Trade Liberalization and Volatility
Evidence from Indian Firms

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Draft

August 2017

ABSTRACT I look at the impact of trade liberalization on product-level sales growth volatility of firms. Exploiting India's externally imposed trade reform to identify trade liberalization effects, I find that while a fall in the tariff on the final product produced by the firm is associated with an increase in volatility in Indian manufacturing firms, a fall in the tariff on intermediate inputs is associated with a decrease in volatility, with the latter effect dominating the former. I hence propose an additional channel for gains from trade liberalization to the ones documented in the literature.

JEL codes: F13, F14, O14

Keywords: Trade liberalization, Volatility, Input diversification, Firm size, Firm level data, India

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I would like to thank Lawrence Edwards, Andrei Levchenko and Mine Senses for invaluable comments. Thanks are also due to participants at the University of Cape Town's departmental seminar, the Trade, Development and Political Economy Workshop, Syracuse University, School of International Affairs, Pennsylvania State University seminar series, the Midwest International Economics Group Meetings, Pennsylvania State University, 2015 and the Annual Growth and Development Conference, Indian Statistical Institute, New Delhi, 2016. All errors and omissions are my own.

1. Introduction

As developing countries have liberalized trade over the past few decades and as advanced economies trade more with developing countries, the debate on the benefits of trade reform for the domestic economy continues to rage in the literature. One concern is that increased international exposure might be associated with increased volatility. Di Giovanni and Levchenko (2009) show that more open industries experience greater output growth volatility. Bergin, Feenstra and Hanson (2009 and 2011) find that employment in the offshoring industry in Mexico is significantly more volatile than the corresponding industry in the United States. More recently, Caselli, Koren, Lisicky and Tenreyro (2015) have argued the opposite. They look at aggregate GDP and argue that trade openness can lower volatility by reducing exposure to domestic shocks and allowing countries to diversify sources of demand and supply across markets.

Despite the contention, the literature concedes that isolating the link between greater trade exposure and volatility is an important exercise. Aggregate volatility has implications for workers, given that volatility may be associated with greater job and income uncertainty. This is particularly relevant for developing countries, where unemployment benefits and welfare are typically non-existent. Volatility in output can also affect price volatility, resulting in greater uncertainty in the macroeconomic climate. This can in turn lead to lower investments in capital, including human capital. Additionally, price volatility can also adversely affect household welfare, particularly in developing countries (Bellemare, Barrett and Just, 2013 for rural households in Ethiopia).

The literature on trade and volatility has focused largely on aggregate analyses at the level of the industry or the macro economy, though recent studies like Kurz and Senses (2013) and Buch, Döpke, Jörg and Strotmann (2009) utilize firm level data to delve into this relationship at a more micro level[1]. A study of volatility at the firm level can provide useful insights into

[1] Kurz and Senses (2013) focus on employment growth volatility. This is related to, but not synonymous with output or sales growth volatility, which is the focus of my study. Looking at employment growth volatility is outside the scope of my paper, and in fact, cannot be done with the data I use in this study due to lack of information on employment. In their study, the authors use data on transactions at the firm level to analyze the relationship between trading status and

factors affecting aggregate volatility, including trade openness. However, establishing a relationship between trade and volatility at the firm level is challenging for two main reasons. First, unobserved firm-specific factors that determine trading status of a firm can also affect volatility. For instance, firms that experience greater volatility in their supply of raw materials from domestic sources might choose to import from abroad. Similarly, firms that face greater volatility for their final product in the domestic market might wish to diversify into foreign markets. Alternatively, technology shocks may make output less volatile, but also increase participation by firms in global markets.

Second, trade can affect output growth volatility via various potential channels, and parsing these out can be difficult. The first channel is that trade can lead to specialization and a less diversified production portfolio, increasing volatility (di Giovanni and Levchenko, 2009). Next, trade liberalization might be associated with changes in the elasticity of demand, affecting how cost or wage shocks translate into volatility (Hasan, Mitra and Ramaswamy, 2007)[2]. Finally, import competition might be associated with changes in firm size and variable profits. Firm size affects volatility because larger firms can better diversify across customers and suppliers and are less volatile (Kelly, Lustig and Nieuwerburgh, 2013). More variable profits allow firms to import inputs from a wider range of countries to tide over shocks in input availability, lowering volatility (Caselli, Koren, Lisicky and Tenreyro, 2015).

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employment growth volatility of US firms. They show that importing firms experience greater employment growth volatility than purely domestic or exporting firms, and attribute this to the fact that these firms can more easily substitute imported inputs for domestic workers in response to a domestic wage shock. Note that this ability of firms to substitute across inputs might actually result in lower output growth volatility.

[2] I note here that there is a potential link between exporting and volatility that several studies have examined (Buch, Döpke, Jörg and Strotmann, 2009). Exporters may experience greater volatility if conditions in their destination markets are more volatile. However, if exporters experience uncorrelated shocks in their destinations, they may experience less volatility (Vannoorenberghe, 2012). My focus is on the relationship between greater import competition due to tariff reform and volatility, and hence, I mostly abstract from discussions on exporting and volatility.

In this study, I tackle both these challenges. I exploit India's trade liberalization episode in the 1990s, characterized by a fall in tariffs across sectors, as a natural experiment to study the impact of trade liberalization on volatility of product-level sales growth (henceforth, volatility) of Indian manufacturing firms. I argue that the tariff reform was exogenous to Indian firms since it was imposed as a part of an IMF restructuring package following a balance of payments crisis, and hence allows me to estimate the impact of greater trade exposure on volatility. I thereby tackle the first challenge.

Further, I am able to tease out some of the channels via which trade may affect volatility. First, since I look at volatility of firm sales in each product that a firm produces, I am able to rule out within-firm specialization in products from trade liberalization as a source of increased volatility (the first channel). Second, I consider decreases in both the tariff on the final product produced by the firm (output tariff), and the tariff on intermediate inputs used in the production of the final product (input tariff), both of which affect elasticity of demand, firm size and variable profits (channels two and three) differently. Third, I am able to disentangle the impact of output and input tariff reductions on volatility via their effects on firm size and variable profits captured by the mark-up, which I calculate using estimated input elasticities as in De Loecker and Warzynski (2012).

I posit a framework where a monopolistically competitive firm faces linear demand. A fall in the input tariff results in a fall in prices for intermediate inputs and hence lowers the firm's marginal cost. This is associated with an increase in firm size and (per-unit) variable profits. If firms pay a fixed cost to import intermediate input varieties, the fall in price and the resulting increase in variable profits can increase the range and variety of inputs available to a firm, which can now source both foreign and domestic varieties. Diversity in input varieties means that one single variety becomes less important in production, and hence production becomes less volatile. Also, in response to a given shock in input markets, firms have a greater ability to substitute toward alternate input varieties, which further reduces volatility[3]. Finally, with lower costs, the firm operates on a less elastic portion of the demand curve, where cost shocks translate to lower volatility. Thus, I hypothesize that a lower input tariff is associated with lower volatility.

