

Trade Reforms and Market Selection: Evidence from Manufacturing Plants in Colombia*

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December 2008

Abstract

We use plant output and input prices to decompose the profit margin into four parts: productivity, demand shocks, mark-ups and input costs. We find that each of these market fundamentals are important in explaining plant exit. Then, we use differences across sectors in the change in tariffs over time following the trade reform in Colombia to assess whether the impact of different components of the profit margin on plant exit changed with increased international competition. We find that greater international competition increases the marginal effect of productivity, and other market fundamentals, on plant exit. To assess the implications for aggregate productivity, we conduct a dynamic simulation to compare the distribution of productivity with and without the trade reform. We find that the improvements in market selection from trade reform help to weed out of the

*We thank Diana Hincapie and Rafael Santos for excellent research assistance, and Roberto Alvarez, Mary Amity, Orazio Attanasio, Sebastian Edwards, Ricardo Hausmann, Larry Kleinman, Ralf Martin, Alejandro Micco, Nina Pacvnik, Carmen Pages, Dani Rodrik, Chad Syverson and John van Reenen as well as participants in seminars at the Harvard Kennedy School, the University of Michigan, Texas A&M, Universitat Pompeu Fabra, Universidad de Los Andes, the NBER Summer Institute, the IDB, the IDB Euro-Latin Network Conference, IMF Annual Research Conference, the Job Reallocation, Productivity Dynamics and Trade Liberalization Conference in Bogotá for valuable comments. Support was provided by NSF Grant SES-0617816, the Tinker Foundation, the IDB, and a GEAR grant from the University of Houston. We are also grateful to Rodrigo Moreira at the National Planning Department for providing data on tariffs.

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market the least productive plants, and increase average productivity. Moreover, we also find evidence that trade liberalization contributes to increasing the growth rate of productivity of incumbent plants as well as to a general improvement in the allocation of activity within industries.

Keywords: Trade liberalization, plant exit, market selection.

JEL Classification: F43, L25, O47

1 Introduction

It is clear that an important means by which market economies restructure and innovate is through the entry and exit of establishments. Consistent with that view, in economies like the U.S., the entry and exit process has been identified as an important component of aggregate productivity growth. Aggregate productivity growth is achieved, in part, by the ongoing market selection process that involves the exit of low productivity and entry of high productivity businesses.¹

Given the importance of business turnover for productivity growth, rigid market institutions and concentrated market structures are expected to affect aggregate productivity by raising barriers to both entry and exit. Barriers on either margin can, in theory, reduce the overall pace of firm and establishment turnover. For example, administrative entry costs can lower entry as well as exit since start-ups would be less likely and this would relieve under-performing incumbents from exit pressures by new entrants. Moreover, recent theoretical models show that poor market institutions (including trade barriers) generate misallocation by introducing idiosyncratic distortions to profitability (see Banerjee and Duflo (2003), Hsieh and Klenow (2007), Restuccia and Rogerson (2007), and Bartelsman, Haltiwanger and Scarpetta (2008)).

Surprisingly, early evidence for developing economies shows that the pace of establishment and firm turnover is typically not that different from that observed for industrialized economies.² This is at odds with the idea that developing economies, which are typically subject to more restrictive institutions, should have a slower pace of reallocation. On the other hand, recent findings from both emerging and transition economies suggest that market reforms improve allocative efficiency (for instance, Bartelsman et al. 2008; Eslava, Haltiwanger, Kugler and Kugler, 2004, 2006, 2009). By contrast to these recent studies, in this paper, we explore the link between market selection and a particular area of market reform – namely, trade liberalization.

Trade liberalization has been a core component of market reforms in developing economies and, in particular, of economies in Latin America. Trade liberalization could affect plant exits and productivity through a number of channels. First, as Pavcnik (2002) argues, increased international competition may induce incumbent firms to become more productive. Second, Melitz (2003) shows that trade liberalization could force lower productivity firms out of the market, cutting off the lower tail of the productivity

¹See, e.g., Baily et al. (1992), Bartelsman and Doms (2000), Foster, Haltiwanger and Krizan (2001, 2006), Foster, Haltiwanger and Syverson (2008), and Olley and Pakes (1996).

²See e.g. Bartelsman et al. (2008) and Tybout (2000).

distribution. In our empirical analysis we focus on the impact of trade on exits as suggested by Melitz (2003), although as will become clear we permit the impact of trade reforms on exit to operate through multiple channels.

An important aspect of trade liberalization in Colombia is substantial variation in terms of the magnitude of trade opening across sectors. This between-sector, within country, variation reflects both substantial differences in the changes in tariffs introduced by trade reforms for different sectors, and substantial differences in the distortions to the distribution of incumbent plants implied by the initial level of tariffs. The large variation in the extent of trade opening across sectors, along with rich longitudinal establishment-level data for the manufacturing sector of Colombia provides a unique opportunity to explore the impact of trade liberalization on market selection. Here, we explore whether increased competition due to trade liberalization in Colombia affected establishment exit, and whether the reduced trade barriers impacted the role of different profit-margin fundamentals in determining plant exit in Colombia. In particular, we explore the impact of trade reforms on the role of idiosyncratic (i.e., plant-level) total factor productivity, demand shocks, mark-ups and cost variation. Finally, we explore whether there is an increase in aggregate productivity associated with increased exit following trade reforms.³

An important and novel feature of our analysis is the separate measurement of physical productivity (rather than revenue-based productivity), idiosyncratic demand, mark-ups and input costs. It is the measurement of each of these components of the profit margin that permits us to evaluate separately the impact that each of these determinants has on plant exit. Unlike previous analyses, we are able to measure these fundamentals separately because the Colombian Manufacturing Survey allows to measure plant-level prices of both inputs and outputs. This unique feature of the data is useful for our purposes in several ways. First, we are able to deflate output with plant-specific deflators, leading to a measure of TFP that has been stripped of idiosyncratic demand effects.

³In our earlier work (i.e., Eslava et al. (2006)), we have provided evidence that market fundamentals became more important determinants of plant exit in the 1990s relative to the 1980s in Colombia. The 1990s was a period of market reforms on many dimensions including trade, financial market, labor market, privatization, and tax reforms. In contrast to this paper, our earlier work made no attempt to identify the impact of particular reforms on market selection. Moreover, the cross-sectional variation of the regulations was not exploited in the earlier work, while here we rely partly on the variability of tariffs across sectors to identify the effects of the trade reforms on market selection. Moreover, in our earlier work, we had less detailed measures of fundamentals (e.g., we lacked a measure of market power).

Our approach contrasts with most of the literature, where the measurement of TFP uses plant-level revenue deflated with a sector-level price index. Given within sector price variability, the standard estimation of TFP confounds high physical efficiency and low prices. Second, we are able to estimate demand shocks at the plant-level due to the availability of plant-level output prices. In our estimation of the demand process, we also permit mark-ups to vary across plants. Consistent with theories of market selection, we find that plants with higher productivity, those facing lower input prices, and those subject to positive demand shocks and with more inelastic demands, are less likely to exit.

Moreover, we find that market fundamentals (with the exception of the mark-up) become more important in determining firm survival, as competition increases due to trade opening. In particular, we find that the marginal effect of productivity on exit increases in sectors with especially large declines in tariffs. Given improved market selection, we explore the implications for aggregate productivity by conducting a dynamic counterfactual simulation of the exit process with the actual tariff levels and leaving the tariffs at their 1985 levels. We find an increase in average plant-level productivity of about 2 log points due to improved market selection with the actual tariffs relative to the 1985 tariffs.

In addition, we consider some alternative channels to put our findings on market selection in context. In particular, following Pavcnik (2002), we use a differences-in-differences specification on continuing plants to quantify the impact of trade reform on within plant productivity growth for continuing plants. Our contributions here relative to Pavcnik (2002) are the use of tariffs that vary within-sector and over time to quantify the extent of trade reform and our use of measures of physical productivity which avoid confounding plant-level price and physical efficiency effects. We find that continuing plants in industries that faced larger tariff reductions have greater within plant growth rates in productivity. Moreover, we consider whether trade reform yields a stronger relationship between market size and productivity as discussed by Olley and Pakes (1996) and Bartelsman et al. (2008). We, indeed, find that sectors facing lower tariffs show larger correlations between market share and productivity.

The rest of the paper proceeds as follows. In Section 2, we discuss the theoretical considerations that motivate our empirical analysis. In Section 3, we describe the market reforms introduced in Colombia during the 1990s. In Section 4, we present the data from the Annual Manufacturing Survey. In Section 5, we show our results on the impact of the profit margin components, and the interaction of these market fundamentals with

trade reforms on exit probabilities. In Section 6, we present the implications of trade-related exits for average productivity and explore alternative channels through which tariff reductions may have affected productivity. We conclude in Section 7.

2 Theoretical Considerations

According to selection models of industry dynamics (e.g., Jovanovic (1982), Hopenhayn (1992), Ericson and Pakes (1995)) producers should continue operations if the discounted value of future profits exceeds the opportunity cost of remaining in operation. At the same time, recent models (e.g., Melitz (2003), Melitz and Ottaviano (2008), and Foster, Haltiwanger and Syverson (2008)) emphasize that many market fundamentals influence variation in profitability across producers. In this literature, producers with market power make decisions on outputs, inputs, and output prices, given productivity shocks, demand shocks, demand elasticity and input price shocks drawn by the producer from a joint distribution. These models also assume that firms face frictions in the market through entry barriers. Typically, producers are assumed not to know their market fundamentals prior to entry, pay an entry fee and obtain their first draw of their market fundamentals from a joint distribution. The market fundamentals are assumed to evolve stochastically over time and consistent with the recent empirical literature are assumed to be highly persistent processes. Given fixed costs of operating each period, the producer makes a decision on whether or not to stay or exit at each point in time. As derived in the recent literature, the canonical exit decision can be modeled as being given by:⁴

$$e_{jt} = \begin{cases} 1 & \text{if } PDV\{\pi(TFP_{jt}, P_{Ijt}, D_{jt}, \varepsilon_{jt}) - C_{jt}\} < 0 \\ 0 & \text{if } PDV\{\pi(TFP_{jt}, P_{Ijt}, D_{jt}, \varepsilon_{jt}) - C_{jt}\} \geq 0 \end{cases}$$

That is, plant j exits if the expected present net discounted value of profits including the fixed cost of operating C_{jt} is negative.⁵ Current and future expected profits, π , (and, in turn, their present discounted value, PDV) gross of fixed costs are a positive function of demand, D_{jt} and productivity shocks, TFP_{jt} , a positive function of the demand elasticity, ε_{jt} (where the latter is negative so an increase implies an increase in

⁴See, e.g., Melitz and Ottaviano (2008) and Foster et al. (2008) for models that yield exit specifications with this full list of market fundamentals (or plant profit margin components).

⁵The fixed cost of operating C_{jt} should be defined as being net of the option value for the plant of waiting to exit. This option value arises due to the irreversibility stemming from sunk entry costs.

the mark-up) and a decreasing function of input price shocks, P_{Ijt} .

