally large amounts of exit in 1991 paired with excess entry in 1992, introducing noise into the statistics for these two years. It presents a breakdown of the manufacturing sector into entering, exiting and continuing plants. Overall, the manufacturing sector remains relatively stable over time, with a high percentage of continuing plants each year. These plants hold more than 90% of total employment over the time period. After 1995, the number of exiting plants systematically exceeds the number of entrants; at the extreme is 1998 where only 303 entrants replace 553 exiting plants.

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[4] One exception to this selection rule has been in place since 1992 whereby all plants belonging to a multi-plant firm are included in the official database, regardless of size or production levels.
[5] In 1992 and again in 1993, the classification system that is used to assign plant identifiers and the rules by which a plant is included in the official database change significantly. These methodological changes make the tracking of each plant over time difficult. By manually tracing plants through the survey waves, most plants' histories have been successfully identified, however.

Table 2 further explores the characteristics of entrant and exiting plants in relation to incumbents. Entry and exit rates follow a pattern similar to that of overall economic activity, with higher entry and lower exit rates during periods of economic growth and the opposite during periods of economic slowdown. Average entry and exit rates over the period are very similar amounting to 9.8% and 9.5%, respectively. Measured both in terms of output and employment, entering and exiting plants are, on average, smaller than incumbents, however, so that based on size measures, they account for significantly less than 9% of sector activity. Entrants contribute on average 4.5% of annual output and 5.9% of incumbent employment. Exiting firms contribute on average 3.9% of output during the year before exit and represent only a slightly lower fraction of incumbent employment with 5.7%.

The final data set consists of an unbalanced panel of 14,806 manufacturing plants amounting to 122,118 plant-year observations. Only 861 plants survive from the first survey in 1977 until the end of the data in 2001. For each plant-year observation, various additional plant characteristics, such as the plant's manufacturing sub-sector, its incorporation status, and its age, are available in addition to input choices and output. Appendix A contains a more detailed description of the data set construction.

III. Estimation Results

We estimate production function parameters at the three-digit ISIC level to analyze as homogenous a sample of producers as possible given that the underlying theoretical model applies to homogeneous product industries. The unit of observation is a plant-year combination. We use the plant's annual value of production measured in millions of peso as our output variable.[6] Inputs into production are specified to be the plant's total number of skilled and unskilled employees, its annual electric energy consumption measured in kilowatt, total annual expenditures on raw materials measured in millions of peso, and the plant's capital stock in millions of peso. The EAM explicitly asks each plant to report the market value of its capital

[6] We follow the literature in estimating an output-based production function instead of its value-added counterpart since using value added as the measure of the plant's production imposes the separability of intermediate inputs from total production.

stock, allowing us to circumvent the perpetual inventory method or related approaches to construct plant-level capital stocks. We correct the reported capital stock measures for inflation adjustments that are added to each plant's capital stock beginning in 1994.[7] Appendix A contains a more detailed definition of individual variables.

All monetary series measured in current Colombian Peso are converted to constant, 2003 Colombian Peso. To deflate the capital series, we use the Producer Price Index (PPI) for the formation of capital goods. We employ the Producer Price Index for intermediate consumption in deflating intermediate input expenditures and the Consumer Price Index in adjusting personnel and other operational expenditures. Last, the industrial output series is deflated using a sector-level deflator constructed from PPIs for three-digit ISIC sectors for the period 1990-2001 and the manufacturing sector's PPI for the initial years 1977-'89. The use of aggregate price indices to deflate plant-level revenue in obtaining output measures has some well-understood downsides. Adjusting plant-level output by a common industry-level deflator entails that within-industry price differences are embodied in the productivity measures, making difficult to separately quantify the contributions of demand and efficiency factors to output (see Griliches et al., 1996). To overcome this problem, Eslava et al. (2004) perform a productivity analysis for Colombia using plant-level data on prices and quantities that is available for a sub-period of our sample, from 1982-98. Since the two papers use different methodological approaches over different periods of time in estimating plant-level productivity, it is not possible to establish the size of the potential estimation bias induced by the use of sector-level deflators in the current work.

Table 3 presents summary statistics for the variables used in estimation, aggregated to the two-digit ISIC sector level. The largest sectors in terms of number of plants are the Food Processing, Textiles, and Machinery sectors. Inputs and output differ systematically across sectors, justifying the division of the sample into sector-level sub-samples during estimation. Food Processing, for example, continues to be among the largest sectors in terms of average annual output and

[7] The methodological changes introduced to the EAM in 1992 and 1993 affect the reported capital series in other dimensions as well. From 1994 onwards, a plant's reported capital stock includes inflation adjustments and investment is recorded at book value to more closely reflect accounting standards of investment rather than representing actual investment outlays. The EAM does not retain the difference between book and market values as a separate variable and we consequently cannot adjust for it in the empirical analysis. Applying the perpetual inventory method to the capital stock beginning in 1994 is infeasible since it frequently yields negative values for the capital stock.

employment, similar to the Chemicals sector that, however, exhibits a less skewed distribution of average plant employment at higher employment levels. Sectors differ most significantly in their energy consumption ranging from energy-intensive sectors such as the Basic Metals sector to labor-intensive sectors such as Textiles and Leather. Across inputs, median input consumption falls short of mean input levels, indicating the presence of a large number of smaller plants operating in sectors with fewer large plants.

Table 4 contains the parameter estimates for the two-stage estimation procedure outlined above using material inputs as a proxy for unobserved productivity. Coefficients are precisely estimated at standard levels of statistical significance with the exception of the capital coefficient that is insignificant for three sectors, Wood, Plastic and Rubber, and Machinery, under the LP estimator. The insignificance of the capital coefficient may be due to artificial variation in the capital series introduced by the methodological changes in the EAM after 1992.[8]

Across industries there is significant variation in the partial elasticity of output with respect to each of the inputs. The average output elasticity with respect to skilled labor equals 0.16, with respect to unskilled labor equals 0.11, with respect to energy consumption 0.08, with respect to materials 0.41, and with respect to capital 0.11. In comparison to the average share of capital in total production cost depicted in Table 4,[9] the estimated capital coefficients are thus low. They are in line, however, with production function estimates found in Fernandes (2003) who studies Colombian productivity over the period 1977-‘91. Similar to our results, she finds capital coefficients ranging from 0.03 to 0.11 using OLS and from 0.01 to 0.13 using the LP estimator. The correlation between the estimated capital elasticities and the capital share is 0.42, in line with the fact that the capital share includes rents, which do not adjust as captured by the estimated elasticities. The most variation in elasticities across sectors occurs for materials, as measured by the standard deviation normalized by the mean of the input’s estimated elasticity across sectors.

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[8] Note that we acknowledge the structural change in the capital series in the first stage of the estimation procedure by allowing for a break in the estimated residual output contribution of capital and materials in 1992. This may not be sufficient, however, to fully remove all artificial capital fluctuations.

[9] The input shares shown in Table 4 represent average cost shares for the period 1981-93 since DANE collected electricity expenditures (as opposed to electricity usage in kilowatt) for this smaller sub-sample of the data only. The cost shares may therefore not accurately reflect average input shares for the full sample.