[3] Koren and Tenreyro's (2013) study attributes this to benefits from technological diversification.

A fall in the output tariff will increase volatility via separate channels. First, a fall in the output tariff increases the elasticity of demand for a firm's final product as consumers avail of more substitutes. This means that a given cost shock would translate into greater changes in output, increasing volatility. Second, the effect of a fall in the output tariff on firm size and lower variable profits is ambiguous and depends on the relative strengths of the changes in intercept and slope of the demand curve. If the downward shift of the intercept due to import competition dominates the increase in demand elasticity, firms are smaller and make lower variable profits, which increases volatility.

My empirical analysis employs data from India at the product-level for Indian manufacturing firms over the period spanning India's trade liberalization. I relate product-level changes in the output and input tariff over time to changes in volatility of sales growth of firm-products. The main analysis employs data from 1989 through 1997 since this was the period where tariff declines were determined by external pressures (Topalova and Khandelwal, 2011). However, I test for robustness of results on an extended sample from 1989 through 2003 to study volatility over a longer time period and ensure that results retain their qualitative flavor. Baseline estimates indicate that a ten percentage point decrease in the input tariff is associated with a 2.4 percent decrease in volatility and a ten percentage point decrease in the output tariff is associated with a 1.4 percent increase in volatility of product sales growth. Results are robust to measuring volatility using an alternate measure, controlling for changes in the product unit-value and controlling for initial levels of volatility.

I then explore the channels through which trade liberalization affects volatility. I note that the trade and product specialization channel is not relevant in my case since my analysis looks within firm-products. Results suggest that the effect of a fall in the input tariff on volatility operates via firm size and the mark-up. This is not true for a fall in the output tariff, which indicates that output tariff effects on volatility potentially operate via their impact on demand elasticity. Further, I explore heterogeneous tariff effects for firms importing raw material, exporting firms and for firms in industries that use more differentiated inputs and are hence more contract intensive.

I find that tariff effects are augmented for firms importing raw material. This is consistent with the idea that the output tariff effect operates by global cost shocks translating to greater volatility with more elastic demand and that the input tariff effect operates by allowing firms to diversify input sources. Note that both these effects are likely to be magnified for importers. Tariff effects are mitigated for exporters. Lastly, the increase in volatility associated with a fall in the output tariff is mitigated in industries that use a greater proportion of differentiated inputs. This lends support to the idea that since more complex products tend to be less volatile (Krishna and Levchenko, 2013), a more elastic demand curve from a lower output tariff is associated with relatively lower volatility in these industries. Finally, consistent with earlier studies, results indicate that overall, trade liberalization effects did not differ systematically across Indian states by level of development, rigidity of labor regulation or location along the coastline.

In addition to its attempt to empirically disentangle the channels through which trade liberalization can affect volatility that have been proposed in the literature, this study highlights an important benefit of trade liberalization that, I believe, has not been previously documented. Greater import competition has been associated with increases in productivity due to reshuffling of resources to more efficient producers (Pavcnik, 2002) and due to pro-competitive effects that reduce market power of domestic producers (Topalova and Khandelwal, 2011). In addition, access to better, cheaper and a wider variety of inputs due to falling input tariffs can result in opportunities for productivity improvements, and can result in product quality upgrading and greater scope of products produced (Amiti and Konings, 2007; Goldberg, Khandelwal, Pavcnik, 2010; Goldberg, Khandelwal, Pavcnik, Topalova, 2010; Amiti and Khandelwal, 2013, Cadot, Carrère and Strauss-Kahn, 2013).

I show that while lower output tariffs may be associated with a slight increase in volatility, a lower input tariff can lower volatility by increasing firm size and variable profits, granting firms the ability to diversify across customers and a wider variety of inputs that they might use to mitigate shocks in intermediate goods markets. I hence argue that trade liberalization can have a stabilizing effect, in addition to a level effect. The rest of my paper proceeds as follows. In section 2, I present a conceptual framework to trace out the effects of a fall in input and output tariffs on volatility. I discuss the empirical specification in Section 3. Section 4 presents the data, Section 5 discusses results and Section 6 concludes.

2. Conceptual framework

In this section, I present a conceptual framework to look at the impact of a fall in tariffs on firm level volatility in product sales. I consider a firm operating in a monopolistically competitive domestic market producing a differentiated good[4]. The firm faces a linear demand curve and constant marginal cost. I now consider impacts of changes in the output and input tariff independently[5]. A fall in the output tariff results in a shift downward and flattening of the firm's demand curve since more imported substitutes are now available to the consumer. A fall in the input tariff lowers the marginal cost since firms can now access intermediate inputs at a lower price. Note that more elastic demand means that cost shocks (for instance, shocks to the domestic wage or the world price of inputs) translate to greater volatility in output. Also, with a fall in the input tariff and lower marginal cost, firms operate on a less elastic portion of the demand curve where the translation of cost shocks is attenuated. Given this framework, I can make the first proposition.

Proposition 1: A fall in the input tariff is associated with a decrease in volatility while a fall in the output tariff is associated with an increase in volatility via tariff effects on the elasticity of demand.

Next, I show in Appendix A, Propositions 1 (A) and 2 (A) that the effect of a fall in the output tariff on firm size (output) and the (per-unit) variable profit is ambiguous and depends on the relative strengths of the change in intercept versus slope of the demand curve. If the effect of a shift down of the intercept dominates the effect of increased elasticity of demand (flattening), a fall in the output tariff is associated with a decrease in firm size and variable profit. On the other hand, the effect of a fall in the input tariff that results in lower firm costs unambiguously increases firm size and variable profit.

I then appeal to two studies that analyze the relationship between volatility on the one hand and firm size (Kelly, Lustig and Nieuwerburgh, 2013) and the number of intermediate input

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[4] I consider a short-run setting, since the empirical analysis in this paper looks at a lagged (by one year) effect of tariffs on firm outcomes.

[5] In other words, I hold the output tariff constant when I consider a change in the input tariff and vice-versa. In the empirical analysis, I examine the relationship between each type of tariff and volatility conditional on the other.

varieties used in production on the other (Koren and Tenreyro, 2013). Kelly, Lustig and Nieuwerburgh (2013) study sales growth volatility and propose a network model of a firm where shocks are transmitted from customers to suppliers. They argue that larger firms have more customer connections and hence lower volatility. This means that in my framework, a fall in the input tariff will be associated with larger firm size and hence lower volatility, while a fall in the output tariff will have ambiguous effects on volatility.