In what follows, we estimate this specification of market selection for Colombia. The estimates for the basic model are of interest in their own right, since Colombia is unique in having rich data with plant-level measures of each of these fundamentals. Moreover, the data permit extracting demand shocks and demand elasticities as determinants of plant-level outcomes such as survival. Our primary purpose is, however, to explore the role of market reforms and, in particular, trade liberalization on the market selection process. Identification of the channels through which trade liberalization impacts market selection is, in our view, an open theoretical and empirical question. For example, Melitz (2003) develops a model where trade liberalization impacts market selection through equilibrium wages. As the economy liberalizes, the more productive plants expand by increasing exports and this drives up the equilibrium wage.⁶ With a higher wage, only incumbents with productivity above a threshold survive. Melitz and Ottaviano (2008) emphasize a different possible channel where trade liberalization increases competition and lowers mark-ups. The lower mark-ups overall imply that the marginal plant in terms of productivity can no longer survive. Another type of channel is suggested by the recent literature on misallocation and productivity (e.g., Banerjee and Duflo (2003), Hsieh and Klenow (2007), Restuccia and Rogerson (2007) and Bartelsman et al. (2008)). In these models, the distortions to markets are characterized as including an idiosyncratic component. In our context, trade barriers potentially yield idiosyncratic distortions as restricted trade can yield favorable treatment for some firms and less favorable treatment of other firms (e.g., trade protection biased towards specific sectors or firms). A key insight from this class of models is that, in addition to the profit-margin components discussed above, these idiosyncratic distortions impact profitability and, in turn, market selection. That is, plant survival becomes less related to its favorable profit-margin fundamentals and more related to its relatively favorable idiosyncratic distortion.

Given the many different possible mechanisms for trade liberalization to impact market selection suggested in the recent theoretical literature, we explore a number of different channels in our empirical analysis with a flexible functional form. Relative to the above model of selection, our empirical strategy is based on an enhanced model of exit which includes idiosyncratic market distortions:

⁶While other interesting studies for Colombia have focused on the impact of trade opening on average wages and the distribution of wages in Colombia (see, e.g., Goldberg and Pavcnik (2005); Attanasio, Goldberg and Pavcnik (2004)), we will not focus here on this channel because our wage data does not provide enough variability nor is it sufficiently disaggregated.

$$e_{jt} = \begin{cases} 1 & \text{if } PDV\{\pi(TFP_{jt}, P_{Ijt}, D_{jt}, \varepsilon_{jt}, \tau_{jt}) - C_{jt}\} < 0 \\ 0 & \text{if } PDV\{\pi(TFP_{jt}, P_{Ijt}, D_{jt}, \varepsilon_{jt}, \tau_{jt}) - C_{jt}\} \geq 0 \end{cases}$$

where τ_{jt} represents market distortions for plant j including those from trade barriers. While we are not able to measure the full set of market distortions impacting any given plant, we have good measures that proxy for such distortions including measures that help identify those sets of plants that are likely to have experienced a change in their distortions. A key working hypothesis of our empirical analysis is that the plants in sectors with the largest decreases in tariffs are, holding other things equal (e.g., including other reforms), more likely to have seen a reduction in their market distortions. As noted above, a key insight from the recent literature is that the presence of idiosyncratic distortions across plants within a sector reduces the marginal effect of fundamentals on the probability of exit.⁷ This insight helps guide and interpret our empirical specification of the market selection models as described below. Our core identifying assumption is that sectors with greater tariff reductions have had a larger reduction in market distortions and, accordingly, fundamentals should become more relevant for market selection in the sectors with greater tariff declines. As will become clear, in practice when we estimate the above specification below, we include many controls and we estimate flexible specifications, including both direct and interaction effects to capture the impact of reforms, with particular attention to trade liberalization.

While estimating the above basic and extended models is the focus of our empirical strategy, we note that some of the impact of trade liberalization on market selection is hypothesized to work through alternative channels. Identifying the changing selection patterns due to say changes in equilibrium wages is an empirical challenge, given the many factors impacting equilibrium wages. Another channel of interest is the impact of market reforms on plant-level markups with that in turn potentially impacting selection. While our empirical analysis permits us to separate out productivity from demand effects, it is beyond the scope of the current work to explore the impact on markups directly. Even though we don't explore all of these other channels, our analysis explores additional channels to those specified above as we investigate the impact of trade reform on within plant productivity growth and the overall allocation of activity.

⁷The analysis in Bartelsman et. al. (2008) shows that an increase in the dispersion of idiosyncratic distortions decreases the marginal effect of market fundamentals like productivity on plant exit.

3 Trade Reforms in Colombia

Colombia underwent substantial changes in trade policy during the past three decades. After considerable trade liberalization in the 1970s, the administration of president Belisario Betancurt implemented a reversal towards protection during the early 1980s in response to the appreciation of the exchange rate, which had contributed to increased foreign competition. Betancurt's policies increased the average tariff level to 27 percent in 1984, but the degree of protection across industries was far from uniform. Manufacturing sectors benefited the most from increased protection as the average tariff in manufacturing rose to 50 percent. However, even within manufacturing some sectors received more protection than others. The sector with the highest protection was textiles and apparel, which had nominal tariffs of nearly 90 percent, and wood products followed with a nominal tariff of 60 percent. These two sectors also had the highest levels of protection through non-tariff barriers.

While barriers to trade were reduced in the second half of the 1980s, trade was largely liberalized in Colombia during the first half of the 1990s. Figure 1 shows average effective tariffs and the standard deviation of effective tariffs starting in 1984.⁸ From this initial level, the figure shows a substantial decline both in average effective tariffs and the dispersion of these tariffs in 1985. The figure then shows a gradual decrease in tariffs which started during the administration of president Virgilio Barco in the late 1980s.

In 1990, the administration of president Cesar Gaviria introduced a comprehensive reform package, which included measures to modernize the state and liberalize markets. Reforms during the 1990s occurred in the areas of trade, financial and labor markets, privatization and the tax system. Probably the most important of all these reforms was the trade reform carried out at the beginning of the 1990s.

The average nominal tariff declined from 27 to about 10 percent overall, and from 50 to 13 percent in manufacturing, between 1984 and 1998. As Figure 1 shows, there was a drastic drop in average effective tariffs and in the dispersion of effective tariffs between 1990 and 1992 during the Gaviria administration. By 1992, the average effective tariff was at 26.6% compared to 62.5% in 1989 and compared to 86% in 1984. Similarly, the dispersion of tariffs fell substantially during the early 1990s, though dispersion across

⁸The effective tariff for a given final good adjusts the nominal tariff levied to the good itself, by subtracting the weighted sum of tariffs on the inputs used to produce that good, where the weights are given by the share of the input in production costs for that good (using the corresponding entry in the Input-Output table).

industries still remained substantial as the standard deviation of tariffs remained at around 0.2. At the same time, between 1990 and 1992, the average non-tariff barrier dropped to 1.1 percent.

After Gaviria's term, Ernesto Samper won the presidential election in 1994 based on a platform which partly opposed trade liberalization and other reforms.⁹ While the new government did not dismantle the existing reforms at the time, it managed to stop the momentum for further liberalization. This is clear in Figure 1, which shows that the average and standard deviation of effective tariffs remain flat after 1992.

The description above makes clear that there were important changes in both the mean level and the dispersion of tariffs across sectors. An interesting aspect of Colombian trade reforms is that at the same time that the overall level of protection was lowered, the sectoral structure of protection was also substantially altered as barriers to trade were lowered to similar levels across sectors irrespective of their initial level. The identification strategy of our analysis of the effect of market reforms on market selection exploits this cross-sectional variation in tariff reductions.

4 Data

Since we are interested in estimating the impact of market fundamentals on exit as trade opens, we require information on tariffs, and on plant characteristics, including: productivity, demand shocks, demand elasticities, and input prices. Also, to control for other ongoing reforms that may have coincided with the trade reforms, in some specifications we require a measure of other regulations. In this section, we provide a description of the data, and we then explain the measurement of physical productivity and demand shocks.

4.1 Data Description

We use data from the Colombian Annual Manufacturing Survey (AMS), an unbalanced panel that registers information on all manufacturing establishments with 10 or more employees. Establishments with less than 10 employees but with a nominal value of production over a certain level are also included.¹⁰ Given that these requirements are

⁹Note that the Colombian electoral system at the time ruled out election for more than one term. This may help explain the depth of the structural reforms in Colombia in the absence of an economic crisis.

¹⁰For instance, for 1998 the value limit was set at U\$35,000.

satisfied, a plant is then included in our sample in a given year if it reports positive production for that year. We have data covering the 1982-1998 period, at an annual frequency. The AMS records include information on the value of production, number of employees, value of materials used, physical units of energy demanded, value of the stock of capital and purchases of capital. Moreover, an establishment also reports the quantities and value of each product it manufactures and of each material it uses. Average unit values of these individual goods and materials can be constructed for each plant from this information, and in turn used to create plant-level indices of prices for outputs and inputs.

4.1.1 Plant-level Prices of Inputs and Output

We start by constructing output and material price indices for each establishment, using the information on individual products and materials for each plant. To create a plant-level index of material prices, we first calculate weighted averages of the price changes of all individual materials used by the plant. The weight assigned to each input corresponds to the average share (over the whole period) of that input in the total value of materials used by the plant.¹¹ Plant-level price indices are then generated recursively from these plant-level price changes. Given the recursive method used to construct the price indices and the fact that we do not have plant-level information for material prices for the years before plants enter the sample, we replace missing values with the average material price in the plant's sector, location, and year. When the information is not available by location, we impute the national average in the sector for that year. A similar method is used to construct output price indices.

We use plant-level output prices to construct physical quantities of output, measured as nominal output deflated with the plant-level price index. Similarly, we construct physical quantities of materials used as nominal value of these materials deflated with the plant-level materials price index. Physical quantities of energy usage are directly reported at the plant-level.

¹¹Since some large outliers appear, we trim the 1% percent tails of the distribution of plant-level price changes. In addition, given that the inflation rate in Colombia has hovered around 18% during the period, we choose to drop observations that show reductions of prices beyond 50% in absolute value or increases in prices beyond 200%.