To justify the use of raw material expenditures as a proxy for unobserved productivity ω, we verify that the estimated productivity series, $\hat{\omega}$, satisfies the properties of a valid proxy assumed by the underlying economic model. In particular, the plant's inter-temporal profit maximization problem yields a monotone policy function with productivity being increasing in the materials proxy for a given level of the capital stock. This property holds across sectors for the empirical relationship between plant-level ω and raw material expenditures. In 9 out of the 10 sectors, a regression of $\hat{\omega}$ on m and k indicates on average a positive relationship between productivity and raw materials usage, controlling for the plant's capital stock, thereby validating the use of the materials proxy.[10,11]

Table 4 furthermore compares the production function coefficients generated by the nonparametric estimator to those obtained from alternative production function estimation methods. We estimate sector-level production functions using ordinary least squares and plant-level fixed effects. Both regressions include an indicator variable to control for the structural break in the capital series after 1992. The results allow us to investigate the extent to which simultaneity present in plants' input choices affects the production function parameters under traditional estimation methods. Simultaneity biases may arise if plants' input choices are responsive to unobserved productivity shocks. Andrews and Marschak (1944) suggest that simultaneity biases may be most severe for inputs that adjust rapidly. Under OLS, estimates of the coefficients on variable inputs are then likely to be biased upwards. If capital as a quasi-fixed input is uncorrelated or only weakly correlated with the unobserved productivity shock, the OLS estimate of the capital coefficient is furthermore likely to be biased downward. The estimated variable-input coefficients are largely consistent with this intuition. The OLS coefficient exceeds its semi-parametric counterpart in 8 out of 10 sectors for skilled labor, in 9 out of 10 sectors for unskilled labor, in all of 10 sectors for energy, and in 6 out of 10 sectors for material inputs. The OLS estimate of the capital coefficient, however, is smaller than the LP estimate in 5 out of 10 sectors. This is not surprising in light of the imprecisely estimated capital coefficient using the LP estimator.

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[10] The relationship does not hold for the Glass sector.
[11] Levinsohn and Petrin (2003) suggest further specification tests of the intermediate input proxy for productivity.

Given production function estimates, a measure of total factor productivity at the plant level can be inferred as

$$T\hat{F}P_{it} = \exp(y_{it} - \hat{\beta}_{ls} ls_{it} - \hat{\beta}_{lu} lu_{it} - \hat{\beta}_{e} e_{it} - \hat{\beta}_{m} m_{it} - \hat{\beta}_{k} k_{it}) \quad \textbf{(1)}$$

Annual sector-level productivity $T\hat{F}P_t$ can then be constructed as a weighted average of each plant's productivity measure, using output shares as weights. Table 5 summarizes the manufacturing sector productivity index derived from the LP estimation methodology. The first column contains an output-weighted average of productivity aggregated across industries that is normalized to one in 1980. Normalization allows us to more clearly track the path followed by productivity with respect to a fixed point in time and across sectors.

During the twenty-three year period of our sample, manufacturing productivity has remained fairly stable. The early 1980s see a fall in productivity relative to 1977, which is reversed during the second half of the 1980s and early 1990s, the period of wide-ranging foreign trade reforms. By the end of the 1990s, however, productivity returns to its earlier levels, possibly due to the economic slowdown during that period. In the last three years of the sample, productivity grows significantly to its highest levels in the sample period.

This pattern holds for both output-weighted average productivity and un-weighted average productivity displayed in the table's second column. Un-weighted productivity is smaller than output-weighted productivity, indicating the higher productivity of larger plants. In general, the productivity distribution is highly skewed as shown by a below-average median productivity and a large standard deviation. Changes in un-weighted average productivity reflect primarily the effect of technological change. Relative to 1980, un-weighted average productivity declines more steeply than output-weighted productivity and fails to return to its 1977 level throughout the sample period. Productivity stagnation arises therefore in part from a slow-down of technological change.

Last, Table 5 compares the evolution of total factor productivity to real labor productivity. Labor productivity increases dramatically and continuously over the entire sample period. By 2001, it has increased by 119% relative to 1977. A significant fraction of the gains in labor productivity arise during the economic slow-down of the 1990s, a period of shrinking employment, but constant or slowly increasing output. The starkly different picture that results from the TFP measures suggests a substitution away from labor to other inputs allowing output and TFP to remain virtually unchanged, while labor productivity increases.

A breakdown of productivity levels by two-digit ISIC industry reveals more nuanced productivity dynamics across manufacturing industries. Figure 1 depicts 2-digit sector level productivity growth rates obtained from the three alternative productivity estimation methods in Table 4, as well as labor productivity. The figure illustrates that across sectors, annual productivity growth rates fluctuate significantly.[12] The productivity growth paths derived from OLS are very similar to those based on the LP estimator. The correlation between the two growth series ranges from 0.89 to 0.99 across sectors. Similar correlation coefficient ranges result when comparing labor productivity to OLS-based and fixed effects-based total factor productivity. In contrast, the labor productivity growth paths differ most significantly from the TFP-based productivity growth series. The correlation coefficient between the labor productivity growth series and the LP TFP growth series, for example, ranges from 0.09 to 0.72 across sectors.[13]

The EAM's change in plant identification methods in 1992 introduces some amount of excess entry and exit into our sample, as shown in Table 1. To investigate whether the data

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[12] We find that high variation in the productivity indices of some sectors often reflect the atypical behavior of a single large plant in a specific year. This is true in particular for the Textiles and Paper sectors. While this may be due to misreported information, we have chosen to keep such plants in the database unless the data error is completely evident.

[13] Syverson (2004) and Eslava et al. (2004) point out that productivity measures may be biased if the production function estimation does not account for the possibility of demand shocks that induce cross-plant variation in investment or materials demand. These would manifest themselves in significant dispersion in the productivity residuals even for homogeneous sectors. To gauge the size of the potential bias due to unexplained demand variation, we compare the observed residual dispersion across industries that vary in the degree of heterogeneity of their products, using one of the internally less homogeneous 2-digit sectors, the Food Processing sector, as a case study. We derive TFP estimates for each of the 4-digit industries based on separate estimations and compare the resulting dispersion in productivity residuals across industries. On average, more heterogeneous industries display higher degrees of dispersion in TFP than homogeneous food industries. These dispersion statistics are more consistent with differing degrees of product differentiation across industries than with the presence of plant-specific demand variation, alleviating some of the concerns about potential biases in the TFP measures. Results are available from the authors upon request.

inconsistencies bias the resulting productivity estimates, we re-estimate the production function for different sub-samples, using the Textiles sector as a case study. We derive productivity estimates from estimated production functions for three time periods based on the two-stage estimation procedure with a materials proxy for TFP. Period 1 extends from 1977 to the year prior to the change in the plant identification system in 1991. Period 2 represents the period under the new identification system from 1992 to 2001. Lastly, our third model combines the two periods and controls for the missing 1991 and 1992 data with a dummy variable included in 1993. Figure 2 compares the TFP estimates derived from the three models to our original TFP series for the textiles sector using the full sample of data. The productivity estimates for the different sub-periods are very similar to our original series, with correlation coefficients ranging from 0.9273 to 0.9958. These results suggest that the data inconsistencies in the two intermediate years of 1991 and 1992 do not introduce significant noise into our TFP series.

To understand differences in productivity dynamics across sectors, we decompose productivity changes following Foster, Haltiwanger, and Krizan (2001) into the contribution of continuing, entering, and exiting plants:

$$\begin{aligned}\Delta T\hat{F}P_t = &\sum_{i\in \mathrm{Cont}} \theta_{i,t-1}\Delta T\hat{F}P_{it} + \sum_{i\in \mathrm{Cont}} \Delta\theta_{it}(T\hat{F}P_{i,t-1} - T\hat{F}P_{t-1}) + \sum_{i\in \mathrm{Cont}} \Delta\theta_{it}\Delta T\hat{F}P_{it} \\ &+ \sum_{i\in \mathrm{Ent}} \theta_{it}(T\hat{F}P_{i,t} - T\hat{F}P_{t-1}) + \sum_{i\in \mathrm{Exit}} \theta_{i,t-1}(T\hat{F}P_{i,t-1} - T\hat{F}P_{t-1})\end{aligned} \tag{2}$$

The first or within term measures the contribution to total productivity change of within plant productivity changes, weighted by the plant's output share of the previous year, $\theta_{i,t-1}$. The between plant component of productivity changes captures changing output shares of firms, weighted by the deviation of plant productivity from industry productivity. An increase in a plant's output share will thus only contribute positively to the industry's overall productivity evolution if the plant's productivity exceeds the industry average. The third term measures the covariance between plants' output share changes and productivity changes. The final components of the decomposition are the productivity contributions of entering and exiting plants.

