Firms and Technology in International Trade: Analysis of Indian Firms

Ruchita Manghnani

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Approved by:

Patrick Conway

Simon Alder

Ivan Kandilov

Helen Tauchen

Jonathan Williams

ABSTRACT

RUCHITA MANGHNANI: Firms and Technology in International Trade: Analysis of Indian Firms.
(Under the direction of Patrick Conway)

The dissertation studies firms and technology in International Trade using data from India. In the first paper, I examine the relationship between exports and productivity. I control for firm variation in prices and retrieve measures of firm productivity. I compute within firm changes in productivity from entering into export markets and decompose gains to productivity from export market entry into two channels- the imports of intermediate inputs and investment in R & D. In the second paper (with Ivan Kandilov and Asli Leblebicioglu), we examine the impact of trade liberalization on investment in imported capital goods. We distinguish between tariffs on capital goods, intermediate inputs and final goods and examine three channels through which reduction in tariffs can impact investment in imported capital goods.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The dissertation falls within the broad area of *Firms and Technology in International Trade: Analysis of Indian Firms*. The dissertation consists of two essays:

1. Exports and Productivity: The Role of Imported Inputs and Investment in R & D

2. Trade Liberalization and Investment in Foreign Capital Goods

There are some common features to the analysis of the two essays. The essays use the firm-level theory of choices in the context of international trade. Essay 1 uses the choices of participating in export markets, import of intermediate inputs and investment in R & D to augment the productivity of the firm. Essay 2 models the dynamic decision of investment in foreign capital goods. Both essays involve the use of econometric panel-data analysis.

The firm level dataset used in both the essays is the CMIE - Prowess, a panel dataset of Indian firms. In addition to the variables included in most firm level datasets, the dataset also has information on foreign exchange transactions (imports and exports by the firm), which makes it suitable to explore answers to the questions asked in the two essays. Among the largest emerging economies, India provides an interesting setting to study the questions asked.

In the *first* essay, I ask if firms become more productive after they enter into export markets. And if so, what are the mechanisms through which firms improve productivity? While trade theory predicts within-firm improvements in productivity related to exports, empirical research has largely failed to identify these gains. Empirical work in the export-productivity literature has, for the most part, used measures of revenue productivity that do not account for pricing heterogeneity across firms.

In my analysis, I control for firm variation in prices by constructing firm specific price deflators. I measure quantity from data on firm revenues using these deflators rather than the traditional industry level price deflator that is generally used in the literature. I explicitly model imports of intermediate inputs and firm R & D into the production function. Most exporters are also importers of intermediate inputs. This export-import complementarity has largely been ignored in the export-productivity literature. While theoretical models emphasize the the market size - investment in R & D route to productivity improvements through export market entry, there is little known on the R & D-productivity link in developing countries.

I estimate the production function parameters using proxy estimators for manufacturing firms using data for the period $1989 - 2005$. I compute within firm productivity changes from export entry using a DID-matching estimator. I find that over a six year period, the difference in productivity growth between export entrants and their non-exporter counterparts is about 11 percentage points. I find that productivity improvements from selling in international markets have largely been understated in the export-productivity empirical literature. I decompose this difference in productivity growth into two channels. I show that about 15 percent of this difference in productivity growth is explained by higher imports of intermediate inputs and about 85 percent is explained by investment in R & D. The evidence suggests that investment in R & D is an important source of within firm productivity gains even in developing countries.

In the *second* essay (co-authored with Ivan T. Kandilov and Aslı Leblebicioğlu), we evaluate the impact of trade liberalization on firm's decision to invest in foreign capital goods. We estimate dynamic investment equations using the system-GMM estimator. Using input-output tables, we construct separate tariffs on capital goods, intermediate inputs and final goods, and control for them simultaneously in our estimations. This allows us to identify the direct effect of lower prices of foreign capital goods as a result of reduction in tariffs on firm investment in imported capital goods.

The previous work on trade and investment have largely been cross country or industry-level studies which have analyzed the impact of output tariff reductions on aggregate investment. The firm-level studies have treated all investment as domestic investment. By separating investment in foreign capital goods from investment in domestic capital goods, we are able to examine the impact of trade liberalization on investment in foreign capital goods which are imported from a handful of developed countries. This relates to the literature on trade liberalization and productivity as we are able to examine one mechanism through which trade liberalization could have contributed to productivity improvements - through the transfer of R & D-intensive capital goods.

Consistent with theory, we find that a reduction in import protection on capital goods and intermediate inputs led to higher firm-level investment in foreign capital goods, whereas reductions in output tariffs resulted in lower investment. We also find that the effects of lower capital goods and intermediate input tariffs were more pronounced for exporters. Firms in the middle range of the productivity distribution benefited the most from reductions in capital goods tariffs. Moreover, we find that following reductions in output tariffs, firms with greater market power lowered investment in foreign capital goods more aggressively and firms in industries with scope for product differentiation and quality upgrading lowered investment less. We show that the investment rate in foreign capital goods increased by 62.31 percent as a result of trade liberalization.

CHAPTER 2

EXPORTS AND PRODUCTIVITY: THE ROLE OF IMPORTED INPUTS AND INVESTMENT IN R & D

2.1 Introduction

In the past few decades, countries across the world have lifted barriers to trade. More firms are now selling their products to global markets while also purchasing inputs from across the world. In India, the number of manufacturing firms reporting positive exports rose from less than 600 in 1989 to about 2500 in the year 2005.[1] At the same time, there have been vast differences in productivity documented across firms. Firms in the 90th percentile have been found to be almost twice as productive as firms in the 10th percentile in several countries including India, China and the U.S.[2] Given the increasing global nature of production, there is a need to understand the role of trade in explaining these vast differences in productivity across firms. This is also important from a policy point of view. If firms improve productivity through exports, there may be a case for export promotion policies by governments to lower entry costs into export markets and encourage exports.

Theoretical models of trade argue that the relationship between exports and productivity should be potentially bidirectional, i.e., both that more productive firms will begin to export and that becoming an exporter makes a firm more productive. Melitz (2003b) models self selection of more productive firms into export markets due to a fixed cost of entry into export markets, while Bustos (2011b), Lileeva and Trefler (2010) and Melitz and Costantini (2007) emphasize export-technology complementarity, where access to larger markets through entry into export markets allows firms to invest in innovative activities and thus improve productivity. Empirical studies have documented

[1]These numbers are based on public firms, which are legally required to report foreign exchange transactions.

[2]See Syverson (2004) for the U.S and Hsieh and Klenow (2009) for China and India

a positive correlation between productivity and export participation. While there is substantial evidence that the more productive firms self-select into exporting, the evidence on whether firms improve productivity post entry into export markets is not so clear cut.[3]

One possible explanation for the lack of evidence (on firms becoming more productive after they begin exporting) could be that previous studies have usually estimated revenue productivity based on industry level average prices rather than firm-specific prices. If firms improve productivity and pass this on to consumers in the form of lower prices, revenue-based measures using industry price deflators will not capture the improvements in productivity.[4] Recent work by Marin and Voigtlander (2013) on Chile suggests that this could be the reason why empirical studies have not been able to find evidence of firms improving productivity after they begin exporting. They compare revenue based measures of productivity that are typically used with marginal costs and find that while firms do not become more productive, as measured by revenue productivity, they do become more efficient as measured by marginal costs, post entry into export markets.[5]

This finding on Chile has highlighted the need to correct for biases that arise from revenue based measures of productivity calculated on the basis of average prices for the industry to understand the relationship between exports and productivity. The dataset I use in this paper contains information on firm prices and allows me to recover measures of physical productivity that account for variation in prices across firms.[6] In this paper I ask, do firms become more productive after

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[3]Several empirical papers have confirmed that more productive firms self select into export markets. For example, see Delgado, Farias, and Ruano (2002) and Bernard and Jensen (1999). Girma, Greenaway, and Kneller (2004) reviews ten papers and finds widespread evidence of the self selection hypothesis. Clerides, Lach, and Tybout (1998), Arnold and Hussinger (2005) and Greenaway, Gullstrand, and Kneller (2005) find that exporting does not improve productivity. This also holds for evidence from fourteen countries presented in ISGEP (2008). Notable exceptions which have found evidence of improvements in productivity post entry into export markets include De Loecker (2007) and Biesebroeck (2005).

[4]Foster, Haltiwanger, and Syverson (2008) use data on physical quantities of a few homogeneous industries in the US and find a negative correlation between price and efficiency. More productive firms charge lower prices and there is wider variation across firms in physical productivity as compared to revenue productivity.

[5]Smeets and Warzynski (2013) estimate value added production functions using firm price deflators and find that these yield higher trade premia in Danish firms as compared to revenue based measures.

[6]While most empirical work ignores price variation, there are a few exceptions. They control for unobserved prices by modeling demand under the assumptions of single product monopolistically competitive firms. Aside from the fact that they usually assume that firms produce only a single product, monopolistic competition implies a optimal price

they enter into export markets? And if so, what are the mechanisms through which firms improve productivity? I examine the role of two possible mechanisms - imports of intermediate inputs and investment in R & D.

A large number of firms are two-way traders i.e., they export final goods while also importing intermediate inputs. An Indian manufacturing firm that exports its products is five times more likely than a non-exporter to also be an importer of intermediate inputs. If firms import intermediate inputs from abroad to improve productivity and reduce marginal costs of production, when imports are not accounted for, differences in measured productivity could possibly be reflecting these differences in the use of imported intermediate inputs across firms. This export-import complementarity, where access to export markets allows firms to pay the fixed costs of importing intermediate inputs and thus improve productivity, has largely been ignored in the export-productivity literature. The export-technology complementarity has been emphasized in theoretical models such as Melitz and Costantini (2007) where access to larger markets allows firms to pay the fixed cost of R & D. I examine the relative contributions of these two channels to productivity improvements of export starters.[7]

I use CMIE Prowess, a panel data set of manufacturing firms from India. I first recover the parameters of the production function by explicitly including imported intermediate inputs and investment in R & D within the production function of the firm while also taking into account heterogeneity in firm prices. I use proxy methods as suggested by Ackerberg, Caves, and Frazer (2015) to estimate the production function parameters. Once I have my measure of productivity, I then use a difference-in-differences matching estimator as proposed by Heckman, Ichimura, and

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where prices are a constant markup over marginal costs where the markup ratio is determined by the elasticity of demand in the industry and is assumed to be the same for all firms in the industry. I observe in the data that a large proportion of the firms are multiproduct firms. The advantage of directly observing product level revenue and price data is that I can directly control for price heterogeneity without making these assumptions.

[7]There is a literature on export-related productivity improvements through *Learning by Exporting*. Firms often get direct technology transfers from foreign buyers they sell to. Also, similar to the *Learning by Doing* framework of Arrow (1962) where learning takes place through activity, as firms in developing countries begin to cater to competitive export markets where consumers are more demanding, they face challenges which might require them to improve quality, upgrade technology as well as management techniques, all of which result in productivity improvements. See Fernandes and Isgut (2015) for a discussion on *Learning by Exporting*.

Todd (1997) to examine whether firms improve productivity when they begin to export and the relative importance of the two channels (imports and investment in R & D).

The paper contributes to the literature in the following ways. *First*, I use a measure of productivity that captures physical productivity, which does not suffer from the drawbacks of productivity measures that are generally used in the trade-productivity literature. I do so by measuring output from firm revenues and firm prices rather than industry prices, as is typically done. *Second*, I explicitly model both imports of intermediate inputs and R & D into the production function. This allows me to examine two mechanisms for productivity improvement and to decompose gains to productivity from export entry into these two channels. *Third*, I use data on firms from India. This country provides an interesting setting to study this question. While theoretical models emphasize the market size - investment in technology route to productivity improvements through export market entry, most of the world R & D takes place in developed nations. In 2011, seven countries accounted for 72 percent of global R & D spending.[8] There is little known on the R & D-productivity link in developing countries.

The results suggest that productivity improvements from selling in international markets have largely been understated in the export-productivity empirical literature. After accounting for firm pricing heterogeneity, I find that over a six year period, the difference in productivity growth between export entrants and their non exporter counterparts is about 11 percentage points. The estimates indicate that about 15 percent of the differences in productivity growth is explained by imports of intermediate inputs, while investment in R & D explains about 85 percent of this difference in productivity growth. Thus, investment in R & D is an important driver of productivity growth even in developing countries like India.

The rest of the paper is organized as follows. Section 2.2 describes the environment the firm operates in and the production technology of the firm. Section 2.4 presents the empirical production function where I discuss the measure of productivity that is used. Section 2.5 is on the estimation strategy employed. Section 2.6 describes the data. I discuss the findings in Section 2.7 and Section

[8]National Science Board. 2014. Science and Engineering Indicators 2014. Arlington VA: National Science Foundation (NSB 14-01)

2.8 concludes.

2.2 The Environment

Each firm i produces output (Q_{it}) using capital (K_{it}), labor (L_{it}), intermediate inputs (X_{it}) and energy inputs (E_{it}) in period t. The firm has a Cobb-Douglas (CD) production function with a nested Constant Elasticity of Substitution (CES) function for intermediate inputs.

$$Q_{it} = e^{\omega_{it}} K_{it}^{\alpha_k} L_{it}^{\alpha_l} E_{it}^{\alpha_e} X_{it}^{\alpha_x} \tag{2.1}$$

where $e^{\omega_{it}}$ is the productivity of the firm. The intermediate input bundle is a CES aggregator of horizontally differentiated material inputs similar to Gopinath and Neiman (2014).[9] The input varieties are imperfect substitutes for each other and the aggregate input bundle is increasing in the number of varieties employed in production.[10] The intermediate input bundle is a CES aggregator of a bundle of domestic intermediate inputs (X_{dit}) and a bundle of imported intermediate inputs (X_{fit}).

$$X_{it} = [X_{dit}^{\rho} + X_{fit}^{\rho}]^{\frac{1}{\rho}} \tag{2.2}$$

The elasticity of substitution between the domestic input bundle and the imported input bundle is given by $\frac{1}{1-\rho}$, where $0 < \rho < 1$. Firm i's use of domestic variety h is represented by d_{hit} and use of foreign variety a is represented by f_{ait}. H_t is the number of of input varieties available domestically within the country, N_t is the number of varieties available in the rest of the world and $n_{it} \leq N_t$ is the number of foreign inputs imported by firm i. The domestic input bundle and the imported input bundle are again CES aggregators of domestically available varieties and imported

[9] Intermediate inputs are commonly modeled as CES functions in the trade and growth literature. See Ethier (1982), Kasahara and Rodrigue (2008), Halpern, Koren, and Szeidl (2011) and Kasahara and Lapham (2013).

[10] An alternate approach in the growth literature has been that of quality ladder type models where intermediate inputs are vertically differentiated (See Aghion and Howitt (1992) and Chapter 4 of Grossman and Helpman (1991)). The dataset used in the paper does not have information about firm specific actual varieties and prices of imported materials. This makes it difficult to make inferences about the quality of imports. The horizontally differentiated varieties framework allows me to derive an expression relating varieties to import intensity (observed in the data) to use in the production function. Moreover, empirical evidence points to the importance of the extensive margin or number of varieties in imports. Goldberg, Khandelwal, Pavcnik, and Topalova (2010), using HS6 level data on imports into India, find that between 1987 and 2000, the extensive margin (varieties not imported in 1987) accounted for over 67 percent of the growth of imported intermediates in India.

varieties of intermediate inputs respectively.

$$X_{dit} = [\sum_{h=1}^{H_t} d_{hit}^{\theta}]^{\frac{1}{\theta}} \tag{2.3}$$

$$X_{fit} = [\sum_{a=1}^{n_{it}} f_{ait}^{\theta}]^{\frac{1}{\theta}} \tag{2.4}$$

Note that while H_t is common to all firms, n_{it} is sub-scripted by i. This is because the number of varieties of inputs imported from abroad varies across firms since the firm pays a fixed cost of importing each variety of the foreign intermediate input. The elasticity of substitution within domestic varieties and also within foreign varieties is $\frac{1}{1-\theta}$, where $0 < \theta < 1$.

The law of motion for evolution of Capital Stock is given by

$$K_{it} = (1-\delta)K_{it-1} + I_{it-1} \tag{2.5}$$

where δ is the per period depreciation rate of capital stock and I_{it-1} is the firm investment in physical capital made in period $t-1$. Physical investment enters into the production process with a lag. Thus, the investment made in $t-1$ enters capital stock in period t. This is the *time to build* assumption commonly used in models of physical capital accumulation (For example, see Olley and Pakes (1996) and Cooper and Haltiwanger (2006)).

I assume that productivity evolves over time as a Markov process, similar to Doraszelski and Jaumandreu (2013) and Aw, Roberts, and Xu (2011). The firm can invest in R & D in period $t-1$ to improve productivity in t.[11] In period $t-1$, the firm expects that its productivity in period t will be $g(\omega_{it-1}, d_{it-1}^k)$ where d_{it-1}^k is the discrete decision to engage in R & D in period $t-1$.

$$g(\omega_{it-1}, d_{it-1}^k) = E(\omega_{it}|\omega_{it-1}, d_{it-1}^k) \tag{2.6}$$

[11] Recent empirical work on productivity estimation has endogenized the productivity evolution process by explicitly modeling factors that could impact productivity. See for example, see De Loecker (2011), De Loecker (2013), Boler, Moxnes, and Ulltveit-Moe (ming)

The expected productivity $g(\omega_{it-1}, d^k_{it-1})$ is increasing in d^k_{it-1} i.e.,

$$E(\omega_{it}|\omega_{it-1}, d^k_{it-1} = 1) - E(\omega_{it}|\omega_{it-1}, d^k_{it-1} = 0) > 0 \tag{2.7}$$

The Markovian assumption implies that

$$\omega_{it} = g(\omega_{it-1}, d^k_{it-1}) + \zeta_{it} \tag{2.8}$$

In period t, the actual realized productivity is ω_{it} and it can be decomposed into expected productivity $g(\omega_{it-1}, d^k_{it-1})$ and a random shock ζ_{it}, which represents the deviation of realized productivity from the firm's expectation. It is a mean zero i.i.d shock and captures the stochastic nature of productivity evolution. It is not anticipated by the firm in period $t-1$ and is, by construction, mean independent of ω_{it-1} and d^k_{it-1}. I assume the specific functional form:

$$\omega_{it} = \gamma_1\omega_{it-1} + \gamma_2 d^k_{it-1} + \gamma_3\omega_{it-1} * d^k_{it-1} + \zeta_{it} \tag{2.9}$$

I expect γ_2 to be positive. I include an interaction term between firm level productivity and the firm's decision to invest in R&D to allow for differences in productivity gains for firms investing in R & D depending on their initial productivity levels. ζ_{it} is the i.i.d error term as mentioned above.

From the production technology specified, the short run marginal cost function is

$$MC_{it} = \left[\frac{\beta}{e^{\omega_{it}} K_{it}^{\alpha_k}} {Q_{it}}^{1-\alpha_v} {w_t}^{\alpha_l} {u_t}^{\alpha_e} {P_{xit}}^{\alpha_x}\right]^{\frac{1}{\alpha_v}} \tag{2.10}$$

where $\beta = \alpha_l^{-\alpha_l}\alpha_e^{-\alpha_e}\alpha_x^{-\alpha_x}$ and $\alpha_v = \alpha_l + \alpha_e + \alpha_x$. The price of labor inputs is w_t, the price of energy inputs is u_t and P_{xit} is the price of the intermediate input bundle of firm i in period t. The price of the intermediate input bundle, P_{xit} is a CES aggregator of the price index of the domestic intermediate input bundle (P_{dt}) and the price index of the imported intermediate bundle (P_{fit}).

$$P_{xit} = [P_{dt}^{\frac{\rho}{\rho-1}} + P_{fit}^{\frac{\rho}{\rho-1}}]^{\frac{\rho-1}{\rho}} \tag{2.11}$$

The price index of the domestic intermediate input bundle is a CES aggregator of the prices of the H_t domestic varieties where p^d_{ht} is the price of domestic variety h in period t.

$$P_{dt} = \left[\sum_{h=1}^{H_t} {p^d_{ht}}^{\frac{\theta}{\theta-1}} \right]^{\frac{\theta-1}{\theta}} \tag{2.12}$$

The price index of the domestic input bundle is identical for all firms since all firms have access to the H_t varieties available domestically within the country. A firm i imports n_{it} varieties in period t where p^f_{at} is the price of foreign variety a. I assume that $p^f_{at} = p^f_t \ \forall\ a$ (similar to Gopinath and Neiman (2014)).[12] This gives the price index of the imported intermediate bundle for firm i.

$$P_{fit} = p^f_t (n_{it})^{\frac{\theta-1}{\theta}} \tag{2.13}$$

The price index of the imported intermediate input bundle is decreasing in n_{it} (since $0 < \theta < 1$). The larger the number of varieties of inputs imported, lower is the price index of the foreign intermediate bundle. From (2.11), (2.12) and (2.13), the price index of the intermediate good bundle is

$$P_{xit} = [P_{dt}^{\frac{\rho}{\rho-1}} + (p^f_t (n_{it})^{\frac{\theta-1}{\theta}})^{\frac{\rho}{\rho-1}}]^{\frac{\rho-1}{\rho}} \tag{2.14}$$

Given that $0 < \theta < 1$ and $0 < \rho < 1$,

$$P_x(P_{dt}, p^f_t, n_{it}) - P_x(P_{dt}, p^f_t, n_{it} - 1) < 0 \tag{2.15}$$

The price index of the intermediate input bundle is decreasing in the number of imported varieties. The larger the number of foreign varieties imported by the firm, the larger is the total number of input varieties used by the firm (since firms will access all domestic varieties) and lower is the

[12] This simplifying assumption allows the firm's choice to be over the number of varieties. This is so because all imported varieties are identical in the way they enter the production function. If the assumption of identical prices was not made, the model would specify the ordering in which the varieties are chosen. This would be of interest if we observed the firm's choice of varieties and quantity of each variety purchased in the data.

price index of the intermediate input bundle.[13] From (2.10) and (2.15),

$$MC(P_{dt}, p_t^f, w_t, u_t, \omega_{it}, K_{it}, Q_{it}, n_{it}) - MC(P_{dt}, p_t^f, w_t, u_t, \omega_{it}, K_{it}, Q_{it}, n_{it} - 1) < 0 \quad (2.16)$$

From (2.10), it can also be seen that

$$\frac{\partial MC(.)}{\partial \omega_{it}} < 0 \quad (2.17)$$

Thus, for a given capital stock, firms with a larger number of imported varieties employed in production (n_{it}) and higher productivity (ω_{it}) have a lower marginal cost of production. The firm can reduce its marginal cost of production in t by importing more varieties of intermediate inputs in t and investing in R & D in $t-1$. However there are fixed costs involved in sourcing inputs from abroad and engaging in R & D. The firm faces a trade off between paying the fixed costs of importing foreign inputs and investing in R & D for a lower marginal cost of production.