4.1.2 Capital Stock

We construct a series of the capital stock for each plant, j , following the perpetual inventory method. Gross investment is generated from the information on fixed assets reported by each plant, using the expression:

$$I_{jt} = K_{jt}^{NF} - K_{jt}^{NI} - d_{jt} - \pi_{jt}^A,$$

where K_{jt}^{NF} is the reported value of fixed assets by plant j at the end of year t , K_{jt}^{NI} is the reported value of fixed assets reported by plant j at the start of year t , d_{jt} is the depreciation reported by plant j at the end of year t , and π_{jt}^A is the reported inflation adjustment to fixed asset value by plant j at the end of year t (only relevant since 1995, the first year in which plants were required by law to consider this component in their calculations of end-of-year fixed assets). We deflate gross investment using a deflator for capital formation from National Accounts' Input-Output matrices (or the equivalent "output utilization matrices" since 1994); the deflator varies in general at the 2-digit sector level, and for a few sectors at a higher level of disaggregation. Denote this deflator as $D_{S(j)t}$ where $S(j)$ is the sector to which plant j belongs. The plant capital stock is, thus, constructed recursively following:

$$K_{jt} = (1 - \delta_{S(j)}) K_{jt-1} + \frac{I_{jt}}{D_{S(j)t}},$$

where $\delta_{S(j)}$ is the depreciation rate for the 3-digit sector to which a plant belongs; we use the depreciation rates calculated by Pombo (1999) for Colombian manufacturing. We initialize the capital stock for each plant using the nominal capital stock first ever recorded (at the beginning of year), $K_{jt_0}^{NI}$, deflated by the average capital deflator for the current and previous years, $D_{S(j)t_0}$ and $D_{S(j)t_0-1}$:

$$K_{jt_0} = \frac{K_{jt_0}^{NI}}{\frac{1}{2}(D_{S(j)t_0} + D_{S(j)t_0-1})}.$$

4.1.3 Employment

The level of employment or the number of workers is reported directly by each establishment. Since hours per worker are not reported in the AMS. We construct a measure labor usage, by using information on average wages at the 3-digit sector level from the Monthly Manufacturing Survey.¹² Our measure of hours per worker in sector $S(j)$ to

¹²Data on sector wages are reported separately for production and non-production workers. We use a weighted average of the wages of those two categories, where the weights are the shares of each type

which plant j belongs is:

$$H_{S(j)t} = \frac{earnings_{S(j)t}}{w_{S(j)t}},$$

where $w_{S(j)t}$ is the measure of sectoral wages at the 3-digit level, and $earnings_{S(j)t}$ is a measure of earnings per worker constructed from our data as

$$earnings_{S(j)t} = \frac{\sum_{j \in S} payroll_{jt}}{\sum_{j \in S} L_{jt}}.$$

4.1.4 Descriptive Statistics of Plant-level variables

Table 1 presents descriptive statistics of the quantity and price variables just described. The price and quantity variables are expressed in logs. We restrict our sample to plants in three-digit sectors with more than 25 establishments in the average year, since we make use of within-sector variation in our analysis below. In the next section, we use the variables summarized in Table 1 to estimate the production function and inverse-demand equation.

Table 1 also shows entry and exit rates. A plant is classified as entering in t if it exists in our sample in year t but not in $t - 1$. Similarly, the plant exits in t if it exists in the sample in t but not in $t + 1$. Note that Table 1 reports entry and exit rates of 7% and 9% respectively, somewhat lower than those reported for developed countries (Davis, Haltiwanger, and Schuh (1996)). Lower entry and exit rates for Colombia are consistent with the perception that developing economies are subject to greater rigidities than more developed countries (see Tybout, 2000, for a discussion of this issue).

4.1.5 Tariffs and Reform data

Our data on effective tariffs come from the National Planning Department. Effective tariffs are available at the product level for each year, using a classification system (and therefore product identifiers) that were created for the Andean Community. Since the tariffs' database also assigns each of these products a four-digit sector ISIC code, we can construct effective tariffs at the four-digit level by averaging effective tariffs across products in a given sector. The only other study of the impact of trade liberalization on productivity with a similar level of disaggregation is that by Treffer (2004). This is

of worker in total sector employment. We deflate the nominal wages using the CPI obtained from the National Department of Statistics.

important because in many instances aggregating tariffs to two-digit ISIC sectors will mask variation that reflects changes in idiosyncratic distortions.

We also use an index of reforms other than trade in some of our specifications. We construct this index from the institutions index produced by Lora (2001). Lora generates indices of market reform in each of five areas: labor regulation, financial sector regulation, trade openness, privatization and taxation. He then averaged those individual indices to construct an index of overall reform. The indices for individual areas of regulation fall in a 0-1 scale, where 0 (1) corresponds to the most (least) rigid institutions in Latin America over the period for each of the five categories that compose the aggregate index. We modify Lora's index in two ways. First, we exclude trade reform from the calculation of the overall index, since we look at trade institutions directly through tariffs. Second, we use a different 0-1 scale, where the index in each category is calculated relative to the minimum and maximum level of reform in Colombia during the period, rather than the minimum and maximum relative to Latin America.

The mean and standard deviation of effective tariffs, as well as the index of other reforms (which only varies over time) are described in Figure 1. As described above, both the mean and the standard deviation of effective tariffs go down significantly between 1984 and 1992, and then show little variation. Figure 1 also shows that the index of other reforms, which goes up during the 1990s when market reforms are implemented, increased at the same time that tariffs were being reduced. This highlights the importance of controlling for other reforms in our estimation.

4.2 Estimation of Productivity and Demand Shocks

We begin by estimating production and demand functions at the plant level, to obtain measures of TFP, demand shifters and the elasticity of demand. Following Eslava, Haltiwanger, Kugler, and Kugler (2004), our TFP estimates are constructed using factor elasticities estimated using downstream demand to instrument inputs, while our demand estimation uses TFP as an instrument. While the primary objective of this section is to derive the measures of the plant-level profit fundamentals (productivity, demand and cost shocks) for our subsequent analysis of market selection, we also explore in this section one of the channels through which trade reform may affect market structure – namely the impact of tariffs on the mark-up.

4.2.1 Total Factor Productivity

We estimate total factor productivity for plant j in year t as the residual from a production function:

$$Y_{jt} = K_{jt}^{\alpha} (L_{jt} H_{jt})^{\beta} E_{jt}^{\gamma} M_{jt}^{\phi} V_{jt},$$

where, Y_{jt} is output, K_{jt} is capital, L_{jt} is total employment, H_{jt} are hours per worker, E_{jt} is energy consumption, M_{jt} are materials, and V_{jt} is a productivity shock.

Our total factor productivity measure is estimated as:

$$TFP_{jt} = \log Y_{jt} - \hat{\alpha} \log K_{jt} - \hat{\beta} (\log L_{jt} + \log H_{jt}) - \hat{\gamma} \log E_{jt} - \hat{\phi} \log M_{jt}. \quad (1)$$

where $\hat{\alpha}$, $\hat{\beta}$, $\hat{\gamma}$, and $\hat{\phi}$ are the estimated factor elasticities for capital, labor hours, energy, and materials. Since productivity shocks are likely to be correlated with inputs, OLS estimates of factor elasticities are likely to be biased. We thus rely on IV estimates, where the instruments are demand-shifters, input prices, and government spending which are likely correlated with input but uncorrelated with productivity shocks. A more detailed description of this estimation and its results can be found in Eslava, Haltiwanger, Kugler and Kugler (2004).¹³

Table 2 presents summary statistics for our TFP measure estimated with instrumental variables (labeled TFP in this Table), and compares it to alternative measures of productivity. All statistics are computed at the three-digit level. We compare our IV TFP measure with a TFP measure estimated using cost shares at the 3-digit level as factor elasticities (TFPC) and with a TFP measure estimated using factor elasticities from an OLS estimation of the production function (TFPO). Our TFP measure is highly correlated with both of these alternatives, with correlation coefficients above 0.85. Thus, in spite of the differences in estimated factor elasticities obtained using various methods, we find that the TFP distribution across plants is similar.¹⁴ The similarity between our

¹³Although the sample differs slightly because we drop observations from the smallest sectors, the estimated factor elasticities are the same as those in Eslava et. al (2004) up to the second decimal place.

¹⁴The finding that the distribution of plant-level TFP is robust to alternative estimation methods is analogous to related findings by Biesebroeck (2006). We also note that there are alternative ways to estimate factor elasticities in the literature such as Olley and Pakes (1996), Levinsohn and Petrin (2003), and Blundell and Bond (1999). The Olley and Pakes and Levinsohn and Petrin methods use a proxy approach to deal with endogenous factors of production. We note two points about these proxy methods. As discussed in Foster et. al. (2008), these proxy methods are less suitable for specifications with both demand shocks and productivity shocks (there is an omitted variable problem in the proxy inversion). Second, we have explored these proxy methods and generated TFP measures and also find the resulting TFP measures highly correlated with our TFP measure.

TFP measure and the cost shares TFP measure suggests that allowing factor elasticities to vary across sectors is not crucial for TFP estimation. In the rest of the paper, we rely on TFP estimates based on our IV estimation.

Table 2 also shows other interesting patterns that we exploit in our analysis in the following sections. First, the table shows considerable dispersion in plant-level prices and TFP within sectors, which is consistent with the association between price and productivity dispersion and frictions pointed out in recent literature. In addition, price dispersion is consistent with the common assumption of product differentiation in the recent literature.

Second, Table 2 shows that TFP (measured either using our preferred measure in row 1 of Table 2 or TFPC which uses the cost share factor elasticities) is inversely correlated with plant-level prices. This is consistent with more productive plants having lower marginal costs and setting lower prices when faced with downward sloping demand curves.¹⁵ We exploit this inverse relationship to estimate demand elasticities and demand shocks in the next section. This finding is also useful to provide insights as to the underlying sources and interpretations of price variation. As noted, price dispersion is consistent with product differentiation. This product differentiation may reflect horizontal or vertical differentiation. As such, some of the price variation may reflect product quality variation. While it is obviously of interest to ultimately sort out the nature of this product differentiation, this is not the focus of the current analysis. However, we note that the inverse correlation between TFP and prices is consistent with more efficient producers moving along downward sloping demand curves.¹⁶ For our purposes, then, if plant-level prices in part reflect variation in product quality (as well as potentially other sources of idiosyncratic demand shocks), our underlying assumption is that such variation in product quality is not correlated with TFP so that TFP serves as a good instrument for the output price in the demand function.

Table 2 also illustrates the importance of being able to measure plant-level prices and physical efficiency. TFP2 is a measure of “revenue” productivity, similar to that

¹⁵One possible concern in interpreting this inverse correlation between TFP and prices is division bias. TFP is physical output per unit input but physical output is based on the ratio of nominal output to plant-level prices. If there is measurement error in prices this can yield an inverse correlation in TFP and prices. To explore the relevance of this concern, we also have estimated the correlation between lagged TFP and current prices. If measurement error in plant-level prices is white noise then this eliminates the division bias. The average within sector correlation of lagged TFP and current prices is -0.59 which is similar in magnitude to the -0.65 correlation between TFP and prices in Table 1.

¹⁶We find that this inverse correlation holds for all 3-digit sectors.

used more frequently in the literature, given the absence of plant-level prices. Similar to the other measures of productivity we have reported, it is calculated using equation (1), but where Y_{jt} is plant-level output divided by sectoral-level prices and M_{jt} is expenditures on materials divided by sectoral-level materials prices. Although TFP and TFP2 are positively related, the correlation coefficient is only 0.68, significantly below the correlation of TFP with both TFPC and TFPO. Moreover, TFP2 is essentially uncorrelated with plant-level prices. Indeed, the relation between prices and productivity, which we exploit in our data to identify demand elasticities and shocks, disappears when sector-level deflators are used. The reason for this is straightforward: variation in TFP2 directly reflects the variation in prices, and the resulting positive correlation with prices offsets the negative correlation with physical productivity (TFP).

4.2.2 Demand Estimation

While productivity is likely to be one of the crucial components of profitability, as discussed in Section 2, other components are also probably important determinants of profitability and survival. For example, even if plants are highly productive, they may be forced to exit the market if faced with large negative idiosyncratic demand shocks. Another important determinant of exits is likely to be the degree of market power of a producer, which empirically can be captured by the mark-up or the inverse of the demand elasticity. In this section, we describe how we estimate both the demand shocks as well as demand elasticities.