Table 6 contains the results of the above decomposition for the manufacturing sector as a whole as well as for 2-digit industries, broken into sub-periods. The sub-periods correspond to the regime of high trade protection from 1977 to 1984, followed by a prolonged period of liberalization from 1985 to 1995 that accelerates during the early 1990s, and finally a partial reversal of reforms from 1996 to 2001. Across sectors, the initial period is marked by negative or very small positive annual growth rates, with the exception of the Chemicals sector, the only sector that displays sustained productivity growth throughout the sample period. The period of policy reforms is, on average, associated with positive growth rates, in particular for the Chemicals, Basic Metals, and Machinery sectors. Finally, the most recent experience of the manufacturing sector is mixed. The Chemicals, Food processing and Machinery sectors experience a renewed drop in productivity growth rates, the two latter to negative levels. The trend is, however, different for all other sectors, which experience an increase in their annual productivity growth rates. Averaged over the period, the Textiles, Paper, Chemicals, Glass, and Basic Metals sectors exhibit large, positive growth rates, while in particular the productivity of the Food Processing and Machinery sectors shrink steadily.

The productivity decomposition indicates that at the aggregate level, the evolution of productivity derives primarily from a continued erosion of within-plant productivity by continuing firms, indicating a lack of technological advance at the plant level. Both the within and between components of productivity change are negative for the manufacturing sector as a whole, while the covariance between productivity and output changes is positive indicating that the drop in within-plant productivity is countered by the reallocation of resources and output to more productive plants. Relative to the contributions to productivity growth by continuing plants, the effect of entry and exit on overall productivity growth is quite significant, in particular during the early and late periods of tighter international trade policy.

IV. The Effect of Trade Protection on Productivity

IV.1. Protection through Tariffs in Colombia, 1979-1999

Prior to 1990, Colombian trade policy is directed at protecting the economy to promote growth through import substitution and to diversify exports away from primary goods. Import quotas in particular drive up domestic prices during this period. Both the implicit tariff levied on imports (the implicit import cost in the form of security deposits with the Colombian Central Bank) and price levels in heavily protected sectors peak in the beginning of the 1970s and again in the second half of the 1980s. Subsequent dramatic trade liberalization measures in the early 1990s cause import restrictions at the aggregate manufacturing sector level to fall to their lowest values over the last 25 years.

The liberalization of the early 1990s does not, however, apply uniformly to all manufacturing sectors. Table 7 compares average effectively paid tariff rates at the three-digit ISIC level in the pre-1990 period to the equivalent measure during the post-1990 period of liberalization. The tariff rates are constructed from four-digit ISIC level data obtained from DANE on the monetary value of imports and the corresponding effective tariff payments for the sample period from 1980 to 2001. Tariff rates averaged across sectors fall by 8.2 percentage points from an average of 16.1% over the period 1980-89 to on average 7.9% over the period 1990-2001. Some of the more heavily protected industries include the Glass and Machinery sectors (two-digit ISIC sectors 36 and 38 respectively) with a majority of three-digit ISIC sub-sector tariff rates exceeding 25% between 1980-‘89. The Machinery sector subsequently experiences one of the highest degrees of liberalization with a decrease in tariff rates within the sector of on average 58.8%.

Figure 3 displays the time series of tariff rates aggregated to the two-digit ISIC level. The figure underlines the stark decline in tariff rates in the early 1990s. It also emphasizes, however, that for a number of sectors, the significant tariff reduction of the early 1990s is later reversed through renewed tariff rate hikes. In most cases, however, tariff rates do not return to their pre-1990 levels by the end of the sample period.

IV.2. Policy Exercise

To provide evidence of the extent to which the evolution of sector-level protection from foreign competition has contributed to systematic changes in productivity within and across industries, we relate the estimated productivity to measures of foreign policy. The setting is ideal for studying whether openness to trade induces productivity growth since the available data covers both the ten years before and after the largest Colombian trade liberalization in the early 1990s. The sample period furthermore covers a series of reforms that lead to significant variation, both within the cross-section and over time, in the available trade policy instruments. According to Bird and Chen (1999), fiscal needs and the pressures of strong lobbying groups drive most of the Colombian policy reforms during the sample period. The data allows us to investigate whether these policies have nevertheless provided microeconomic incentives that help to sustain productivity levels.

As measures of protection from foreign competition, we use the effectively paid tariff rates at the four-digit ISIC sector level discussed above. Ideally, a measure of effective protection would be preferable. Building such a measure, however, requires specific knowledge of the imported component of inputs at the sector-level. This data is currently not available. We assume furthermore that the trends in effectively paid tariff rates are representative of other trade policy instruments that affect a sector's protection from foreign competition, such as quotas.

To further control for the impact of foreign trade on productivity we construct the sector-level real devaluation rate for two-digit ISIC industries, using data on the nominal Peso-Dollar exchange rate from the Central Bank of Colombia and sector-level inflation rates for both Colombia and the US, based on producer price indexes for the period 1990-99 for Colombia and 1982-99 for the US and manufacturing-sector producer price index for the earlier years.[14] The data were obtained from the Colombian Central Bank and the US Department of Labor Statistics.

We estimate a panel regression model at the plant level of the following form:

$$\begin{aligned} T\hat{F}P_{ijt} = \alpha_0 + \sum_{k=1,\dots,3} \left(\alpha_{0k} s_{kt} + \alpha_{1k} ET_{jt} s_{kt} + \alpha_{2k} ET_{j(t-1)} s_{kt} + \alpha_{3k} DEV_{jt} s_{kt} + \alpha_{4k} DEV_{j(t-1)} s_{kt} \right) \\ + v_i + \varsigma_t + \varepsilon_{ijt} \end{aligned} \quad \textbf{(3)}$$

Here, $T\hat{F}P$ denotes the (log) plant-level total factor productivity resulting from our estimation in section III. *ET* is the 4-digit sector-level effectively paid tariff rate. *DEV* denotes the 2-digit

[14] We use real devaluation instead of the real exchange rate because the latter is unavailable at the sector level.

sector-level real devaluation rate of the Colombian peso. The policy variables are interacted with three size-class indicators, *s*, to account for differential impacts across plant sizes.[15] We also include size dummies explicitly in the panel estimation and 4-digit sector fixed effects to control for specific sector characteristics that may affect productivity. The 4-digit sector fixed effects also help control for the possible endogeneity of effectively paid tariff rates. Since policy variables are not available at the plant level, standard errors are corrected for clustering at the 4-digit sector level, the lowest level of dis-aggregation among the variables. Table 8 presents the estimation results.

The results indicate some interesting response patterns. Devaluation rates are associated with higher plant level productivity. Devaluation makes domestic plants more competitive in foreign markets, and it may improve their productivity through increased incentives to export and compete with possibly more efficient foreign counterparts. This result is consistent with productivity growth caused by learning-by-doing. Unexpectedly, the estimated effect is significant for all size firms when the one-period lag of the devaluation rate is considered. However, it increases with the firm's size. A higher effect for bigger plants is intuitive since these plants tend to be more connected to international markets. Higher exposure to foreign competition and to foreign markets has, as expected, a positive and statistically significant effect on productivity.

The response in productivity to lagged effective tariff rates shows that, in general, plants in industries with higher effective tariff protection exhibit lower productivity. The estimated coefficients on one-period lagged effective tariff rates are statistically significant and indicate a negative relationship between productivity and tariff protection for both medium and large plants. In absolute value, the effect is bigger for larger plants. The coefficient for small plants, however, is not significantly different from zero. The coefficient on the current period effective tariff is also negative and significant for large plants, but insignificant for the two other size categories.

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[15] The small-size dummy equals one if plant employment is less than 50. A medium-sized plant has employment larger than or equal to 50 and less than 200. The large-size dummy equals one if plant employment is greater than or equal than 200.

The small-size dummy variable has a significant negative coefficient, confirming that smaller plants have on average lower productivity levels than medium-sized plants. The coefficient on the large size dummy is positive and significantly different from zero. This result is consistent with the previous one, and it reflects the fact that larger plants are more efficient in their production, probably due to economies of scale. Alternatively, this result may be interpreted as suggesting that more productive firms are likely to hold higher market shares and thus are larger in size.