A firm that exports, i.e., sells its products in both domestic and foreign markets, is more likely to undertake the fixed cost of investing in R & D and purchasing imported varieties of intermediate inputs as compared to a firm that only sells in the domestic market. In appendix A.1, I present a framework to develop the intuition for why *incentives* for investing in R & D and importing intermediate inputs *vary by export status*.

I assume that single product firms compete in monopolistically competitive domestic and foreign markets. The vector $\Psi_{it} = (d_i^x, K_i, w_t, u_t, P_{dt}, p_t^f, f_i^n, \Phi_t^D, \Phi_t)$ represents the environment of the firm where f_i^n is the fixed cost of importing each foreign variety and Φ_t^D and Φ_t are industry aggregates (in domestic and foreign markets) and the other variables are as defined before. I also assume that the firm's environment Ψ_{it}, is taken as given by the firm, is constant over time ($\Psi_{it} = \Psi_{it+1}$) and the firm has perfect foresight over it. The firm chooses the number of imported varieties and whether to invest in R & D or not. Since I am interested in how productivity evolves differently for an exporter versus a non exporter and how this is determined by the import and R & D behavior of the firm, I focus on these two decisions. I emphasize that the assumptions made

[13]This comes from the production technology specified and (2.2), (2.3) and (2.4).

here are for the theoretical framework and that in the estimations, I adopt a more flexible approach. For example, I do not assume single product firms or impose a market structure in the empirical section. I directly use the information on all products and prices of firms, a large number of which are multiproduct firms. Given that caveat, I give the basic implications that come out of the model below and direct the interested reader to appendix A.1 for more details.

First, *The marginal increase in variable profits from importing an additional variety of the intermediate input is higher for an exporter ($d_i^x = 1$) compared to a non exporter ($d_i^x = 0$). It follows that the optimal number of imported varieties is non decreasing in export status.*

$$\pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})|d_i^x = 1 > \pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})|d_i^x = 0 \tag{2.18}$$

$$n^*(\omega_{it}, \Psi_{it}|d_i^x = 1) \geq n^*(\omega_{it}, \Psi_{it}|d_i^x = 0) \tag{2.19}$$

Here, variable profits π_{it} are gross profits before deducting any fixed costs and $n^*(.)$ refers to the optimal number of varieties.

Second, *The expected marginal increase in variable profits in $t+1$ from investing in R & D in t is higher for an exporter compared to a non exporter. This would imply that the probability of engaging in R & D is increasing in export status.*

$$\begin{split}[E(\pi_{it+1}|\omega_{it}, d_i^k = 1, \Psi_{it}) - E(\pi_{it+1}|\omega_{it}, d_i^k = 0, \Psi_{it})]|d_i^x = 1 > \\ [E(\pi_{it+1}|\omega_{it}, d_i^k = 1, \Psi_{it}) - E(\pi_{it+1}|\omega_{it}, d_i^k = 0, \Psi_{it})]|d_i^x = 0\end{split} \tag{2.20}$$

What this implies is that exporters and non exporters have different incentives to import intermediate inputs and invest in R & D. This will result in different productivity trajectories for exporters compared to non exporters. A preliminary data exploration of the relationship between export status and R & D and import indicators does indicate that export-import and export-R & D are highly correlated. In Table 2.1, I report the coefficients of three regressions - R & D status on export status, import status on export status and the natural log of import intensity on export status. Each of these regressions control for firm size and a full set of industry and year effects. All coefficients are positive and significant. Exporters have a higher probability of investing in R & D (the difference between exporters and non exporters is 0.12), are more likely to import intermediate inputs from abroad (the difference between exporters and non exporters is 0.27) and spend a higher proportion of their expenditure on intermediate inputs on imports (the average difference between exporters and non exporters is 6.10 percentage points.)

Table 2.1: Imports and R & D by Export Status

R & D Status	Import Status	Import Intensity
0.120***	0.265***	0.061***
(0.078)	(0.097)	(0.020)

Notes: Number of Observations is 45,835. Each column is a separate regression of the dependent variable on export status. Regressions control for firm size, Industry and Year effects. *** p<0.01, ** p<0.05, * p<0.1.

2.3 Empirical Production Function

In this section, I discuss the measure of total productivity used. Physical quantities and varieties of material inputs (both domestic and foreign) are not observed in the data. I move from the production technology as given by (2.1) and (2.2) to a specification which uses expenditure on intermediate inputs (domestic and foreign) as described in subsection 2.4.1. I also discuss how I retrieve estimates that reflect physical productivity by using firm level price deflators to measure output from firm revenues in subsection 2.4.2. This is in contrast to the literature which uses industry price deflators to measure output from firm revenues. The use of industry price deflators to measure output has some inherent problems which are addressed if information on firm prices is used instead.

2.3.1 The Production Function and Imports

From the production technology for the intermediate input bundle, the price of the intermediate input bundle and the optimal demand functions for the domestic and imported intermediate input bundle, we can write the price of the intermediate input bundle in terms of the price of the domestic input bundle (P_{dt}), the total expenditure on intermediate inputs ($M_{it} = P_{it}X_{it}$) and the expenditure on domestic intermediate inputs ($M_{dit} = P_{dt}X_{dit}$) . (See appendix A.2)

$$P_{xit} = P_{dt} \left(\frac{M_{it}}{M_{dit}} \right)^{\frac{\rho-1}{\rho}} \tag{2.21}$$

Since data on physical quantities of each of the input varieties used by the firm are not observed, I substitute for X_{it} with $\frac{M_{it}}{P_{xit}}$ in the expression for the production technology of the firm. From (2.1) and (2.30), the production function can thus be written as

$$Q_{it} = e^{\omega_{it}} K_{it}^{\alpha_k} L_{it}^{\alpha_l} E_{it}^{\alpha_e} \left(\frac{M_{it}}{P_{dt}} \right)^{\alpha_x} \left(\frac{M_{it}}{M_{dit}} \right)^{\alpha_\chi} \tag{2.22}$$

where $\alpha_\chi = \alpha_x \left(\frac{1-\rho}{\rho} \right)$.

Usually, when production functions are estimated (including in the exports and productivity literature), the role of imported inputs is ignored. The last term in (2.31) is not included and the general form of the production function estimated is

$$Q_{it} = e^{\omega_{it}} K_{it}^{\alpha_k} L_{it}^{\alpha_l} E_{it}^{\alpha_e} \left(\frac{M_{it}}{P_{dt}} \right)^{\alpha_x} \tag{2.23}$$

Expenditure on inputs is deflated by a common input price deflator (usually a wholesale price index or an industry producer price index or a material inputs deflator). The term $\left(\frac{M_{it}}{M_{dit}} \right)^{\alpha_\chi}$ gets subsumed in the estimate of productivity $e^{\omega_{it}}$. If all firms purchased all their inputs domestically, $\left(\frac{M_{it}}{M_{dit}} \right)^{\alpha_\chi}$ would disappear and (2.31) would reduce to (2.32).

However, for some firms, a portion of the expenditure on intermediate inputs is on inputs sourced from abroad. From (2.14) and (2.30),

$$\frac{M_{it}}{M_{dit}} = 1 + \left[\frac{p_t^f (n_{it})^{\frac{\theta-1}{\theta}}}{P_{dt}} \right]^{\frac{\rho}{\rho-1}} \tag{2.24}$$

$\frac{M_{it}}{M_{dit}}$ is increasing in n_{it} and $\left(\frac{M_{it}}{M_{dit}} \right)^{\alpha_\chi}$ represents the advantage that accrues to a firm when it sources some of its intermediate inputs from abroad. For a given level of capital, labor, energy and expenditure on intermediate inputs, a higher import intensity represented by a larger $\frac{M_{it}}{M_{dit}}$ allows the firm to produce a higher output.

Thus, we can think of firms with larger n_{it} (i.e., firms importing more foreign varieties) and ω_{it} having a lower marginal cost of production as seen in section 2.2. Analogously, firms with higher import intensity ($\frac{M_{it}}{M_{dit}}$) and higher ω_{it} are able to produce a higher level of output for a given level of inputs.

The natural log of the production function (2.31) of firm i can be written as

$$q_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_e e_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \omega_{it} + \epsilon_{it} \tag{2.25}$$

The lower case letters q, l, k, e, m, χ refer to the natural log of quantity, labor, capital, energy, expenditure on intermediate inputs and import intensity ($\frac{M}{M_d}$) of intermediate inputs respectively.

The measure of total productivity of interest is $\alpha_\chi \chi_{it} + \omega_{it}$, the first component of which is attributable to imports of intermediate inputs by the firm and the second to firm R & D. Firms can improve total productivity and lower marginal costs of production by importing foreign intermediate inputs and engaging in R &D. The second component of the firm's total productivity ω_{it}, is known to the firm when it makes its decisions on inputs but is not observed in the data. Lastly, ϵ_{it} represents measurement error and idiosyncratic shocks to production.

2.3.2 Measuring Output based on Revenues and Prices

Since firm revenue $R_{it} = P_{it} * Q_{it}$, firm output can be measured from firm revenues and firm prices. If q_{it}, p_{it} and r_{it} are the natural logarithm of firm output, firm prices and firm revenue respectively,

$$q_{it} = r_{it} - p_{it} \tag{2.26}$$

Data on firm prices are often not available. Papers that estimate firm-level productivity (including the export-productivity literature) typically measure firm output by deflating firm revenues by an industry price deflator (p_{It}) which is common to all firms within an industry I. So they measure the natural log of firm output as

$$\widetilde{q}_{it} = r_{it} - p_{It} \tag{2.27}$$

Using (2.35) and (2.36), if we substitute for $\widetilde{q}_{it} = q_{it} - (p_{it} - p_{It})$ into (2.34), the production function becomes

$$\widetilde{q}_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_e e_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \widetilde{\omega}_{it} + \epsilon_{it} \tag{2.28}$$

where,

$$\widetilde{\omega}_{it} = (p_{it} - p_{It}) + \omega_{it} \tag{2.29}$$

If firms operated in perfectly competitive markets where each firm was a price taker and charged the industry price (i.e, $p_{it} = p_{It}$), (2.34) and (2.37) would be equivalent to each other. However, when we deviate from the assumption of perfect competition (i.e, $p_{it} \neq p_{It}$), two problems arise.

The first is the omitted price bias. In the absence of firm prices, if industry prices are used to measure output as $\widetilde{q}_{it}$ instead of q_{it}, the estimates of the coefficients of the production function will be biased. As long as $E[(p_{it} - p_{It})z_{it}] \neq 0$, where z_{it} refers to the vector of inputs, the use of industry level price deflators to deflate revenues to proxy for output will yield incorrect estimates of the coefficients of the production function. (See Klette and Griliches (1996) for a detailed exposition of the omitted price bias).[14]

The second problem is specific to the export-productivity question when we try to estimate within firm changes to total productivity from export entry. If firms face downward sloping demand curves and pass on some of the benefits of gains in productivity to consumers by lowering prices, p_{it} falls as ω_{it} rises. In this case, using estimates of productivity from (2.37) will underestimate gains to firms' post export market entry.[15]

[14]Everything else being equal, firms charging higher prices would have lower market shares. They would sell fewer units of output and employ fewer inputs i.e., price and inputs would be negatively correlated. However, more productive firms also need fewer inputs to produce the same output. So the relationship may not be so clear cut.

[15]Theoretical models of trade such as Melitz (2003b) model firms as operating in monopolistically competitive markets. In equilibrium, firms charge a price in domestic and export markets which is a constant mark up over marginal cost. The mark ups are given by the inverse of the elasticity of demand in the two markets. If firms improve productivity and reduce marginal costs, these models predict a complete pass through of these gains to consumers in the form of lower prices.

There is a wide variation in price changes across firms in a given industry in any year. I discuss concerns with using industry level price deflators to deflate firm revenues and use that to proxy for quantities by using the example of the transport equipment industry. Table 2.2 shows the yearly price change (over the previous year) for the transport equipment industry. The last column (6) gives the yearly price change as given by the Output Deflator of the transport equipment industry at the aggregate industry level as calculated by the Central Statistical Organization, Government of India. The average growth rates from the industry level indices are positive for every year in the period. Column (5) gives the standard deviation of firm price changes for each year as observed in the firm dataset.

Table 2.2: Price Changes in Transport Equipment Industry

	(1)	(2)	(3)	(4)	(5)	(6)
	Price Decline		Price Increase		Firm Data	WPI
Year	% of Firms	Mean	% of Firms	Mean	Std. Dev.	Industry Level
1990	6.06	-0.21	93.94	0.13	0.11	0.11
1991	13.64	-0.07	86.36	0.11	0.10	0.09
1992	6.06	-0.22	93.94	0.18	0.15	0.11
1993	7.77	-0.07	92.23	0.12	0.12	0.07
1994	32.52	-0.07	67.48	0.09	0.12	0.03
1995	27.52	-0.12	72.48	0.13	0.17	0.07
1996	24.54	-0.11	75.46	0.13	0.15	0.08
1997	25.00	-0.11	75.00	0.11	0.14	0.06
1998	43.03	-0.10	56.97	0.09	0.14	0.04
1999	44.68	-0.09	55.32	0.09	0.14	0.03
2000	37.08	-0.09	62.92	0.10	0.13	0.03
2001	36.86	-0.10	63.14	0.11	0.16	0.06
2002	52.80	-0.09	47.20	0.11	0.15	0.02
2003	43.80	-0.10	56.20	0.09	0.14	0.00
2004	42.69	-0.10	57.31	0.12	0.16	0.00
2005	32.02	-0.10	67.98	0.14	0.18	0.05

Notes: Column (6) shows price change for the for Transport Equipment Industry using the industry price deflator from the Government of India Price Statistics (WPI) from the 1993-94 price series. Columns (1)-(5) are constructed from firm level price data.

Columns (1) and (2) report the percentage of firms that experienced decline in prices over the previous year and the mean reduction in prices over the previous year for firms with negative growth, while columns (3) and (4) give the percentage of firms that experienced positive growth in prices over the previous year and the average increase in prices for the firms with positive growth. For example, in the year 2000, 37 % of firms saw on average a nine percent fall in their prices from 1999 while 63 % of the firms experienced a ten percent increase in prices on average. Price changes of firms varied widely as can be seen by the standard deviation. The use of the industry level deflator would assume that every firm experienced a three percent increase in prices over the previous year. Deflating revenues by the industry deflator would underestimate the quantity changes for firms with price changes less than three percent and overestimate the quantity changes for firms with growth in prices over three percent. This would imply that productivity change is underestimated for firms that experience a change in price of less than three percent and overestimated for firms that experience a change in price greater than three percent.

Information on prices allows me to estimate (2.34). I construct firm specific price deflators, which vary across firms within an industry, unlike industry level deflators that are common to all firms in an industry. I thus recover estimates of the production function coefficients and ω_{it} that do not suffer from the shortcomings discussed above.

2.4 Empirical Production Function

In this section, I discuss the measure of total productivity used. Physical quantities and varieties of material inputs (both domestic and foreign) are not observed in the data. I move from the production technology as given by (2.1) and (2.2) to a specification which uses expenditure on intermediate inputs (domestic and foreign) as described in subsection 2.4.1. I also discuss how I retrieve estimates that reflect physical productivity by using firm level price deflators to measure output from firm revenues in subsection 2.4.2. This is in contrast to the literature which uses industry price deflators to measure output from firm revenues. The use of industry price deflators to measure output has some inherent problems which are addressed if information on firm prices is used instead.

2.4.1 The Production Function and Imports

From the production technology for the intermediate input bundle, the price of the intermediate input bundle and the optimal demand functions for the domestic and imported intermediate input bundle, we can write the price of the intermediate input bundle in terms of the price of the domestic input bundle (P_{dt}), the total expenditure on intermediate inputs ($M_{it} = P_{it}X_{it}$) and the expenditure on domestic intermediate inputs ($M_{dit} = P_{dt}X_{dit}$) . (See appendix A.2)

$$P_{xit} = P_{dt}\left(\frac{M_{it}}{M_{dit}}\right)^{\frac{\rho-1}{\rho}} \tag{2.30}$$

Since data on physical quantities of each of the input varieties used by the firm are not observed, I substitute for X_{it} with $\frac{M_{it}}{P_{xit}}$ in the expression for the production technology of the firm. From (2.1) and (2.30), the production function can thus be written as

$$Q_{it} = e^{\omega_{it}}K_{it}^{\alpha_k}L_{it}^{\alpha_l}E_{it}^{\alpha_e}\left(\frac{M_{it}}{P_{dt}}\right)^{\alpha_x}\left(\frac{M_{it}}{M_{dit}}\right)^{\alpha_\chi} \tag{2.31}$$

where $\alpha_\chi = \alpha_x\left(\frac{1-\rho}{\rho}\right)$.

Usually, when production functions are estimated (including in the exports and productivity literature), the role of imported inputs is ignored. The last term in (2.31) is not included and the general form of the production function estimated is

$$Q_{it} = e^{\omega_{it}}K_{it}^{\alpha_k}L_{it}^{\alpha_l}E_{it}^{\alpha_e}\left(\frac{M_{it}}{P_{dt}}\right)^{\alpha_x} \tag{2.32}$$

Expenditure on inputs is deflated by a common input price deflator (usually a wholesale price index or an industry producer price index or a material inputs deflator). The term $\left(\frac{M_{it}}{M_{dit}}\right)^{\alpha_\chi}$ gets subsumed in the estimate of productivity $e^{\omega_{it}}$. If all firms purchased all their inputs domestically, $\left(\frac{M_{it}}{M_{dit}}\right)^{\alpha_\chi}$ would disappear and (2.31) would reduce to (2.32).

However, for some firms, a portion of the expenditure on intermediate inputs is on inputs sourced from abroad. From (2.14) and (2.30),

$$\frac{M_{it}}{M_{dit}} = 1 + \left[\frac{p_t^f(n_{it})^{\frac{\theta-1}{\theta}}}{P_{dt}}\right]^{\frac{\rho}{\rho-1}} \tag{2.33}$$

$\frac{M_{it}}{M_{dit}}$ is increasing in n_{it} and $\left(\frac{M_{it}}{M_{dit}}\right)^{\alpha_\chi}$ represents the advantage that accrues to a firm when it sources some of its intermediate inputs from abroad. For a given level of capital, labor, energy and expenditure on intermediate inputs, a higher import intensity represented by a larger $\frac{M_{it}}{M_{dit}}$ allows the firm to produce a higher output.

Thus, we can think of firms with larger n_{it} (i.e., firms importing more foreign varieties) and ω_{it} having a lower marginal cost of production as seen in section 2.2. Analogously, firms with higher import intensity ($\frac{M_{it}}{M_{dit}}$) and higher ω_{it} are able to produce a higher level of output for a given level of inputs.

The natural log of the production function (2.31) of firm i can be written as

$$q_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_e e_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \omega_{it} + \epsilon_{it} \tag{2.34}$$

The lower case letters q, l, k, e, m, χ refer to the natural log of quantity, labor, capital, energy, expenditure on intermediate inputs and import intensity ($\frac{M}{M_d}$) of intermediate inputs respectively.

The measure of total productivity of interest is $\alpha_\chi \chi_{it} + \omega_{it}$, the first component of which is attributable to imports of intermediate inputs by the firm and the second to firm R & D. Firms can improve total productivity and lower marginal costs of production by importing foreign intermediate inputs and engaging in R & D. The second component of the firm's total productivity ω_{it}, is known to the firm when it makes its decisions on inputs but is not observed in the data. Lastly, ϵ_{it} represents measurement error and idiosyncratic shocks to production.

2.4.2 Measuring Output based on Revenues and Prices

Since firm revenue $R_{it} = P_{it} * Q_{it}$, firm output can be measured from firm revenues and firm prices. If q_{it}, p_{it} and r_{it} are the natural logarithm of firm output, firm prices and firm revenue respectively,

$$q_{it} = r_{it} - p_{it} \tag{2.35}$$

Data on firm prices are often not available. Papers that estimate firm-level productivity (including the export-productivity literature) typically measure firm output by deflating firm revenues by an industry price deflator (p_{It}) which is common to all firms within an industry I. So they measure the natural log of firm output as

$$\widetilde{q}_{it} = r_{it} - p_{It} \tag{2.36}$$

Using (2.35) and (2.36), if we substitute for $\widetilde{q}_{it} = q_{it} - (p_{it} - p_{It})$ into (2.34), the production function becomes

$$\widetilde{q}_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_e e_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \widetilde{\omega}_{it} + \epsilon_{it} \tag{2.37}$$

where,

$$\widetilde{\omega}_{it} = (p_{it} - p_{It}) + \omega_{it} \tag{2.38}$$

If firms operated in perfectly competitive markets where each firm was a price taker and charged the industry price (i.e, $p_{it} = p_{It}$), (2.34) and (2.37) would be equivalent to each other. However, when we deviate from the assumption of perfect competition (i.e, $p_{it} \neq p_{It}$), two problems arise.

The first is the omitted price bias. In the absence of firm prices, if industry prices are used to measure output as $\widetilde{q}_{it}$ instead of q_{it}, the estimates of the coefficients of the production function will be biased. As long as $E[(p_{it} - p_{It})z_{it}] \neq 0$, where z_{it} refers to the vector of inputs, the use of industry level price deflators to deflate revenues to proxy for output will yield incorrect estimates of the coefficients of the production function. (See Klette and Griliches (1996) for a detailed exposition of the omitted price bias).[16]

The second problem is specific to the export-productivity question when we try to estimate within firm changes to total productivity from export entry. If firms face downward sloping demand curves and pass on some of the benefits of gains in productivity to consumers by lowering prices, p_{it} falls as ω_{it} rises. In this case, using estimates of productivity from (2.37) will underestimate gains to firms' post export market entry.[17]

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[16]Everything else being equal, firms charging higher prices would have lower market shares. They would sell fewer units of output and employ fewer inputs i.e., price and inputs would be negatively correlated. However, more productive firms also need fewer inputs to produce the same output. So the relationship may not be so clear cut.

[17]Theoretical models of trade such as Melitz (2003b) model firms as operating in monopolistically competitive markets. In equilibrium, firms charge a price in domestic and export markets which is a constant mark up over marginal cost. The mark ups are given by the inverse of the elasticity of demand in the two markets. If firms improve productivity and reduce marginal costs, these models predict a complete pass through of these gains to consumers in the form of lower prices.