Our demand shock measure is estimated as the residual from estimating a demand equation, which in its simplest form may be written (in logs) as:

$$\log Y_{jt} = \varepsilon_j \log P_{jt} + \log D_{jt}.$$

In this case, the demand shock is estimated using the following expression:

$$d_{jt} = \log \widehat{D}_{jt} = \log Y_{jt} + \widehat{\varepsilon}_j \log P_{jt}, \quad (2)$$

where d_{jt} is the demand shock faced by firm j at time t and $\widehat{\varepsilon}_j$ is the estimated elasticity of demand, which may potentially vary across plants or sectors.

Using OLS to estimate the demand function is likely to generate an upwardly biased estimate of demand elasticities because demand shocks are positively correlated to both output and prices, so that $\widehat{\varepsilon}$ will be smaller in absolute value than the true ε . To eliminate the upward bias in our estimates of demand elasticities, we use TFP as an instrument

for P_{jt} since TFP is negatively correlated with prices but unlikely to be correlated with demand shocks (Eslava et al., 2004).¹⁷ Also, to avoid potential problems from measurement error and associated division bias, we use lagged TFP as the instrument.

Columns (1) and (2) of Table 3 report the OLS and IV results from the simple demand equation. For consistency with other estimations reported below, the estimation is done pooling establishments from all sectors and controlling for sector effects at the 2-digit level. OLS results presented in Column (1) yield an estimated elasticity of -0.87. Meanwhile, IV results in Column (2), which use (lagged) TFP as an instrument for output, show a much higher average elasticity (in absolute value) of -2.12.

We also estimate a different demand specification, where we let the demand elasticity vary over time and by a plant’s location. To do this, we include the “density of roads” in the state in which the plant is located both as a control and as an interaction variable in the demand specification. The idea behind including density of roads is that this is a good proxy for access to markets, so that we should expect demand to increase as the density of roads increases and also competition to increase as access to markets improves. In this case, the demand equation may be written as,

$$\log Y_{jt} = \lambda_0 + \lambda_1 \log P_{jt} + \lambda_2 \text{Density}_{R(j)t} + \lambda_3 \text{Density}_{R(j)t} \times \log P_{jt} + \psi_{S(j)} + \log D_{jt},$$

where $\text{Density}_{R(j)t}$ is measured in kilometers of paved roads per square kilometer of total area of the state $R(j)$ in which plant j is located, and $\psi_{S(j)}$ are 2-digit sector effects.¹⁸ We also include national level GDP growth as an additional control, to make sure that the variation of roads over time is not reflecting other aggregate effects. In this case, the demand shock is again estimated as the residual from the demand equation, while the demand elasticity may be written as:

¹⁷In the macro literature on TFP there is considerable attention paid to measured cyclical fluctuations in TFP being associated with unmeasured changes in factor utilization (see, e.g., Basu and Fernald (2000)). As such, at the aggregate level, the assumption of measured TFP and aggregate demand shocks being uncorrelated may be problematic. However, we are mostly exploiting cross sectional variation in plant-level TFP with the variance of idiosyncratic shocks an order of magnitude larger than any aggregate shocks. Moreover, the idiosyncratic TFP and demand shocks we estimate are highly persistent suggesting that issues about cyclical factor utilization are dwarfed by the highly persistent idiosyncratic shocks (thus, inducing relatively little idiosyncratic variation in unmeasured factor utilization). Also, to the extent that energy usage proxies for capacity utilization, we would be taking this out of our TFP measure.

¹⁸For each state, we have this indicator for each decade (1980s and 1990s). The data were provided by CEDE.

$$\widehat{\varepsilon}_{R(j)t} = \lambda_1 + \lambda_3 \text{Density}_{R(j)t}. \quad (3)$$

Column (3) of Table 3 reports results for this specification. As expected, we find that increased road density increases the demand for output. Also, increased road density increases the demand elasticity (in absolute terms), consistent with the idea that greater competition due to greater access to markets makes demand more responsive to changes in prices. In Table 4, we report the implied average demand elasticity from this specification. The average elasticity when we allow for road density to enter the demand equation is -2.1, which is close to that estimated in Column (2) of Table 3. Moreover, as expected, all estimated elasticities are negative. In what follows, we use this variation in elasticities across plants in our analysis of survival. We acknowledge, however, that it would be interesting to explore richer demand structures that permitted richer variation in plant-level markups. We leave the latter for future work and note that such work would be the appropriate forum for exploring the impact of trade and other reforms on markups.¹⁹

5 Effects of Market Fundamentals and Tariffs on Plant Exit

As discussed in Section 2, the characterization of the exit decision implies that the plant ceases operations if its net present discounted value of profits (inclusive of fixed costs of operating) is negative. Assuming that the fixed cost, u_{jt} , is drawn from a normal distribution, we can in practice estimate a plant's probability of exit using a probit model, where we specify the probability of exit between t and $t + 1$ as a function of measures of market fundamentals in period $t - 1$.²⁰

¹⁹One idea suggested by Chad Syverson would be to use our data to compute plant-specific markups directly. That is, use our plant-specific cost data to estimate marginal costs at the plant level and then compute markups at the plant-level. Investigating the properties of such markups including how they vary across different types of plants and how they may have changed in response to market reforms is an interesting empirical agenda that we plan to pursue in future related work.

²⁰To justify a probit we require that there be some unobserved heterogeneity beyond the fundamentals that we measure to account for the variation in the data on plant exit. One obvious candidate is variation in the fixed cost of operating each period. Alternatively, there could be some other component of operating profits that is unobserved but uncorrelated with the fundamentals that we do observe. For ease of exposition, we refer to this stochastic unobserved heterogeneity as a stochastic fixed cost in the text.

$$\Pr(e_{js(j)R(j)t}) = \Pr(\kappa_S + \theta_G GDP_t + \theta_1 TFP_{jt-1} + P'_{Ijt-1} \Theta_2 + \theta_3 D_{jt-1} + \theta_4 \varepsilon_{R(j)t-1} \leq u_{jt}), \quad (4)$$

where $e_{js(j)R(j)t}$ takes the value of 1 if the plant j in sector $S(j)$ and region $R(j)$ exits between periods t and $t + 1$; κ_S are 2-digit industry effects; GDP_t is the growth of aggregate gross domestic product in year t ; TFP_{jt-1} measures productivity in period $t - 1$, P_{Ijt-1} is a vector of energy and materials prices in period $t - 1$, D_{jt-1} is a demand shifter in period $t - 1$, $\varepsilon_{R(j)t-1}$ is the price elasticity of demand for plant j in region $R(j)$ in period $t - 1$, and u_{jt} is an i.i.d. normally distributed error term.²¹

Table 4 reports summary statistics for the determinants of exit included in equation (4) (except for input prices which are reported in Table 1), as well as for effective tariffs and indices of trade and other reforms, which will be included in an expanded specification.

Table 5 reports the marginal effects obtained from estimating the baseline specification in equation (4), with more controls in each subsequent column. Marginal effects are calculated setting all right hand side variables at their mean levels. Column (1) reports the effect of productivity and input prices on plant exit when sector fixed effects and aggregate GDP growth are included, but idiosyncratic demand effects are left out. As expected, higher lagged productivity is negatively related to the probability of exit, while higher lagged energy and material prices are positively related with the probability of leaving the market. In particular, a one standard deviation increase in TFP from its mean level yields a 1.2 percentage point decrease in the probability of exit, and a one standard deviation increase in energy and material prices yields respective increases of 1.3 and 2.4 percentage points in the probability of exit. Since the average exit probability is 10%, these effects reflect large percentage changes in the probability of exit.

The magnitudes of all the estimated coefficients are larger when idiosyncratic demand effects are included. Column (2) includes the output price as a rough control for demand, while Columns (3) and (4) include our measures of demand shifts and elasticities. The results in Column (3) controlling for demand shocks show that a one standard deviation

²¹We use fundamentals dated at time $t - 1$ to predict exit from t to $t + 1$ given possible measurement and endogeneity issues in period t (the period just prior to exit). Our data are calendar year data but there may be mid-year exits which may yield measurement error in fundamentals for part year plants. Moreover, if the process of exit itself as the plant shuts down impacts fundamentals there is a problem of reverse causality. The use of period $t - 1$ information mitigates both of these concerns.

increase in TFP and demand yields respective reductions of 1.3 and 3.9 percentage points in the probability of exit, while a one standard deviation increase in energy and material prices yield a 1.5 and 3.3 percentage points increase, respectively, in the probability of exit.²² When we control for the degree of market power in Column (4), the effect of the demand shock is even larger, while the effects of productivity and prices are very similar. In this specification, a one standard deviation increase in the demand shifter and in the elasticity of demand reduces the probability of exit by 4 and 0.25 percentage points, respectively. As usual, since the price elasticity of demand is strictly negative, a larger demand elasticity (i.e., closer to zero) is associated with more inelastic demand, so that more market power reduces exit.²³

In order to assess the impact of trade reform on market selection, we add the sectoral tariffs as well as interactions of these with market fundamentals to the baseline probit specification. We also include an index for other contemporaneous reforms which occurred at the same time as the trade reform. This index summarizes the degree of flexibility in the areas of labor and capital market regulations as well as the extent of market orientation in terms of the tax system and privatizations. Since the 1990s were characterized by the introduction of widespread reforms in all of these areas, it is important to control for other reforms to make sure that tariffs are not picking up these additional institutional changes. The following equation is estimated:

$$\begin{aligned} \Pr(e_{jS(j)R(j)t}) = & \Pr(\kappa_S + \theta_G GDP_t + \theta_1 TFP_{jt-1} + P'_{Ijt-1} \Theta_2 + \theta_3 D_{jt-1} + \theta_4 \varepsilon_{R(j)t-1} \\ & + \theta_5 \tau_{S(j)t} + \theta_{5,1} TFP_{jt-1} \times \tau_{S(j)t} + (P_{Ijt-1} \times \tau_{S(j)t})' \Theta_{5,2} \\ & + \theta_{5,3} D_{jt-1} \times \tau_{S(j)t} + \theta_{5,4} \varepsilon_{R(j)t-1} \times \tau_{S(j)t} \\ & + \theta_6 R_t + \theta_{6,1} TFP_{jt-1} \times R_t + (P_{Ijt-1} \times R_t)' \Theta_{6,2} \\ & + \theta_{6,3} D_{jt-1} \times R_t + \theta_{6,4} \varepsilon_{R(j)t-1} \times R_t \leq u_{jt}) \end{aligned} \quad (5)$$

where $e_{jS(j)R(j)t}$, κ_S , GDP_t , TFP_{jt-1} , P_{Ijt-1} , D_{jt-1} , and $\varepsilon_{R(j)t}$ are defined as in equation (4). $\tau_{S(j)t}$ is the tariff in sector $S(j)$ in year t , R_t stands for the index of reforms

²²We report results with the output price included directly into the exit equations to show that the effect of the demand shock is similar whether we disaggregate the mark-up and idiosyncratic demand or whether we take a rougher measure. To the extent that there are any concerns about being able to separate the demand shock and elasticities, it is comforting to note that the results in Column (2) and those in Columns (3) and (4) are similar.