In estimation, we do not explicitly instrument for the tariff protection variables. At the sector-level, policy measures may be endogenous to productivity measures if less efficient producers have high lobbying powers. To the extent that lobbying takes place, it is likely to be more prevalent among large sectors with strong organizations and political clout. This moderates the endogeneity concern since the average plant does not generally have the ability to enforce sector-level policy changes. The inclusion of 4-digit sector-level fixed effects further helps to mitigate possible endogeneity of this sort.

V. Conclusions

Despite limitations in the available data, this paper provides a set of interesting results on productivity dynamics of the Colombian manufacturing sector. Our findings indicate that the economic slowdown of the second half of the 1990s has eroded productivity gains from opening the economy to foreign markets in the early 1990s, with overall manufacturing productivity in 1998 falling below the levels of two decades earlier. This is caused, in particular, by a decline in within-plant productivity, likely due to a slow-down in technological progress. The decade associated with trade liberalization, 1985-95, sees productivity improvements due to both output reallocation towards more productive plants and positive net entry effects relative to the manufacturing sector's earlier performance. Both types of productivity gains have been partially reversed by 1999.

A breakdown of productivity levels by two-digit ISIC industry reveals significant differences in productivity dynamics across manufacturing industries. The only sector that displays sustained productivity growth relative to 1977 is the Basic Metals sector, while the Paper, Basic Metals and Machinery sectors experience only slight, but volatile productivity improvements during 1977-2001. A productivity decline in some of the largest manufacturing sectors, including Food Processing, explains the change in productivity at the aggregate level. These sectors are also the ones for whom the within-plant decrease in productivity is the most pronounced. For sectors that gain in productivity over the sample, such as the Glass and Textiles sectors, output reallocation over time towards more productive plants is central to productivity growth.

The paper then investigates the role of international trade policy in affecting plant behavior by relating the estimated plant-level productivity to measures of preferential policy treatments. Our econometric analyses indicate that effective tariff rates are consistently negatively related to productivity, with significantly stronger impacts in the post-liberalization period. In light of the overall trends in productivity, the results underline that international exposure is only one of the factors that influence plants' productivity and that the positive effects of trade policy reforms have not been sufficiently large to date to counteract the overall stagnation in productivity levels.

VI. Appendix A
Construction of Plant-Level Data Set

The initial data set contains 181,143 plant-year observations. For a plant to be included in the final database used in the empirical analysis, it has to satisfy the following criteria:

- The estimation methodology requires multiple annual observations per plant. Consequently, only plants with two or more observations during the period 1977-2001 remain in the database. We drop 4,225 observations that correspond to plants that appear only once throughout the sample period.

- When a plant reports a sector change from a four-digit ISIC industry to another, this change is treated as the liquidation of the plant and the entry of a new plant. There are 6,176 4-digit sector changes.

- When there is a gap of one year during which a plant does not participate in the survey, the information for the missing year is obtained by linear interpolation. This applies to 2,292 cases. When the reporting gap is longer, as is the case for 1,264 observations, the plant's entire history is dropped from the database.

- The official DANE database consists of the universe of Colombian plants with a workforce in excess of 10 employees. To more accurately capture plant entry and exit by small plants around the 10-employee cut-off, the following procedure is adopted. We use data only for those plants that report an employment level at or above 15 employees in at least one of two consecutive years. By dropping plants with consistently between 10 and 15 employees, we eliminate the most likely plants that could shrink in employment below the 10-employee cutoff from one year to the next, but not actually exit the industry altogether. A firm with 15 employees or more that disappears from the database is thus treated as having exited under the assumption that it is unlikely for the plant to lose in excess of 40% of its workforce over a one-year period. We drop 43,129 plant-observations for which reported employment is less than 15 employees in consecutive years. This procedure generates 727 new instances in which a plant appears in only one year. These plants are dropped from the dataset.

- We drop observations corresponding to 2,176 plants because of missing data. We furthermore exclude observations corresponding to 1,066 plants from the final database because either their intermediate input usage or their energy consumption is less than or equal to zero.

- For internal consistency over time, we subtract inflation adjustments from the reported capital values beginning in 1992.

VII. Appendix B

Table 1
Break-down of Manufacturing Sector into Entering, Exiting, and Continuing Plants, 1977-2001

Year (t)	Total Number of Plants	Entering Plants, (t-1) to (t)	Exiting Plants, (t) to (t+1)	Continuing Plants, (t-1) to (t)
1977	3635	3,635	0	0
1978	4042	407	434	3,201
1979	4040	430	462	3,148
1980	4026	449	455	3,122
1981	3990	418	380	3,192
1982	4092	481	422	3,189
1983	4122	452	422	3,248
1984	4090	391	350	3,349
1985	4209	468	352	3,389
1986	4325	468	305	3,552
1987	4486	466	344	3,676
1988	4568	425	369	3,774
1989	4631	432	321	3,878
1990	4564	254	404	3,906
1991	4610	450	540	3,620
1992	*5132*	*1,062*	*381*	*3,689*
1993	5173	422	441	4,310
1994	5166	433	512	4,221
1995	5183	529	436	4,218
1996	5210	463	517	4,230
1997	5101	408	563	4,130
1998	4841	303	553	3,985
1999	4579	291	467	3,821
2000	4349	237	435	3,677
2001	3914	0	3,914	0

Notes:
(1) Plants remain in the database only if they appear for a minimum of two years, resulting in zero entering plants between 2000 and 2001 and zero exiting plants between 1977
(2) Entering plants denote plants that appear for the first time in the respective year's Census. Similarly, exiting plants denote plants that appear for the last time in the respective year's

Table 2
Entry and Exit in the Colombian Manufacturing Sector

	Plant Entry					Plant Exit				
Year	Entry Rate	Output Share of Entrant Plants	Output relative to Incumbents	Employment relative to Incumbents	Real Labor Productivity relative to Incumbents	Exit Rate	Output Share of Exiting Plants	Output relative to Incumbents	Employment relative to Incumbents	Real Labor Productivity relative to Incumbents
1978	10.60	2.93	3.14	5.92	53.03	10.74	3.56	3.81	6.09	62.52
1979	10.64	3.06	3.33	5.42	61.43	11.46	4.98	5.41	6.08	89.03
1980	11.13	4.83	5.33	6.48	82.30	11.35	4.61	5.10	7.69	66.27
1981	10.43	4.17	4.48	6.58	68.09	9.40	2.92	3.14	5.37	58.37
1982	11.90	4.15	4.45	6.67	66.80	10.28	2.77	2.98	5.88	50.59
1983	11.01	3.71	3.97	6.00	66.12	10.28	2.80	2.99	5.66	52.85
1984	9.52	2.52	2.67	5.28	50.57	8.43	2.89	3.06	4.78	64.03
1985	11.28	2.79	3.03	5.18	58.45	8.25	5.15	5.59	4.64	120.61
1986	10.97	4.07	4.36	6.19	70.37	6.92	2.54	2.72	4.52	60.12
1987	10.58	3.03	3.24	5.57	58.24	7.60	3.44	3.67	4.87	75.45
1988	9.39	3.85	4.18	5.28	79.16	8.02	3.94	4.27	4.44	96.10
1989	9.39	3.86	4.09	4.95	82.65	6.98	1.81	1.92	3.29	58.27
1990	5.52	1.73	1.81	2.89	62.74	8.81	2.88	3.02	4.64	64.99
1991	9.81	4.01	4.55	4.58	99.24	11.09	7.67	8.69	10.46	83.02
1992	*21.80*	*12.61*	*15.02*	*15.83*	*94.87*	*7.39*	*3.40*	*4.04*	*5.85*	*69.12*
1993	8.19	4.83	5.32	6.45	82.50	8.53	4.32	4.75	5.38	88.43
1994	8.38	5.57	6.13	6.01	102.13	9.89	3.64	4.01	6.90	58.08
1995	10.22	5.49	6.00	7.28	82.39	8.39	2.97	3.25	5.35	60.74
1996	8.91	4.16	4.47	5.54	80.66	10.03	2.79	3.00	6.11	49.11
1997	7.91	4.09	4.38	6.13	71.33	11.33	2.56	2.74	4.82	56.95
1998	6.10	2.77	2.95	3.59	82.05	11.74	3.35	3.57	5.65	63.15
1999	6.18	3.17	3.44	4.25	81.02	10.46	4.72	5.13	6.15	83.37
2000	5.31	3.30	3.51	4.05	86.69	10.53	2.88	3.07	4.65	66.10

Notes:
(1) Plant entry denotes plants that enter between the prior year (t-1) and the current year (t), while plant exit occurs between the current year (t) and the following year (t+
(2) Output is measured as the plant's real value of production in millions of peso and real labor productivity is measured as the plant's real value of production divided by total employment.