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Columns (1) and (2) report the percentage of firms that experienced decline in prices over the previous year and the mean reduction in prices over the previous year for firms with negative growth, while columns (3) and (4) give the percentage of firms that experienced positive growth in prices over the previous year and the average increase in prices for the firms with positive growth. For example, in the year 2000, 37 % of firms saw on average a nine percent fall in their prices from 1999 while 63 % of the firms experienced a ten percent increase in prices on average. Price changes of firms varied widely as can be seen by the standard deviation. The use of the industry level deflator would assume that every firm experienced a three percent increase in prices over the previous year. Deflating revenues by the industry deflator would underestimate the quantity changes for firms with price changes less than three percent and overestimate the quantity changes for firms with growth in prices over three percent. This would imply that productivity change is underestimated for firms that experience a change in price of less than three percent and overestimated for firms that experience a change in price greater than three percent.

Information on prices allows me to estimate (2.34). I construct firm specific price deflators, which vary across firms within an industry, unlike industry level deflators that are common to all firms in an industry. I thus recover estimates of the production function coefficients and ω_{it} that do not suffer from the shortcomings discussed above.

2.5 Estimation Strategy

The empirical strategy involves two steps. First, I recover the parameters of the the production function and calculate estimates of total productivity ($\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}}$). Next, I use difference-in-differences propensity score matching to examine the impact of starting to export on efficiency.

2.5.1 Recovering the Production Function Parameters

I estimate the parameters of (2.34) using proxy estimators for each industry separately. These methods use a control function in a firm specific decision to proxy for productivity and control for the simultaneity bias that arises because input demand and unobserved productivity are correlated. I follow Ackerberg et al. (2015) who extends Olley and Pakes (1996) and Levinsohn and Petrin (2003).[18]

Under the time to build assumption for capital, capital used in production in period t is known in period $t-1$. Given the restrictive labor laws in India on hiring, firing and closing down plants, there are adjustment costs to labor.[19] I assume like Ackerberg et al. (2015), that labor is not completely mobile and is chosen at $t - b$ where $0 < b < 1$. Firms make decisions on importing intermediate inputs. There are fixed costs to imports which involve searching for suppliers, navigating customs procedures and getting delivery of inputs across borders. Under this setup, material inputs are not fully adjustable. I assume material inputs are chosen at $t - c$ where $0 < c < 1$. Energy inputs are fully flexible and are chosen at period t after capital, labor, material inputs (domestic and imported) and productivity is observed.[20]

The demand function for energy inputs is given by $e_{it} = h(k_{it}, l_{it}, m_{it}, \chi_{it}, \omega_{it})$. Under the

[18]Ackerberg et al. (2015) argue that the labor parameter cannot be consistently identified in the Olley and Pakes (1996) and Levinsohn and Petrin (2003) method. They use the Value added production function because of concerns that the variable inputs would be perfectly correlated and thus collinear. While I use the gross output production function, I report the correlation matrix of all the input variables used in the production function in Table A.1 in appendix A.3. While the inputs are positively correlated as is expected, they are not perfectly correlated (with all correlations below .75).

[19]See Hasan, Mitra, and Ramaswamy (2007) for a discussion on labor market regulations and rigidities in India.

[20]The exact ordering of the timing assumptions of when labor and material inputs are chosen does not impact the empirical estimation. The only assumption needed for the empirical estimation is that energy is chosen after observing other inputs and productivity.

monotonicity assumption (the demand for the variable input $h(k_{it}, l_{it}, m_{it}, \chi_{it}, \omega_{it})$ is strictly increasing in ω_{it}), the energy demand function can be inverted to proxy for unobserved productivity. $\omega_{it} = h^{-1}(k_{it}, l_{it}, m_{it}, \chi_{it}, e_{it})$ is the inverse demand function for energy.

Under the Ackerberg et al. (2015) method, no coefficient of the production function is estimated in the first stage. The first stage is used to get a consistent estimate of expected output ($\widehat{\phi}_{it}(.)$).

$$q_{it} = \phi_{it}(l_{it}, k_{it}, m_{it}, \chi_{it}, e_{it}) + \epsilon_{it} \tag{2.39}$$

where

$$\phi_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \alpha_e e_{it} + h^{-1}(k_{it}, l_{it}, m_{it}, \chi_{it}, e_{it}) \tag{2.40}$$

In addition to the firm variables in $h^{-1}(.)$, I also include year dummies to account for macro trends that could impact input demand.[21]. Once $\widehat{\phi}_{it}(.)$ is estimated for any candidate candidate values of the coefficients, productivity can be written as

$$\omega_{it}(\overline{\alpha}) = \widehat{\phi}_{it} - (\overline{\alpha}_0 + \overline{\alpha}_l l_{it} + \overline{\alpha}_k k_{it} + \overline{\alpha}_x m_{it} + \overline{\alpha}_\chi \chi_{it} + \overline{\alpha}_e e_{it}) \tag{2.41}$$

For the candidate values of the coefficients, the productivity series can be used to estimate the productivity evolution as given by

$$\omega_{it} = \gamma_1 \omega_{it-1} + \gamma_2 d^k_{it-1} + \gamma_3 \omega_{it-1} * d^k_{it-1} + \zeta_{it} \tag{2.42}$$

From (2.41) and (2.42), ζ_{it} can be recovered for the candidate values of the coefficients. ω_{it} is decomposed into two parts. The first part constitutes the conditional expectation of productivity based on the information set known in period $t-1$. The second, ζ_{it}, is the deviation from the expectation. ζ_{it} is mean independent of the information known in $t-1$ and is not correlated with the past decisions of the firm. This provides the basis for the instruments for identifying the

[21] I use a fifth degree polynomial in capital, labor, material inputs, labor and energy to get an estimate of $\widehat{\phi}_{it}$.

coefficients through GMM using the moment conditions.

$$E(\zeta_{it}(\alpha,\gamma)Z_{it}) = 0 \tag{2.43}$$

The instrument set includes current capital k_{it} (since it is chosen in $t-1$) and lagged values of the other variables (l_{it-1}, m_{it-1}, χ_{it-1}, e_{it-1}, d^k_{it-1}, $\widehat{\phi}_{it-1}(.)$ and $\widehat{\phi}_{it-1}(.) * d^k_{it-1}$) to identify the production function parameters and the parameters of the productivity evolution process since they are all uncorrelated with ζ_{it}.

2.5.2 Gains from Exporting

The overall productivity is $\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}}$, which is constituted of two parts. The first is productivity due to imports of intermediate inputs and the second is productivity due to investment in R & D. To examine the impact of entry into export markets on firm productivity, I follow the micro-econometrics literature on program evaluation and estimate the average effect of treatment on the treated (ATT).[22]

In the context of this paper, treatment (W) is the entry into export markets and the outcome of interest (Y_{is}) is productivity of firm i in period s. I define an export entrant as a firm that enters into the export market for the first time and is an exporter for a minimum of two years. Also, the firms should have an observed history of at least two years in the data prior to export entry.

Since I do not observe the counter-factual of the outcome of interest had the treated firm not entered into the export market, I estimate propensity scores as proposed by Rosenbaum and Rubin (1983) to find a control group as close as possible to the treated group. W takes the value 1 if the firm begins to export and 0 otherwise. To get a value for the counter-factual outcome if the exporting firm had not entered the export market, the control group is from the group of never exporters. The propensity score or the probability of entry into export markets is

$$P(W_{it} = 1) = \Phi\left(f(\omega_{it-1}, k_{it-1}, l_{it-1}, d^k_{it-1}, \chi_{it-1})\right) \tag{2.44}$$

[22]See Imbens and Wooldridge (2009) for a comprehensive overview.

where $P(W_{it} = 1)$ is the probability of the firm starting to export at period t, Φ is the cumulative normal distribution and $f(.)$ is a polynomial of the variables. I also include a full set of year and industry effects in the equation. The panel dataset allows me to implement a Difference-in-Differences (DID) matching estimator as suggested by Heckman et al. (1997). Blundell and Costa Dias (2000) note that combining matching with DID allows for the possibility of unobservables affecting participation if they can be represented by separable firm specific and /or time specific components.

Matching treated and control groups on propensity scores requires two assumptions. The common support assumption requires the possibility of a non treated counterpart for each treated firm. It is given by $P(W = 1)|P < 1$, where P is the propensity score.

The conditional mean assumption requires that the expected change in outcome of the treated firm had it not been treated should be the same as the expected change in outcome of the control firm i.e., $E(Y^0_{t'} - Y^0_{t-1}|P, W = 1) = E(Y^0_{t'} - Y^0_{t-1}|P, W = 0)$. Here, $t - 1$ denotes the time period just prior to export entry, $t' = t + i$ where $i = 1, 2, 3, 4...$ denote time periods after export entry and $(Y^0_{t'} - Y^0_{t-1})$ denotes the change in the outcome of interest between the two periods in the untreated state.

The treatment on the treated is given by

$$\delta^{\tau} = \frac{1}{N}\left(\sum_{i \in T}(Y^1_{it'} - Y^1_{it-1}) - \sum_{j \in C} w_{ij}(Y^c_{jt'} - Y^c_{jt-1})\right) \tag{2.45}$$

Here N refers to the number of firms that start to export, T refers to the treated group i.e., the export starters and C refers to the control group of never exporters. Each firm $i \in T$ is matched to firms in the control group and w_{ij} is the weight on each firm j in the control group as a match for firm i. [23] $Y^1_{it'} - Y^1_{it-1}$ is the change in the outcome variable for the export entrant between t' and $t - 1$ and $Y^c_{jt'} - Y^c_{jt-1}$ is the change in the outcome variable for the control firms between t' and $t - 1$.

[23]For example, a nearest neighbor matching with one neighbor would mean that for firm $i \in T$, the firm most similar to firm i in the control group C would have $w_{ij} = 1$ and all the remaining firms in C would have $w_{ij} = 0$.

The outcomes of interest are $(\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}})$ as well as the individual components $\widehat{\alpha_\chi}\chi_{it}$ and $\widehat{\omega_{it}}$, to examine whether overall productivity improves on export entry as well as the relative importance of the two different channels.

2.6 Data

The firm level variables are from the Prowess dataset provided by the Center for Monitoring of the Indian Economy (CMIE). This is a panel dataset of Indian firms in the organized sector. It includes both listed and unlisted firms. The dataset has been used in several papers including Goldberg et al. (2010) and Topalova and Khandelwal (2011).

I use data on firm observations from 1989 to 2005. For these years, there is information on all the firm variables used in the production function estimation as well as quantities and sales values of products of firms. There are data on $5,850$ manufacturing firms with $45,835$ firm year observations. The firms belong to thirteen major industry groups.[24] Industries are classified according to the National Industrial Classification (NIC 2008). There is a one to one correspondence between the NIC and ISIC (The United Nations International Standard Industrial Classification).

The dataset is appropriate for this study because it tracks firm performance over time for a variety of variables. In addition to the usual variables on revenue and inputs, which are relevant for productivity estimation, it also contains data on variables relating to firm activity in international markets (exports and imports) as well as on investment in knowledge (R & D spending). It also has product level data on all products produced by the firm which allows for the construction of firm specific price deflators.

All input variables have been deflated to $1989-90$ levels using deflators from the $1993-94$ price series. Energy, Wages and Capital Stock were deflated by the power and fuel, wholesale price index and machinery deflators respectively. I created input price deflators for each industry by passing output deflators through the input-output matrix for each industry. Summary statistics for the variables used in the production function are reported in Table 3.3.

The measure of quantity I use is the firm sales revenue deflated by the firm specific price

[24] I exclude minor industries such as printing, coke and petroleum products etc., where the number of firm year observations are too few to allow for estimation of the production function parameters.

deflator. The import intensity term is the total expenditure on intermediate inputs divided by the expenditure on domestic inputs. All firm output and input variables (quantity, labor, capital, energy, material inputs and import intensity) are expressed as natural logarithms while the export and R & D indicator are discrete variables. There are 544 export entrants where an export entrant is as defined in subsection 2.5.2.

The dataset contains information on the number of units sold as well as total sales value of the product for each product of the firm. This gives us unit values of the product. There are data on about $150,000$ product year observations. $1,658$ firms are single product firms throughout the period while the remaining firms sell two or more products at at least some point in the period. Products are assigned a product code based on the product classification developed by CMIE Prowess. Each product code is matched to a five digit industry.

I follow Eslava, Haltiwanger, Kugler, and Kugler (2004), Eslava, Haltiwanger, Kugler, and Kugler (2010) and Ornaghi (2008) to construct firm-specific price deflators as Tornqvist indices of the weighted average growth of prices of all products produced by the firm. (See appendix A.2.1). I report the summary statistics for price deflators constructed from the firm data as well as industry deflators from the price series data from the Government of India Statistics Division in the last two rows of Table 3.3.

Table 2.3: Summary Statistics

Variable	Mean	St. Dev.	Min	Max
Output (q)	5.114	1.676	-3.271	12.00
Labor (l)	2.176	1.708	-3.405	9.731
Capital (k)	4.102	1.652	-3.096	11.51
Intermediate Inputs (m)	4.215	1.784	-3.478	10.66
Energy (e)	1.470	1.931	-3.885	8.749
Import Intensity (χ)	0.132	0.214	0	1.627
Export Indicator	0.555	0.496	0	1
R & D Indicator	0.253	0.434	0	1
Firm Deflator	193.6	98.81	9.391	4,200
Industry Deflator	198.8	50.29	100	367.1

Notes: Firm Inputs and Output variables are in natural logs. Output is firm revenue deflated by the firm specific price deflators. The number of observations is 45,835 and the number of firms is 5,850.

2.7 Results

I begin by estimating the parameters of the production function (2.34) and the endogenous productivity evolution process (2.42) as described in subsection 2.5.1. The estimates are presented in subsection 2.7.1. In subsection 2.7.2, I discuss the baseline results of the gains from starting to export on overall productivity. I also present the estimates from the two separate components - productivity growth from imports of intermediate inputs, and productivity growth from R & D. Finally, in subsection 2.7.3, I present results from robustness checks.

2.7.1 Production Function Parameters: Imports and R & D

Tables 2.4, 2.5 and 2.6 present the results for the parameters of the production function and productivity evolution process. All these three sets of parameters are estimated simultaneously for the output production function where output of the firm is constructed from deflating firm revenues with the firm specific price deflator.

Table 2.4 reports the estimation results for the production function parameters for thirteen major manufacturing industry groups. $\alpha_l, \alpha_k, \alpha_x, \alpha_e$ represent the share of labor, capital, material inputs and energy inputs respectively in the production function. The magnitude of these parameters are reasonable across industries for these different inputs.[25]

The table also presents the output from the Wald test for constant returns to scale. The null hypothesis of constant returns to scale is rejected in seven out of the thirteen industries at the 10 percent level (and in six of the thirteen at the 5 percent level). Marin and Voigtlander (2013) use marginal cost as their measure of efficiency to capture productivity improvements through export entry. Marginal costs may decline not just because of productivity improvements but also with changes in capital stock. They show in their paper that, under the assumption of constant returns to scale, changes in marginal costs would reflect changes in productivity.

[25]Once the coefficients are estimated, the ω values are calculated. In appendix A.3, I graph the overall distribution of ω in Figure A.1. I also plot the ω values by year in Figure A.2

Table 2.4: Production Function Coefficients

	Constant α_0	Labor α_l	Capital α_k	Material α_x	Energy α_e	Wald χ^2 (p-value)	Observations
Food & Beverages	2.130***	0.241***	0.035**	0.525***	0.125***	13.079	5,340
	(0.098)	(0.012)	(0.017)	(0.017)	(0.014)	(0.000)	
Textiles & Apparel	1.329***	0.069***	0.105***	0.704***	0.031**	86.960	5,471
	(0.060)	(0.013)	(0.012)	(0.020)	(0.015)	(0.000)	
Paper & Products	1.196***	0.088**	0.114***	0.723***	0.031*	5.850	1,464
	(0.110)	(0.045)	(0.024)	(0.047)	(0.016)	(0.016)	
Basic Chemicals	1.890***	0.215***	0.164***	0.520***	0.015	10.420	3,518
	(0.126)	(0.052)	(0.052)	(0.046)	(0.050)	(0.001)	
Chemical Products	1.514***	0.436***	0.053	0.660***	-0.166*	0.320	1,469
	(0.243)	(0.115)	(0.049)	(0.083)	(0.088)	(0.570)	
Pharmaceuticals	1.621***	0.315***	0.057**	0.619***	0.014	0.020	2,538
	(0.114)	(0.041)	(0.028)	(0.054)	(0.039)	(0.894)	
Rubber & Plastic	2.019***	0.125**	0.220***	0.435***	0.189**	2.420	2,438
	(0.212)	(0.051)	(0.061)	(0.080)	(0.095)	(0.120)	
Mineral Products	1.348***	0.091*	0.127***	0.575***	0.251***	3.050	1,811
	(0.098)	(0.051)	(0.033)	(0.047)	(0.046)	(0.081)	
Basic Metals & Products	1.403***	0.064***	0.090***	0.726***	0.073***	16.060	4,896
	(0.054)	(0.017)	(0.023)	(0.019)	(0.013)	(0.000)	
Computer & Electronics	0.977***	0.180***	0.072	0.864***	-0.034	2.650	1,485
	(0.146)	(0.059)	(0.063)	(0.060)	(0.061)	(0.103)	
Electrical Equipment	1.150***	0.132***	0.127***	0.774***	-0.041	0.280	2,246
	(0.088)	(0.034)	(0.019)	(0.029)	(0.028)	(0.597)	
Machinery	1.303***	0.118**	0.042	0.722***	0.162**	6.580	2,353
	(0.196)	(0.060)	(0.052)	(0.042)	(0.066)	(0.010)	
Transport Equipment	1.151***	0.142***	0.094***	0.693***	0.052*	0.690	2,493
	(0.116)	(0.041)	(0.036)	(0.047)	(0.029)	(0.405)	

Notes: Standard errors in parentheses are clustered at firm level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The Wald Test for Constant Returns to Scale hypothesis $\alpha_l + \alpha_k + \alpha_x + \alpha_e = 1$ reports the test statistic as well as the p-value in parentheses.

When technology does not exhibit constant returns to scale, changes in marginal costs would also be capturing changes in capital stock. In the context of Indian manufacturing, where about half the industries do not exhibit constant returns to scale, the approach used in this paper, where productivity is directly measured, is more appropriate rather than the use of marginal cost as a measure to capture productivity changes.

Table 2.5 presents the estimates of the imported inputs term in the production function. α_χ is the estimate on the import intensity term (χ) in the production function where χ takes a value 0 if the firm does not import from abroad (since in that case, $M_{it} = M_{dit}$ and χ is the natural log of $\frac{M_{it}}{M_{dit}}$). χ is increasing in the expenditure share on imported intermediate inputs. The coefficient (α_χ) is positive in all thirteen industries. Everything else held equal, firms that import a larger share of their intermediate inputs from abroad are able to produce higher output with the given inputs.

To illustrate, in the transport equipment industry, a 10 percent increase in the $\frac{M_{it}}{M_{dit}}$ ratio (which is approximately a 9 percent decline in the expenditure share of domestic inputs in total inputs), while holding all inputs fixed (capital, labor, energy and total expenditure on intermediate inputs) will result in a 5.4 percent increase in total output.

The table also presents the implied values for ρ which are calculated from the estimates of α_x and α_χ for each of these industries since $\alpha_\chi = \alpha_x \left(\frac{1-\rho}{\rho}\right)$. The elasticity of substitution between the domestic and imported input bundle is given by $\frac{1}{1-\rho}$. The CES model restricts the value of ρ to be between 0 and 1. The implied values for ρ for all the thirteen industry groups falls within this range.

Table 2.6 presents the estimates of the endogenous productivity process. The coefficient γ_1 measures the impact of previous period firm productivity on current productivity and is positive in all industries. The coefficient γ_2 measures the average impact of the lagged discrete decision to invest in R & D on current productivity and is positive in all industries. Firms that undertake investment in R & D have on average, 2 to 5 percent higher productivity than firms that do not.

However, the impact of doing R & D on productivity varies with the firm's initial productivity level. The coefficient on the interaction term γ_3 captures the idea that the productivity effects from investing in R & D depends on the firm's initial productivity level. In twelve of the thirteen

Table 2.5: Imports in the Production Function

	Imports	
	α_χ	ρ
Food & Beverages	0.467***	0.529
	(0.131)	
Textiles & Apparel	0.386***	0.646
	(0.129)	
Paper & Products	0.078	0.903
	(0.138)	
Basic Chemicals	0.258*	0.668
	(0.139)	
Chemical Products	0.298	0.689
	(0.329)	
Pharmaceuticals	0.137	0.819
	(0.474)	
Rubber & Plastic	0.096	0.819
	(0.174)	
Mineral Products	0.144	0.800
	(0.338)	
Basic Metals & Products	0.234*	0.756
	(0.131)	
Computer & Electronics	0.066	0.929
	(0.160)	
Electrical Equipment	0.351*	0.688
	(0.182)	
Machinery	0.318	0.694
	(0.212)	
Transport Equipment	0.540***	0.562
	(0.165)	

Notes: Standard errors in parentheses are clustered at firm level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2.6: Productivity Evolution: Past Productivity and Investment in R & D

	ω_{t-1}	d^k_{t-1}	$\omega_{t-1} X d^k_{t-1}$
	γ_1	γ_2	γ_3
Food & Beverages	0.052	0.016*	0.697***
	(0.047)	(0.009)	(0.087)
Textiles & Apparel	0.321**	0.025***	0.500***
	(0.144)	(0.007)	(0.161)
Paper & Products	0.422***	0.046*	0.095
	(0.095)	(0.024)	(0.309)
Basic Chemicals	0.762***	0.000	-0.391***
	(0.047)	(0.028)	(0.139)
Chemical Products	0.662***	0.024**	0.354**
	(0.096)	(0.012)	(0.165)
Pharmaceuticals	0.565***	0.032***	0.322**
	(0.081)	(0.009)	(0.140)
Rubber & Plastic	0.778***	0.024**	0.151*
	(0.039)	(0.011)	(0.081)
Mineral Products	0.094	0.042***	0.960***
	(0.331)	(0.008)	(0.333)
Basic Metals & Products	0.694***	0.024***	0.273***
	(0.042)	(0.005)	(0.051)
Computer & Electronics	0.224	0.011	0.432*
	(0.164)	(0.023)	(0.238)
Electrical Equipment	0.001	0.035***	0.845***
	(0.001)	(0.010)	(0.087)
Machinery	0.317	0.033***	0.994**
	(0.241)	(0.012)	(0.415)
Transport Equipment	0.521***	0.022***	0.397*
	(0.123)	(0.005)	(0.240)

Notes: Standard errors in parentheses are clustered at firm level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

industries, this term is positive. This implies that the productivity gains from investing in R & D is higher for more productive firms in almost all industries across the board. To illustrate, the difference in productivity growth is 1.9 percentage points for a median productivity firm that engaged in R & D in the previous period compared to one that did not engage in R & D in the previous period. This difference is about 18.6 percentage points for a firm in the 90th percentile of productivity. [26]

2.7.2 Gains from Export Entry

I begin by graphically showing the productivity trajectory of an export entrant who has starting exporting in period $t = 0$. Figure 2.1 depicts the productivity trajectory for the export entrant using measures of revenue productivity as well as physical productivity.[27] I plot average productivity on the vertical axis while the horizontal axis depicts time. Here, revenue productivity is the productivity measure retrieved when sales revenue are deflated by industry deflators and this is used to proxy for output in the production function. Physical productivity measures I have used are where sales revenues are deflated by firm specific deflators and used as a measure of firm output in the production function.