²³Many empirical papers on market selection include controls for plant size and age in their specification. In our view, inclusion of such effects is typically as a proxy for unobserved market fundamentals. In our case, we have a very rich set of fundamentals. For example, while we do not include size as a control, our demand shock measure captures variation in scale not due to variation in productivity.

other than trade at time t .²⁴ We regard this flexible specification with interactions as consistent with the canonical model of plant exit discussed in Section 2. In particular, this specification permits us to test and explore our primary hypothesis – that is, that plants in sectors with a greater reduction in tariffs will exhibit a decline in market distortions and, in turn, the marginal effect of market fundamentals on exit will increase. The interaction effects in the above specification are designed to test this hypothesis. We control for GDP growth rather than time effects since much of the variability of tariffs we want to exploit, in particular the general pattern of trade liberalization, occurs over time.

Given the presence of interaction terms, note that, for instance, the marginal effect of productivity in model (5) is now given by:

$$\frac{\partial \Pr(e_{jS(j)R(j)t})}{\partial TFP_{j,t-1}} = F'(X'_{jt}\Theta)[\theta_1 + \theta_{5,1}\tau_{S(j)t} + \theta_{6,1}R_t] \quad (6)$$

where F' is the marginal density for the normal distribution, and $X'_{jt}\Theta$ summarizes all covariates and coefficients in (5). A similar expression applies for the marginal effects of other fundamentals.

Table 6 reports results of specifications that include interaction terms as in equation (5). Each row reports the marginal effect for the corresponding variable, following the example of equation (6). Marginal effects are calculated at the mean value for all variables, except for tariffs, which are allowed to vary across columns. For Column (1) tariffs are set at 60%, and for Column (2) they are set at 20%. Since the mean value of tariffs is 56%, the effects reported in Column (1) are close to what is obtained by setting tariffs at their mean values. These marginal effects are based on the estimation of equation (5), which includes interaction of all fundamentals with both effective tariffs and the index of reforms other than trade. Column (3) of Table 6 reports the difference between the effects in Columns (1) and (2), and its standard error.

Results from Column (1) show that the effects of fundamentals are in general consistent with those estimated with the more parsimonious model reported in Table 5. The two exceptions are the marginal effects of energy prices and the demand elasticity, which are not statistically significant. In addition, we find that trade liberalization increased

²⁴While there may be reasons to think that tariffs could be affected by lobbies due to political economy factors, the fact that tariffs here are described at the sector- rather than the plant-level mitigates the concern of potential endogeneity in this estimation. Moreover, we conduct a robustness check, which is described below, to ensure that our results hold even in the sectors where it is most likely that a given establishment could have enough power to influence tariffs.

the importance of productivity, input prices, and demand shocks as determinants of a plant's probability of exiting. The effect of a reduction in effective tariffs from 60% to 20%, similar to the reduction in tariffs experienced in Colombia in the early nineties, can be explored by comparing Columns (1) and (2) of Table 6.²⁵ We find that a reduction in tariffs increases the impact that plant productivity, input prices, and demand shocks have on the exit probability. In particular, with the change in tariffs we are analyzing, the marginal effect of an increase in productivity is a reduction of the probability of exit by 1.4 percentage points if tariffs are at 60%, and by 2.0 points if tariffs are at 20%. The marginal effect of an increase in demand shocks is to reduce the probability that a plant exits by 2.3 percentage points if tariffs are at 60%, and by 2.4 percentage points if tariffs are at 20%. Similarly, the marginal effect of an increase in material prices goes from 1.9 to 2.8 percentage points. The estimated effect of a change in energy prices more than doubles when moving from 60% to 20% tariffs, and while each individual effect is insignificant their difference is significant at the 10% level. Moreover, Column (3) of Table 6 shows that, with the exception of the demand elasticity, all other differences in the marginal effects of the fundamentals between the 60% and 20% tariffs are significant. Again, in considering the magnitude of these effects it is useful to recall that the average exit rate is 10%. As such, these predicted effects are large relative to the average exit probability.

The change in the marginal effect of the demand elasticity shows that, while with high tariffs market power reduces the probability of exit, the same is not true after a reduction in tariffs to 20%. Neither of these marginal effects evaluated at 20% and 60% tariffs are individually significant, but the difference is consistent with what is predicted by theory. That is, increased competition through a reduction in tariffs diminishes the role of mark-ups in accounting for variation in the probability of exit. Interestingly, although a one standard deviation increase in tariffs reduces exit by 1 percentage point, the change is not statistically significant. Instead the impact of tariffs is through its interactions with the fundamentals as discussed above.²⁶

²⁵Given the large changes in tariffs we are evaluating, we follow this approach rather than calculating the cross derivative of the probability of exit with respect to the fundamental and to tariffs, as suggested by Ai and Norton (2003).

²⁶As mentioned, we do not control for time effects because they soak up part of the variability of tariffs that we want to exploit. For completeness, however, we have run similar regressions where GDP growth is replaced with time effects. As in our baseline case, we still find enhanced market selection after trade liberalization, as productivity becomes a more important determinant of exit at lower levels of tariffs. The fact that this effect is present when including time dummies probably indicates that the

As a summary measure of the overall impact of these interaction effects, we conducted the following counterfactual. Using the estimated probability of exit specification, we compare the plant-level predicted probability of exit when tariffs take on their actual values in each year to the predicted probability of exit when we fix tariffs at their 1984 levels (all other explanatory variables are held at their mean values in both scenarios). Figure 2 shows this comparison and indicates that the mean predicted probability of exit would have been higher every year with the actual tariffs than if tariffs had stayed at their 1984 levels, with the difference being particularly acute during the 1990s. The difference between these two predictions is in the 0.6 to 1 percentage point range during the 1990s – again a large effect relative to the average exit rate. Note as well that this counterfactual likely understates the impact of tariff reform on average exit rates since it neglects the impact of tariff reform on the distribution of fundamentals.²⁷

We also conducted a number of robustness checks.²⁸ One possible concern is that the variation in tariff reductions across sectors is endogenous. To address this possibility, we constructed a Herfindahl Index and dropped the 20% most concentrated 4-digit sectors in our sample according to this index. We do this to dispel concerns that, even though tariffs are measured at the sector- rather than the plant-level, in very concentrated sectors individual establishments could have influenced the tariff rate in the sector. The results are remarkably similar to those that include even the most concentrated sectors in the sample. In addition, it is important to point out that the correlation between the Herfindahl Index and tariffs is -0.05 and insignificant. If the lobbying story was behind the higher tariffs in a sector, we would expect the correlation between the Herfindahl Index and tariffs to be positive and significant. In addition, we checked the robustness of our results to alternative measures of tariffs. As an alternative, we substituted the main effect and interactions terms of effective tariffs for nominal tariffs and the results are very similar.²⁹

cross-sectional variability of tariffs is what matters for market selection. The other effects of tariffs on the determinants of exit show similar qualitative effects when including time dummies, but become less precise.

²⁷That is, the counterfactual in Figure 2 is a static counterfactual with the t-1 market fundamentals used to predict exit in period t and not a dynamic counterfactual simulation where the distribution of fundamentals is allowed to change over time due to the impact of selection over time. We undertake such dynamic simulation below.

²⁸The results are not shown but are available upon request.

²⁹We prefer the effective tariffs measure because it captures the total effect of trade liberalization including the effect of competition in the output market as well as increased access to input markets, while nominal tariffs only capture the first effect.

In addition, we explored concerns about biases in the estimation of shocks and demand elasticities if product quality and TFP move together. First, we estimated the correlation between TFP and relative prices and dropped the 4-digit sectors with the top 20% correlations (i.e. those exhibiting *less negative* correlations) which may be presumably the sectors where TFP and product quality move together. The results from these estimations are also similar but not as precise, probably given the smaller sample. Second, to address the potential biases in the estimation of demand shocks and elasticities, we estimate the interacted model (5), but leaving out the level and interaction effects of the demand shocks and elasticities and including instead level and interaction effects of the output price. The results are similar though, not surprisingly, less precise since, as noted in Table 2, TFP and output prices are strongly negatively correlated.

Two additional robustness checks are worth mentioning. We explored whether the impact of trade reforms takes time to have an impact by including the change in tariffs (in addition to the tariff level) in the specification. We found that the results reported in Table 6 are robust to inclusion of the change of tariffs as an additional explanatory variable and the latter was by itself not significant. We also explored whether our results are robust to the exclusion of the plant-year observations in 1991-92. Given changes in processing of the longitudinal identifiers in the plant-level data in those years, these are the years for which we had to devote considerable effort to develop consistent longitudinal identifiers. We found that the results in Tables 5 and 6 are robust to the exclusion of these years.

6 Effects of Tariffs on Average Productivity

In this section we explore various channels through which tariffs and increased foreign competition may have affected average productivity in the manufacturing sector. We begin by exploring the implications of improved market selection for average productivity.³⁰ We then explore whether greater international competition increased productivity by changing the behavior of incumbent establishments. First, trade liberalization may yield within plant increases in productivity through a variety of effects (see, e.g., Pavcnik (2002)) including incentives to invest in technology in response to increased competition and greater exposure to the world production technology frontier. Second, reduced distortions can lead to an overall improved allocation of activity. That is, increased

³⁰Increased average plant-level productivity with other things equal lead to increased aggregate productivity.

competition is likely to move production from low towards high productivity plants, strengthening the correlation between market share and plant-level productivity.

6.1 Trade Induced Exits and Productivity

The analysis on exits above suggests that productivity, demand shocks, and input prices have become more important in determining which plants remain in operation. These results imply that greater competition due to trade liberalization is weeding out the least productive plants and keeping the most productive plants in operation. Thus, one may expect market selection to contribute to increased average productivity. This contribution is likely cumulative since weeding out low productivity plants in a given year implies that market selection in subsequent years will be based on an already improved selection of plants.

In this section, we investigate the possible contribution of trade reforms to average plant-level productivity via a selection effect. Focusing on the selection effect alone, we generate an estimate of average plant-level productivity with two alternative selection scenarios. In one scenario, we use the actual values of tariffs to predict exit using our estimated selection model, and estimate the implied path of average productivity. In the second scenario, we set tariffs at their 1984 value and then generate the dynamic path of selection that would have occurred from 1985 onwards.³¹ Since productivity, demand and input shocks were also changing during the period, we carry out a dynamic simulation of the process of exit of Colombian plants that allows us to hold the contribution of changes in the shock processes constant.

Our dynamic simulation works as follows. First, we take the set of plants in 1985 with their actual values of fundamentals. We use the estimated probit model (5) to generate a predicted set of exiters and survivors for 1986. In generating the predicted exiters and survivors, we assign all plants at risk a value of 0 (exit) or 1 (survive) by taking appropriate random draws from a binary distribution with the estimated probability of exit. For one scenario the tariffs are set at the 1985 (true) values and for the other scenario the tariffs are set at the 1984 values. For the establishments that are predicted to survive, we then generate the 1986 fundamentals using AR(1) processes estimated for each fundamental (i.e., TFP, demand shocks, cost shocks) using the entire sample of plants.³² We then add to that set of plants, the actual 1986 entrants with their actual

³¹Note that the 1984 tariffs were the highest tariffs observed during our entire sample period.