Table 3
Plant-level Input and Output Choices by 2-digit ISIC(2)

Variable	Food Processing	Textiles	Leather	Wood	Paper	Industrial & Other Chemicals	Rubber & Plastic Products	Glass	Basic Metals	Machinery
Employment										
Average	98.67	98.66	76.30	49.65	89.13	123.50	82.92	105.88	176.60	80.64
Median	37.00	38.00	32.00	28.00	35.00	52.00	39.00	41.00	41.00	35.00
Std.Dev.	199.81	244.14	133.66	78.39	182.69	190.38	142.40	179.99	558.59	142.46
Capital Stock (000 2003 dollars)										
Average	1,112.53	459.18	199.20	263.36	1,194.70	1,555.59	728.45	1,820.14	4,542.03	443.85
Median	124.26	39.09	41.49	38.10	106.27	185.88	130.90	133.82	156.71	76.09
Std.Dev.	5,990.60	3,870.79	704.25	1,730.91	7,048.23	6,524.37	2,819.22	8,694.59	25,391.46	1,827.05
Energy Consumption (000 kw)										
Average	1,202.52	683.05	273.48	255.12	1,902.48	2,295.66	1,108.98	3,569.54	15,230.24	412.25
Median	217.06	49.12	39.29	51.95	68.89	150.86	264.45	217.95	238.73	74.72
Std.Dev.	4,063.00	4,681.60	919.95	1,441.99	12,164.40	10,075.31	3,033.85	13,403.93	68,260.52	1,302.39
Material Imputs (000 2003 dollars)										
Average	2,821.29	658.43	615.17	270.23	1,372.56	3,062.47	1,106.17	710.40	3,192.88	1,138.44
Median	481.94	134.01	135.69	89.41	168.57	494.31	278.67	89.80	300.73	154.59
Std.Dev.	6,717.71	2,817.60	1,819.76	988.92	4,442.72	8,751.43	2,924.86	1,805.37	6,759.01	8,323.68
Output (000 2003 dollars)										
Average	4,803.68	1,392.42	971.91	661.19	3,057.76	7,027.51	2,180.25	3,610.48	6,943.96	2,041.50
Median	912.04	254.55	244.72	216.62	458.68	1,324.78	538.89	479.69	603.10	348.13
Std.Dev.	11,839.17	6,727.01	2,603.71	2,513.05	9,234.83	17,721.56	6,494.26	9,727.73	17,418.54	11,769.90
Sector size										
Number of plants	669	960	228	245	377	343	315	282	71	992

Note:
All entries represent input and output measures, as well as sector size measures, that have been averaged over the period of the sample, 1977-2001.

Table 4
Results from Alternative Production Function Estimation Methods
(standard errors in parentheses)

Variable	L-P	OLS	FE	Share	L-P	OLS	FE	Share
	Food Processing				Textiles			
Skilled Labor	0.141	0.223	0.187	0.042	0.156	0.255	0.212	0.052
	(0.003)	(0.005)	(0.005)		(0.005)	(0.004)	(0.005)	
Unskilled Labor	0.063	0.050	0.097	0.053	0.115	0.245	0.129	0.144
	(0.002)	(0.004)	(0.004)		(0.004)	(0.004)	(0.004)	
Energy	0.060	0.199	0.129	0.013	0.105	0.203	0.139	0.025
	(0.002)	(0.004)	(0.004)		(0.003)	(0.003)	(0.004)	
Materials	0.394	0.445	0.398	0.745	0.306	0.262	0.289	0.517
	(0.019)	(0.003)	(0.003)		(0.023)	(0.002)	(0.003)	
Capital	0.165	0.129	0.079	0.147	0.116	0.088	0.085	0.262
	(0.024)	(0.004)	(0.004)		(0.029)	(0.003)	(0.003)	
Dummy		-0.206	-0.108			0.148	0.104	
		(0.009)	(0.008)			(0.007)	(0.007)	
Obs.				16,748				24,008
	Leather				Wood			
Skilled Labor	0.185	0.284	0.152	0.052	0.172	0.168	0.212	0.095
	(0.006)	(0.007)	(0.007)		(0.007)	(0.008)	(0.009)	
Unskilled Labor	0.076	0.106	0.079	0.142	0.095	0.150	0.120	0.194
	(0.005)	(0.006)	(0.007)		(0.006)	(0.007)	(0.008)	
Energy	0.036	0.092	0.083	0.014	0.078	0.122	0.091	0.020
	(0.004)	(0.005)	(0.006)		(0.005)	(0.005)	(0.006)	
Materials	0.484	0.481	0.586	0.652	0.521	0.527	0.492	0.472
	(0.025)	(0.005)	(0.006)		(0.073)	(0.005)	(0.007)	
Capital	0.085	0.072	0.062	0.141	0.036	0.075	0.059	0.219
	(0.021)	(0.004)	(0.005)		(0.045)	(0.004)	(0.005)	
Dummy		0.043	0.006			-0.057	-0.024	
		(0.053)	(0.010)			(0.010)	(0.011)	
Obs.				5,692				6,132
	Paper				Industrial & Other Chemicals			
Skilled Labor	0.149	0.205	0.202	0.069	0.104	0.139	0.193	0.084
	(0.006)	(0.009)	(0.007)		(0.006)	(0.007)	(0.008)	
Unskilled Labor	0.196	0.317	0.103	0.092	0.158	0.183	0.066	0.071
	(0.004)	(0.006)	(0.005)		(0.004)	(0.005)	(0.006)	
Energy	0.030	0.157	0.086	0.025	0.045	0.098	0.132	0.022
	(0.003)	(0.005)	(0.004)		(0.004)	(0.005)	(0.006)	
Materials	0.228	0.235	0.438	0.543	0.464	0.463	0.437	0.637
	(0.017)	(0.004)	(0.005)		(0.059)	(0.004)	(0.006)	
Capital	0.149	0.173	0.055	0.272	0.175	0.163	0.069	0.186
	(0.028)	(0.005)	(0.004)		(0.043)	(0.005)	(0.005)	
Dummy		0.062	0.062			-0.116	0.047	
		(0.012)	(0.008)			(0.012)	(0.011)	
Obs.				9,436				8,564

Table 4 (continued)
Results from Alternative Production Function Estimation Methods
(standard errors in parentheses)