As can be seen in the graph, the export entrant's revenue productivity is more or less stagnant over the six years following export entry. On the other hand, the average productivity (physical) of the export entrant increases and continues to rise from the time the firm begins to export. These different productivity trajectories highlight the need to retrieve measures of productivity that capture physical productivity to estimate gains from export entry. I refer to the physical productivity measure as total productivity.

While Figure 2.1 shows that average total productivity rises for an export entrant, it does not indicate how differently productivity would have evolved had the firm not started exporting. In Figure 2.2, I graph how the productivity trajectory of an export entrant compares with a non exporter

[26] Median productivity of a firm in the transport industry equals $-.008$ while a 90th percentile firm has productivity which equals $.414$. The parameters of the productivity process in the transport industry are $\gamma_1 = 0.521$, $\gamma_2 = .022$ and $\gamma_3 = 0.397$

[27] These productivity trajectories are based on 348 export entrants for which data are available for the entire period under consideration

Figure 2.1: Productivity Trajectory for Export Entrant (Revenue vs. Physical Productivity)

Average Firm Specific Total Productivity

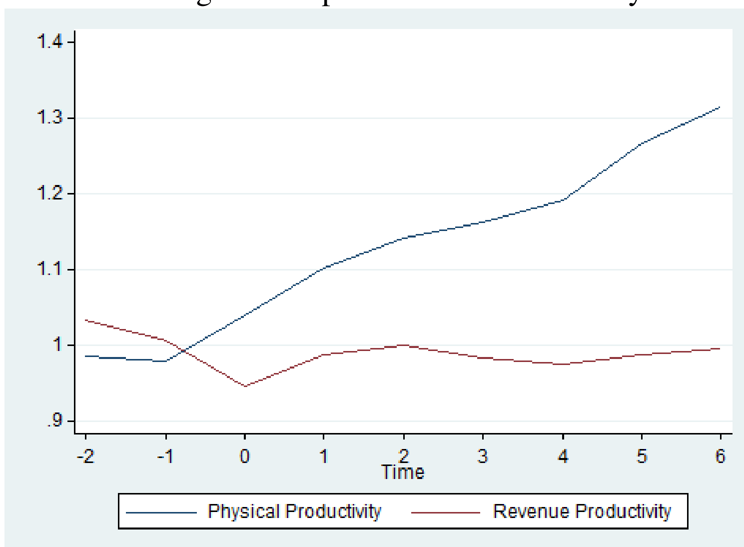
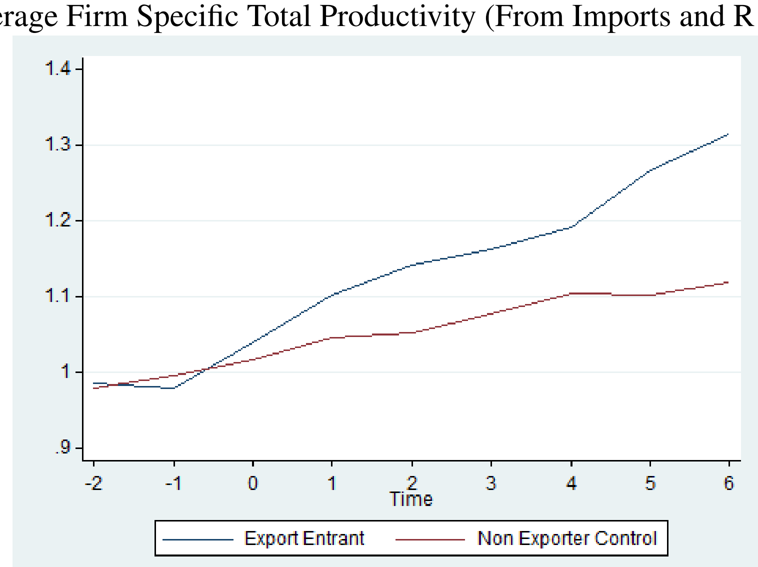


Figure 2.2: Productivity Trajectory for Export Starter vs. Non Exporter Counterpart

Average Firm Specific Total Productivity (From Imports and R & D)



control firm.[28] While both the export entrant and the non exporter counterpart see an increase in average productivity after the firm enters the export market, the average productivity of the exporter rises faster than the average productivity of its non exporter counterpart. They have similar trajectories prior to export entry. However, after the firm begins to export, their trajectories diverge and the gap between them widens over time.

In Table 2.7, I present the results to show how entering into an export market impacts productivity. Since the variables are in natural logarithms and log differences are growth rates, the coefficients of the DID estimator can be interpreted as the difference in growth rates over time for the export entrant as compared to the non exporter counterpart.[29] The firm begins exporting in period t and $t+i$ where $i = 1, 2, ..$ refers to the time period i years after the firm enters the export market.

Table 2.7: Productivity Growth over Time from Export Entry: Matching Results

	Total Productivity $\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}}$	Imports $\widehat{\alpha_\chi}\chi_{it}$	R & D $\widehat{\omega_{it}}$
t+1	0.063**	0.001	0.061**
	(0.028)	(0.004)	(0.029)
t+2	0.072***	0.008	0.065**
	(0.024)	(0.006)	(0.027)
t+3	0.067*	0.011*	0.055*
	(0.035)	(0.006)	(0.033)
t+4	0.081**	0.017***	0.065*
	(0.033)	(0.006)	(0.035)
t+5	0.092**	0.019***	0.074**
	(0.036)	(0.005)	(0.035)
t+6	0.103***	0.017***	0.087**
	(0.038)	(0.005)	(0.039)

Notes: Nearest Neighbor matching using three neighbors with replacement. The number of treated is 348. Block Bootstrap Standard errors given in parentheses (200 replications). *** p<0.01, ** p<0.05, * p<0.1

The first column presents the average treatment of the treated δ^τ for overall productivity $(\widehat{\alpha_\chi}\chi_{it}+$

[28].The control firm was chosen as described in subsection 2.5.2 using nearest neighbor matching techniques.

[29]For example, if a export entrant experienced 15% productivity growth and a non exporter counterpart experienced a 5% productivity growth, the coefficient on δ^τ would be .10 which reflects that export entrants productivity growth rate was 10 percentage points higher.

$\widehat{\omega_{it}}$). In the first year after export entry ($t+1$), the average productivity growth (with respect to $t-1$) is about 6.3 percentage points higher for an export entrant as compared to a non exporter control. Over a four year period after export entry, the export entrant's total productivity grows by 8.1 percentage points more than a non exporter counterpart and over the six year period, the difference in growth was more than 10 percentage points. The export entrant starts to experience a higher growth from the first period following entry into the export market and the difference in overall growth persists over six years following export entry. The estimate of δ^{τ} is significant for every time period for the six years.

Column 2 of Table 2.7 presents the estimates of the coefficients (δ^{τ}) for the component of productivity attributable to imports ($\widehat{\alpha_{\chi}}\chi_{it}$) and column 3 presents the coefficients (δ^{τ}) for component of productivity attributable to firm investment in R & D ($\widehat{\omega_{it}}$). While the coefficients are positive and significant for both components, they are much larger in magnitude for the R & D component. The estimates of δ^{τ} in $t+3$ are 0.011 (0.006) and 0.055 (0.033) for the import component of productivity and the R & D component of productivity respectively and in $t+6$ are 0.017 (0.005) and 0.087 (0.039). Thus, over a six year period, the difference in productivity growth from the R & D component (compared to pre-entry levels) between an export entrant and a non exporter counterpart is 8.7 percentage points while this difference is 1.7 percentage points for the imports component.

The coefficients in Table 2.7 were estimated by following the same set of export entrants (and their non-exporter counterparts) over the six year period. The sample of export entrants is thus restricted to firms that are observed for every year in the dataset for at least six years after export entry. To check that the results are not driven by sample selection, I estimate the coefficients for all export entrants as defined in subsection 2.5.2. Thus the number of export entrants is not constant but varies by period depending on the number of years for which they are observed after they begin to export. For example, an export entrant that begins exporting in 2003 is only observed for two years after entry into the export market since the dataset ends at 2005. The results from the unrestricted sample are presented in Table 2.8.

Table 2.8: Productivity Growth from Export Entry (All export entrants): Matching Results

	t+1	t+2	t+3	t+4	t+5	t+6
Total Productivity	0.056**	0.079***	0.079**	0.098***	0.117***	0.112**
$(\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}})$	(0.026)	(0.028)	(0.037)	(0.031)	(0.037)	(0.046)
Imports	0.008**	0.015***	0.015***	0.018***	0.016***	0.015***
$(\widehat{\alpha_\chi}\chi_{it})$	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)	(0.005)
R & D	0.048*	0.064**	0.064*	0.081**	0.102***	0.098**
$(\widehat{\omega_{it}})$	(0.026)	(0.028)	(0.037)	(0.031)	(0.036)	(0.046)

Notes: Nearest Neighbor matching using three neighbors with replacement. The number of treated varies by year (544 to 364). Block Bootstrap Standard errors given in parentheses (200 replications). *** p<0.01, ** p<0.05, * p<0.1

The first row shows the δ^τ for total productivity and the second and third rows show the estimates of δ^τ for productivity growth from imports and productivity growth from R & D while the columns give the time period. The results are very similar to the restricted sample results. In $t + 1$ the estimates for δ^τ for total productivity, productivity from imports and productivity from R & D are 0.056 (.026), 0.008 (.003) and 0.048 (0.026) respectively and three years after export entry ($t+3$), they are 0.079 (0.037), 0.015 (0.004) and 0.064 (0.037) respectively. Over a six year period, overall productivity growth is 11.2 percentage points higher for a export entrant compared to its non exporter counterpart with the percentage difference in growth being 1.5 percentage points for the import component and 9.8 percentage points for the R & D component. Thus, as with the restricted sample, while both imports and R & D contribute to productivity growth, the contribution of the R & D channel is much larger.

2.7.3 Robustness Checks

I verify whether the results from subsection 2.7.2 are robust to concerns about foreign firms possibly driving the productivity growth of exporters or the possibility of export entrants having different growth rates than their non exporter counterparts prior to export entry in anticipation of selling in foreign markets or the choice of matching estimator.

Domestic vs. Foreign Firms

The period of study coincides with the easing of entry requirements of foreign firms into India. Prowess defines foreign firms as firms incorporated outside India or owned by foreigners (private or Government).[30] One concern might be that the results may be driven by foreign firms as these firms already have contacts with foreign suppliers of inputs and can more easily access technology. They are thus more likely to import foreign inputs and engage in R & D. I drop the 90 foreign firms from the sample and check whether the average treatment effect on the treated is different when only the sample of domestic firms is considered.

Table 2.9 presents the results for the sample of domestic firms. The estimate of δ^{τ} is 0.063 $(.026)$ in $t+1$ and increase to 0.115 $(.041)$ in $t+6$. Thus, six years post entry into export markets, domestic firms grow by 11.6 percentage points more than the control firms with respect to their pre-entry productivity levels. The estimates for the separate components of productivity from imports and R & D mirror the baseline results for entire sample. While both imports and R &D contribute to the differences in productivity trajectories of export entrants and their non exporter counterparts, the contribution of the R & D component is much greater in magnitude. The coefficients illustrates that foreign firms are not driving the results and that the estimates are significant and of similar magnitude even when only domestic firms are considered.

Productivity Growth Prior to Export Entry

One possible concern could be that export entrants experience a positive productivity shock prior to export entry which carries over to the post entry period. Alternatively they could begin preparations to export prior to the export entry by engaging in R & D and imports of foreign inputs. Since I match on pre-entry productivity levels as well as pre-entry import intensity and R & D, export entrants and their non-exporter counterparts are similar on these indicators. Furthermore, I check if there are differences in pre-entry growth rates of productivity for three periods prior to starting to export. The results are presented in Table 2.10. The average growth rates for export entrants and their non exporter counterparts prior to entry into export markets are not different

[30] This is an time invariant firm specific variable.

Table 2.9: Productivity Growth over Time from Export Entry (Domestic Firms): Matching Results

	Total Productivity $\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}}$	Imports $\widehat{\alpha_\chi}\chi_{it}$	R & D $\widehat{\omega_{it}}$
t+1	0.063**	0.003	0.060**
	(0.026)	(0.004)	(0.027)
t+2	0.081***	0.009	0.071**
	(0.029)	(0.006)	(0.031)
t+3	0.091***	0.013**	0.078**
	(0.033)	(0.006)	(0.036)
t+4	0.105***	0.018***	0.087**
	(0.037)	(0.006)	(0.037)
t+5	0.107***	0.020***	0.087**
	(0.038)	(0.006)	(0.040)
t+6	0.115***	0.018***	0.097**
	(0.041)	(0.005)	(0.044)

Notes: Nearest Neighbor matching using three neighbors with replacement. The number of treated is 322. Block Bootstrap Standard errors given in parentheses (200 replications). *** p<0.01, ** p<0.05, * p<0.1

from each other.

Table 2.10: Productivity Growth prior to entry

Productivity Growth	Export Entrant	Non Exporter Control	t Statistic (Difference)	$p > \|t\|$
t_{-1} *to* t_0	0.033	0.019	0.67	0.504
t_{-2} *to* t_{-1}	0.064	0.038	0.77	0.44
t_{-3} *to* t_{-2}	0.021	0.024	-0.08	0.935

Alternate Matching

Finally, I check whether the results are robust to alternate matching estimators. The main results presented in section 2.7.2 used the nearest neighbor matching with three neighbors. Increasing the number of neighbors in the nearest neighbor matching may involve a trade off between bias and variance. Tables A.2 and A.3 in appendix A.3.1 presents the results from using five neighbors. The results are very similar to the ones presented in Tables 2.7 and 2.8 in section 2.7.2.

2.8 Conclusion

Trade theory has emphasized within-firm productivity improvements from selling in international markets. However, empirical work has mostly failed to identify gains to the firm from exports. Recent evidence from Chile on falling marginal costs of products, post entry into export markets, suggests that the measure of productivity used could explain this absence of evidence. I revisit the export-productivity question where I retrieve firm-level productivity measures that account for pricing heterogeneity.

I find evidence that firm productivity grows faster after firms begin to export. Over a six-year period, the difference in productivity growth between export entrants and their non exporter counterparts is about 11 percentage points. Thus, I find that productivity improvements from selling in international markets have largely been understated in the export-productivity empirical literature.

I explore the export-R & D complementarity and export-import complementarity and decompose gains from export entry from these two channels. Access to foreign markets to sell its products allows firms to undertake activities foreign sourcing and R & D that improve its productivity. The estimates suggest that about 15 percent of the differences in productivity growth is accounted for by imports of intermediate inputs, while investment in R & D explains about 85 percent of this difference in productivity growth. Thus, despite world R & D being concentrated in seven developed countries, I document that it is an important driver of productivity improvements even in developing countries like India.

The earlier empirical papers which did not find evidence of productivity gains for exporters did not account for firm variation in prices while estimating productivity. Some preliminary evidence on India also indicates that revenue productivity (where revenue is deflated using industry deflators to proxy for output) of exporters is more or less unchanged after firms begin exporting. This suggests a need for a greater understanding of pricing behavior and mark-ups of exporters after they begin selling in international markets. I leave this as a topic for future research.

CHAPTER 3

TRADE LIBERALIZATION AND INVESTMENT IN FOREIGN CAPITAL GOODS (CO-AUTHORED WITH IVAN T. KANDILOV AND ASLI LEBLEBICIOĞLU)

3.1 Introduction

One of the often emphasized benefits of international trade is that it stimulates investment in new technologies and thereby enhances productivity and stimulates economic growth (e.g. Keller (2004)). For developing countries, investment in new technologies entails importing capital goods since the production of capital equipment, as well as that of R&D intensive goods, is concentrated in a few developed countries (Eaton and Kortum (2001)). In the last few decades, a large number of developing countries and emerging economies have significantly reduced trade barriers in an attempt to boost economic growth (e.g. Brazil, Chile, Colombia, Mexico, and India). However, only a few studies have investigated the impact of trade liberalization on capital accumulation. In this paper, we estimate the effect of the Indian trade liberalization in the 1990s on investment in foreign capital goods using firm-level panel data from India. To our knowledge, our work provides the first estimate of the elasticity of imported capital with respect to tariffs on capital equipment.

In our work, we distinguish between two kinds of investment the firm can make - investment in imported capital goods and investment in domestic capital goods. Furthermore, in our empirical specification, we use input-output tables to construct three distinct tariff measures - tariffs on capital goods, tariffs on intermediate inputs, and tariffs on final products. We estimate the impacts of all three types of tariffs on firms investment decisions. By separating the effects of the tariff on capital goods from that of intermediate inputs, we are able to evaluate the direct channel (via reduction in the price of foreign capital) through which trade liberalization impacts investment decisions. In doing so, we provide a direct estimate of the price elasticity of investment in imported capital goods, and the gains from trade liberalization through reductions in the price of foreign capital.

The 1990s trade liberalization episode in India provides a natural setting to study this question. High tariff and non-tariff barriers characterized India's trade policy regime in the decades preceding the 1990s. The Indian economy experienced a balance of payment crisis in 1991. Support from the IMF in the crisis was contingent on economic reforms. As part of the IMF conditions, trade barriers on imports were significantly reduced in the years that followed. Between 1989 and 1997, the average tariff rates on final goods, intermediate inputs and capital inputs declined by 50 to 65 percentage points, with considerable variation in reductions across industries.

We motivate the empirical specification by providing a theoretical framework in which monopolistically competitive firms import both capital goods and intermediate inputs and sell their output domestically where they face competition from foreign producers. The dynamic problem of the firm involves an investment decision, where domestic and foreign capital investment are imperfect substitutes for each other. The firm maximizes the expected present value of the stream of profits and optimally decides how much to invest in domestic and in foreign capital goods.[1] The model predicts that by reducing the relative price of imported capital goods, lower capital good tariffs boost investment in foreign equipment. Similarly, a reduction in the intermediate input tariff leads to an increase in investment, since lower input prices raise the marginal profitability of capital used in production. On the other hand, lower output tariffs expose firms to greater foreign competition and erode the marginal profitability of capital, which leads to lower investment in foreign capital goods.

To test these predictions, we use a panel dataset on Indian manufacturing firms obtained from the CMIE Prowess database for the period from 1990 to 1997. To identify the impacts of the three types of tariffs on investment in foreign capital goods, we take advantage of India's trade liberalization in the early 1990s that led to plausibly exogenous variation in the tariffs across manufacturing subsectors in that time period. Empirically, we estimate the reduced form dynamic investment equation implied in our theoretical framework by using the system-GMM estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). The use of firm-level panel data allows

[1]The implications from our theoretical and empirical model are in terms of the investment rate for foreign capital goods $\left(\frac{I_M}{K}\right)$. We use investment and investment rate interchangeably throughout the paper.

us to control for time invariant firm level unobservables relevant to the firms investment decision, as well as time-varying unobservable shocks common to all firms. In addition, we are also able to include other firm-level relevant factors, such as export status and mark-up, that influence how tariff reductions might impact the firm's investment decision.

Consistent with our theoretical framework, we find that the reduction in capital-good tariffs led to an increase in investment in foreign capital goods, but not in domestic capital goods. Specifically, we show that a 10 percentage point decrease in the capital-good tariff led to a 9.44 percent increase in the average firms investment rate in foreign capital goods. A similar 10 percentage point reduction in the intermediate-input tariff led to a 6.11 percent increase in investment in foreign capital. Also in line with theory, we find that the reduction in the output tariff affected investment adversely. By increasing competition and lowering the marginal profitability of capital, a 10 percentage point reduction in the output tariff brought about a 4.72 percent decline in investment in foreign capital. Combining the effects of the three types of tariffs, we find that the trade liberalization in India resulted in a net increase of 62.31 percent in the manufacturing sector investment rate over the course of our sample period (1990-1997). Hence, given the average investment rate $\left(\frac{I_M}{K}\right)$ of 0.036 over the sample period, our results imply that the trade liberalization increased the investment rate to 0.058.

We also find that there is substantial heterogeneity across firms in how they responded to reductions in tariffs. We find that the net impact of the trade liberalization ranged between 4 and 167 percent increase in investment rates across different industries, and that firms in the middle of the productivity and size distributions benefitted the most from lower tariffs on capital goods. Moreover, we show that following the reductions in output tariffs, firms with greater market power lowered investment in foreign capital goods more aggressively, and firms in industries with more scope for product differentiation and quality upgrading (Khandelwal (2010)) lowered investment less. Additionally, we find that the effects of lower capital goods and lower intermediate input tariffs were more pronounced for exporters.

Our paper contributes to the growing literature that evaluates the impact of trade liberalization on capital accumulation. The estimates we obtain from investment Euler equations complement the findings in Bas and Berthou (2013), who show that reductions in tariffs on intermediate inputs increased the probability of importing capital goods for firms in the middle range of the productivity distribution. Moreover, our paper extends the results in Kandilov and Leblebicioglu (2012) on the impact of trade liberalization on firm investment in Mexico. In their paper, they treat all investment as domestic investment and examine how lower tariffs influence investment decisions through the marginal profitability of capital as a result of greater competition and lower costs of variable inputs. In this paper, we additionally analyze the direct effect of changes in the price of imported capital goods (through changes in tariffs on capital equipment) on investment in foreign capital goods. Hence, we provide the first direct evidence showing that the largest gains from trade liberalization for capital accumulation occurs through the reduction in the price of foreign capital.[2]

Our work is also related to the broader literature on trade liberalization and productivity. Evidence from Colombia, Chile, Indonesia and India suggest that lower tariffs lead to efficiency gains for firms. Topalova and Khandelwal (2011) and Amiti and Konings (2007) find positive effects of both lower input and output tariffs on productivity in India and Indonesia, respectively. Fernandes (2007), Muendler (2004), and Pavcnik (2002) show that tariff liberalization led to higher firm-level productivity in Colombia, Brazil, and Chile, respectively. Tybout and Westbrook (1995) suggest that average costs fell in most industries following the Mexican trade liberalization. Similarly, Tybout, De Melo, and Corbo (1991) find evidence that Chilean industries which experienced relatively large reductions in protection also experienced relatively large improvements in average efficiency levels.[3] One mechanism through which trade liberalization can improve efficiency is by lowering the cost of investing in highly efficient, R& D-intensive capital goods that are produced in a short-list of technologically advanced countries (see Table 3.1 for the list of countries

[2]Previous studies on trade policy reform and aggregate investment have been cross country or industry level studies which have analyzed the impact of output tariff reductions. See Wacziarg and Welch (2008) and Ibarra (1995) for examples.