³²The AR(1) processes assume a mean-zero normally distributed error. Our projections based on these processes include a random draw of a mean zero normal distribution, with the standard deviation

value of fundamentals. Next, we repeat the simulation of exit and survival – again using alternatively the 1986 (true) tariffs and the other the 1984 tariffs. We continue this process iteratively for all plants which allows us to generate two counterfactual distributions of plants up to 1998.

Using these two counterfactual distributions of plants, we calculate key moments of the distributions. In particular, we calculate the path of average productivity for each year for the two dynamic simulations. We note that since the shock processes for fundamentals are being held constant in these dynamic simulations, any difference in average TFP between the two scenarios responds to differences in the exit process associated with the alternative trade policies.

Our results are reported in Table 7. Column (1) reports the means and standard deviations of the log of TFP when the exit process assumes that tariffs are at their actual levels for each 4-digit industry for the entire sample of plants. Column (2) reports the mean for the case in which exit is projected keeping tariffs at their 1984 values. Finally, Column (3) reports the difference between these two columns and t-statistics for these mean differences. We conduct these simulations for all years as described above. In reporting the results, we find it instructive to report results for pooled years so that we compare and contrast the period when tariffs remained relatively high, 1986-1991, to the period during which tariffs were substantially reduced, 1992-1998. Our results indicate that the change in tariffs from the initial 1984 level generate insignificant gains in average TFP between 1986 and 1991. By contrast, the results show a large gain in average TFP between 1992 and 1998 of 2.8 log points which is significant at the 1% level for the entire sample of plants. As a separate, but closely related experiment, we repeat these dynamic simulations but exclude the entrants from the analysis, to explore the extent to which the differences in selection across the two scenarios yields differences for only the 1985 incumbents. The results in columns (4)-(6) of Table 7 show smaller gains in TFP from the reduction in tariffs relative to the 1984 level when the simulation is carried out for the 1985 incumbents alone. This suggests that part of the channel through which improved market selection has a positive impact on productivity is better market selection for recent entrants.

Table 8 helps us to see that this change in average TFP is indeed driven partly by the weeding out of less efficient plants. Columns (1) and (2) in Table 8 report the mean, standard deviation, and the 10th, 50th and 90th percentile of the simulated TFP in 1998 for the sample of plants predicted to survive up to that year given the actual and

of the residuals from the AR(1) estimation for each of the fundamentals.

1984 tariffs, respectively. The simulated TFP for plants in the lowest decile of simulated TFP has a cut point 3 log points higher when choosing the plants predicted to survive with actual tariffs compared to when the 1984 tariffs are used. Thus, lower tariffs indeed increase the productivity at the lower end of the distribution. At the same time, we also observe higher productivity at the median and at the highest decile of the distribution (i.e., 5 and 2 log points higher, respectively) when choosing the plants predicted to survive with actual instead of the 1984 tariff levels.

To put the results in Tables 7 and 8 into perspective, we note that over the 1992 to 1998 period the average industry in Colombia experienced an increase in total factor productivity of 12 log points. The results in Table 7 are interpretable as the impact on the average industry. As such, the results suggest that the improved market selection accounts for about 23 percent of the overall gain over this period.³³

6.2 Effects of Trade on Reallocation and Productivity Growth of Incumbents

While the focus in our paper has been on the impact of trade on plant exits and, in turn, on productivity, we are also interested in examining the impact of reduced tariffs on the productivity of continuing establishments.

First, Pavcnik(2002) argues that continuing plants may be induced to become more productive through increased international competition and greater exposure to best practices world-wide. To examine this hypothesis, we estimate a simple differences-in-differences specification regressing the log first difference of TFP for continuing plants on year effects, detailed industry effects and the change in tariffs (at the 4-digit level). Results are presented in Column (1) of Table 9. We find evidence that continuing plants in industries with larger tariff reductions have greater within plant growth rates in productivity. The point estimate suggests that reducing tariffs from 60 to 20 percent (approximately the average size of the tariff reduction) would yield a within plant increase in productivity of about 2.8 log points. This within plant effect is roughly comparable with the increase in average plant productivity we estimated from selection. Put together with the results in the prior section, the trade reforms appear to have increased average plant-level productivity both by chopping off the lower tail and via increased

³³Note that the Olley and Pakes (1996) decomposition of industry-level productivity includes a term which is average plant-level productivity. As such, changes in average plant-level productivity can be interpreted as directly contributing to industry level productivity.

productivity among continuing plants.

Second, trade reform may have improved the overall allocation of activity.³⁴ Using the Olley and Pakes (1996) (OP) methodology, we compute the covariance between market share and plant-level productivity for every 3-digit sector in each year. We then estimate a simple differences-in-differences specification with the dependent variable being the 3-digit yearly OP cross-term and the explanatory variables including industry effects, year effects and 3-digit tariffs. In the second column of Table 9, we find that sectors with lower tariffs experience a larger increase in the OP cross-term. The point estimate suggests that reducing tariffs from 60 to 20 percent increases the OP cross-term by 7.8 log points. This improved allocation is a large effect relative to either the within plant increases for continuing plants or the market selection effects discussed above. Note however that this effect may be partly driven by the market selection effects we discuss above. That is, more productive plants may increase their market share not only at the expense of less productive continuing plants but also at the expense of less productive plants which exited the market.

Finally, we note that this simple difference-in-difference methodology can be used with overall industry level productivity to quantify the overall effect of trade reforms on average industry productivity. The third column of Table 9 shows the results for this specification. This exercise indicates that a reduction in tariffs from 60 percent to 20 percent increases average industry productivity by 8.2 log points. This latter effect is the combined effect of improved average plant-level productivity and improved allocation. As indicated, there is not an exact decomposition of the role of market selection in this context since it contributes to both increases in average plant-level productivity (the results in the prior section) and improvements in allocation. Finding the overall contribution of market selection would require more structure modeling both the changes of productivity and market shares of incumbents and the contribution of entering and exiting plants.

³⁴While the shedding of less productive plants may be one reason for an improvement of the allocation of activity, more dynamic internal adjustments for incumbent plants and entry of more productive establishments may also work in the same direction. In this sense, the analysis of the size-productivity correlation after reform conducted in this section is broader than the analysis of plant exit above.

7 Conclusion

We find that plant profit margin fundamentals are important determinants of plant exits. Our analysis goes further than the existing literature by analyzing the impact of a rich set of profit margin fundamentals rather than relying on proxies. In particular, we find that higher physical productivity, higher demand, lower input costs and higher mark-ups reduce the probability that plants exit. In exploring the role of trade reforms, we find that lower effective tariffs increase the marginal impact of productivity, demand shocks and input costs on plant exit. As a result, lower effective tariffs have changed the nature of market selection and increased exit during the period of trade reform in Colombia. Most notably, as a result of intensified foreign competition, productivity becomes a more important determinant of survival after trade liberalization.

All of these findings point towards a greater impact of competitive forces on plant selection due to trade reform. Given evidence of intensified competition, we then investigate the implied impact on average productivity. For this purpose, we conduct counter-factual exercises that show what productivity would have been if plant survival had continued as with the 1984 tariffs and with actual levels. In particular, we quantify the implied average plant-level productivity using plant exit probabilities holding tariffs at their beginning of the period levels and at their actual levels. Average plant-level productivity is about 2.8 log points higher than it would have been in the absence of improved market selection. These results, thus, suggest a truncation of the productivity distribution on the left due to greater exit of less productive plants after trade reforms. Our findings are consistent with the prediction in the Melitz (2003) model, and other related models, of an increase in the productivity threshold required for plant survival after trade liberalization. This finding about the impact of trade liberalization on productivity is similar to the finding in Treffer's (2004) study for Canada conducted at a similar level of disaggregation as ours. However, in contrast to our study, Treffer's study does not focus on the impact of profit margin fundamentals on exit or on the process behind greater market selection.

Moreover, we also find that trade reform is associated with an increase in within plant productivity growth and improved allocation of activity within sectors for incumbent plants. These latter findings are also quantitatively important and fit in with the overall story of improved market competition yielding increases in productivity through a variety of complementary channels.

References

- [1] Ai, Chunrong and Edward Norton. 2003. "Interaction terms in logit and probit models," *Economics Letters*, 80: 123-129.
- [2] Attansio, Orazio, Pinelopi Goldberg and Nina Pavcnik. 2004. "Trade Reforms and Wage Inequality in Colombia," *Journal of Development Economics*, 74(2): 331-366.
- [3] Aw, Bee-Yan, Siaomin Chen, and Mark Roberts. 1997. "Firm-level Evidence on Productivity Differentials, Turnover and Exports in Taiwanese Manufacturing, NBER Working Paper 6235.
- [4] Baily, Martin, Charles Hulten and David Campbell. 1992. "Productivity Dynamics in Manufacturing Establishments," *Brookings Papers on Economic Activity: Microeconomics*, 187-249.
- [5] Banerjee, Abhijit and Esther Duflo. 2005. "Growth Theory through the Lens of Development Economics," *Handbook of Economic Growth*, eds., Steve Durlauf and Philippe Aghion, Vol. 1A.
- [6] Bartelsman, Eric and Mark Doms. 2000. "Understanding Productivity: Lessons from Longitudinal Microdata," *Journal of Economic Literature*, 38(2): 569-594.
- [7] Bartelsman, Eric and Phebus Dhrymes. 1998. "Productivity Dynamics: U.S. Manufacturing Plants 1972-1986," *Journal of Productivity Analysis*, 9(1): 5-34.
- [8] Bartelsman, Eric, Ricardo Caballero and Richard Lyons. 1994. "Customer- and Supplier-Driven Externalities," *American Economic Review*, 84(4): 1075-1084.
- [9] Bartelsman, Eric, John Haltiwanger and Stefano Scarpetta. 2008. "Cross Country Differences in Productivity: The Role of Allocative Efficiency," mimeo.
- [10] Basmann, Robert. 1960. "On Finite Sample Distributions of Generalized Classical Linear Identifiability Test Statistics," *Journal of the American Statistical Association*, 55: 650-659.
- [11] Basu, Susanto and John Fernald. 1997. "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy*, 105(2): 249-283.
- [12] Basu, Susanto and John Fernald. 2000. "Why is Productivity Procyclical? Why do We Care?" *NBER Working paper no. 7940*.