Koren and Tenreyro (2013) propose a model where a firm produces a final good by combining a variety of inputs. Formally, they consider

$$y(j,t) = \left[\sum_{i \in I(j,t)} \chi_i(t) l_i(j,t)^{1-1/\epsilon}\right]^{\epsilon/(\epsilon-1)} \quad (2.1)$$

Here, firm j's output at time t is $y(j,t)$. i indexes domestic and foreign input varieties from a set of varieties $I(j,t)$, l_i is labor allocated to the operation of input i, ε is the elasticity of substitution between varieties and $\chi_i(t)$ is the productivity of variety i. I assume that $\varepsilon > 1$. Varieties may be hit by shocks, after which they cease to become productive (or contribute to production). This framework encompasses situations where input varieties become suddenly unavailable to producers (or available at very high prices) due to weather related shocks, policy or political factors, or hold-ups from suppliers due to contracting issues.

Boehm, Flaaen and Pandalai (2014) analyze the role of multinationals in transmitting shocks in intermediate input supplies to output internationally in the aftermath of the Tōhoku earthquake and tsunami in Japan, where, along with the massive and unfortunate loss of lives, resultant disruptions in power, infrastructure provision and port services affected domestic and foreign shipments of Japanese exports. Similarly Antras (2015) discusses a case where the Chinese government in 2004 banned all imports of Brazilian soybean since it found traces of carboxin (a toxic fungicide) in a shipment, thereby leaving Chinese soybean crushers and indeed, Brazilian soybean suppliers with stranded cargo.

Shocks are independent across varieties and arrive with a Poisson process, such that the input's productive lifetime follows an exponential distribution with parameter γ. Hence, conditional on working at time zero, the distribution of $\chi_i(t)$ is

$$\chi_i(t) = \begin{cases} 1 & with\, probability \quad e^{-\gamma t} \\ 0 & with\, probability \quad 1 - e^{-\gamma t} \end{cases} \quad (2.2)$$

Substituting into (2.1)

$$y(j,t) = \left[\sum_{i:\chi_i(t)=1} l_i(j,t)^{1-1/\epsilon}\right]^{\epsilon/(\epsilon-1)} \quad (2.3)$$

Let $n(j,t)$ denote the overall number of varieties, out of which $k(j,t)$ are not productive. Since varieties enter the production function symmetrically, firms allocate the same number of workers to each variety. Let $l(j,t)$ the amount of labor allocated to each productive variety. Then,

$$y(j,t) = l(j,t)[n(j,t) - k(j,t)]^{\epsilon/(\epsilon-1)} \tag{2.4}$$

Labor productivity is given by,

$$\omega(n,k) = [n(j,t) - k(j,t)]^{1/(\epsilon-1)} \tag{2.5}$$

Koren and Tenreyro (2013) show that the variance of output per unit of labor $Var(\text{dln}\omega)/dt$ is decreasing in n for all $n \geq 1$. In other words,

$$\frac{\partial \ln Var}{\partial n} < 0 \tag{2.6}$$

Also, in this framework, firms that use more varieties are more productive due to the love-of-variety effect. They can hence produce a given amount of output with fewer workers, and since labor is the only cost of production, earn higher operating profits. Hence, firm operating profit is increasing in $n(j,t)$. Now, assume that firms pay a fixed cost of importing each intermediate variety, which, for simplicity, is the same across varieties[6]. In importing varieties, firms equate the marginal benefit from employing an additional variety to the fixed cost of importing it. Firms can utilize an increase in variable profits to import additional varieties by paying the fixed cost of importing them. This expands the set of intermediate varieties $n(j,t)$. In other words, an increase in variable profits is associated with an increase in n and from (2.6), lower volatility.

The idea here is that trade liberalization increases access to a variety of intermediate inputs. When input tariffs fall, prices of intermediate inputs (both foreign and domestic) fall. If importing each variety is associated with a fixed cost, a fall in input prices may allow firms to import a wider variety of intermediate inputs. Indeed, Goldberg, Khandelwal, Pavcnik and Topalova (2010) find that over the period of India's trade liberalization, falling input tariffs were associated with imports of a greater variety of intermediate inputs by Indian firms, whose imports were virtually throttled in the period before the reforms. Given access to a greater variety of intermediates, each intermediate can become less important for production and firms

[6] Product-specific importing fixed costs are now a common feature of models capturing firm level trade, for instance, Halpern, Koren and Szeidl (2015).

can better mitigate shocks in intermediate input markets by substituting towards other varieties. Hence, in my framework, a fall in the input tariff will be associated with greater variable profit and hence lower volatility, while a fall in the output tariff will have ambiguous effects on variable profit and hence volatility. This leads to a second proposition.

Proposition 2: A fall in the input tariff is associated with a decrease in volatility while a fall in the output tariff is associated with ambiguous effects on volatility via tariff effects on firm size and variable profits.

A few implications of the framework emerge. Cost shocks may be more prevalent for importing firms relative to non-importers. Similarly, importers may be better able to diversify intermediate input usage with trade liberalization. This means that trade liberalization effects are likely to be exacerbated for importing firms. Exporters may be better able to smooth shocks given that they operate in multiple markets. Trade liberalization effects on volatility may hence be mitigated for them. Finally, if more complex products inherently tend to be less volatile (Krishna and Levchenko, 2013), firms in industries that use more differentiated inputs may see a weaker relationship between a fall in the output tariff and volatility. If diversification across input varieties is more difficult in these industries, given that inputs are customized and have to be contracted, the relationship between a fall in the input tariff and volatility may also be attenuated in these industries.

3. Empirical analysis

This section presents the empirical specification and identification strategy and details measures used in the analysis. The goal of the paper is to analyze the relationship between trade liberalization, captured by a fall in tariffs, and product-level sales growth volatility of Indian firms. To do this, I employ the following simple linear specification:

$$lnY_{ijw} = \alpha_1 + \beta_1 Input\ tariff_{jw} + \beta_2 Output\ tariff_{jw} + \gamma_{ij} + \delta_w + \epsilon_{ijw} \qquad (3.1)$$

Here, Y_{ijw} captures firm i's volatility in product j in time window w. I consider two time windows, 1989-1993 and 1994-1998. I underscore that my choice of time period is dictated by the plausible exogeneity of tariffs given that the reforms were externally driven. Tariffs are lagged by one period. Hence, the tariff for window one is the average tariff for 1988-1992, while the tariff for window two is the average tariff for 1993-1997. In my preferred estimation of (3.1), I include a set of firm-product and window fixed effects. The firm-product fixed effects account for unobserved firm-product specific shocks that determine volatility and tariffs jointly. Window fixed effects account for unobserved shocks that vary between the two time windows.