[3]Also, there exists a literature that relates exporting opportunities to investment. For example, using data from Mexico during 1994-2004, Iacovone and Javorcik (2008) show that future exporters increase product quality (unit value) and investment before they start servicing the foreign market. Similarly, Alvarez and Lopez (2005) use data from Chile and present evidence that exporters invest more, perhaps to upgrade product quality, even before they enter the foreign market compared to firms that supply to the domestic market alone.

Table 3.1: Trading partner share of total imported capital

Rank	Trading Partner	Imported Capital (Percent of Total)
1	U.S.	20.14
2	Japan	16.80
3	Germany	16.73
4	U.K.	6.60
5	Singapore	4.98
6	France	4.96
7	Italy	4.63
8	Switzerland	3.10
9	Korea	2.18
10	Taiwan	1.91
	All Other	17.98
	Total	100.00

Note: Average percentage of total (over the sample period from 1990 to 1997)

India imported capital goods from during our sample period). Our paper provides insight into this mechanism and complements the findings in Mutreja, Ravikumar, and Sposi (2014), who use a neoclassical growth model with Ricardian trade to show that trade in capital goods has quantitatively important effects on economic development.[4]

The rest of the paper is organized as follows. Section 3.2 describes the trade liberalization experience in India. In Section 3.3, we develop a theoretical framework which motivates the empirical specification. In Section 3.4 we describe the data and how we construct the tariffs of interest. Section 3.5 presents our empirical model, and section 3.6 discusses our findings. Finally, section 3.7 concludes the paper.

3.2 Background on Tariff Liberalization

India adopted a highly restrictive trade policy post-independence. It was characterized by high tariff and non-tariff barriers on imports across industries. In the 1980s, the government began the process of gradual deregulation of the economy in order to promote exports. However, import tariff rates continued to be high. In 1990, the average tariff rate was over 90 percent while the maximum

[4]In particular, Mutreja et al. (2014) find that cross-country income differences would decline by more than 50 percent if trade barriers are eliminated.

tariff rates in some industries were close to 300 percent.

A combination of several factors contributed to the balance of payment crisis of 1991. The conflict in the Middle East resulted in high oil prices and a fall in worker remittances from abroad. There was a decline in export growth due to slow growth in India's major trading partners. This combined with political uncertainty led to a loss in investor confidence and large capital outflows from the country (see Cerra and Saxena (2002)). Foreign exchange reserves reached dangerously low levels. The Government requested a standby arrangement with the IMF in August 1991. IMF aid was conditional on India undertaking the process of liberalizing its economy. One of the conditions was the reduction in the levels and dispersion of tariffs on imports. Trade barriers on imports into India were reduced in the years that followed.

By 1997, import tariffs were cut to less than half of 1992 levels. Figure 3.1 shows the evolution of mean tariff levels on final goods, intermediate inputs and capital goods between 1989 and 2001. In addition to a reduction in average tariff levels, the standard deviation of final-good tariffs, intermediate-input tariffs and capital-input tariffs also reduced over the period as can be seen in Figure 3.2. Thus, industries with the highest tariff levels experienced the largest cuts.[5] Table 3.9 provides the details of the changes in tariffs on final goods, intermediate inputs and capital goods across all two digit manufacturing industries. While there was variation in 1990 tariff levels across industries, the table convincingly shows that the tariff reductions in final goods, intermediate inputs and capital inputs occurred across the board in all industry groups.

Figure 3.1 and Table 3.9 also show that most of the reductions in tariffs took place in the years immediately following the crisis between 1992 and 1997. While tariff cuts continued into the second half of the period (between 1997 and 2001), they had more or less leveled off in the later years. Tariffs on final goods dropped from 85 percent to 42 percent between 1992 and 1997 and fell further to 34 percent by 2001. Similarly, tariffs on capital goods fell from 83 percent to 34 percent between 1992 and 1997, and further to 30 percent by 2001 while tariffs on intermediate

[5]Average Tariffs for manufacturing was calculated as the simple average of tariffs of all two digit manufacturing industries, where the tariffs on the two digit industries was the simple average of all four digit industries within each two digit industry. The standard deviation of tariffs was calculated across five digit industry levels, the lowest industry classification.

inputs reduced from 72 to 32 percent between 1992 and 1997, and to 29 percent by 2001. These patterns are displayed across the major industries.

Figure 3.1: Average Tariff Rates (In Percent)

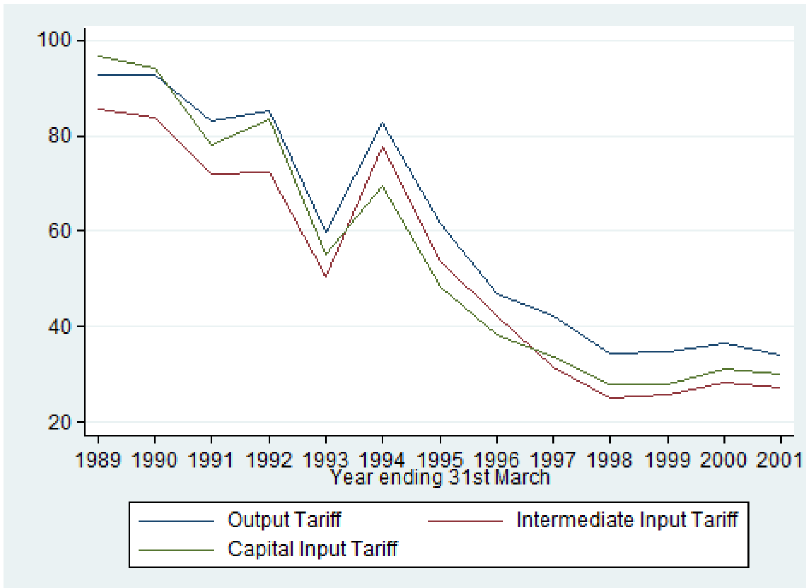
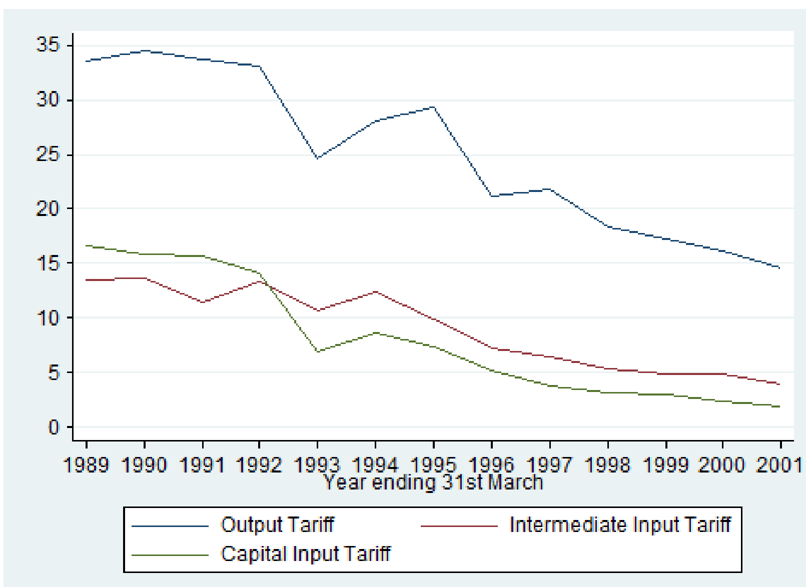


Figure 3.2: Standard Deviation of Tariffs



We confine our study to the early part of the trade liberalization episode i.e., until 1997. We do so because of concerns about trade policy being endogenously determined in the period after 1997. The literature on the political economy of trade policy has recognized that groups of firms and workers can influence governments when trade policy is set or that governments may protect industries with low productivity or investment levels (see, for example, Grossman and Helpman (1994); Hillman (1982)). In India, economic policy is broadly set according to five-year plans. Trade policy was determined in the Second Plan (1956-1961) and had not changed over the years even as industries evolved over time. Given the earlier inward looking economic policies and the crisis of 1991, Hasan et al. (2007) argue that tariff reforms in 1992 came as a surprise and were externally driven.

Topalova and Khandelwal (2011) use the Annual Survey of Industry data to check whether the changes in tariffs between 1987 and 1997 across industries were motivated by political considerations. They use a range of industry characteristics such as employment, wages and average factory size to capture electoral power, industry concentration measures and political pressure groups and find no correlation between tariff reductions and pre-reform industry characteristics in 1987. By the end of the Eight Plan (1992-1997), external pressures had abated. India continued with trade reforms in the Ninth Plan (1997-2002). Trade policy in later years could have been influenced by political factors. Topalova and Khandelwal (2011) find evidence that in the years after 1997, tariff cuts may have been more selective to protect less efficient industries. Thus, similar to Goldberg et al. (2010), Topalova and Khandelwal (2011) and De Loecker, Goldberg, Khandelwal, and Pavcnik (2012), we focus on the first half of the period of trade reforms until 1997.

We extend the analysis on trade endogeneity in Topalova and Khandelwal (2011) by providing additional evidence that tariff levels between 1992-1997 were uncorrelated with the firm outcome measures we consider in this paper. One potential issue that may affect the reliability of our estimates of the impact of tariff liberalization on firm-level investment decisions is if the Indian policy makers chose import-protection measures in response to industry-level investment rates in domestic and foreign capital goods. If this was indeed the case, we would expect current investment rates in domestic and foreign capital goods to predict future measures of import protection.

We calculate industry level investment rates in foreign and domestic capital as the sales weighted average of firm-level investment rates in foreign and domestic capital goods respectively.[6] We then

[6]Here, industry refers to the four digit industry level.

Table 3.2: Trade Policy Endogeneity: Current Trade Policy (Tariffs) and Past Investment

Dependent Variable	(1) Output Tariff	(2) Intermediate Tariff	(3) Capital Tariff
Panel A			
Investment in Foreign Capital Goods	-0.775	-0.201	0.392
	(1.331)	(0.686)	(0.425)
Observations	673	673	673
R-squared	0.814	0.903	0.945
Panel B			
Investment in Domestic Capital Goods	0.059	-0.001	0.237
	(0.225)	(0.142)	(0.143)
Observations	673	673	673
R-squared	0.814	0.903	0.945

Notes: Panel A presents the panel regressions of current trade policy tool on lagged investment rate in foreign capital goods. Panel B presents the regressions of current trade policy tool on lagged investment rate in domestic capital goods. Estimations include controls for years and four-digit industry and are weighted by the number of firms in each four-digit industry in each particular year. Standard errors are robust and they are clustered at the four-digit industry level.

regress industry-level output tariffs, intermediate-input tariffs and capital-good tariffs in period $t + 1$ on industry-level domestic investment rates in period t. The results are presented in Table 3.2, Panel A. We also regress regress industry-level output tariffs, intermediate-input tariffs and capital-good tariffs in period $t + 1$ on industry level investment rates in imported capital goods during period t and present the results in Table 3.2, Panel B. We control for industry and year fixed effects in these regressions and weight each industry by the number of firms in the industry in the particular year.

The results show that for the period of our study, none of the three tariff rates (on final output, intermediate inputs and capital goods) depend on industry level investment rates in either domestic or foreign capital goods. None of the six estimated coefficients are statistically significant, with a mix of positive and negative estimates.

3.3 Theoretical Framework

In order to motivate the empirical specification, and to illustrate how tariffs on capital goods, intermediate inputs and final output can affect the investment decisions of a firm, we present a simple model of investment. We consider the investment problem of a monopolistically competitive firm that imports some of its capital, in addition to some of its variable inputs of production, and sells its output in the domestic market, where it faces foreign competition. Investment in domestic and imported capital goods are imperfect substitutes. At the beginning of period t, the firm optimally chooses the level of variable inputs, output price, and how much to invest in the two types of capital.

We assume that individuals consume a continuum of imperfectly substitutable domestic and foreign goods ($x(z)$ and $x^*(z)$, respectively), and the consumption basket is formed by the following CES aggregator:

$$X_t = \Big(\int_0^a x(z)^{\frac{\theta-1}{\theta}} \, dz + \int_a^1 x^*(z)^{\frac{\theta-1}{\theta}} \, dz \Big)^{\frac{\theta}{\theta-1}} \tag{3.1}$$

where X_t is the aggregate final good. The aggregate price index, P_t is given by:

$$P_t = \left[\int_0^a p_t(z)^{1-\theta} \, dz + \int_a^1 \left(\tau_t^O p_t^*(z) \right)^{1-\theta} \, dz \right]^{\frac{1}{1-\theta}} \tag{3.2}$$

where $p_t(z)$ is the price of a domestic variety z in the interval [0,a) , and $p_t^*(z)$ is the price of a foreign competitor z^* in the interval [a,1]. The effective price of a foreign good is $\tau_t^O p_t^*(z)$, where τ_t^O is the output tariff levied on foreign products.

The demand faced by the firm selling its output in an imperfectly competitive market is given by

$$x_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\theta} X_t \tag{3.3}$$

where x_{it} is the demand for firm i's product, p_{it} is the price the firm charges, and P_t and X_t are the aggregate price level and aggregate demand, respectively, as defined above. The parameter $\theta > 1$ denotes the price elasticity of demand, which depends upon the substitutability between the varieties.

Firm i enters period t with K_{it-1} units of capital. Given the demand function and the amount of capital the firm enters with, the firm optimally chooses the price of its output, in addition to the level of domestic and foreign variable inputs. Hence, at the beginning of each period, firm i maximizes profits conditional on all available information:

$$\Pi_{it} = \max_{p_{it}, L_{it}, L^*_{it},} \left[x_{it} p_{it} - w_t L_{it} - \left(\tau^I_t w^*_t \right) L^*_{it} \mid \Omega_{t-} \right] \tag{3.4}$$

subject to

$$x_{it} = F(K_{it-1}, L_{it}, L^*_{it})$$

where x_{it} is the product demand given in equation (3.3); L_{it} and L^*_{it} are the domestic and foreign inputs with prices (in units of the domestic currency) w_t and w^*_t, respectively, and τ^I_t is the tariff imposed on imported inputs; and Ω_{t-} is the information set available at the beginning of period t.

In every period, the firm also decides how much to invest in capital stock. Due to a one period time-to-build lag, the new capital resulting from total investment in period t becomes productive in the following period $t+1$. The firm chooses total investment expenditures I_{it} to maximize the expected present value of current and future profits subject to the standard capital accumulation equation.

$$V_{it}(K_{it-1}) = \max_{I_{it}} \left\{ \Pi_{it} - G\left(K_{it-1}, I_{it}\right) - I_{it} + \beta E_t \left[V_{it+1}(K_{it}) \right] \right\} \tag{3.5}$$

subject to

$$K_{it} = (1-\delta) K_{it-1} + I_{it} \tag{3.6}$$

where Π_{it} be the optimal variable profit of firm i from the optimization problem (3.4), β is the discount factor, δ is the rate of depreciation, and $G\left(K_{it-1}, I_{it}\right)$ denotes the cost of altering the capital stock, which leads to a loss of a fraction of total investment. The first order conditions of the firm's problem (Appendix B.1) yield the Euler equation:

$$1 + \frac{\partial G\left(K_{it-1}, I_{it}\right)}{\partial I_{it}} = \beta E_t \left[\frac{\partial \Pi_{it+1}}{\partial K_{it}} - \frac{\partial G\left(K_{it}, I_{it+1}\right)}{\partial K_{it}} + (1-\delta) \left(1 + \frac{\partial G\left(K_{it}, I_{it+1}\right)}{\partial I_{it+1}} \right) \right] \tag{3.7}$$

This implies that along the optimal path, the marginal cost of investing in a new unit of capital equals the present discounted value of the marginal return to capital. The marginal return depends on the marginal profitability of capital (net of adjustment costs) and the value of undepreciated capital.

Total investment is a constant elasticity of substitution (CES) aggregator of purchases of domestic and imported capital goods:

$$I_{it} = \left[(1-\mu_i)^{\frac{1}{\omega}} I_{Dit}^{\frac{\omega-1}{\omega}} + \mu_i^{\frac{1}{\omega}} I_{Mit}^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}} \tag{3.8}$$

where I_{Dit} and I_{Mit} are the purchases of domestic and imported capital goods, $\omega > 0$ is the elasticity of substitution between them, and μ_i is the weight on imported capital goods in the investment basket.[7] We normalize the price of the investment basket to 1, and denote the relative price of imported capital goods with $\tau_t^K P_{Mt}$, where τ_t^K is the tariff imposed on foreign capital goods. From the firm's cost-minimization problem (Appendix B.2), we obtain the following demand function for imported capital goods:

$$I_{Mit} = \mu_i \left(\tau_t^K P_{Mt}\right)^{-\omega} I_{it} \tag{3.9}$$

This demand function reveals the direct mechanism through which tariffs on capital goods affect investment in foreign capital goods. All else constant, a reduction in the tariffs on capital goods, τ_t^K, lowers the relative price of investment in foreign capital, and thereby increases the demand for it.

Output tariffs and the tariffs on intermediate inputs affect investment in foreign capital goods through the marginal profitability of capital. In order to characterize the marginal profitability of capital, $\frac{\partial \Pi_{it+1}}{\partial K_{it}}$, we use the first order conditions from the optimization problem (3.4) and assume that the production function, $F(\cdot)$, is homogeneous of degree one. We differentiate the resulting

[7] We assume that the elasticity of substitution between domestic and foreign capital goods is constant across firms and across time, but the weights, μ_i, are firm-specific.

profit function to obtain the expression for the marginal profitability of capital (Appendix B.3):

$$\frac{\partial \Pi_{it}}{\partial K_{it-1}} = \left[\frac{1}{K_{it-1}} \left(\frac{x_{it}p_{it}}{\psi} - w_t L_{it} - \left(\tau_t^I w_t^*\right) L_{it}^* \right) \mid \Omega_{t-} \right] \tag{3.10}$$

where $\psi = \frac{\theta}{\theta-1}$ denotes the mark-up (price-to-cost margin). We can see from equation (3.10) that a reduction in input tariffs lowers costs and raises the marginal profitability of capital and investment.

From equation (3.10), we can also see how output tariffs affect investment decisions. Changes in output tariffs affect marginal profitability of capital through changes in foreign competitors' prices and as a result, the firm's revenue, $x_{it}p_{it}$.

$$\frac{\partial \left(x_{it}p_{it}\right)}{\partial \tau_t^O} = \frac{\partial \left(x_{it}p_{it}\right)}{\partial P_t} \frac{\partial P_t}{\partial \tau_t^O} = \theta \frac{x_{it}p_{it}}{\tau_t^O} \left(\frac{1}{P_t}\right)^{1-\theta} \left[\int_a^1 \left(\tau_t^O p^*(z)\right)^{1-\theta}) \, dz \right] > 0 \tag{3.11}$$

The positive relationship in expression (3.11) between sales and output tariffs implies that a reduction in τ_t^O lowers the effective price individuals pay on foreign varieties, and thereby reduces the demand for firm i's product. As a result, the reduction in output tariff lowers marginal profitability of capital and investment.

Equation (3.10) reveals an additional important factor that mediates the relationship between investment and changes in tariffs. The firm's mark-up, ψ which is closely linked to the degree of competition, as well as the industry structure, plays an important role in determining the sensitivity of investment to changes in tariffs. The higher the mark-up ratio, the more adversely affected will a firm be by a reduction in output tariffs due to the import competition that lower tariffs generate. On the other hand, the reduction in output tariffs may not affect low mark-up firms as much, since they have already been exposed to ample domestic competition.[8]

To characterize the investment Euler equation (3.7), we adopt the standard convex adjustment cost assumption, and adopt the following functional form:

$$G\left(K_{t-1}, I_t\right) = \frac{\gamma}{2} \left(\frac{I_t}{K_{t-1}} - \frac{\bar{I}}{K} \right)^2 K_{t-1} \tag{3.12}$$

[8] Since $\psi = \frac{\theta}{\theta-1}$, $\frac{\partial \psi}{\partial \theta} < 0$ and $\frac{\partial^2 (x_{it}p_{it}/\psi_i)}{\partial \tau_t^O \partial \theta} < 0$, we will have that $\frac{\partial^2 (x_{it}p_{it}/\psi_i)}{\partial \tau_t^O \partial \psi} > 0$

where γ is the adjustment cost parameter, and $\frac{\bar{I}}{K}$ is the steady-state value of the investment rate. We can obtain the fully-parametrized investment equation by substituting the partial derivatives of the adjustment cost function in equation (3.12), and the marginal profitability of capital in equation (3.10) into the Euler equation in (3.7). Furthermore, by combining the demand for imported capital goods in equation (3.9) with the Euler equation, we can obtain the decision rule for investment in foreign capital. Given the functional forms, this generates a non-linear equation in the variables of interest. In order to simplify the interpretation of the coefficients and to obtain an equation that can be used as the basis for our empirical specification, we linearize the Euler equation using a first-order Taylor approximation around the steady state. After linearizing and rearranging the terms, we obtain the following investment equation:

$$\frac{I_{Mit}}{K_{it-1}} = E_t \left[\phi_0 + \phi_1 \frac{I_{Mit+1}}{K_{it}} + \phi_2 \frac{S_{it+1}}{K_{it}} - \phi_3 \frac{Z_{it+1}}{K_{it}} - \phi_4 \frac{Z^*_{it+1}}{K_{it}} + \phi_5 \left(\tau^K_{t+1} P_{Mt+1} \right) - \phi_6 \left(\tau^K_t P_{Mt} \right) \right] \tag{3.13}$$

where S_{it+1} is the value of total sales $(x_{it+1} p_{it+1})$, Z_{it+1} is the cost of domestic inputs $(w_{t+1} L_{it+1})$, and Z^*_{it+1} is the cost of imported inputs $(\tau^I_{t+1} w^*_{t+1} L^*_{it+1})$. The ϕ's are positive constants that are functions of the structural parameters of the model. See the Appendix for the details of the Taylor approximation and the expressions for the ϕ's.[9] Equation (3.13), which presents the first-order approximation of the model, shows that the investment process depends on future investment, expected sales, expected domestic costs and imported input costs, as well as the current and expected prices of imported capital. The coefficients on the tariff terms suggest that if the current tariff rates on capital goods are high, then the firm's investment in foreign capital goods during that period will be low. At the same time, if the firm expects tariff rates to be higher in the future, keeping current rates constant, they will choose to invest more today to circumvent the higher rates in the future.