- [13] Bigsten, Arne, Paul Collier, Stefan Dercon, Bernard Gauthier, Jan Gunning Anders Isaksson, Abena Oduro, Remco Oostendrop, Cathy Pattillo, Mans Soderbom, Michel Sylvain, Francis Teal and Albert Seufack. 1997. "Exports and Firm-level Efficiency in the African Manufacturing Sector," University of Montreal.
- [14] Chen, Tain-jy and De-piao Tang. 1987. "Comparing Technical Efficiency Between Import-Substitution-Oriented and Export-Oriented Foreign Firms in a Developing Country," *Journal of Development Economics*, 36: 277-289.
- [15] Davis, Steven, John Haltiwanger and Scott Schuh. 1996. *Job Creation and Destruction*. Cambridge, Mass.: MIT Press.
- [16] Edwards, Sebastian. 2001. *The Economic and Political Transition to an Open Market Economy: Colombia*. Paris: OECD.
- [17] Ericson, Richard and Ariel Pakes. 1995. "Markov-Perfect Industry Dynamics: A Framework for Empirical Work," *Review of Economic Studies*, 62(1): 53/82.
- [18] Eslava Marcela, John Haltiwanger, Adriana Kugler and Maurice Kugler. 2009. "Factor Adjustments after Deregulation: Panel Evidence from Colombian Plants," forthcoming in *Review of Economics and Statistics*.
- [19] Eslava Marcela, John Haltiwanger, Adriana Kugler and Maurice Kugler. 2006. "Plant Turnover and Structural Reforms in Colombia," *IMF Staff Papers*, 53: 58-75.
- [20] Eslava Marcela, John Haltiwanger, Adriana Kugler and Maurice Kugler. 2004. "The Effects of Structural Reforms on Productivity and Profitability Enhancing Reallocation: Evidence from Colombia," *Journal of Development Economics*, 75(2): 333-371.
- [21] Foster, Lucia, John Haltiwanger, and Chad Syverson. 2008. "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?," *American Economic Review*, 98(1): 394-425.
- [22] Foster, Lucia, John Haltiwanger, and Cornell Krizan. 2001. "Aggregate Productivity Growth: Lessons from Microeconomic Evidence," in Edward Dean Michael Harper and Charles Hulten, eds., *New Developments in Productivity Analysis*. Chicago: University of Chicago Press.

- [23] Goldberg, Pinelopi and Nina Pavcnik. 2005. "Trade, Wages, and the Political Economy of Trade Protection: Evidence from the Colombian Trade Reforms," *Journal of International Economics*, 66(1): 75-105.
- [24] Hall, Robert. 1990. "Invariance Properties of Solow's Productivity Residual," in Peter Diamond, ed., *Growth/Productivity/Unemployment*. Cambridge: MIT Press.
- [25] Harrison, Ann. 1994. "Productivity, Imperfect Competition, and Trade Reform: Theory and Evidence," *Journal of International Economics*, 36: 53-73.
- [26] Hsieh, Chang-tai and Peter Klenow. 2008. "Misallocation and Manufacturing TFP in China and India," Mimeo.
- [27] Hopenhayn, Hugo. 1992. "Entry, Exit, and Firm Dynamics in Long Run Equilibrium," *Econometrica*, 60(5): 1127-50.
- [28] Jovanovic, Boyan. 1982. "Selection and the Evolution of Industry," *Econometrica*, 50(3): 649-670.
- [29] Kugler, Adriana and Maurice Kugler. 2009. "Labor Market Effects of Payroll Taxes in Developing Countries: Evidence from Colombia," forthcoming in *Economic Development and Cultural Change*.
- [30] Kugler, Adriana. 2005. "Wage-Shifting Effects of Severance Payments Savings Accounts in Colombia," *Journal of Public Economics*, 89(2-3): 487-500.
- [31] Kugler, Adriana. 1999. "The Impact of Firing Costs on Turnover and Unemployment: Evidence from the Colombian Labor Market Reform," *International Tax and Public Finance Journal*, 6: 389-410.
- [32] Kugler, Maurice. 2006. "Spillovers from Foreign Direct Investment: Within or Between Industries?," *Journal of Development Economics*, 80(2): 444-477.
- [33] Levinsohn, James and Amil Petrin. 1997. "Productivity, Industry Dynamics, and International Competition: A Structural Econometric Approach," University of Michigan, Mimeo.
- [34] Liu, Lili. 1996. "Entry-Exit, Learning and Productivity Change: Evidence from Chile," *Journal of Development Economics*, 42: 217-42.

- [35] Lora, Eduardo. 2001. "Structural Reforms in Latin America: What Has Been Reformed and How to Measure It," Inter-American Development Bank Working Paper No. 466.
- [36] Lora, Eduardo. 2000. "What Makes Reforms Likely? Timing and Sequencing of Structural Reforms in Latin America," Inter-American Development Bank Working Paper No. 424.
- [37] Lora, Eduardo. 1997. "A Decade of Structural Reforms in Latin America: What Has Been Reformed and How to Measure It," Inter-American Development Bank Working Paper No. 348.
- [38] Melitz, Marc. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6): 1695-1726.
- [39] Melitz, Marc and Gianmarco Ottaviano. 2008. "Market Size, Trade, and Productivity," *Review of Economic Studies*, 75(1): 295-316.
- [40] Olley, Steven and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6): 1263-1310.
- [41] Pack, Howard. 1984. *Productivity, Technology, and Industrial Development: A Case Study in Textiles*. New York: Oxford University Press.
- [42] Pavcnik, Nina (2002), "Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants," *Review of Economic Studies*, 69: 245-76.
- [43] Pombo, Carlos. 1999. "Productividad Industrial en Colombia: Una Aplicacion de Numeros Indices," *Revista de Economia del Rosario*.
- [44] Restuccia, Diego and Richard Rogerson. 2007. "Policy Distortions and Aggregate Productivity with Heterogeneous Plants," NBER Working Paper No. 13018.
- [45] Roberts, Mark and Dylan Supina. 1996. "Output Price, Markups, and Producer Size," *European Economic Review*, 40(3-5): 909-21.
- [46] Roberts, Mark and Dylan Supina. 1996. "Output Price and Markup Dispersion in Microdata: The Roles of Producer Heterogeneity and Noise," in Michael Baye, ed., *Advances in Applied Microeconomics*, Vol. 9. JAI Press.

- [47] Roberts, Mark and James Tybout. 1996. *Industrial Evolution in Developing Countries: Micro Patterns of Turnover, Productivity and Market Structure*. New York: Oxford University Press.
- [48] Shea, John. 1997. "The Input-Output Approach to Instrument Selection," *Journal of Business and Economic Statistics*, 11(2): 145-155.
- [49] Shea, John. 1993. "Do Supply Curves Slope Up?" *Quarterly Journal of Economics*, 108(1): 1-32.
- [50] Syverson, Chad. 2004. "Market Structure and Productivity: A Concrete Example," *Journal of Political Economy*, 112(6): 1181-1233.
- [51] Syverson, Chad. 2002. "Price Dispersion: The Role of Product Substitutability and Productivity," University of Chicago, Mimeo.
- [52] Topalova, Petia. 2006. "Trade Liberalization and Firm Productivity: The Case of India," IMF Working Paper No. 04/28.
- [53] Treffer, Daniel. 2004. "The Long and Short of the Canada-U.S. Free Trade Agreement," *American Economic Review*, 94(4): 870-895.
- [54] Tybout, James. 2000. "Manufacturing Firms in Developing Countries: How Well Do They Do, And Why?," *Journal of Economic Literature*, 38(1): 11-34.
- [55] Tybout, James and Daniel Westbrook. 1995. "Trade Liberalization and Dimensions of Efficiency Change in Mexican Manufacturing Industries," *Journal of International Economics*, 39(1-2): 53-78.

Table 1: Descriptive Statistics

Variable	
Output	10.71 (1.75)
Capital	8.43 (2.09)
Labor	10.98 (1.16)
Energy	11.44 (1.89)
Materials	9.92 (1.87)
Output Prices	-0.11 (0.58)
Energy Prices	0.37 (0.49)
Material Prices	-0.03 (0.46)
Entry Rate	0.07 (0.25)
Exit Rate	0.09 (0.28)
N	85,203

Notes: This table reports means and standard deviations of the log of quantities and of log price indices deviated from yearly log producer price indices. The sample has been restricted to plants in three-digit sectors that have reports for more than 25 plants per year in average, and to plants also included in Table 2 (those for which TFP can be calculated). The entry and exit rates are the number of entrants divided by total plants and number of exiting plants divided by total number of plants. A plant that enters in t is defined as a plant that reported positive production in t but not in $t-1$, while a plant that exits in t is one that reported positive production in t but not in $t+1$.

Table 2: Descriptive statistics for different measures of TFP

TFP Measure	Standard deviation	Correlation Coefficients Matrix				
		TFP	TFP2	TFPC	TFPO	RP1
		(1)	(2)	(3)	(4)	(5)
TFP	0.7668	1	0.69	0.90	0.86	-0.65
TFP deflating output and materials with sector-level prices (TFP2)	0.6079		1	0.53	0.40	-0.00
TFP with factor elasticities equal to cost shares (TFPC)	0.7657			1	0.86	-0.64
TFP with factor elasticities from OLS (TFPO)	0.6620				1	-0.72
Output prices relative to PPI (RP1)	0.5604					1
N		85,203	85,203	85,203	85,203	85,203

Notes: This table reports standard deviations and correlation coefficients for different measures of TFP and for the plant-level output prices. All figures are simple means of statistics calculated at the three-digit sector level. The exception is the total number of observations for the calculation of each correlation coefficient, reported in the last line, which includes all sectors. The factor elasticities used to estimate TFP (column (1)) are obtained from a 2SLS estimation of the production function, as described in the text. The equivalent factor elasticities used for TFPC (column (3)) are cost shares calculated at the three-digit sector level. For column (4), factor elasticities are obtained from an OLS estimation of the production function. Meanwhile, TFP2 in column (2) uses the same factor elasticities as in column (1), but the price indices used to deflate output and materials are calculated at the three-digit sector level rather than at the plant level. Sector level price indices are calculated as the geometric mean of plant level price indices for a given three-digit sector, using output shares as weights. Relative output prices RP1 are constructed as the log difference between plant level price indices and the aggregate log Producer Price Index, and reported in column (5).

Table 3: Demand Estimation

Instrument: TFP from 2SLS estimation of the production function

Regressor	OLS	2SLS	2SLS
	(1)	(2)	(3)
Relative Price	-0.8735 (0.0104)	-2.1209 (0.0194) [0.3852]	-1.7709 (0.0490) [0.3873]
Relative Price × Road Density			-1.2960 (0.1725) [0.3586]
Road Density			0.7395 (0.0565) [1.0000]
Root MSE	1.6169	1.7689	1.7627
N	73,697	73,697	73,697

Notes: This table reports results from estimating demand functions. Standard Errors are in parentheses. First Stage R^2 in square brackets. The dependent variable is physical output in logs, and the regressor “Relative Price” is the log difference between plant-level price and the yearly PPI . The estimated coefficients do not vary across sectors, but all regressions include two-digit sector fixed effects. The two-stage least squares regression in column (2) instruments price with the 2SLS TFP measure, lagged one period. The regression in Column (3) includes as a regressor an index of the kilometers of paved roads per squared kilometer of area in the state in which the plant is located. An interaction between this index and the relative price is also included. This interaction is instrumented using an interaction between the plant’s TFP (lagged) and the road density index. The regression in column (3) also controls for aggregate activity, given potential correlation with the increasing coverage of roads over time.