3.1 Volatility measures

Product-level volatility is calculated as the standard deviation of product sales growth in each window. Here, I can only include firm-products that have at least two unique sales growth values in each window. This measure is given by[7]

$$\sigma_{ijw} = [\frac{1}{w}\sum_{t=0}^{w-1}(G_{ijt} - \overline{G_{ijw}})^2]^{1/2} \tag{3.2}$$

where σ_{ijw} is the volatility measure for product j produced by firm i for the window w, $t = 0$ is the first year of the window, G_{ijt} is growth in the logarithm of S_{ijt}, where S_{ijt} is sales of product j produced by firm i at time t and $\overline{G_{ijw}}$ is the mean growth over the window w.

I perform an additional robustness check by using an alternate measure of volatility. I calculate volatility using a residual approach as follows[8]. First, the following equation is estimated separately for each window:

$$G_{ijt} = lnS_{ijt} - lnS_{ijt-1} = \theta_{ij} + \mu_{ts} + \vartheta_{ijt} \tag{3.3}$$

G_{ijt} is growth in the logarithm of S_{ijt}, where S_{ijt} is sales of product j produced by firm i at time t, θ_{ij} is a firm-product fixed effect, μ_{ts} are time by industry (2-digit) fixed effects and ϑ_{ijt} is an idiosyncratic error term. I then obtain predicted residuals, which capture deviations in sales growth from the firm-product average for that window, after accounting for industry and time specific shocks to growth. I then calculate volatility as the standard deviation of the residual for the window

$$Y_{ijw} = \sqrt{\frac{1}{w}\sum \hat{\vartheta}_{ijt}^{\,2}} \tag{3.4}$$

where w is the length of the window and $\hat{\vartheta}_{ijt}$ are predicted residuals. The advantage of this approach is that it allows me to control for unobserved sector and time specific shocks to

[7] This measure is used by both di Giovanni, Levchenko and Mejean (2014) and Kurz and Senses (2013).

[8] This measure is also used by Kurz and Senses (2013).

volatility common across all firms. Note that volatility measures can only be calculated for firm-products that appear for at least three consecutive years in the window-period.

3.2 Tariffs

I capture trade liberalization by a fall in the import tariff associated with each product. The output tariff is the average tariff rate for product j over the window w. The input tariff is calculated by first obtaining a weighted average of tariff rates applied to products that are used as inputs in the production of product j, defined as:

$$Input\ tariff_j = \sum_p s_{pj} Output\ tariff_p \quad (3.5)$$

where s_{pj} is the value share of input p in product j. I obtain value shares from India's input-output table for 1994-95. Input tariffs are calculated for each year and then averaged over the window.

I argue that India's trade reform provides a unique opportunity to study the effect of trade liberalization on volatility. India's tariff reform was introduced as a result of an adjustment program imposed by the IMF after a balance-of-payments crisis. Tariffs fell significantly across manufacturing sectors. Both input and output tariffs fell sharply between 1989 and 1997. The tariff reform was unanticipated by Indian firms and tariff changes, particularly in the first phase of the reform, were uncorrelated with pre-reform firm and industry characteristics (Topalova and Khandelwal, 2011). I confirm this in my data by examining the correlation between volatility in the (initial) first window-period and changes in the output and input tariffs between the two window-periods. I find that the correlation is very low (-0.05 and 0.01 for the output and input tariff respectively). Hence, to a large extent, using India as a case allows me to account for bias introduced by unobserved shocks driving volatility and tariff cuts simultaneously. Finally, as a robustness check, I estimate my baseline specification by including an interaction term between initial volatility and window-period fixed-effects to account for the possibility that tariff changes may be correlated with initial volatility.

3.3 Other measures

Teasing out the channels through which trade liberalization affects volatility requires measures of firm size, mark-ups and product unit-values. I measure firm size as total firm sales (across all products) and the unit-value as sales divided by quantity sold for each firm-product. I estimate the average mark-up charged by firms for each product in my analysis.[9] I employ the approach proposed in De Loecker and Warzynski (2012). I calculate the mark-up for each firm from input elasticities estimated using a firm level Cobb-Douglas production function for firms in each 2-digit industry group using the Levinsohn-Petrin (2003) method of productivity estimation with the Ackerberg, Caves and Frazer (2015) correction[10].

In an extended analysis, I look at heterogeneous effects of trade liberalization across firms and industries, and finally, across Indian states. Specifically, I first study the effects of trade liberalization differentially for exporting firms and for firms importing raw material. I do this by interacting the input and output tariff with an indicator variable that takes on a value of one if the firm exports a positive value or imports raw material in any year in the window. Next, I examine the effects of trade liberalization across industries that require varying proportions of differentiated inputs in production. I interact my tariff variable with an industry-level measure obtained from Nunn (2007) that is the fraction of differentiated inputs required for production (measuring contract-intensity of the product)[11]. Finally, I also interact tariff variables with a state-level dummy that equals one if the state is a pro-employer state (Besley and Burgess, 2004), a coastal state or an economically lagging state (Krishna, Mitra and Sundaram, 2010).

4. Data

Data for the analysis are obtained from the Center for Monitoring the Indian Economy's (CMIE) Prowess database, which captures data from annual income statements and balance sheets of publicly listed companies. Given its nature, the database is not representative of informal and small firms in India. However, firms in the database together comprise 60 to 70

[9] Data requirements for calculating the mark-up are stringent and I am able to calculate a mark-up only for a sub-sample of firms from the universe of manufacturing firms available in Prowess over the time period. To maximize sample size, I use the estimated firm level mark-ups to calculate the average mark-up charged by firms for each product in my final analysis sample.

[10] Input elasticities are reported in Appendix Table B2.

[11] Contract intensity measures are for the US for 1997. However, I argue that the ranking of most contract-intensive products (or products that use more differentiated inputs) should remain similar across countries assuming similar technology. This data can be accessed at http://scholar.harvard.edu/nunn/pages/data-0 (accessed in July 2014).

percent of the economic activity in the organized industrial sector. Product level information, which is crucial for this study, is available for about 85 percent of firms (Goldberg, Khandelwal, Pavcnik and Topalova, 2010). Information on the firm's industry and location is available in the database.