Variable	L-P	OLS	FE	Share	L-P	OLS	FE	Share
	Rubber & Plastic Products				Glass			
Skilled Labor	0.140	0.186	0.205	0.045	0.315	0.345	0.433	0.049
	(0.006)	(0.007)	(0.008)		(0.008)	(0.012)	(0.012)	
Unskilled Labor	0.113	0.140	0.103	0.086	0.076	0.204	0.101	0.122
	(0.005)	(0.006)	(0.006)		(0.007)	(0.009)	(0.008)	
Energy	0.048	0.078	0.111	0.033	0.197	0.237	0.267	0.055
	(0.004)	(0.004)	(0.005)		(0.005)	(0.006)	(0.008)	
Materials	0.554	0.568	0.489	0.575	0.159	0.129	0.053	0.256
	(0.046)	(0.005)	(0.006)		(0.031)	(0.003)	(0.003)	
Capital	0.032	0.082	0.047	0.260	0.220	0.180	0.043	0.518
	(0.031)	(0.004)	(0.005)		(0.042)	(0.006)	(0.006)	
Dummy		0.137	0.197			0.015	0.052	
		(0.008)	(0.009)			(0.016)	(0.013)	
Obs.				7,884				7,051
	Basic Metals				Machinery			
Skilled Labor	0.099	-0.012	0.176	0.047	0.141	0.183	0.189	0.055
	(0.014)	(0.017)	(0.020)		(0.003)	(0.004)	(0.005)	
Unskilled Labor	0.112	0.248	0.119	0.091	0.125	0.144	0.092	0.104
	(0.011)	(0.013)	(0.016)		(0.003)	(0.003)	(0.004)	
Energy	0.064	0.149	0.123	0.045	0.060	0.083	0.072	0.013
	(0.008)	(0.010)	(0.014)		(0.002)	(0.002)	(0.003)	
Materials	0.475	0.484	0.461	0.371	0.537	0.578	0.547	0.655
	(0.138)	(0.008)	(0.010)		(0.018)	(0.002)	(0.003)	
Capital	0.113	0.136	0.055	0.447	0.026	0.073	0.047	0.167
	(0.077)	(0.009)	(0.011)		(0.026)	(0.002)	(0.004)	
Dummy		0.259	0.355			0.153	0.187	
		(0.026)	(0.023)			(0.007)	(0.005)	
Obs.				1,778				24,809

Table 5
Descriptive Statistics, Manufacturing Sector Total Factor and Labor Productivity

	Total Factor Productivity				Labor Productivity
Year	Output-Weighted Average	Average	Median	Standard Deviation	Output-Weighted Average
1977	1.175	0.404	0.154	0.874	0.997
1978	1.102	0.433	0.165	1.268	1.022
1979	1.031	0.476	0.175	1.189	0.995
1980	1.000	0.461	0.172	0.971	1.000
1981	1.054	0.477	0.166	2.503	1.012
1982	1.105	0.471	0.158	3.285	1.014
1983	1.013	0.456	0.173	1.086	1.077
1984	1.154	0.437	0.156	1.171	1.175
1985	1.175	0.449	0.156	1.249	1.302
1986	1.199	0.445	0.152	1.334	1.355
1987	1.324	0.464	0.138	3.553	1.431
1988	1.262	0.445	0.142	1.703	1.530
1989	1.195	0.475	0.149	2.093	1.568
1990	1.162	0.514	0.152	2.960	1.567
1991	1.151	0.482	0.153	2.592	1.590
1992	*1.387*	*0.387*	*0.123*	*1.042*	*1.373*
1993	1.197	0.444	0.139	1.339	1.484
1994	1.197	0.439	0.146	1.113	1.563
1995	1.149	0.465	0.162	1.125	1.676
1996	1.145	0.479	0.160	1.224	1.762
1997	1.136	0.510	0.164	1.372	1.827
1998	1.170	0.521	0.160	1.616	1.871
1999	1.753	0.647	0.106	6.200	1.842
2000	1.854	0.670	0.104	6.731	2.051
2001	1.718	0.728	0.117	6.538	2.187

Note:
Output-weighted total factor- and real labor productivity are normalized to one in 1980 for comparison purposes. They represent output_weighted averages across sectors.

Table 6
Decomposition of Total Factor Productivity Growth, 1977 – 2001

Sector	Period	Annual Growth Rate (%)	Decomposition						
			Within	Between	Covariance	Entry	Exit	Total Continuers	Net Entry
Manufacturing	1977 - 1984	-1,017	-2,216	-2,508	3,462	-0,468	-0,713	-1,262	0,245
	1985 - 1995	0,751	-0,893	-2,682	3,389	1,882	0,946	-0,185	0,936
	1996 - 2001	11,167	-2,388	-0,319	3,698	9,644	-0,531	0,991	10,175
	Average	3,634	-1,832	-1,836	3,517	3,686	-0,099	-0,152	3,785
31 Food Processing	1977 - 1984	-1,110	-2,971	-3,435	5,222	-0,565	-0,638	-1,183	0,073
	1985 - 1995	1,388	-2,980	-2,063	5,170	1,195	-0,066	0,128	1,260
	1996 - 2001	-0,472	-2,192	-1,899	4,928	0,513	1,821	0,837	-1,308
	Average	-0,065	-2,714	-2,466	5,107	0,381	0,373	-0,073	0,008
32 Textiles	1977 - 1984	1,135	0,495	-0,730	1,812	-1,474	-1,032	1,576	-0,442
	1985 - 1995	0,836	0,548	-1,259	1,690	4,689	4,832	0,980	-0,144
	1996 - 2001	11,395	5,689	-0,357	4,176	0,082	-1,805	9,508	1,887
	Average	4,455	2,244	-0,782	2,559	1,099	0,665	4,021	0,434
33 Wood	1977 - 1984	-3,610	-2,217	-0,383	1,730	-1,787	0,953	-0,870	-2,740
	1985 - 1995	1,598	-1,069	-2,180	3,544	1,804	0,501	0,295	1,303
	1996 - 2001	4,525	1,258	-1,001	3,368	-0,958	-1,858	3,624	0,900
	Average	0,837	-0,676	-1,188	2,881	-0,313	-0,134	1,016	-0,179
34 Paper	1977 - 1984	-1,063	-1,076	-1,855	1,488	-0,175	-0,555	-1,443	0,380
	1985 - 1995	1,219	0,666	-1,730	1,818	0,697	0,232	0,755	0,465
	1996 - 2001	11,253	-3,216	-1,664	2,795	12,359	-0,979	-2,085	13,338
	Average	3,803	-1,209	-1,750	2,034	4,294	-0,434	-0,925	4,728
35 Chemicals	1977 - 1984	15,301	-5,215	-2,211	23,364	-1,057	-0,420	15,938	-0,637
	1985 - 1995	21,191	-6,029	0,018	29,765	-0,846	1,717	23,754	-2,563
	1996 - 2001	0,912	-2,075	-0,471	3,088	0,041	-0,329	0,542	0,370
	Average	12,468	-4,440	-0,888	18,739	-0,621	0,323	13,411	-0,943
36 Glass	1977 - 1984	1,730	0,638	-1,593	3,013	-0,413	-0,085	2,058	-0,327
	1985 - 1995	2,461	0,225	-1,916	3,388	0,721	-0,043	1,697	0,764
	1996 - 2001	3,125	-1,120	-1,333	4,807	0,465	-0,305	2,355	0,770
	Average	2,439	-0,085	-1,614	3,736	0,258	-0,144	2,036	0,402
37 Basic Metals	1977 - 1984	-0,259	-2,018	-1,986	3,597	-0,625	-0,774	-0,408	0,149
	1985 - 1995	9,274	3,508	-1,815	5,224	0,988	-1,368	6,918	2,356
	1996 - 2001	9,160	1,818	0,414	7,104	-0,998	-0,822	9,336	-0,176
	Average	6,058	1,103	-1,129	5,308	-0,212	-0,988	5,282	0,776
38 Machinery	1977 - 1984	-3,735	-7,611	-6,221	9,831	-0,457	-0,723	-4,001	0,266
	1985 - 1995	3,071	0,847	-1,429	3,466	-0,413	-0,600	2,884	0,187
	1996 - 2001	-0,182	-2,989	-2,036	5,495	-0,932	-0,280	0,470	-0,652
	Average	-0,282	-3,251	-3,229	6,264	-0,601	-0,534	-0,216	-0,066

Note:
Productivity measures aggregated to the 2-digit sector level omit 3-digit sectors that were excluded from the estimation due to data problems (313 - Beverages, 314 - Tobacco, 353 - Petroleum Refineries, and 354 - Products of petroleum and coal).