Table 4: Descriptive Statistics of Determinants of Survival

Variable	
Lagged TFP	1.1745 (0.7765)
Lagged Demand Shock (Column 2 Table 3)	10.6125 (1.8368)
Lagged Demand Shock (Column 3 Table 3)	10.6170 (1.8326)
Lagged Demand Elasticity (Column 3 Table 3)	-2.0978 (0.1562)
Reforms Other than Trade	0.4508 (0.1220)
Effective Tariffs	0.5599 (0.3854)
GDP Growth	0.0408 (0.0121)
N	57,886

Notes: This table reports means and standard deviations of the variables used to estimate exit probabilities. TFP is calculated using factor elasticities from a 2SLS estimation procedure, while demand shocks and demand elasticities come from the estimations reported in Table 3. The Index of Other Reforms is constructed using all components of the Lora Overall Reform Index, except those included in the Trade Index. Each of the sub-components of Lora's index has been re-scaled to be 0 in the year of less liberalization in Colombia and 1 in the year of most liberalization in Colombia. Effective Tariffs are available at the four-digit level, calculated from data by the National Planning Department.

Table 5: Determinants of Exit Probability

	(1)	(2)	(3)	(4)
Lagged Productivity	-0.0161** (0.0014)	-0.0300** (0.0019)	-0.0166** (0.0013)	-0.0163** (0.0013)
Lagged Energy Prices	0.0070** (0.0021)	0.0084** (0.0021)	0.0077** (0.0020)	0.0074** (0.0020)
Lagged Materials Prices	0.0129** (0.0024)	0.0219** (0.0026)	0.0178** (0.0023)	0.0180** (0.0023)
Lagged Output Prices		-0.0296** (0.0026)		
Lagged Demand Shock (Column 2 Table 3)			-0.0215** (0.0006)	
Lagged Demand Shock (Column 3 Table 3)				-0.0216** (0.0006)
Demand Elasticity (Column 3 Table 3)				-0.0158** (0.0064)
Sector Effects	YES	YES	YES	YES
GDP Growth	YES	YES	YES	YES
Likelihood Ratio	572.48 (12df)	700.62 (13df)	1730.67 (13df)	1737.40 (14df)
N	57,886	57,886	57,886	57,886

Notes: This table reports marginal effects from a Probit estimation of the probability of exit, where exit is 1 for plant i in year t if the plant produced in year t but not in year $t+1$. Standard errors in parentheses. Marginal effects are evaluated at mean values of all the independent variables. All specifications include sector effects at the two-digit level as well as plant-level productivity, energy prices, and materials prices. Column (2) includes output prices, column (3) includes a measure of demand shocks estimated using column (2) in Table 3. Column (4) includes measures of the demand shock and demand elasticity estimated using column (3) of Table 3. * indicates significance at the 10% level, ** indicates significance at the 5% level.

Table 6: Determinants of Exit Probability in a Model with Reforms and Tariffs.

	Ef. Tariffs at 60% (1)	Ef. Tariffs at 20% (2)	Difference (3)
Lagged Productivity	-0.0144** (0.0014)	-0.0197** (0.0021)	0.0053** (0.0020)
Lagged Energy Prices	0.0003 (0.0021)	0.0046 (0.0031)	-0.0043* (0.0027)
Lagged Materials Prices	0.0190** (0.0025)	0.0276** (0.0038)	-0.0086** (0.0035)
Lagged Demand Shock	-0.0226** (0.0007)	-0.0242** (0.0010)	0.0016* (0.0009)
Lagged Demand Elasticity	-0.0068 (0.0065)	0.0057 (0.0107)	-0.0125 (0.0092)
Effective Tariffs	-0.0028 (0.0041)	-0.0028 (0.0042)	0.0000 (0.0001)
Other Reforms Index	YES	YES	
Interactions with Other Reforms Index	YES	YES	
Sector Effects	YES	YES	
GDP Growth	YES	YES	
N	57,886	57,886	57,886

Notes: This table reports marginal effects and standard errors from a Probit estimation of the probability of exit where exit is 1 for plant i in year t if the plant produced in year t but not in year $t+1$. Standard errors in parentheses. Marginal effects are evaluated at mean values of all variables, except for effective tariffs. In Column (1) effective tariffs are set at a value of 60%, while in Column (2) they are set at 20%. Column (3) reports the difference between effects when tariffs are at 20% and at 60%. The specification includes sector effects at the two-digit level, as well as plant-level productivity, energy prices, materials prices and demand shocks and elasticities. Effective tariffs and interactions of effective tariffs with all of the plant-level regressors are also included. Similarly, we include an index of reforms other than trade reform, and interactions of this index with all of the plant-level regressors. The TFP measure is obtained using the factor elasticities from a 2SLS estimation procedure. The demand shock and demand elasticity measures used for this Table come from the demand specification reported in Column (3) of Table 3. * indicates significance at the 10% level, ** indicates significance at the 5% level.

Table 7: Average TFP(t) using exit between t-1 and t as projected by exit model

Average TFP _t (Using projected TFP _{it} for Simulated Continuers and actual TFP _{it} for actual Entrants)						
Sample	All Plants			1985 Incumbents		
	Actual Tariffs (1)	1984 Tariffs (2)	Difference (3)	Actual Tariffs (4)	1984 Tariffs (5)	Difference (6)
1986-1991	1.1007 (0.7861)	1.0901 (0.8053)	0.0105 [1.41]	1.0655 (0.7705)	1.0522 (0.7971)	0.0133 [1.57]
1992-1998	1.1015 (0.9229)	1.0737 (0.9349)	0.0278 [2.80]	1.0422 (0.9000)	1.0218 (0.9345)	0.0204 [1.57]
1986-1998	1.1011 (0.8488)	1.0829 (0.8646)	0.0181 [2.99]	1.0570 (0.8203)	1.0410 (0.8503)	0.0160 [2.23]

This table reports the simple mean of TFP for groups of plants simulated to participate in the market using the estimated probit model reported in columns (1) and (2) of Table 6. Standard deviations in parentheses in columns (1), (2), (4) and (5); T statistics for mean differences in square brackets in columns (4) and (6). The probability that a plant exits is estimated using actual values of all independent variables, including tariffs, in the results reported in columns (1) and (4), while tariffs are set at their 1984 value in the results reported in columns (2) and (5). Figures in columns (1)-(3) include plants that entered after 1985, while columns (4)-(6) only include plants present in 1985.

Table 8: Descriptive Statistics of Simulated TFP in 1998

	All Plants		1985 Incumbents	
	Actual Tariffs (1)	1984 Tariffs (2)	Actual Tariffs (3)	1984 Tariffs (4)
mean	1.1042	1.0656	1.0134	0.9933
standard deviation	0.9448	0.9562	0.9318	0.9480
10th percentile	-0.0763	-0.1068	-0.1573	-0.1720
50th percentile	1.0946	1.0410	1.0018	0.9784
90th percentile	2.3143	2.2912	2.2317	2.1667

This table reports descriptive statistics for the simulated distribution of TFP. The simulation uses actual tariffs in columns (1) and (2) and 1984 tariffs in columns (3) and (4). Figures in columns (1) and (2) include plants that entered after 1985, while columns (3) and (4) only include plants present in 1985.

Table 9: Alternative Effects of Trade Reform on Aggregate and Plant-level Productivity.

	TFP Change (Plant level) (1)	OP Cross Term (3 digit sectors) (2)	Industry Productivity (3 digit sectors) (3)
Tariffs		-0.1939 (0.0726)	-0.2051 (0.0906)
Change in tariffs	-0.0747 (0.0190)		
Sector Effects	YES	YES	YES
Year Effects	YES	YES	YES
R2	0.0129	0.7779	0.8268
N	56,113	336	336

Standard errors in parentheses. Column (1) is a regression at the plant level, controlling for sector effects (4-digit level) and for year effects. Columns (2) and (3) are regressions at the 3-digit sector level, controlling for sector effects (3-digit level) and for year effects. Our industry productivity measure in column (3) is the output-weighted plant-level log TFP.

Figure 1. Effective tariffs and reform index, 1984-1998

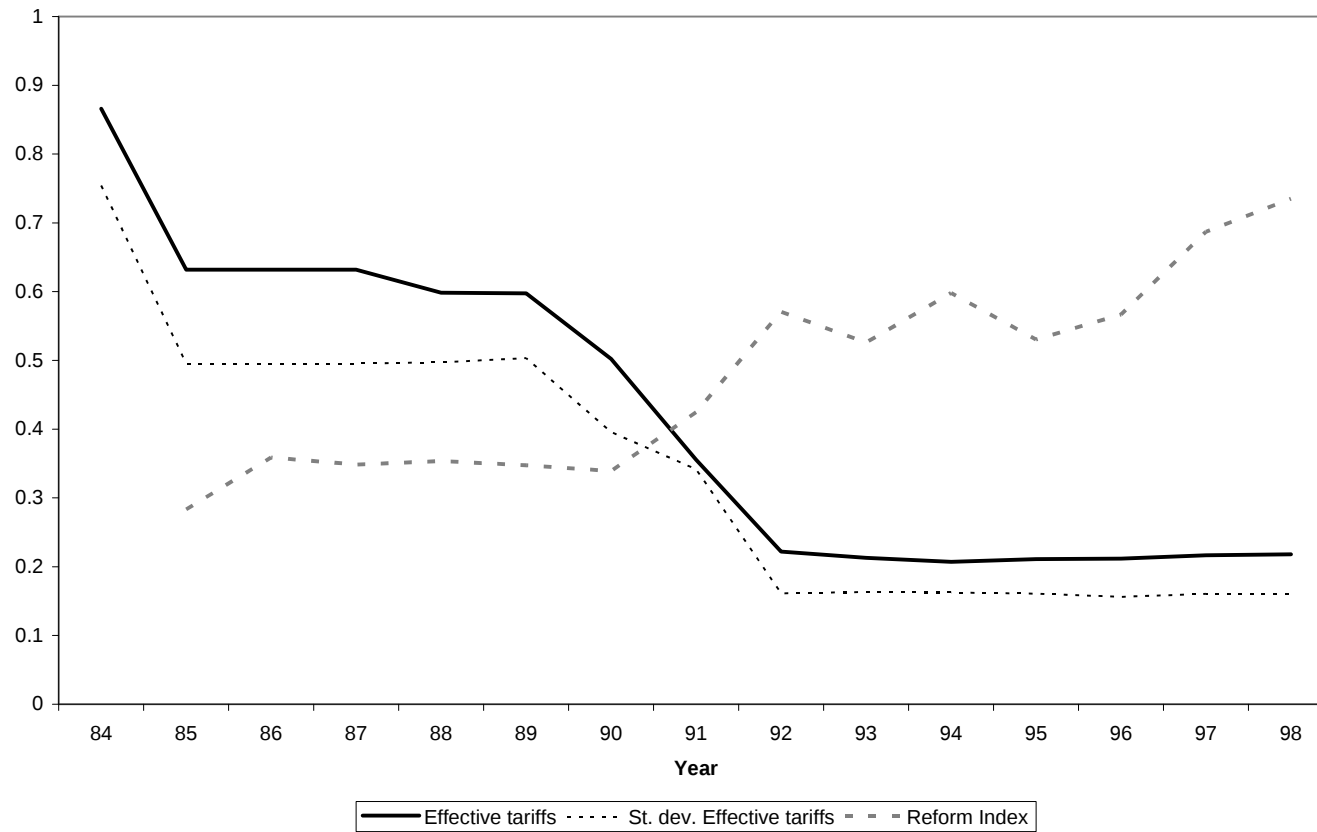


Figure 2: Predicted exit probability: actual tariffs vs. 1984 tariffs