[9] We can similarly obtain a linear equation for total investment or investment in domestic capital goods, which can be used to estimate the impact of trade liberalization on total investment or on investment in domestic capital goods.

3.4 Data

The firm-level variables are from Prowess, a panel data of Indian firms. The data are collected by the Centre for Monitoring of the Indian Economy (CMIE), and contain information on listed and unlisted firm and accounts for about 70 percent of the organized industrial activity.[10] In addition to the variables commonly found in most firm-level data-sets (capital stock, sales, wages, expenditure on intermediate inputs etc.), the data also contain information on the foreign exchange transactions of firms, including the imports of capital goods. This information, along with the capital stock series allows us to construct the domestic and foreign capital investment measures for the firms.

Firms are classified into industries based on the 2008 National Industrial Classification (NIC). The NIC 2008 classification is based on the International Standard Industrial Classification (ISIC) Rev.4. We use data on manufacturing firms (NIC two digits, 10 through 31). For the period of the study, we have data on 9,486 firm-year observations. The 2,512 unique firms in the data-set are classified into 99 four digit industry groups. To construct firm-level total investment expenditures, we take the annual difference in the current value of the gross fixed assets, which measures the value of the firm's capital. As imports of capital goods measure investment expenditures in foreign capital, we subtract imports of capital goods from total investment expenditures to calculate investment in domestic capital goods.

As shown in Section 3.3, firm's market power could determine how investment rates respond to changes in tariffs. Firms with high market power can be more sensitive to reductions in output tariffs due to increased competition from abroad, while they can also be less sensitive to changes in intermediate input tariffs. We use use firm-level markups as a proxy for market power in our estimations. We construct the markup variable using the information provided in Prowess. Following Campa and Goldberg (1999), we define the average markup, ψ_i, for firm *i* (averaged over our sample period from 1990 to 1997) as

$$\psi_i = \frac{value\,of\,sales_i + \Delta inventories_i}{payroll_i + cost\,of\,materials_i} \tag{3.14}$$

[10]The data have been used in several papers including Goldberg et al. (2010)and Topalova and Khandelwal (2011).

We examine whether the scope for quality differentiation within an industry impacts how firms respond to reductions in output tariffs. Firms belonging to industries with "long" quality ladders or greater scope for product differentiation may be less sensitive to reductions in output tariffs since firms may upgrade quality in order to not lose out on the marginal profitability. The data on quality ladders, a proxy for vertical differentiation, are from Khandelwal (2010). The variable is a time invariant industry specific measure. The data were made available at the four-digit SIC (rev.1987) classification and were matched to the NIC 2008 industrial classification.

We supplement the firm-level data with information on policy variables. The data on final goods tariffs are from Topalova and Khandelwal (2011). These data were made available based on the NIC 1987 three digit classification and were matched to NIC 2008 four digit industries.[11] We use the data on output tariffs to construct input tariffs similar to Amiti and Konings (2007) by passing output tariff through the input-output (I-O) matrix. However, unlike Amiti and Konings (2007) who construct an aggregate input tariff, we construct separate tariffs for intermediate inputs and capital goods. Classification of Industries into intermediate and capital goods was done based on the United Nations classification by Broad Economic Categories. We use the Input-Output Transactions Table from India for $1993 - 1994$ to obtain the weights for constructing the intermediate inputs and capital inputs tariffs. Sectors $77 - 84$ and $87 - 96$ are classified as capital goods industries and the remaining sectors up until sector 98 are classified as intermediate inputs industries. The sectors from the I-O Table were matched to the NIC Industries and the input tariffs were constructed as follows:

$$\tau_{kt}^{j} = \sum_{s} w_{sk}^{j} \tau_{st} \tag{3.15}$$

where j refers to capital or intermediate inputs, τ_{kt}^{j} is the j input tariff of industry k in period t, w_{sk}^{j} is the value share of industry s in output of industry k and τ_{st} is the output tariff of industry s in period t. The weights are constructed from the I-O coefficient matrix of $1993 - 1994$ such that $\sum_s w_{sk}^{j} = 1$ for each j. See appendix B.5 for details.

[11] The NIC 1987 three digit industries correspond to NIC 2008 four digit industries. However, because of reclassification of industrial groups over time, in some cases, they were matched to five digit industries.

Table 3.3: Summary Statistics

Variable	Mean	St. Dev.	Min	Max
Investment in Foreign Capital Goods $\left(\frac{I_{Fijt}}{K_{ijt-1}}\right)$	0.036	0.187	0	10.05
Investment in Domestic Capital Goods $\left(\frac{I_{Dijt}}{K_{ijt-1}}\right)$	0.243	0.669	0	22.62
Sales $\left(\frac{S_{ijt}}{K_{ijt-1}}\right)$	3.298	6.114	0.004	409.9
Cash-Flow $\left(\frac{C_{ijt}}{K_{ijt-1}}\right)$	-0.248	0.869	-32.62	3.956
Average Markup (ψ_i)	0.618	0.088	0	1.128
Output Tariff $\left(\frac{\tau^O_{jt}}{100}\right)$	0.594	0.244	0.088	3.263
Intermediate Input Tariff $\left(\frac{\tau^I_{jt}}{100}\right)$	0.543	0.182	0.142	1.115
Capital Input Tariff $\left(\frac{\tau^K_{jt}}{100}\right)$	0.532	0.198	0.260	1.274
License	0.113	0.273	0	1
FDI	0.579	0.419	0	1
Quality ladder	2.283	0.299	1.219	3.325
Herfindahl index	0.141	0.149	0.016	1

Notes: The number of observations is $9,486$ and the number of firms is $2,512$.

During the trade liberalization episode in the 1990s, the Indian government also introduced other industrial reforms. These policy changes include liberalizing the licensing requirements (for setting up and expanding capacity) and lowering of entry barriers to foreign investment. In order to identify the distinct effects of trade liberalization, we control for these concurrent reforms in our empirical specifications. The data on these policy variables are from Topalova and Khandelwal (2011). The data are coded between 0 and 1 and are industry and time varying. They represent the share of products in an industry subject to licensing requirements (License) and the share of products which have automatic approval for foreign investment (FDI).

The data on trading partner share of total imported capital goods presented in Table 3.1 are from the World Bank Trade, Production and Protection (1976-2004) database. Table 3.3 presents the summary statistics for investment rates, and all the explanatory variables (both firm-level variables and policy variables) used in our specifications.

3.5 Empirical Investment Equation and Estimation

The theoretical framework in Section 3.3 motivates the relationship between investment and different types of tariffs. For brevity, we refer to the tariffs on intermediate inputs as input tariffs and the tariffs on capital goods as capital tariffs. The theoretical framework illustrates how capital, input and output tariffs affect investment decisions, and it also suggests other firm-specific determinants of investment (such as sales and costs). Because our main goal is to estimate the impact of trade liberalization on investment, instead of focusing on the structural process, we estimate a reduced form equation for investment in foreign capital goods.[12]

We start by estimating the following baseline specification, which takes equation (3.13) as its basis, and focuses on the main effect of tariffs on investment:

$$\frac{I_{Mijt}}{K_{ijt-1}} = \alpha_1 \frac{I_{Mijt-1}}{K_{ijt-2}} + \alpha_2 \frac{S_{ijt}}{K_{ijt-1}} + \alpha_3 \frac{S_{ijt-1}}{K_{ijt-2}} + \alpha_4 \frac{C_{ijt}}{K_{ijt-1}} + \alpha_5 \frac{C_{ijt-1}}{K_{ijt-2}} + \alpha_6 \tau^K_{jt} + \alpha_7 \tau^I_{jt} + \alpha_8 \tau^O_{jt} + \upsilon_i + \eta_t + \varepsilon_{ijt} \tag{3.16}$$

where $\frac{I_{Mijt}}{K_{ijt-1}}$ denotes the investment rate in imported capital goods (I_M) for firm i, in industry j in year t; and $\frac{S_{ijt}}{K_{ijt-1}}$ and $\frac{C_{ijt}}{K_{ijt-1}}$ are the firm's total sales and cash flow, respectively, normalized by its capital stock.[13] The terms τ^K_{jt}, τ^I_{jt}, and τ^O_{jt} denote the capital, input, and output tariff measures for industry j, in year t, respectively. Note that we include industry specific input, capital and output tariffs as measures of protection in the baseline specification (3.16) simultaneously. It is important to include all of these three measures together in the model because they are positively correlated (see Figure 3.1). As we demonstrate in the results section, if we exclude one or more from the specification, for example if we only include output tariffs, omitted variable bias becomes a potential issue.

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[12]In their review of the empirical literature on microeconometric models of investment, Bond and Van Reenen (2008) note that this type of reduced form model can be interpreted as representing an empirical approximation to the underlying investment process.

[13]The normalization by capital stock naturally arises in a model with quadratic adjustment costs, and it allows us to control for the size of the firm.

In order to address some of the econometric issues in estimating the empirical relationship between investment and these tariff measures, we modify equation (3.13) in a number of ways. First, following Fazzari, Hubbard, and Petersen (1988), we include cash flow as a proxy for financing constraints, which arise due to capital market imperfections. Cash flow can be an important determinant of investment for Indian firms, since firms might find it difficult to smooth investment via external capital markets.[14] Empirically, cash flow is constructed as the difference between sales and total costs, adjusted for taxes and depreciation.[15] Because costs and cash flow are highly correlated, we include only cash flow in the specification in order to minimize collinearity problems. Second, to allow for serial correlation in sales and cash flow, we include the current and the lagged values of those variables. Moreover, we include the lagged investment rate to control for the autocorrelation that may arise due to adjustment costs. Since the adjustment costs presumably depends on all investment expenditures, in more exhaustive specifications, we include the lagged investment rates for both foreign and domestic capital goods.

The specification also includes firm specific fixed effects, υ_i, that capture the time-invariant plant-level determinants of investment, as well as year dummies, η_t, that capture aggregate economy-wide fluctuations. Macroeconomic factors common to all firms, such as changes in the exchange rates, will be captured by these year effects. However, firms in different industries might face different economic conditions or different productivity trends. In order to allow for industry-specific productivities, we include interaction terms between two-digit industry dummies and a linear time-trend. Moreover, in some specifications, we include interaction terms between the time trend and a full set of state dummies in order to control for economic trends that differ across various regions. Finally, we assume that the error term, ε_{ijt}, is i.i.d with $E(\varepsilon_{ijt}) = 0$.

In order to analyze the heterogeneity in the investment behavior of firms, we augment the baseline specification (3.16) in several ways. First, to check how the impact of trade liberalization

[14] Examples of previous work that have shown the importance of financing constraints for investment in developing countries include Jaramillo, Schiantarelli, and Weiss (1996), Love (2003), and Harrison, Love, and McMillan (2004).

[15] Total costs include domestic and imported material costs, as well as labor costs and costs of industrial and non-industrial services.

on investment depends on the firm's mark-up, we include an interaction term between the average mark-up of the firm and the output tariff measure. As discussed in Section 3.3, a reduction in output tariffs can reduce investment more in high mark-up firms, as they begin to face more stiff competition from abroad and experience a decrease in marginal profitability. Hence, we expect this interaction term to intensify effects of the output tariffs.

Next, we examine whether the scope for quality differentiation within an industry impacts how a firm responds to increased competition. We include an interaction term betwen output tariffs and the quality ladder index and an interaction term between the Herfindahl index of domestic competition and the quality ladder index to examine how the impact of greater foreign and domestic competition on firm investment in foreign capital goods is mediated by the level of vertical differentiation in the industry.

We then move on to some sub-sample analysis with respect to importing and exporting status of the firm. We recognize that imported intermediate goods may be complementary to imported capital goods. Therefore, importers of intermediates might not only respond to reductions in input tariffs more strongly, but also respond to reductions in capital tariffs more intensely. To examine this, we estimate the baseline specification for the sub-sample of firms that are importers of intermediate inputs. We also provide sub-sample analysis for exporters versus non-exporters.

We also analyze the the heterogeneity in the impact of lower tariffs on investment in imported capital goods based on where firms are located in the productivity distribution. We classify firms into four quartiles based on their productivity levels and generate dummies. We then interact these dummy variables with the tariff measures, and estimate an augmented investment equation with twelve tariff interaction terms (three tariff measures times the quartile dummies).

We estimate the dynamic investment equation (3.16) and the augmented specifications using the *system-GMM estimator* of Arellano and Bover (1995) and Blundell and Bond (1998). This estimator for panel data sets with short time dimension addresses the potential biases that arise from the correlation between the firm fixed effects, υ_i, and the lagged dependent variable, $\frac{I_{Mijt-1}}{K_{ijt-2}}$, as well as the endogeneity of sales, $\frac{S_{ijt}}{K_{ijt-1}}$, and cash flow, $\frac{C_{ijt}}{K_{ijt-1}}$. The system-GMM estimator combines the first-difference equations, whose regressors are instrumented by their lagged levels, with equations in levels, whose regressors are instrumented by their first-differences.[16] We treat all of the firm-specific variables as endogenous, and use lagged values dated $t-2$ and $t-3$ as the GMM-type instruments.[17] We also include lags 2 and 3 of total intermediate costs and other expenses in the set of GMM-type instruments. We employ and report the second order serial correlation tests and the Sargan-Hansen tests of over-identification to check the validity of our instruments. In all specifications, we cluster the standard errors at the NIC five-digit industry level.[18]

3.6 Results

We start by estimating the impact of capital, input and output tariffs on firm's investment in foreign capital goods in India, as specified in equation (3.16). In this first set of results, we evaluate the average impact of the trade liberalization on investment in imported capital goods, and illustrate how changes in capital, input and output protection measures affect investment differently, as our theoretical framework suggests. Next, we present results from alternative specifications that include past tariffs, and specifications for total investment, and investment in domestic capital goods. In doing so, we show that the significant gains from trade liberalization emerged from investment in foreign capital goods, and not domestic capital goods. In subsection 3.6.3, we document the importance of the firm's market power, and the the product market's scope for differentiation in mediating the effects of trade liberalization on investment in foreign capital. In subsection 3.6.4, we analyze whether exporting status and importing intermediate inputs matter for investment in imported capital goods. Next, we discuss the heterogeneity in the impact of the trade liberalization across firms of different size an productivity levels in subsection 3.6.5. Finally, in subsection 3.6.6, we evaluate the overall impact of the trade liberalization in India on the investment in foreign

[16]The *system-GMM estimator* builds on the *difference-GMM estimator* of Arellano and Bond (1991), which uses only the differenced equations, instrumented by the lagged levels of the regressors. If the regressors are persistent, then their lagged levels are shown to be weak instruments. See Arellano and Bover (1995) and Blundell and Bond (1998) for more details. To avoid this drawback of the *difference-GMM estimator*, we opt for the *system-GMM estimator*.

[17]In some specifications, including lagged value dated $t-2$ of the investment rate as a GMM-type instrument violates the validity of the Sargan-Hansen tests of over-identification. In those cases, we include only the lagged value dated $t-3$ of the investment rate in the instrument set.

[18]All the estimations and tests were done using the *xtabond2* command in Stata.

capital goods at the aggregate and industry levels.

3.6.1 Main Effects of Trade Liberalization on Investment in Foreign Capital Goods

Table 3.4 presents the results from our baseline specification (3.16) for investment in foreign capital goods, which includes firm and year fixed effects, as well as industry specific time trends.[19] In order to highlight the importance of distinguishing between tariffs on capital goods, intermediate inputs, and final products to evaluate the impact of trade liberalization on investment decisions, first we present the results from a specification with just the output tariff measure. In the second and third columns, we progressively add input and capital goods tariff measures, and evaluate the direct and indirect effects of trade liberalization on investment decisions.

Column (1) of Table 3.4 shows that, as our theoretical model suggests, the coefficient on output tariffs is positive, but it's not statistically significant. The positive coefficient suggests that a reduction in output tariffs might lower the marginal profitability of capital due to intensified foreign competition, and thereby lower investment in imported capital. When we add input tariffs in column (2), the coefficient on output tariffs increases slightly but remains insignificant. The negative coefficient on input tariffs, albeit being small and insignificant, suggests that a reduction in input tariffs may increase investment in foreign capital by lowering the cost of intermediate inputs and therefore increasing the marginal profitability of capital. Next, we include tariffs on capital goods in column (3). As expected, the coefficient on capital-good tariffs is negative and it is highly significant, providing direct evidence for the notion that trade liberalization allows firms to invest more in foreign capital by making them cheaper. The coefficient on output and input tariffs remain insignificant.

In column (4), we augment the specification with a measure of licenses, which measures the share of products that are subject to an industrial license, and with a measure of openness to

[19] Notes on Table 3.4: Number of observations is 9,486 and number of firms is 2,512. The estimates and standard errors are obtained from the two-step system GMM procedure with the Windmeijer (2005) small-sample correction. Standard errors are clustered at the 5 digit NIC level, and are in parentheses. All firm-specific regressors are treated as endogenous. A set of year effects and industry-specific time trends are included in all specifications. The p-values for the Hansen over-identification test and the second order serial correlation tests are reported. ***, **, * denote significance at the 1, 5, and 10% level, respectively. Lags 2 and 3 of the investment rate, sales and cash-flow intermediate input costs and other operating costs are included as GMM-type instruments. All industry-level variables are included as IV-type instruments.

Table 3.4: Main Effects of Trade Liberalization on Investment in Foreign Capital Goods

Dependent Variable: $\frac{I_{Mijt}}{K_{ijt-1}}$	(1)	(2)	(3)	(4)	(5)	(6)
Lagged foreign capital investment $\left(\frac{I_{Mijt-1}}{K_{ijt-2}}\right)$	0.086***	0.086***	0.086***	0.086***	0.088***	0.087***
	(0.009)	(0.009)	(0.009)	(0.010)	(0.008)	(0.010)
Sales $\left(\frac{S_{ijt}}{K_{ijt-1}}\right)$	0.003	0.003	0.003	0.003	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Lagged sales $\left(\frac{S_{ijt-1}}{K_{ijt-2}}\right)$	0.002*	0.002*	0.002	0.002*	0.001*	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Cash-flow $\left(\frac{C_{ijt}}{K_{ijt-1}}\right)$	0.013	0.013	0.013	0.013	0.016	0.016
	(0.021)	(0.021)	(0.021)	(0.021)	(0.019)	(0.020)
Lagged cash-flow $\left(\frac{C_{ijt-1}}{K_{ijt-2}}\right)$	0.015*	0.015*	0.015*	0.015*	0.011	0.012
	(0.008)	(0.009)	(0.009)	(0.009)	(0.008)	(0.009)
Output tariff $\left(\frac{\tau^O_{jt}}{100}\right)$	0.010	0.015	0.017	0.014	0.016*	0.017*
	(0.010)	(0.012)	(0.011)	(0.011)	(0.008)	(0.009)
Input tariff $\left(\frac{\tau^I_{jt}}{100}\right)$		-0.017	-0.015	-0.017	-0.016	-0.022
		(0.015)	(0.012)	(0.014)	(0.010)	(0.015)
Capital goods tariff $\left(\frac{\tau^K_{jt}}{100}\right)$			-0.032***	-0.028**	-0.030***	-0.034**
			(0.012)	(0.012)	(0.008)	(0.014)
License				-0.011*	-0.011*	-0.013**
				(0.006)	(0.006)	(0.006)
FDI				-0.013	-0.012	-0.011
				(0.009)	(0.010)	(0.009)
Lagged domestic capital investment $\left(\frac{I_{Dijt-1}}{K_{ijt-2}}\right)$						-0.007*
						(0.004)
Regional time trends	no	no	no	no	yes	yes
Hansen-Sargan test (p-value)	0.638	0.585	0.654	0.513	0.642	0.715
1st order serial correlation test (p-value)	0.007	0.007	0.007	0.007	0.007	0.007
2nd order serial correlation test (p-value)	0.251	0.252	0.250	0.245	0.225	0.209

FDI, both of which are obtained from Topalova and Khandelwal (2011). The results show that the coefficients on the tariff measures remain very similar to the estimates presented in column (3). While the coefficients on both licence coverage and FDI openness are negative, only the former is significant. This result suggests that the higher the share of products subject to licensing in an industry, the lower the investment in imported capital goods will be. In column (5), we further augment the specification with state-specific time-trends, capturing, for example, different dynamic productivity trends across the states in India.[20] Accounting for the state-level variation increases the precision of the estimates, and yields a coefficient on output tariffs that is significant at the 10 percent level. The coefficient on capital goods tariffs remain highly significant at the 1 percent level when we include state-specific time trends, and the coefficient on input tariffs remain insignificant.

In the last column, we augment the general specification in column (5) with the lagged investment rate for domestic capital. A high level of investment in domestic capital goods in the previous year can lead the firm to invest less (more) in imported capital goods if the two types of goods are substitutes (complements). The negative and significant (at the 10 percent level) estimate in column (6) suggest that foreign and domestic capital goods can be substitutes, and as such, large domestic capital investments can be followed by smaller investments in foreign capital. The estimates also show that the coefficients on tariff measures increases slightly in magnitude when we account for past investment in domestic capital.

Focusing on the most general specification in column (6) of Table 3.4, we can quantify the impact of reductions in tariffs on investment in imported capital goods. The estimated coefficient on the capital goods tariffs of -0.034 indicates that the semi-elasticity of the investment rate, $\frac{I_{Mijt}}{K_{ijt-1}}$, with respect to capital goods tariffs is 0.00944 at the sample mean, which suggests that a 10 percentage point reduction in the capital goods tariffs leads to a 9.44 percent increase in investment in foreign capital goods.[21] Although the coefficient on input tariffs of -0.022 is not statistically

[20]The state indicators in our data is that they are based on the state where the firm head-quarter is located, which might not necessarily be the location where the investment and the production take place.

[21]The semi-elasticity of the investment rate, $\frac{I_{Mijt}}{K_{ijt-1}}$, with respect to capital goods tariffs, τ_{jt}^{K}, at the sample mean is

significant, it suggests that a similar 10 percentage point reduction in input tariffs can lead to a 6.11 percent increase in invested in foreign capital goods. The larger and statistically significant impact of the change in capital goods tariffs is not surprising, since lowering capital goods tariffs directly increases the demand for foreign capital goods by making them cheaper. The input tariffs, on the other hand, work indirectly through the demand for imported intermediate inputs. When intermediate inputs become cheaper as a result of a reduction in input tariffs, firms are able to import more intermediate inputs, increasing the marginal profitability of capital. This suggested mechanism conforms with the findings in Bas and Berthou (2013), who find that the reductions in input tariffs increased the probability of importing capital goods for Indian firms. Lastly, we evaluate the effect of output tariffs. The coefficient of 0.017 suggests that a 10 percentage point reduction in output tariffs leads to a 4.72 percent decrease in investment in imported capital goods by enhancing foreign competition and thereby reducing the marginal profitability of capital.