I focus on manufacturing firms. I use data for the years 1988 through 1998 for my baseline analysis, though I lose the first year in my analysis, since I calculate growth rates for firm product-level sales for the volatility measures. In a robustness check, I use an extended panel from 1988 through 2002. I use information on sales and quantity sold for firm-products[12]. I run firm level regressions to calculate the mark-up, firm sales and raw material expenditure volatility. For these, I use firm level information on firm sales, physical capital measured by net fixed assets, raw material expenditure, salaries and wages paid, the value of firm level raw material imports and the value of exports. Summary statistics for firm level variables are presented in Appendix Table B1. All nominal values are deflated to 1993 rupee (in millions) values using an industry-level Wholesale Price Index. I classify a firm as a raw material importer (exporter) in a given window if it imports a positive value of raw material (exports a positive amount) in any year in that window. My final analysis sample includes 3,123 firm-products[13]. Tariff data are nominal rates of protection at the commodity (product) level.[14]

Tables 1 (A) and (B) provide summary statistics for the final analysis sample. Table 1 (A), Rows (1) and (2) provide percentages of firms that import raw material and export respectively in the two windows and show that the percentage of firms importing and exporting

[12] The CMIE Prowess database comes with its own product codes for products produced by firms that correspond closely to the Harmonized System (HS) 4-digit classification. My tariff data are at the commodity level, which corresponds to commodity codes in India's Input Output Transactions Table (IOTT) 1994. I map both these to Harmonized System (HS) codes and thereby assign tariffs to each CMIE product.

[13] Note that my final analysis sample only includes cases where volatility measures can be calculated for both window-periods (1989 – 1993 and 1994 – 1998).

[14] A description of the tariff data can be found in Hasan, Mitra and Ramaswamy, 2007.

increased between the two windows spanning trade liberalization[15]. Rows (3) and (4) report output and input tariff rates for each window. The output tariff fell drastically from 147 percent to 57 percent (a 60 percent decrease), while the input tariff fell from 145 percent to 52 percent (a 64 percent decrease) between the two windows. Table 1(B) reports mean volatility for broad industry groups. Except for Metals and Machinery, volatility generally declines as products get more capital-intensive. Food is the most volatile and Rubber, Plastics and Non-metallic minerals, Transport Equipment and Other Manufacturing are the least.

5. Results

In this section, I present baseline results in Section 5.1, conduct robustness tests in Section 5.2 and explore channels through which trade liberalization affects volatility in Section 5.3. Further, in Sections 5.4 and 5.5, I explore heterogeneous trade liberalization effects across importers of raw materials, exporters, firms in industries using differentiated intermediate inputs and firms located in Indian states differing in their location, level of development and labor market flexibility.

5.1 Trade Liberalization and Volatility

Table 2 presents results for specification (3.1). To reiterate, the hypotheses are that a fall in the output tariff is associated with greater volatility through the demand elasticity channel and through the firm size and mark-up channels if the shift in intercept is stronger than the flattening of the demand curve with trade liberalization. A fall in the input tariff is associated with lower volatility through the demand elasticity, firm size and mark-up channels.

The first column of Table 2 includes window and product fixed-effects. Hence, it relates changes in volatility of firm sales in products that experienced large tariff cuts relative to products that experienced smaller cuts. Column (2) adds firm fixed-effects to account for unobserved firm-specific factors driving volatility. Results from Column (1) show that consistent with the hypotheses, a ten percentage point decrease in the output tariff is associated with a 1.2 percent increase in volatility, while a ten percentage point decrease in the input tariff

[15] Note that these percentages are not representative of the whole of Indian manufacturing, since the Prowess database includes mainly publicly listed formal firms.

is associated with a 3.7 percent decrease in volatility. Both effects are statistically significant. From column (2), controlling for firm fixed-effects, these magnitudes decrease to a 1.1 percent increase and 2.5 percent decrease in volatility for output and input tariff reductions respectively. Also, the output tariff effect is no longer precisely estimated.

To account for unobserved shocks at the firm-product level, I present results with firm-product fixed-effects in column (3). Hence, I relate changes in volatility between the two windows for each firm-product to changes in the input and output tariffs. I use this as my preferred specification. Results from column (3) show that a ten percentage point decrease in the output tariff is associated with a 1.2 percent increase in volatility, while a ten percentage point decrease in the input tariff is associated with a decrease of 2.4 percent in the volatility of growth of firm-product sales. Both coefficients are statistically significant.

5.2 Robustness Checks

I conduct a set of robustness checks in Table 3. In column (1), I use the alternate volatility estimated using the residual approach described in Section 3 (equations (3.2) and (3.4)). I find that results remain similar in sign and magnitude. In column (2), I address the concern that tariff decreases may be correlated with unobserved initial conditions, which might bias my estimates. I interact initial firm-product volatility with window effects. Results suggest that the coefficients on the tariff variables are consistent in sign and significance, while magnitudes of the effects are larger, suggesting that not accounting for pre-existing trends underestimates the impact of a fall in tariffs on firm-product volatility.

Finally, I analyze the impact of trade liberalization on volatility over a longer time period 1989 through 2003. I now consider two windows of seven years each. Results in Column (3) suggest that a fall in the output tariff is associated with an increase in volatility, though this effect is attenuated for the extended panel. A ten percentage point fall in the input tariff is associated with a decrease in volatility of six percent, much greater than in the early phase of trade liberalization. Broadly, the qualitative result that the impact of input tariff declines on volatility is stronger than the impact of output tariff declines remains.

5.3 Trade Liberalization and Volatility: Channels

I now work on isolating the channels through which output and input tariff declines affect volatility. First, note that since I look at product sales for each firm, I am able to rule out specialization by firms in their more competitive products as a source of increased volatility due to trade liberalization. Second, if the impact of tariff reductions works by altering mark-ups charged on products, I would observe tariff effects disappear once I control for the mark-up. In Column (1) of Table 4, I control for the average product-level mark-up charged by firms. Indeed, I find that the input tariff effect is lower and no longer statistically significant. This indicates that the effect of input tariff reductions on volatility operates through the mark-up channel, where lower firm costs due to lower intermediate input prices increase the per-unit variable profit, allowing firms to diversify across input varieties, lowering volatility. On the contrary, I find that the coefficient on the output tariff is roughly of the same magnitude and still statistically significant. This suggests that the effect of a reduction in the output tariff may not work through the mark-up.

In Column (2), I argue similarly for firm size. If trade liberalization effects on volatility operated through the firm-size channel, then controlling for firm-size should attenuate coefficients on the input and output tariff. Again, in Column (2), I find that while the input tariff coefficient drops in size and is no longer significant, the coefficient on the output tariff, though slightly smaller in magnitude, is still significant. This finding is consistent with the idea that the input tariff effect works by allowing firms to increase in size due to lower costs and diversify across customers leading to a decrease in volatility. There is no evidence that the output tariff effect operates through an effect on firm size. Results from this analysis point to the output tariff effect possibly operating through its effect on the elasticity of demand. A lower output tariff is associated with a more elastic demand curve so that cost shocks translate to greater volatility.