Table 7
Average Import Tariff as Percent of Total Value of Imported Goods by Three-Digit ISIC(2) Manufacturing Sector, 1980-1989 and 1990-2001 (%)

	1980-1989					1990-2001				
3-digit ISIC	Mean Tariff Rates	St. Dev. of Tariff Rates	Mean Real Devaluation	St. Dev. of Real Devaluation	Acummulated Real Devaluation	Mean Tariff Rates	St. Dev. of Tariff Rates	Mean Real Devaluation	St. Dev. of Real Devaluation	Acummulated Real Devaluation
311	16.16	4.07	4.38	7.53	50.03	8.70	3.59	-0.85	9.62	-13.48
312	18.60	3.51	4.38	7.53	50.03	10.16	4.11	-0.85	9.62	-13.48
313	30.13	8.76	4.38	7.53	50.03	9.02	4.81	-0.85	9.62	-13.48
314	7.14	2.48	4.38	7.53	50.03	5.23	3.95	-0.85	9.62	-13.48
321	21.30	3.87	4.79	7.38	56.38	10.00	2.10	1.46	10.15	13.79
322	6.88	7.54	4.79	7.38	56.38	14.35	8.85	1.46	10.15	13.79
323	8.83	5.46	4.79	7.38	56.38	9.70	6.96	1.46	10.15	13.79
324	13.93	16.42	4.79	7.38	56.38	17.47	7.58	1.46	10.15	13.79
331	15.61	9.98	3.65	9.79	37.57	8.29	3.89	2.23	9.64	25.06
332	28.32	14.59	3.65	9.79	37.57	16.02	4.95	2.23	9.64	25.06
341	6.35	0.90	7.93	7.51	110.15	4.72	1.54	1.37	9.05	13.58
342	2.27	0.49	7.93	7.51	110.15	3.89	1.76	1.37	9.05	13.58
351	11.95	1.26	6.23	7.60	79.05	4.62	1.34	0.96	8.75	8.37
352	17.94	2.26	6.23	7.60	79.05	9.48	2.37	0.96	8.75	8.37
353	1.65	1.00	6.23	7.60	79.05	5.11	4.29	0.96	8.75	8.37
354	20.36	3.72	6.23	7.60	79.05	10.04	4.33	0.96	8.75	8.37
355	22.32	3.62	6.23	7.60	79.05	15.57	8.32	0.96	8.75	8.37
356	38.76	4.93	6.23	7.60	79.05	15.66	3.76	0.96	8.75	8.37
361	24.96	3.10	5.53	8.52	66.64	15.29	2.36	-0.86	10.45	-14.32
362	26.35	2.65	5.53	8.52	66.64	12.27	4.90	-0.86	10.45	-14.32
369	22.75	3.84	5.53	8.52	66.64	12.18	2.83	-0.86	10.45	-14.32
371	14.87	3.87	5.39	7.74	65.11	5.76	2.44	2.99	5.44	40.64
372	9.57	2.00	5.39	7.74	65.11	3.02	0.83	2.99	5.44	40.64
381	31.23	4.98	6.04	7.69	75.79	11.53	4.47	1.69	7.05	19.69
382	14.54	2.91	6.04	7.69	75.79	7.68	3.92	1.69	7.05	19.69
383	25.13	3.95	6.04	7.69	75.79	9.62	4.15	1.69	7.05	19.69
384	27.57	3.72	6.04	7.69	75.79	11.26	4.46	1.69	7.05	19.69
385	21.40	2.80	6.04	7.69	75.79	7.99	2.63	1.69	7.05	19.69

Notes:
Average sector-level import tariff rates are computed as the value of tariffs paid relative to the value of imports at the 3-digit ISIC level. Source: DANE Colombia

Table 8
Panel Analysis
(standard errors in parentheses)

Dependent Variable: ln(TFP)	Time Period: 1981 - 2001
Constant	6.20*** (0.037)
Tariff Rate$_{(t)}$*Small Size Dummy	-0.04 (0.134)
Tariff Rate$_{(t)}$*Medium Size Dummy	-0.13 (0.148)
Tariff Rate$_{(t)}$*Large Size Dummy	-0.35** (0.188)
Tariff Rate$_{(t-1)}$*Small Size Dummy	0.04 (0.110)
Tariff Rate$_{(t-1)}$*Medium Size Dummy	-0.30** (0.150)
Tariff Rate$_{(t-1)}$*Large Size Dummy	-0.42** (0.180)
Real Devaluation Rate$_{(t)}$*Small Size Dummy	0.09 (0.081)
Real Devaluation Rate$_{(t)}$*Medium Size Dummy	0.27*** (0.061)
Real Devaluation Rate$_{(t)}$*Large Size Dummy	0.32*** (0.084)
Real Devaluation Rate$_{(t-1)}$*Small Size Dummy	0.14* (0.077)
Real Devaluation Rate$_{(t-1)}$*Medium Size Dummy	0.29*** (0.075)
Real Devaluation Rate$_{(t-1)}$*Large Size Dummy	0.38*** (0.100)
Small Size Dummy	-0.41*** (0.036)
Large Size Dummy	0.40*** (0.048)
No. Observations	92.816
No. Groups	79
F(14, 78)	90,87

Notes:
Standard errors are robust standard erors that correct for the clustered nature of the data at the 4-digit ISIC level.
* denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Figure 1
Change in Productivity: Alternative Estimation Methods

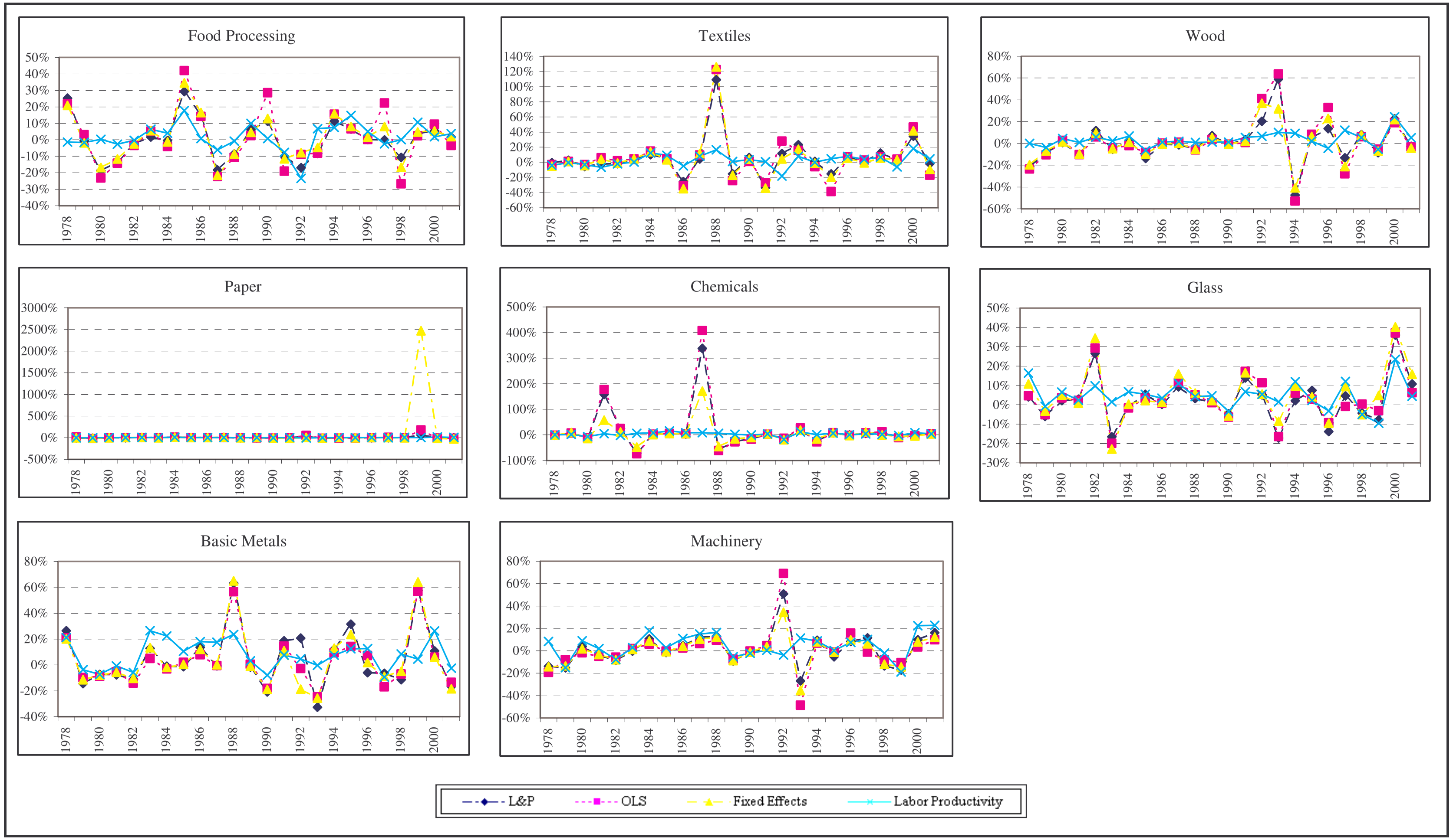


Figure 2
Change in Productivity in the Textiles Sector:
Alternative Sample Periods using the LP Estimator