Turning to the other determinants of investment, lagged investment in foreign capital goods is positive and statistically significant in all six specifications, demonstrating the serial correlation in investment in imported capital goods. In terms of other firm-specific determinants, the coefficient on lagged sales is statistically significant at the 10 percent level in all specifications, and the lagged cash-flow is positive and significant at 10 percent in some of the cases. All specifications in Table 3.4 are supported by the tests of over-identifying restrictions, for which the Hansen test statistic fails to reject the validity of the instrument sets. Moreover, the tests for serial correlation, which are applied to the residuals in the first differenced equations ($\Delta\varepsilon_{ijt}$), show that we can reject the null-hypothesis of no first-order serial correlation, but cannot reject the null-hypothesis of no second order serial correlation.[22] The fact that the errors only have first order autocorrelation confirms the validity of instruments dated $t-2$ and $t-3$.

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calculated as -0.00034/0.036=0.00944.

[22]Assuming that the residuals, ε_{ijt}, in equation (3.16) are i.i.d, we expect $\Delta\varepsilon_{ijt}$ in the first-differenced equations to have first order autocorrelation.

3.6.2 Alternative Specifications

In this subsection, we consider alternative specifications for evaluating the impact of trade liberalization on firm's investment. We begin by augmenting the most general specification in column (6) of Table 3.4 with the lagged value of the capital goods tariff measure. The theoretical investment equation we obtain (see equation (3.13)) suggests that both the current and the expected tariffs on capital goods matter for inter-temporal investment decisions. Since the empirical specification in (3.16) corresponds to the theoretical investment equation lagged by one-period, both the contemporaneous (dated t) and the lagged capital tariffs (dated $t-1$) can affect foreign capital investment decisions taken in period t. Column (1) of Table 3.5 presents the estimates obtained from this augmented equation. The coefficient on the contemporaneous capital tariff rate of -0.048 is larger in magnitude compared to the baseline estimates in Table 3.4, and is significant at 10 percent, implying that the firms choose to invest more in foreign capital goods in a given year if the tariff rates on capital goods are lowered during that year. On the other hand, the coefficient on the lagged capital tariff measure is positive, albeit not significant. This result suggests that firms facing high tariff rates in the past year might have postponed purchasing foreign capital goods, and they increase their investment in these goods in the following period when the tariffs were lowered.

Next, we investigate whether trade liberalization has impacted total investment and investment in domestic capital goods similarly. Column (2) of Table 3.5 presents the results for estimating equation (3.16) for total investment, and column (3) presents the results for investment in domestic capital goods. We would expect the input and output tariffs to have the same effect on investment in domestic capital goods and on foreign capital goods, since both tariff measures affect the marginal profitability of capital (see equation (3.10)), which would matter for investment decisions in both types of capital goods. However, how capital goods tariffs affect investment in domestic capital goods is a priori ambiguous. If domestic and foreign capital goods are substitutes, a reduction in capital goods tariffs should lower investment in domestic capital goods, as the reduction makes foreign capital goods relatively cheaper. If they are complements, however, cheaper foreign capital goods could also make the firm purchase more domestic capital goods.

Table 3.5: Alternative Specifications

Dependent Variable– Investment rate:	(1) Foreign capital	(2) Total	(3) Domestic capital
Lagged foreign capital investment $\left(\frac{I_{Mijt-1}}{K_{ijt-2}}\right)$	0.089***		
	(0.009)		
Lagged domestic capital investment $\frac{I_{Dijt}}{K_{ijt-1}}$	-0.001		0.040*
	(0.006)		(0.024)
Lagged total investment $\frac{I_{Tijt}}{K_{ijt-1}}$		0.055	
		(0.034)	
Sales $\left(\frac{S_{ijt}}{K_{ijt-1}}\right)$	0.003	0.023***	0.019***
	(0.002)	(0.006)	(0.005)
Lagged sales $\left(\frac{S_{ijt-1}}{K_{ijt-2}}\right)$	0.001	0.014	0.012
	(0.001)	(0.012)	(0.011)
Cash-flow $\left(\frac{C_{ijt}}{K_{ijt-1}}\right)$	0.016	-0.134	-0.125
	(0.019)	(0.239)	(0.207)
Lagged cash-flow $\left(\frac{C_{ijt-1}}{K_{ijt-2}}\right)$	0.010	0.231	0.190
	(0.006)	(0.188)	(0.157)
Output tariff $\left(\frac{\tau_{jt}^{O}}{100}\right)$	0.014*	0.047	0.027
	(0.008)	(0.058)	(0.062)
Input tariff $\left(\frac{\tau_{jt}^{I}}{100}\right)$	-0.020	0.125	0.143
	(0.015)	(0.093)	(0.090)
Capital goods tariff $\left(\frac{\tau_{jt}^{K}}{100}\right)$	-0.048*	-0.065	-0.053
	(0.027)	(0.118)	(0.105)
Lagged capital goods tariff $\left(\frac{\tau_{jt-1}^{K}}{100}\right)$	0.013		
	(0.025)		
License	-0.011*	-0.034	-0.023
	(0.006)	(0.033)	(0.029)
FDI	-0.011	-0.006	-0.004
	(0.010)	(0.036)	(0.032)
Number of observations	9,486	9,486	9,486
Number of firm	2,512	2,512	2,512
Hansen-Sargan test (p-value)	0.628	0.484	0.547
1st order serial correlation test (p-value)	0.00677	7.79e-08	7.38e-08
2nd order serial correlation test (p-value)	0.230	0.432	0.608

While the sign of the coefficients on output and capital tariff measures in columns (2) and (3) are similar to the estimates for investment in foreign capital goods in Table 3.4, they are not statistically significant. Contrary to our expectations, the coefficient on input tariff measure is positive, but not significant, in both specifications. It is not surprising that the results for total investment resembles the results for investment in domestic capital goods, since on average investment in domestic capital goods makes up 87 percent of total investment expenditures. These results imply that an important benefit of trade liberalization accrue from enhanced ability of firms to invest in foreign capital goods.

3.6.3 Mark-ups and Quality Ladder

In this subsection, we analyze the roles of market power, degree of competition, and the product market's scope for quality differentiation in mediating the impact of output tariffs on firm investment in foreign capital goods. The theoretical framework in Section 3.3 suggests that the effect of output tariffs can be increasing in the size of the firm's mark-up. A firm with higher market power, i.e., with a higher mark-up, can be affected more adversely by lower output tariffs because of the heightened import competition that erodes the marginal profitability of the firm. To check for this, we include an interaction term between the average mark-up of the firm and the output tariff measure in our main specification.

The results are presented in column (1) of Table 3.6.[23] As expected, the interaction term between the average mark-up of the firm and the output tariff is positive with a coefficient of 0.190 and is highly significant. Unlike the interaction term, the coefficient on the output tariff measure is negative (-.092) and significant. The coefficients jointly suggest that a 10 percentage point reduction in output tariffs at the sample mean (the mean mark-up in the sample is .618) leads to a 7.06 percent decrease in investment in imported capital goods. The positive interaction term implies that a firm with a mark-up one standard deviation higher than the mean reduced investment

[23]Notes on Table 3.6: The first column augments the baseline model in column (6) of Table 3.4 with an interaction term between the output tariff measure with the average mark-up of the firm,ψ_i^H. Column (2) augments the baseline model in column (6) of Table 3.4 with an interaction term between the output tariff measure with the quality ladder index, the Herfindahl index measuring the competition at the 4-digit NIC industries, and the interaction term between the Herfindahl index and the quality ladder measure. See Table Table 3.4 for additional notes.

in imported capital goods by 11.71 percent due to intensified foreign competition. In this extended specification, the coefficient on capital-good tariffs increases in magnitude and is significant at the 1 percent level, and the coefficient on input tariffs is similar to the baseline specification.

In column (2) of Table 3.6, we analyze the role of product differentiation and quality upgrading on investment in foreign capital goods. To that end, we augment the baseline specification with an interaction term between the quality ladder index constructed by Khandelwal (2010) and output tariffs (capturing the foreign competition), in addition to an interaction term between the quality ladder index and a Herfindahl index of domestic competition at the four digit industry level.[24] The quality ladder index, which is time-invariant, measures the the scope for quality differentiation in the industry. The adverse effects of both domestic and foreign competition on investment should be lower in industries with "long" quality ladders, since it is more feasible for the firms to upgrade the quality of their products in order not lose marginal profitability. As in the baseline specification, the coefficient on output tariff is positive and significant, while its interaction with the quality ladder index is negative and significant at 10 percent. The two coefficients jointly imply that a 10 percentage point reduction in the output tariffs leads to a 5.8 percent decline in the investment in foreign capital goods given the quality ladder's sample mean of 2.283. A similar 10 percentage point reduction in output tariffs in an industry with a bigger scope for quality upgrading (one standard deviation above the mean) leads to a smaller decline in investment of 3.74 percent. When we turn our attention to domestic competition, we find that enhanced competition increases investment in foreign capital goods for industries at the mean of the quality ladder distribution. Specifically, we find that a one standard deviation reduction in the Herfindahl index (corresponding to higher levels of competition) leads to a 6.24 percent increase in investment in foreign capital goods. The positive interaction shows that as the scope for quality differentiation increases, investment in foreign capital goods increases also for less competitive industries.

[24] We construct the Herfindahl index as the sum of squared sales share of firms in each four digit NIC industry.

Table 3.6: Mark-ups and Quality Ladder

Dependent Variable: $\frac{I_{Mijt}}{K_{ijt-1}}$	(1)	(2)
Lagged foreign capital investment $\left(\frac{I_{Mijt-1}}{K_{ijt-2}}\right)$	0.087***	0.087***
	(0.010)	(0.010)
Sales $\left(\frac{S_{ijt}}{K_{ijt-1}}\right)$	0.003	0.003
	(0.002)	(0.002)
Lagged sales $\left(\frac{S_{ijt-1}}{K_{ijt-2}}\right)$	0.002	0.002*
	(0.001)	(0.001)
Cash-flow $\left(\frac{C_{ijt}}{K_{ijt-1}}\right)$	0.017	0.015
	(0.020)	(0.020)
Lagged cash-flow $\left(\frac{C_{ijt-1}}{K_{ijt-2}}\right)$	0.011	0.012
	(0.009)	(0.009)
Output tariff $\left(\frac{\tau^O_{jt}}{100}\right)$	-0.092**	0.078**
	(0.044)	(0.037)
Output tariff*mark-up $\left(\frac{\tau^O_{jt}}{100} * \psi^H_i\right)$	0.190***	
	(0.068)	
Output tariff*Log quality ladder indicator		-0.025*
		(0.014)
Input tariff $\left(\frac{\tau^I_{jt}}{100}\right)$	-0.022	-0.032*
	(0.014)	(0.018)
Capital goods tariff $\left(\frac{\tau^K_{jt}}{100}\right)$	-0.039***	-0.037**
	(0.014)	(0.018)
Herfindahl index		-0.150**
		(0.069)
Herfindahl index*quality ladder indicator		0.059*
		(0.032)
License	-0.013*	-0.012*
	(0.007)	(0.006)
FDI	-0.013	-0.011
	(0.009)	(0.008)
Lagged domestic capital investment $\left(\frac{I_{Dijt-1}}{K_{ijt-2}}\right)$	-0.007*	-0.007*
	(0.004)	(0.004)
Number of observations	9,485	9,486
Number of firms	2,511	2,512
Hansen-Sargan test (p-value)	0.768	0.821
1st order serial correlation test (p-value)	0.007	0.007
2nd order serial correlation test (p-value)	0.211	0.216

3.6.4 Importers of Intermediate Inputs and Exporters

In this subsection, we provide some sub-sample analysis with respect to the importing status and exporting status of the firms. Equation (3.10) in Section 3.3 illustrates how a reduction in input tariffs, τ_t^I, can increase investment by lowering the cost of using imported inputs, and thereby raising the marginal profitability of capital. Hence, a firm requiring the use of imported inputs should benefit more from a reduction in input tariffs. Moreover, firms that use imported intermediate inputs that are complements to imported capital goods in the production process might invest more when capital becomes cheaper as a result of lower capital goods tariffs. To test whether importing intermediate goods matters for foreign capital investment decisions, we estimate the comprehensive specification in column (6) of Table 3.4 on firms that are importers of intermediate inputs, and exclude non-importers from the sample. We classify a firm as an importer of foreign intermediate inputs if it has imported intermediate inputs for at least two years between 1989-1997. This lowers the number of firms in the sample from 2,512 to 1,911. The results are reported in the first column of Table 3.7. The coefficient on output tariffs remain similar to the baseline estimates, and is significant at the 5 level while the coefficent on capital goods tariff increases slightly in magnitude to -0.037 and is significant at the 1 percent level. Moreover, the coefficient on input tariffs increases in magnitude, and becomes significant at the 5 percent level. The estimate of -0.030 suggests that a 10 percentage point reduction in input tariffs increases investment in foreign capital by 7.32 percent for firms that import intermediate inputs. These results are consistent with the findings in Bas and Berthou (2013), who find that the reduction in input tariffs between 1999-2006 in India (12 percentage points) led to an increase in the probability of importing capital goods of 2.6 percent for the average firm, and almost 4 percent for the average firm importing intermediate goods.

Next, we consider the exporting status of the firms. Firms that export can have higher investment profiles, since such firms are typically more productive and are larger in size, and therefore might respond more to reductions in tariffs. Columns (2) and (3) of Table 3.7 present the results from estimating our main specification for exporters and non-exporters separately. We categorize a firm as an exporter if the firm exported for at least two years between 1990-1997. The estimates

Table 3.7: Intermediate good importers and Exporting

Dependent Variable: $\frac{I_{Mijt}}{K_{ijt-1}}$	(1) Importers only	(2) Exporters	(3) Non-exporters
Lagged foreign capital investment $\left(\frac{I_{Mijt-1}}{K_{ijt-2}}\right)$	0.087***	0.089***	0.074***
	(0.008)	(0.008)	(0.012)
Sales $\left(\frac{S_{ijt}}{K_{ijt-1}}\right)$	0.003	0.003	0.001
	(0.002)	(0.002)	(0.002)
Lagged sales $\left(\frac{S_{ijt-1}}{K_{ijt-2}}\right)$	0.002	0.002	-0.000
	(0.001)	(0.001)	(0.002)
Cash-flow $\left(\frac{C_{ijt}}{K_{ijt-1}}\right)$	0.015	0.009	0.010
	(0.019)	(0.013)	(0.014)
Lagged cash-flow $\left(\frac{C_{ijt-1}}{K_{ijt-2}}\right)$	0.012	0.016	0.002
	(0.010)	(0.016)	(0.004)
Output tariff $\left(\frac{\tau^{O}_{jt}}{100}\right)$	0.017**	0.020	0.012
	(0.007)	(0.015)	(0.098)
Input tariff $\left(\frac{\tau^{I}_{jt}}{100}\right)$	-0.030**	-0.038**	0.013
	(0.013)	(0.018)	(0.046)
Capital goods tariff $\left(\frac{\tau^{K}_{jt}}{100}\right)$	-0.037***	-0.034*	-0.036
	(0.012)	(0.020)	(0.151)
License	-0.010**	-0.012*	-0.017
	(0.004)	(0.007)	(0.052)
FDI	-0.003	-0.012	-0.011
	(0.005)	(0.013)	(0.025)
Lagged domestic capital investment $\left(\frac{I_{Dijt-1}}{K_{ijt-2}}\right)$	-0.007*	-0.005	-0.001
	(0.004)	(0.007)	(0.007)
Number of observations	8,016	7,014	2,472
Number of firms	1,911	1,607	905
Hansen-Sargan test (p-value)	0.641	0.376	0.817
1st order serial correlation test (p-value)	0.00767	0.0142	0.0359
2nd order serial correlation test (p-value)	0.214	0.284	0.327

Notes: The first column reports the estimates obtained using a sample of firms that export for at least for two years between 1989-1997. Column (2) reports the estimates obtained using a sample of firms that export for at least for two years during the sample period. Column (3) reports the estimates obtained using a sample of firms that do not export. See Table Table 3.4 for additional notes.

of both the input and capital tariffs are negative for the exporters, and they are significant at the 5 and 10 percent levels, respectively. In column (2), the coefficient on the capital tariff measure is the same size as the one obtained for the full sample (-0.034, see column (6) of Table 3.4), where as the coefficient on the input tariff measure is much larger at -0.038. These estimates suggest that a 10 percentage point reduction in tariffs on capital goods increases investment in foreign capital goods by 8.5 percent and a 10 percentage point reduction in tariffs on inputs, increases investment in foreign capital goods by 9.5 percent.[25] The estimate of the effect of output tariffs is also similar in size to the one obtained using the full sample; however, it is not statistically significant. We present the results for non-exporters in column (3). Unlike the impacts we uncover for exporters, we do not find statistically significant effects of lower tariffs on investment in foreign capital goods for non-exporters.

3.6.5 Heterogeneity in the Impact of Lower Tariffs

In this subsection, we analyze the heterogeneity in the impact of lower tariffs on investment in imported capital goods. Building on the work of Melitz (2003a), theoretical and empirical studies such as Bustos (2011a) and Bas and Berthou (2013) have shown that faced with lower tariffs, firms will have an incentive to upgrade technology given the expanded export opportunities or the cheaper inputs. Both studies suggest that this incentive is not the same for all firms. It varies with productivity and the impact of changes in tariffs is greater for firms in the middle-range of the productivity distribution. Similar patterns are likely to exist in India. For example, as tariffs on capital goods or intermediate inputs decline, firms in the middle of the productivity distribution are most likely to experience the largest incentive to invest due to the lower prices of imported capital goods and intermediate inputs. Lower tariffs can spur investment for these firms, which were likely on the margin in investing in imported or domestic capital goods. On the other hand, the incentive of cheaper capital goods and imported intermediate goods might not be large enough for the least efficient firms, as for these firms, the marginal profitability of capital would be quite low before and after the fall in tariffs. Similarly, the most productive establishments might not increase their

[25]The mean foreign capital goods investment rate is higher for exporters at 0.040, compared to the 0.0361 for the full sample.

investments by much because they would have likely already achieved a high investment rate based on the high expected level of sales prior to trade liberalization.

To test empirically for heterogeneity in the impact of India's trade liberalization on firm-level investment, we divide all firms into 4 groups - the four quartiles of productivity distribution. We then estimate the following expanded version of our baseline specification (3.16):

$$\frac{I_{Mijt}}{K_{ijt-1}} = \alpha_1 \frac{I_{Mijt-1}}{K_{ijt-2}} + \alpha_2 \frac{S_{ijt}}{K_{ijt-1}} + \alpha_3 \frac{S_{ijt-1}}{K_{ijt-2}} + \alpha_4 \frac{C_{ijt}}{K_{ijt-1}} + \alpha_5 \frac{C_{ijt-1}}{K_{ijt-2}} + \\ + \sum_{r=1}^{4} \gamma^r_{\tau^K} (\tau^K_{jt} \times Q^r_{ij}) + \sum_{r=1}^{4} \gamma^r_{\tau^I} (\tau^I_{jt} \times Q^r_{ij}) + \sum_{r=1}^{4} \gamma^r_{\tau^O} (\tau^O_{jt} \times Q^r_{ij}) + \upsilon_i + \eta_t + \varepsilon_{ijt} \quad (3.17)$$

where r indexes the four quartiles of the productivity distribution and Q_{ij} is the indicator variable equal to one when firm i belongs to quartile r. We classify firms into the four quartiles using two alternate measures of productivity. The first measure we use is total factor productivity (TFP). We estimate the Cobb Douglas production function using a control function approach in the spirit of Olley and Pakes (1996), Levinsohn and Petrin (2003) and Ackerberg et al. (2015) using material inputs as a proxy for unobserved productivity. We use the mean TFP levels of the firms to classify them into the four quartiles and present the estimates in column (1) of Table 3.8. The second measure we use is firm-size based on mean sales to classify firms into the four quartiles, we present the estimates in column (2) of Table 3.8.

In general, the results are consistent with expectations and imply that the impact of lower capital goods tariffs is the highest for the middle quartiles. The impact of the reduction of capital goods tariffs on investment in imported capital goods is largest for firms in the third quartile. The magnitudes of the estimates at -.075 (column 1) and -0.044 (column 2), are larger than the average impact of -0.034 that we estimated for all firms in our baseline specification (3.16) (see Table 3.4). The estimates of the capital goods tariffs is significant at the 5 percent level under both the alternate ways of classifying firms into the four quartiles. The effects of lower input tariffs and output tariffs are less precisely estimated. The coefficients on output tariffs suggest that the smaller and less productive firms (in the first and second quartiles) were largely unaffected by foreign

Table 3.8: Heterogeneity of the impacts across size groups

Dependent Variable: $\frac{I_{Mijt}}{K_{ijt-1}}$	(1) Productivity quartiles	(2) Sales quartiles
Capital goods tariff– First quartile	-0.033	-0.072
	(0.024)	(0.048)
Capital goods tariff– Second quartile	-0.025	-0.026
	(0.029)	(0.023)
Capital goods tariff– Third quartile	-0.075**	-0.044**
	(0.029)	(0.022)
Capital goods tariff– Fourth quartile	-0.017	-0.032
	(0.026)	(0.021)
Input tariff– First quartile	0.005	0.017
	(0.028)	(0.050)
Input tariff– Second quartile	-0.019	-0.025
	(0.031)	(0.022)
Input tariff– Third quartile	-0.016	0.003
	(0.031)	(0.022)
Input tariff– Fourth quartile	-0.047	-0.030
	(0.030)	(0.024)
Output tariff– First quartile	-0.006	0.005
	(0.013)	(0.108)
Output tariff– Second quartile	0.019	0.001
	(0.018)	(0.011)
Output tariff– Third quartile	0.055*	0.004
	(0.031)	(0.023)
Output tariff– Fourth quartile	0.022	0.030*
	(0.018)	(0.016)

Notes: The reported coefficients are the interaction terms between the corresponding tariff measure and the dummy for the four quartiles. The firms are classified into four quartiles based on average total factor productivity (column 1) or average size measured by sales (column 2).

competition while the larger and more productive firms faced more stiff foreign competition and lowered investment. These results show that not all firms responded to changes in tariffs in a similar way and this highlights the importance of controlling for heterogeneity in uncovering the impact of trade liberalization on investment in foreign capital goods.