In Column (3), I consider an alternate channel through which trade liberalization might affect volatility of firm-product sales growth. Krishna and Levchenko (2013) argue that more complex products tend to be more volatile. If trade liberalization is associated with changes to product complexity, and if unit-values can serve as a rough proxy for product complexity, adding this control will enable me to account for this particular channel. Results in Column (3) show that the coefficient estimates on the output and input tariffs similar in sign, magnitude and significance to the baseline estimate in Table 2, Column (3), ruling out this channel.

The two channels empirically supported so far are that a fall in the input tariff is associated with an increase in mark-up and firm size, allowing firms to diversify across input varieties and customers, lowering volatility. Since there is no support for these channels driving the negative relationship between the output tariff and volatility, a potential channel is that a fall in the output tariff is associated with an increase in the elasticity of demand so that cost shocks translate to more volatility in sales growth. These ideas imply that a fall in the output tariff should be associated with an increase in volatility of raw material expenditure growth, while a fall in the input tariff should be associated with a decrease in raw material expenditure growth volatility. I explore these implications empirically.

A caveat of my database is that raw-material expenditures are not allocated across products within a firm. Hence, I can only examine firm level raw material expenditure growth volatility. It is possible that firms mitigate some shocks to intermediate inputs by substitution across products and it is likely that a firm level analysis will underestimate the negative impacts of a decline in the output tariff. From Column (4), I find that a fall in the output tariff is associated with greater volatility of raw material expenditure growth at the firm level, but this effect is not statistically significant. A potential reason for this is that firms might mitigate shocks in intermediate input markets by altering allocation of inputs across products. Product-level data on raw material usage might be better able to tease out this channel. A fall in the input tariff is associated with a statistically significant decrease in the volatility of raw-material expenditure growth, providing further support to the idea that a fall in the input tariff is associated with lower volatility in sales growth through a stabilizing effect on intermediate input expenditures.

Finally, in Column (5), I look at the impact of trade liberalization on firm level sales growth volatility. Coefficient estimates on the output and input tariff indicate that a fall in the output tariff is associated with an increase in firm sales growth volatility, while a fall in the input tariff is associated with a decrease in firm sales growth volatility. The input tariff effect is statistically significant, while the output tariff effect is not. There is hence no empirical support for the idea that trade liberalization is associated with specialization within firms toward particular products, increasing volatility.

To summarize, there is empirical support for the idea that a fall in the input tariff is associated with lower volatility by altering firm size and variable profits, allowing firms to diversify across intermediate inputs. A fall in the output tariff is associated greater volatility of product sales growth, though this effect potentially operates through a more elastic demand curve translating cost shocks to greater volatility.

5.4 Heterogeneous Effects across Firms

In Table 5, I exploit data on the trading status of firms. I then look at heterogeneous effects across raw material importers and exporters and across industries that employ more differentiated intermediate inputs. I ask if results are consistent with the channels proposed in the conceptual framework and further examined in Section 5.3. In column (1), I interact both tariff variables with indicator variables for if a firm is a raw material importer or an exporter in any year in the window period. Results in column (1) suggest that the impact of a fall in the output and input tariffs on volatility is much stronger for firms that directly import raw material from abroad. Trade liberalization effects on volatility are hence magnified for importing firms. This is consistent with my proposition that a fall in the input tariff allows firms to diversify across intermediate inputs if direct importers are better able to access input varieties from abroad. Similarly, if direct importers face greater shocks in the global market for intermediate inputs, a fall in the output tariff would be associated with greater volatility for them, as seen in Column (1). Column (1) also suggests that trade liberalization effects on volatility are mitigated for exporters, lending some evidence for the notion that exporters are better able to mitigate global shocks and better access a variety of intermediate inputs, given their diversification across multiple markets.

In Column (2), I interact each tariff variable with a measure of contract intensity from Nunn (2007). Nunn classifies a product as contract-intensive if it uses a greater fraction of differentiated inputs. The idea is to ascertain if products that require more differentiated inputs into production see differential changes in volatility due to trade liberalization. Firms in industries that use more differentiated (and therefore potentially more complex) inputs may experience fewer shocks to these inputs since more complex inputs are less volatile. Such firms may also be less able to exploit cost gains to diversify across intermediate input varieties since complex varieties may be more customized and require contracting. In this case, we would observe the effects of a fall in the output and input tariff to be mitigated for firms in these industries. From Column (2), I find that while there is no evidence for a differential effect of the input tariff for industries employing more differentiated inputs, the output tariff effect is indeed mitigated for these industries.

5.5 Heterogeneous Effects across States

In Table 6, I ask if trade liberalization in India was associated with differential effects on volatility across firms in states with relatively stringent labor regulation (column (1)), in coastal versus inland states (column (2)) and in leading versus economically lagging states (column (3)). Data on labor regulation are from Besley and Burgess (2004) and data on leading and lagging states are obtained from Krishna, Mitra and Sundaram (2010). If tariff transmission to domestic prices differs across regions in the country given India's shortfalls in infrastructure and service delivery that have resulted in high transport costs within the country, then I expect the effects of trade liberalization to vary across geographical regions within the country.

Broadly, I find little evidence for such heterogeneous effects. The interactions of tariff variables with the flexible (labor regulation) and coastal state dummies (Columns (1) and (2)) are not statistically significant, suggesting that trade liberalization effects were uniform across these states. These results are consistent with earlier work by Goldberg, Khandelwal and Pavcnik (2010) who also document lack of differential trade liberalization effects on firm product scope across Indian states during the period of the reform. From Column (3), I find weak evidence that firms in economically lagging states experienced smaller increases in volatility from a fall in the output tariff. If lagging states have poor transport infrastructure (Krishna, Mitra and Sundaram, 2010), transmission of tariff changes to domestic prices may be hampered, mitigating the effects of global price shocks for firms in these states.

6. Conclusion

In this study, I look at the impact of trade liberalization on product-level volatility of sales growth. I find evidence that a decrease in the output tariff is associated with greater volatility, and a decrease in the input tariff is associated with lower volatility for Indian manufacturing firms, with the latter effect dominating the former. My study highlights an additional channel for gains from trade. Though greater exposure to global shocks in a more competitive environment may increase volatility, gains associated with cheaper and better access to intermediate input varieties can allow firms to diversify across customers and mitigate shocks in intermediate input markets, lowering volatility. Hence, trade liberalization can have a stabilizing effect on firm growth in addition to the numerous level effects documented in the literature.

This is particularly relevant for developing economies, where mechanisms to effectively deal with volatility in prices and uncertainty in employment are limited and a majority of the population lives without access to adequate social security nets.

Table 1(A): Descriptive Statistics

	1989-1993	1994-1998
Importers of Raw Material (% firms)	58	61
Exporters (% firms)	57	62
Output Tariff (%)	147	57
Input Tariff (%)	145	52

Source: CMIE data, author's calculations; Hasan, Mitra and Ramaswamy (2007) for tariff data.
Notes: A firm is classified as an importer (exporter) if it imports (exports) in any year in the relevant time-period. Tariffs are nominal rates of protection.