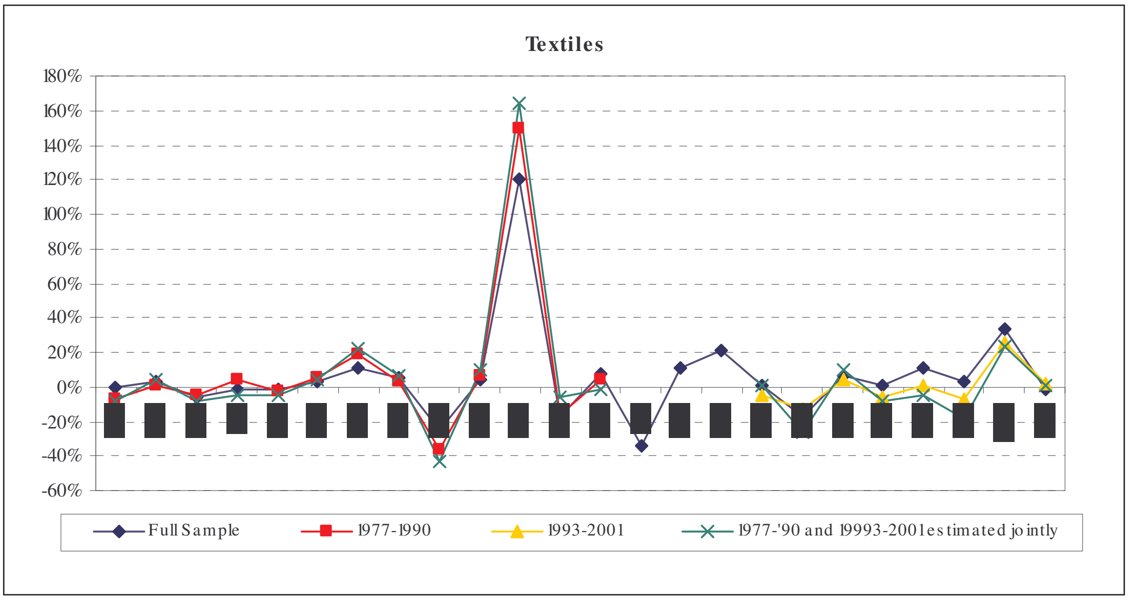
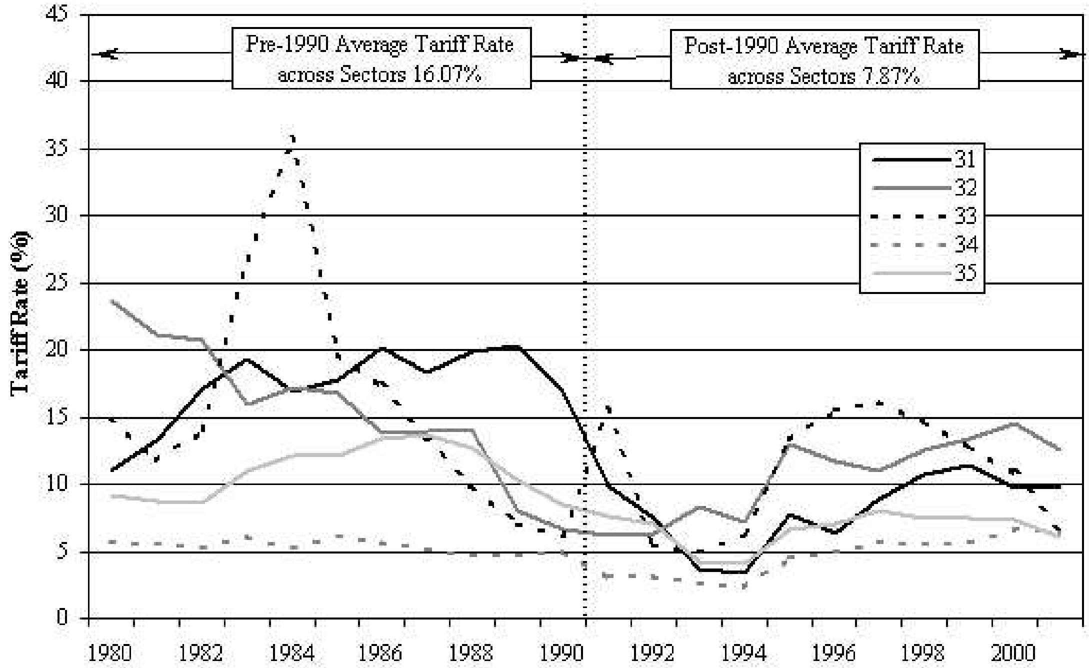
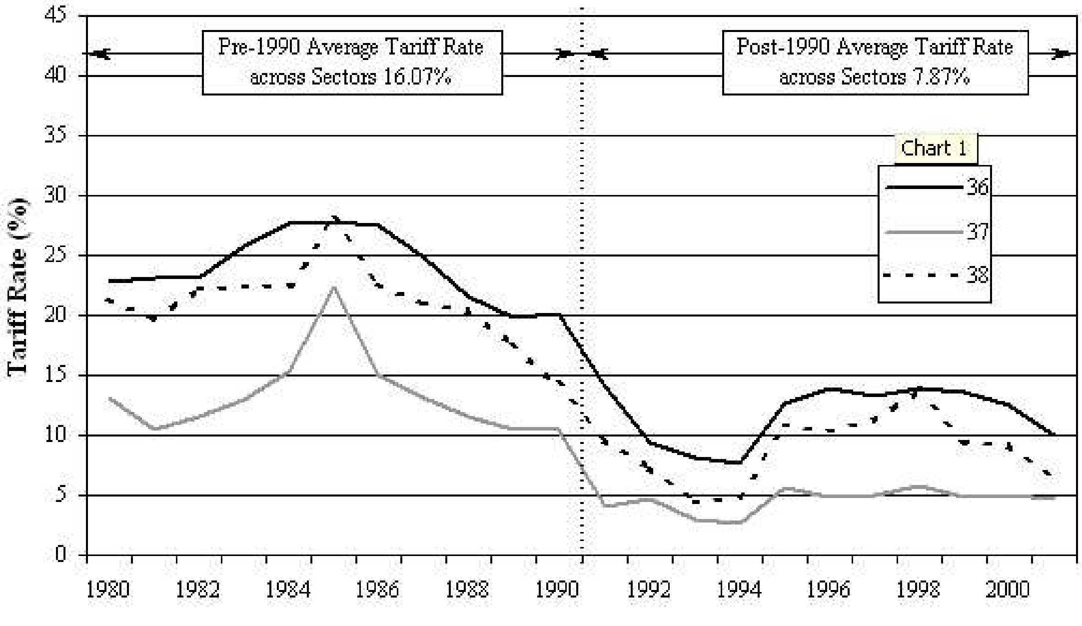


Figure 3
Average Tariff Rates by Two-Digit ISIC Sector, 1977-2001





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