Table 2(B): Mean Volatility, 1989-1998

Broad Industry Group	**Mean Volatility**
Food	0.44
Textiles/apparel	0.41
Leather/Wood/Paper	0.43
Chemicals	0.39
Pharmaceuticals	0.39
Rubber/Plastics/Nonmetallic Minerals	0.32
Metals	0.44
Machinery	0.44
Transport Equipment	0.33
Other Manufacturing[2)]	0.33

Source: CMIE data, author's calculations
Note: 1) Volatility is calculated as the standard deviation of growth in firm-product sales and averaged over the two window-periods 1989-1993 and 1994-1998. 2) Other Manufacturing includes product categories like jewellery, toys, sports goods, musical instruments and medical instruments and supplies.

Table 2: Tariff Reform and Volatility, 1989 – 1998

	(1)	(2)	(3)
Lagged Output tariff	-0.0012*	-0.0011	-0.0012*
	[0.001]	[0.001]	[0.001]
Lagged Input tariff	0.0037***	0.0025*	0.0024**
	[0.001]	[0.001]	[0.001]
Window fixed effects	Yes	Yes	Yes
Product fixed effects	Yes	Yes	No
Firm fixed effects	No	Yes	No
Firm x Product fixed effects	No	No	Yes
Observations	6,246	6,246	6,246
R-squared	0.152	0.479	0.007

Notes: 1) The dependent variable is the log of volatility in product-level sales growth for each firm over two windows – 1989-1993 and 1994-1998. It is calculated as the standard deviation of growth in firm-product sales. Tariffs are average product-level tariffs for 1988-1992 and 1993-1997 2) The analysis includes 3,123 firm-products. 3) Standard errors in parentheses are clustered at the product level. 4) *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Tariff Reform and Volatility, Robustness Checks

	(1)	(2)	(3)
	Alternate volatility measure	Initial volatility x window effect	Longer panel: 1989 - 2003
Lagged Output tariff	-0.0011**	-0.0022***	-0.0006
	[0.001]	[0.001]	[0.001]
Lagged Input tariff	0.0023*	0.0044***	0.0058***
	[0.001]	[0.002]	[0.002]
Observations	6,246	6,246	8,372
R-squared	0.026	0.334	0.025
Firm-products	3,123	3,123	4,186

Notes: 1) The dependent variable is volatility in product-level sales growth for each firm measured using the residual approach in column (1) and as the standard deviation of growth in firm-product sales in columns (2) and (3). Volatility is calculated over two windows 1989-1993 and 1994-1998 in columns (1) and (2) and over two windows 1989-1995 and 1996-2003 in column (3). Tariffs are average product-level tariffs for 1988-1992 and 1993-1997 in columns (1) and (2) and for 1988-1994 and 1995-2002 in column (3). 2) Column (2) includes interactions of initial window-period volatility of firm-products and window-period dummies. 3) All columns include window and firm-product fixed effects. 4) Standard errors in parentheses are clustered at the product level. 5) *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Tariff Reform and Volatility, 1989 – 1998, Channels

	(1)	(2)	(3)	(4)	(5)
	Firm-product: Volatility	Firm-product: Volatility	Firm-product: Volatility	Firm: Input volatility	Firm: Volatility
Lagged Output tariff	-0.0011*	-0.0010*	-0.0013**	-0.0006	-0.0006
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Lagged Input tariff	0.0022	0.0017	0.0022*	0.0046*	0.0060***
	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]
Ln(Mark-up)	-0.0500				
	[0.035]				
Ln(Firm size)		-0.1624***			
		[0.034]			
Ln(Unit-value)			0.0293		
			[0.021]		
Window fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	No	Yes	Yes
Firm-product fixed effects	Yes	Yes	Yes	No	No
Observations	5,617	6,246	5,932	4,837	4,837
R-squared	0.010	0.014	0.008	0.054	0.056

Notes: 1) The dependent variable is volatility in product-level sales growth in columns (1) through (3), volatility in growth of raw material expenses at the firm level in column (4) and volatility in firm level sales growth in column (5) all calculated as the standard deviation of growth. It is calculated over two windows 1989-1993 and 1994-1998. Tariffs are average product-level tariffs for 1988-1992 and 1993-1997. 2) Regressions in columns (4) and (5) are at the firm level, and not at the firm-product level. Hence, tariffs are 2-digit industry-level tariffs. 3) Column (1) includes the average mark-up charged by firms for a particular product as a control variable. Column (2) includes firm size, measured by total firm sales as a control variable. Column (3) includes the unit-value of a firm-product as a control variable. 4) Observations in columns (1) and (3) are fewer because a mark-up and unit-value could not be calculated for all products and firms. 5) Standard errors in parentheses are clustered at the product level in columns (1) and (2) and at the industry level in columns (3) and (4). 6) *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5: Tariff Reform and Volatility, 1989 – 1998, Heterogeneous Effects across Firms

	(1)	(2)
Lagged Output tariff	-0.0005	-0.0024**
	[0.001]	[0.001]
Lagged Input tariff	-0.0015	0.0018
	[0.001]	[0.002]
Lagged Output tariff x Raw Material Importer	-0.0044***	
	[0.001]	
Lagged Input tariff x Raw Material Importer	0.0059***	
	[0.001]	
Lagged Output tariff x Exporter	0.0042***	
	[0.001]	
Lagged Input tariff x Exporter	-0.0028**	
	[0.001]	
Lagged Input tariff x Contract Intensity		0.0046**
		[0.002]
Lagged Input tariff x Contract Intensity		-0.0017
		[0.002]
Observations	6,246	6,246
R-squared	0.022	0.009
Firm-products	3,123	3,123

Notes: 1) The dependent variable is the log of volatility in product-level sales growth for each firm over two windows – 1989-1993 and 1994-1998. It is calculated as the standard deviation of growth in firm-product sales. Tariffs are average product-level tariffs for 1988-1992 and 1993-1997. 2) 'Raw Material Importer' ('Exporter') are dummy variables that equal one if the firm imported (exported) a non-zero rupee amount of raw material (exports) in any year in the window. 3) Contract intensity is an index from Nathan Nunn (2007), measuring the fraction of differentiated inputs used in production in each industry. 4) All columns include window and firm-product fixed effects. 5) Standard errors in parentheses are clustered at the product level. 6) *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6: Tariff Reform and Volatility, 1989 – 1998, Heterogeneous Effects across States

	(1)	(2)	(3)
Lagged Output tariff	-0.0014*	-0.0005	-0.0017**
	[0.001]	[0.001]	[0.001]
Lagged Input tariff	0.0030**	0.0018	0.0035***
	[0.001]	[0.002]	[0.001]
Lagged Output tariff x Flexible labor state	0.0000		
	[0.002]		
Lagged Output tariff x Coastal state		-0.0006	
		[0.002]	
Lagged Output tariff x Lagging state			0.0026*
			[0.001]
Lagged Input tariff x Flexible labor state	-0.0002		
	[0.002]		
Lagged Input tariff x Coastal state		0.0011	
		[0.002]	
Lagged Input tariff x Lagging state			-0.0024
			[0.002]
Observations	5,642	6,086	6,064
R-squared	0.007	0.007	0.008
Firm-products	2,821	3,043	3,032

Notes: 1) The dependent variable is the log of volatility in product-level sales growth for each firm over two windows – 1989-1993 and 1994-1998. It is calculated as the standard deviation of growth in firm-product sales. Tariffs are average product-level tariffs for 1988-1992 and 1993-1997. 2) Flexible labor state refers to a state with flexible labor regulations (pro-employer states), obtained from Besley and Burgess (2004). 3) Coastal state refers to a state situated on India's coastline and hence has a major port. 4) Lagging state refers to a state with per capita income lower than the average for South Asia, obtained from Krishna, Mitra and Sundaram (2010). 5) Number of observations differ across columns with availability of state-level variables. 6) All columns include window and firm-product fixed effects. 7) Standard errors in parentheses are clustered at the product level. 8) *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Appendix A
Conceptual Framework - Propositions

Consider a firm operating in a monopolistically competitive domestic market producing a differentiated good. I consider a short-run setting, since the empirical analysis in this paper looks at a lagged (by one year) effect of the import tariff on firm outcomes. The firm faces competition from imported varieties. Imports of the final good produced by the firm are subject to a tariff t (the output tariff) and intermediate inputs used by the firm can be imported with an import tariff i (the input tariff). For the purposes of this section, I look at impacts of output and input tariff changes independently. In the empirical analysis, I look at the effect of each tariff conditional on the effect of the other.

Suppose that the firm's demand curve is linear, given by

$$p = a(t) - b(t)q \tag{1}$$

where $a(t), b(t), a'(t)$ and $b'(t)$ are greater than zero and $\frac{d\varepsilon}{dt} < 0$ where ε is the elasticity of demand. This captures the idea that a fall in the import tariff is associated with a shift down and flattening of the firm's demand curve since consumers can now avail of imported substitutes. The firm's marginal cost is constant and is a function of the import tariff, since a lower import tariff allows firms to access cheaper intermediate inputs, lowering cost. Hence, the firm's marginal cost is given by

$$c = c(i) \tag{2}$$

such that $c'(i) > 0$. I assume that changes in the output

Proposition 1 (A) *The effect of a fall in the output tariff has ambiguous effects on firm output and (per-unit) variable profit.*

Profit maximization for the firm implies that the firm sets marginal revenue equal to marginal cost. Hence

$$\begin{aligned} a(t) - 2b(t)q &= c(i) \qquad (3)\\ q* &= \frac{[a(t) - c(i)]}{2b(t)} \qquad (4) \end{aligned}$$

Then

$$\frac{dq*}{dt} = \frac{2b(t)a'(t) - [a(t) - c(i)]2b'(t)}{4b(t)^2} \tag{5}$$

Therefore

$$\frac{dq*}{dt} > 0 \text{ iff } \frac{a'(t)}{a(t)} > \frac{b'(t)}{b(t)} \frac{[a(t) - c(i)]}{a(t)} \tag{6}$$

In other words, the effect of a fall in the output tariff on firm output depends on the relative strength of the change in the intercept versus slope of the demand curve. With a stronger shift in the intercept, equation 6 shows that a fall in the output tariff is associated with a fall in firm output. If the tariff reduction has a greater effect on the elasticity of demand, the associated output is larger. Also, focussing on the mark-up defined as the difference between the price charged and marginal cost

$$\frac{d[p * -c]}{dt} = \frac{dp*}{dt} = \frac{dp}{dq}\frac{dq*}{dt} = -b(t)\frac{dq*}{dt} \tag{7}$$

From 6, $\frac{d[p * -c]}{dt} < 0$ if $\frac{dq*}{dt} > 0$, or the shift in the intercept associated with a reduction in the output tariff is stronger than the change in demand elasticity and vice-versa.

Proposition 2 (A) *The effect of a fall in the input tairff is associated with an increase in firm output and (per-unit) variable profit.*

From 3,

$$\frac{dq*}{di} = \frac{-1}{2b(t)}c'(i) < 0 \tag{8}$$

and

$$\frac{d[p * -c]}{dt} = \frac{dp*}{di} - c'(i) = \frac{dp}{dq}\frac{dq*}{dt} = -b(t)[\frac{-1}{2b(t)}c'(i)] - c'(i) \tag{9}$$

Hence,

$$\frac{d[p * -c]}{dt} = \frac{-c'(i)}{2} < 0 \tag{10}$$

Appendix B
Production Function Estimation

Table B1: Summary Statistics for Firm level Variables

	Mean	SD	Minimum	Maximum
Ln(Sales)	5.43	1.80	-2.62	13.19
Ln(Salaries and Wages)	1.79	1.88	-2.79	8.91
Ln(Net Fixed Assets)	4.27	1.74	-2.62	11.57
Ln(Raw Material Expenditure)	4.58	1.81	-2.78	11.93

Source: CMIE data, author's calculations.
Notes: Data are from 1988-1998. Nominal values in 1993 rupees (in millions).

Table B2: Input Elasticities for Industry Groups from a Cobb-Douglas Production Function

Industry	Labor	Capital	Materials
Food	0.35	0.05	0.52
Beverages, Tobacco	0.43	0.01	0.55
Textiles	0.19	0.11	0.68
Apparel	0.12	0.01	0.93
Leather, Wood	0.02	0.04	1.06
Paper, Media	0.26	0.22	0.60
Petroleum	0.62	0.07	0.39
Chemicals	0.28	0.13	0.63
Pharmaceuticals	0.37	-0.03	0.69
Rubber, Plastic	0.34	0.04	0.55
Non-metallic Minerals	0.09	0.54	0.43
Basic Metals	0.44	0.05	0.57
Metal Products	0.31	-0.22	0.70
Computers, Electronics	0.42	-0.15	0.77
Electrical Equipment	0.26	0.05	0.76
Machinery	0.45	0.14	0.44
Motor Vehicles, Transport Equipment	0.18	0.16	0.64
Furniture and Other	0.27	0.18	0.51

Source: CMIE data, author's calculations.
Notes: Data are from 1988-1998. Production functions estimated using the Levinsohn-Petrin (2003) approach with the Ackerberg, Caves and Frazer (2015) correction.