3.6.6 Overall Impact of the Trade Liberalization on the Investment in Foreign Capital Goods in India's Manufacturing Sector

Finally, in this subsection, we evaluate the overall impact of India's trade liberalization between 1990 and 1997 on the investment rate in foreign capital goods $\left(\frac{I_{Mijt}}{K_{ijt-1}}\right)$ in the manufacturing sector. We also separate and compare the respective contributions of the three major trade barriers- tariffs on capital goods, intermediate inputs and final output- which declined substantially as part of the trade liberalization process. In 1990, the average output, intermediate input, and capital goods tariffs were 95, 85, and 94 percent, respectively. By the end of our sample period in 1997, the three average tariff rates had dropped to 39, 34, and 33 percent, respectively.

Given the overall decrease in these trade barriers, our baseline estimates in column (6) of Table 3.4 imply that the 61-percentage-point decline in capital goods tariffs led to a 57.58 percent increase in the average investment in foreign capital goods. On the other hand, the 56-percentage-point decline in output tariffs led to a 26.43 percent decline in the average investment in foreign capital goods. Combining these two opposing effects, we get a net positive effect of 31.15 percent increase in the average investment in foreign capital. Even though it is statistically insignificant, if we add the economically significant impact of the 51-percentage-point decline in the intermediate input tariffs, which resulted in a 31.16 percent increase in investment, we find a net increase of 62.31 percent. Hence, given the average investment rate $\left(\frac{I_M}{K}\right)$ of 0.036 over the sample period, our results imply that the trade liberalization increased the investment rate to 0.058.

Not surprisingly, the net impact of the trade liberalization on the investment rate differs across the manufacturing industries, driven by the differences in the decline in three tariff measures, and the average foreign capital investment rate in each of the industries. In Table 3.9, we report the initial and the final average tariff rates for the two-digit NIC-industries in our sample, along with the change in the investment in foreign capital goods caused by the reduction in each tariff measure.

The last column presents the combined effect of the reductions in output, input, and capital goods measures. While the net impact is positive for all of the industries, there is substantial variation in the net gains. Among the industries that witnessed the largest net increase in their investment in foreign capital goods are "Coke and Petroleum Products" (167 percent increase), "Beverages" (159 percent increase), and "Food Products" (156 percent increase). These are also the industries that benefitted most from the reduction in capital goods tariffs. On the other hand, the net increase in the foreign capital investment in the "Motor Vehicles and Trailers" (13 percent), "Furniture" (10 percent), and "Recorded Media" (4 percent) industries relatively small, despite the substantial reduction in industries, due to the fact that these industries had relatively large foreign capital investment rates to begin with.

Table 3.9: Tariff Changes and Impacts By Industry

	Output Tariff			Input Tariff			Capital Goods Tariff			
Industry	1990	1997	impact	1990	1997	impact	1990	1997	impact	net impact
Coke and Petroleum Products	80	30	-47	56	19	44	123	32	170	167
Beverages	155	127	-26	83	37	56	100	32	130	159
Food Products	85	35	-60	73	31	66	93	31	149	156
Non-Metallic Mineral Products	89	47	-37	76	34	48	105	34	127	139
Pharmaceuticals	99	40	-44	93	35	55	100	33	99	109
Wood Products	65	32	-21	72	24	39	96	33	79	97
Fabricated metal Products	100	32	-35	80	30	34	106	32	77	76
Chemicals and Chemical Products	112	39	-34	92	34	35	106	32	70	71
Basic Metals	94	29	-36	74	28	32	98	32	72	69
Machinery and Equipment	74	29	-26	87	32	41	77	31	52	68
Electrical Equipment	83	43	-17	92	33	33	86	35	45	60
Rubber and Plastic Products	108	45	-19	118	35	32	109	33	45	58
Paper Products	81	24	-27	65	21	27	91	32	56	56
Leather Products	82	37	-14	86	25	24	92	36	35	45
Other Transport Equipment	74	43	-11	90	33	27	82	43	29	44
Tobacco Products	100	50	-20	84	35	25	76	30	37	42
Wearing Apparel	100	50	-15	93	46	18	78	31	28	32
Textiles	94	50	-11	88	44	15	84	30	28	31
Computer, Electronic Products	111	32	-18	92	34	17	99	39	27	26
Motor Vehicles, Trailers	97	45	-5	92	33	7	95	42	10	13
Furniture	103	48	-4	94	32	6	88	32	8	10
Recorded Media	58	20	-1	68	20	2	90	34	3	4

Notes: The tariff rates are in percentages. The values recorded under the “impact” columns are calculated using the estimates in column (6) of Table 3.4, and the sales weighted average foreign capital investment rate in each two digit NIC-industry. See footnote 21 for the details of the tariff change impact calculations. The industries are ranked based on the net effect of the reductions in the three tariff measures.

3.7 Conclusion

Using firm-level data from the Indian manufacturing sector, we evaluate the impact of lower capital tariffs, as well as input and output tariffs, on firms' investment in foreign capital goods. Our study improves upon previous work along two dimensions. First, it distinguishes investment in imported capital goods from other investment, and shows that trade liberalization contributed to capital accumulation through its impact on investment in foreign capital good, rather than domestic investment. Second, employing input-output tables, we construct capital goods tariffs that are distinct from tariffs on intermediate inputs and final consumption goods. This allows us to estimate the price elasticity of investment in foreign capital goods.

Theory suggests three mechanisms through which trade liberalization can affect investment in foreign capital goods. Lower capital goods tariffs has a direct positive effect of investment decisions, as they lower the price of foreign capital goods. Lower input tariffs increases firm's profitability, and therefore investment as it improves access to cheaper inputs, while lower output tariffs bring about more intense import competition, which results in lower profits and investment. The estimates in our analysis conform to these predictions. Employing data that cover a period of broad trade liberalization in India in the 1990s, we find that a 10 percentage point decrease in the capital goods tariffs led to a 9.44 percent increase in the average firms investment rate in foreign capital goods. A similar 10 percentage point reduction in input tariffs led to a 6.11 percent increase in investment in foreign capital. Also as predicted by theory, we find that the reductions in output tariffs affect investment adversely. When we combine the effects of the three types of tariffs, we find that the trade liberalization in India resulted in a net increase of 62.31 percent in the manufacturing sector investment rate over the course of our 7 year sample period (1990-1997).

APPENDIX A

APPENDIX FOR EXPORTS AND PRODUCTIVITY: THE ROLE OF IMPORTED INPUTS AND INVESTMENT IN R & D

A.1 Export-Import and Export-R & D Complementarity: A Framework

I present a simple framework to motivate the export-import and export-investment in R & D complementarities that are observed in the data.

A.1.1 Variable Profits

The firm operates in monopolistically competitive markets and produces a single product, which it can sell in the domestic market or abroad. This demand structure is commonly used in models of international trade (see Melitz (2003b)). The demand functions of the firm in the domestic (Q_{it}^D) and export (Q_{it}^X) markets are given by

$$Q_{it}^D = Q_t^{ID}\left(\frac{P_{it}^D}{P_t^{ID}}\right)^{-\sigma} = \Phi_t^D (P_{it}^D)^{-\sigma} \tag{A.1}$$

$$Q_{it}^X = Q_t^{IX}\left(\frac{P_{it}^X}{P_t^{IX}}\right)^{-\sigma} = \Phi_t^X (P_{it}^X)^{-\sigma} \tag{A.2}$$

P_{it}^D and P_{it}^X are prices of the firm in the domestic and export markets, Q_t^{ID}, Q_t^{IX}, P_t^{ID} and P_t^{IX} are the industry output and price indices in the two markets, $\sigma > 1$ is the constant elasticity of demand, Φ_t^D and Φ_t^X represent industry aggregates.

A firm that sells only in the domestic market $(d^x = 0)$ sets optimal price $p_{it} = \frac{\sigma}{\sigma-1} MC_{it}$ where $MR = MC$. If a firm is an exporter $(d^x = 1)$, it maximizes its joint profits in the two markets and sets price so that $MR_D = MR_X = MC$ i.e, marginal revenues are equal in the two markets and equal the marginal cost of production. The optimal variable profits π_{it} in period t is given by:

$$\pi_{it}(d^x = 0) = \frac{\lambda}{\sigma}\left[\Phi_t^D \left(\frac{\sigma}{\sigma-1}\right)^{(1-\lambda)\alpha_v} \left(\frac{e^{\omega_{it}} K_{it}^{\alpha_k}}{\beta {w_t}^{\alpha_l} {u_t}^{\alpha_e} {P_{xit}}^{\alpha_x}}\right)^{\sigma-1}\right]^{\frac{1}{\lambda}} \tag{A.3}$$

$$\pi_{it}(d^x = 1) = \frac{\lambda}{\sigma}\left[(1+\Phi_t)\Phi_t^D \left(\frac{\sigma}{\sigma-1}\right)^{(1-\lambda)\alpha_v} \left(\frac{e^{\omega_{it}} K_{it}^{\alpha_k}}{\beta {w_t}^{\alpha_l} {u_t}^{\alpha_e} {P_{xit}}^{\alpha_x}}\right)^{\sigma-1}\right]^{\frac{1}{\lambda}} \tag{A.4}$$

where π_{it}, the optimal variable profits (gross), depends on whether the firm sells only in the domestic market ($d^x = 0$) or whether it is an exporter and sells in both domestic and export markets ($d^x = 1$). Here, $\Phi_t = \frac{\Phi_t^X}{\Phi_t^D}$, $\beta = \alpha_l^{-\alpha_l}\alpha_e^{-\alpha_e}\alpha_x^{-\alpha_x}$, $\alpha_v = \alpha_l+\alpha_e+\alpha_x$ and $\lambda = 1+(1-\alpha_v)(\sigma-1) \geq 1$. In the specific case of constant marginal cost where $\alpha_v = 1$, λ will take the value 1.

A.1.2 Import and R & D Decision

The firm's environment is represented by the vector $\Psi_{it} = (d_i^x, K_i, w_t, u_t, P_{dt}, p_t^f, f_i^n, \Phi_t^D, \Phi_t)$. Here f_i^n is the fixed cost of importing each foreign variety. I assume that the firm takes its environment as given and chooses the number of imported varieties and whether to invest in R & D or not. Since the aim is to understand why and how firms improve productivity after they enter into export markets, I abstract from modeling the firm's decision to export or invest in physical capital stock. There is a well established literature which models more productive firms self selecting into export markets since they find it worth while to pay the entry and fixed costs of exporting for a higher per period variable profit from exporting. For example, see Melitz (2003b). There is also a long literature on investment in capital stock, where under varying assumptions about the nature of adjustment costs, firms make investment decisions where they equate the marginal cost of capital adjustment to the expected marginal gains from investment.

Since I am interested in how productivity evolves differently for an exporter versus a non exporter and how this is determined by the import and R & D behavior of the firm, I focus on these two decisions. I emphasize that these are simplifying assumptions which do not impact the empirical estimation since I do not structurally model selection into export markets, R & D status, investment in physical capital or number of varieties imported. In the empirical estimation, I recognize that these are endogenous variables while I estimate productivity. I then use matching methods (where I match on pre-entry productivity levels, capital stock as well as a host of other factors which are recognized to determine export entry) to compare productivity evolution for export entrants versus non exporters. The purpose of this basic framework is to develop the intuition for why *incentives* for investing in R & D and importing intermediate inputs *vary by export status*. Given this caveat, I proceed.

The firm pays a fixed cost of importing each foreign variety of the intermediate input (f_i^n) and chooses the number of varieties (n_{it}) to maximize net profits.

$$\Pi(\omega_{it},\Psi_{it}) = Max_{n_{it}}\ \pi_{it}(\omega_{it},d_i^x,K_i,w_t,u_t,P_{dt},p_t^f,\Phi_t^D,\Phi_t,n_{it}) - n_{it}f_i^n \qquad \text{(A.5)}$$

The optimal number of varieties is denoted by $n^*(\omega_{it},\Psi_{it})$. The firm finds it optimal to import an additional variety as long as the increase in variable profits from the additional variety is larger than f_i^n.

Since R & D in year t impacts productivity in $t+1$, the decision to invest in R & D is a dynamic problem for the firm. Investment in R & D involves a per-period fixed cost, f_i^k. The Bellman equation is given by:

$$V(\omega_{it};\Psi_{it}) = \Pi(\omega_{it};\Psi_{it}) + Max_{d_{it}^k}\ \left\{\delta E[V(\omega_{it+1}|\omega_{it},d_{it}^k=1;\Psi_{it}) - f_i^k], \delta E[V(\omega_{it+1}|\omega_{it},d_{it}^k=0;\Psi_{it})]\right\} \qquad \text{(A.6)}$$

I assume that the firm's environment $\Psi_{it} = (d_i^x,K_i,w_t,u_t,P_{dt},p_t^f,f_i^n,\Phi_t^D,\Phi_t)$ is constant over time ($\Psi_{it}=\Psi_{it+1}$) and firms have perfect foresight about it. This is a simplifying assumption to isolate the impact of R & D. Investment in R & D in $t-1$ impacts ω_{it} in t. The firm invests in R & D in t if

$$E[V(\omega_{it+1}|\omega_{it},d_{it}^k=1;\Psi_{it})] - f_i^k > E[V(\omega_{it+1}|\omega_{it},d_{it}^k=0;\Psi_{it})] \qquad \text{(A.7)}$$

A.1.3 Comparative Statics by Export Status

From (A.3) and (A.4), the change in variable profits (gross) from importing an additional variety is given by:

$$\pi_{it}(.,n_{it}) - \pi_{it}(.,n_{it-1}) = \frac{\lambda}{\sigma}\left[(1+\Phi_t d_i^x)\Phi_t^D\left(\frac{\sigma}{\sigma-1}\right)^{(1-\lambda)\alpha_v}\left(\frac{e^{\omega_{it}}K_{it}^{\alpha_k}}{\beta {w_t}^{\alpha_l}{u_t}^{\alpha_e}}\right)^{\sigma-1}\right]^{\frac{1}{\lambda}}\Delta_{it} \qquad \text{(A.8)}$$

where $d_i^x = 0,1$ is an indicator variable for export status and

$$\Delta_{it} = \left[\left(\frac{1}{P_x(P_{dt},p_t^f,n_{it})}\right)^{\frac{\sigma-1}{\lambda}} - \left(\frac{1}{P_x(P_{dt},p_t^f,n_{it}-1)}\right)^{\frac{\sigma-1}{\lambda}}\right] \qquad \text{(A.9)}$$

From (2.15) and (A.9) and since $\frac{\sigma-1}{\lambda} > 0$, $\Delta_{it} > 0$. Thus, the marginal change in profit from buying an additional imported variety is positive i.e., $\pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1}) > 0$. Furthermore, since $1 + \Phi_t > 1$ and $\lambda \geq 1$), it follows that

$$\pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})|d_i^x = 1 > \pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})|d_i^x = 0 \tag{A.10}$$

The marginal increase in variable profits from importing an additional variety of the intermediate input is higher for an exporter compared to a non exporter, everything else being equal. It follows that the optimal number of imported varieties is non decreasing in export status i.e.,

$$n^*(\omega_{it}, \Psi_{it}|d_i^x = 1) \geq n^*(\omega_{it}, \Psi_{it}|d_i^x = 0) \tag{A.11}$$

Next, I move to investment in R & D. First, from (A.3) and (A.4), it is straightforward to see that variable profits are increasing in ω_{it} for both exporters and non exporters, i.e.,

$$\frac{\partial \pi_{it}(.)}{\partial \omega_{it}} = \frac{\sigma - 1}{\lambda}\pi_{it}(.) > 0 \tag{A.12}$$

Furthermore, since $1 + \Phi_t > 1$ and $\frac{\sigma-1}{\lambda} > 0$, it follows from (A.3), (A.4) and (A.12) that everything else being equal, this increase is greater for exporters as compared to non exporters.

$$\frac{\partial \pi_{it}(.)}{\partial \omega_{it}}|d_i^x = 1 > \frac{\partial \pi_{it}(.)}{\partial \omega_{it}}|d_i^x = 0 \tag{A.13}$$

From (2.7) and (A.13),

$$\begin{aligned}&[E(\pi_{it+1}|\omega_{it}, d_i^k = 1, \Psi_{it}) - E(\pi_{it+1}|\omega_{it}, d_i^k = 0, \Psi_{it})]|d_i^x = 1 > \\ &\qquad [E(\pi_{it+1}|\omega_{it}, d_i^k = 1, \Psi_{it}) - E(\pi_{it+1}|\omega_{it}, d_i^k = 0, \Psi_{it})]|d_i^x = 0\end{aligned} \tag{A.14}$$

Investment in R & D in t increases expected variable profits of $t + 1$ more for an exporter as compared to a non exporter. Thus, other things being equal, an exporter will have a higher probability of doing R & D.

A.2 Imports in the Empirical Production Function

The nested Cobb Douglas- CES structure of the firm's production function as specified in (2.1) and (2.2) allows for the sequential solving of the firm's problem. The firm's demand for the domestic intermediate input bundle X_{dit} and the imported intermediate input bundle X_{fit} is given by solving

$$Min\ P_{dt}X_{dit} + P_{fit}X_{fit} \tag{A.15}$$

$$s.t\ [X_{dit}^{\rho} + X_{fit}^{\rho}]^{\frac{1}{\rho}} \geq X_{it}$$

The optimal demand functions for the domestic and imported intermediate input bundles are given by

$$X_{dit} = \left[\frac{P_{dt}}{P_{xit}}\right]^{\frac{1}{\rho-1}} X_{it} \tag{A.16}$$

$$X_{fit} = \left[\frac{P_{fit}}{P_{xit}}\right]^{\frac{1}{\rho-1}} X_{it} \tag{A.17}$$

Here the demand for the intermediate input bundle X_{it} is the input demand function for the Cobb Douglas technology specified in (2.1)

$$X_{it} = \frac{\alpha_x}{P_{xit}} \left[\frac{Q_{it}}{e^{\omega_{it}} K_{it}^{\alpha_k}}\right]^{\frac{1}{\alpha_l+\alpha_e+\alpha_x}} \left[\frac{w_t}{\alpha_l}\right]^{\frac{\alpha_l}{\alpha_l+\alpha_e+\alpha_x}} \left[\frac{p_t^e}{\alpha_e}\right]^{\frac{\alpha_e}{\alpha_l+\alpha_e+\alpha_x}} \left[\frac{P_{xit}}{\alpha_x}\right]^{\frac{\alpha_x}{\alpha_l+\alpha_e+\alpha_x}} \tag{A.18}$$

Here, w_t is the price of labor inputs, p_t^e is the price of energy inputs and P_{xit} is the price of the intermediate input bundle of firm i in period t.

$$P_{xit} = [P_{dt}^{\frac{\rho}{\rho-1}} + P_{fit}^{\frac{\rho}{\rho-1}}]^{\frac{\rho-1}{\rho}} \tag{A.19}$$

The total expenditure on intermediate inputs is M_{it} and is given by $M_{it} = P_{it}X_{it}$ where X_{it} is the optimal demand for intermediate inputs. The total expenditure on domestic intermediate inputs is M_{dit} and is given by $M_{dit} = P_{dt}X_{dit}$ where X_{dit} is the optimal demand for the domestic intermediate input bundle. From (2.2), (A.16), (A.17), and (A.19),

$$\frac{M_{it}}{M_{dit}} = \left[\frac{P_{xit}}{P_{dt}}\right]^{\frac{\rho}{\rho-1}} \tag{A.20}$$

Rearranging the terms of (A.20) gives (2.30) in subsection 2.4.1 in the text.

A.2.1 Firm Price Deflators

Firm specific price deflators are calculated using firm level product data. Using data on product level total revenue and quantity of each product, I get the price of each product of a firm. I then construct firm price deflators similar to Eslava et al. (2004) and Eslava et al. (2010). The growth in prices of firm i is given by the weighted average of the growth in prices of all products of the firm where the weights are given by the share of the product revenues in total revenue of the firm.

$$\Delta P_{it} = \sum_{h=1}^{H} \overline{s}_{hit} \Delta ln(P_{hit}) \tag{A.21}$$

where

$$\Delta ln(P_{hit}) = ln(P_{hit}) - ln(P_{hit-1}) \tag{A.22}$$

and

$$\overline{s}_{hit} = \frac{s_{hit} + s_{hit-1}}{2} \tag{A.23}$$

where s_{hit} is the share of product h in revenue of firm i in period t. The industry base price was set at 100 for 1989. Industry price indices for each year was calculated by recursively adding the weighted growth in prices of all firms with weights given by firm share in total industry share in that year. The firm's initial price was set at the industry average at the particular year it was first observed similar to Eslava et al. (2004) and subsequently,

$$\Delta P_{it} = P_{it-1} + \Delta ln(P_{it-1}) \tag{A.24}$$

Since price growth had large outliers (both at the upper and lower tails), I winsorized price changes at the 3rd and 97th percentile by year.

A.3 Correlation Matrix and Additional Figures

Table A.1: Correlation of Input Variables

	Labor	Capital	Material Inputs	Import Intensity	Energy
Labor	1				
Capital	0.686	1			
Material Inputs	0.6916	0.6802	1		
Import Intensity	0.1773	0.1966	0.1898	1	
Energy	0.7146	0.7314	0.6993	0.126	1

Notes: Variables are all natural logarithms of inputs used in the right hand side of the production function. All correlations are significant at the one percent level.

Figure A.1: Distribution of ω

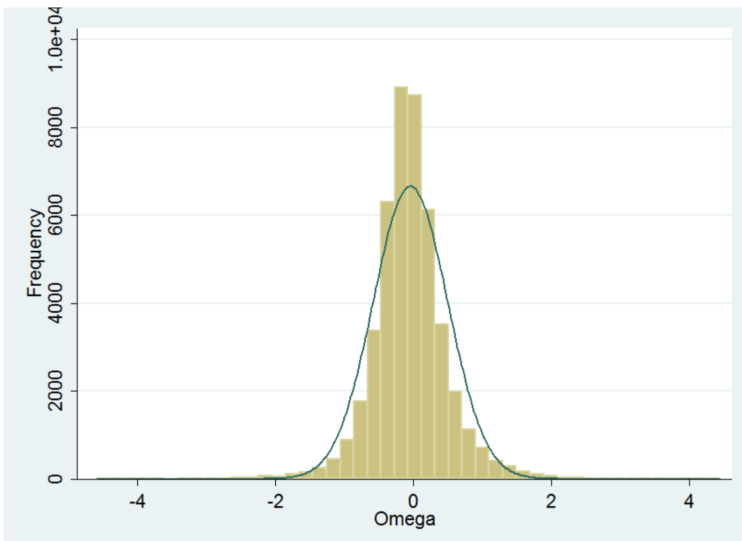
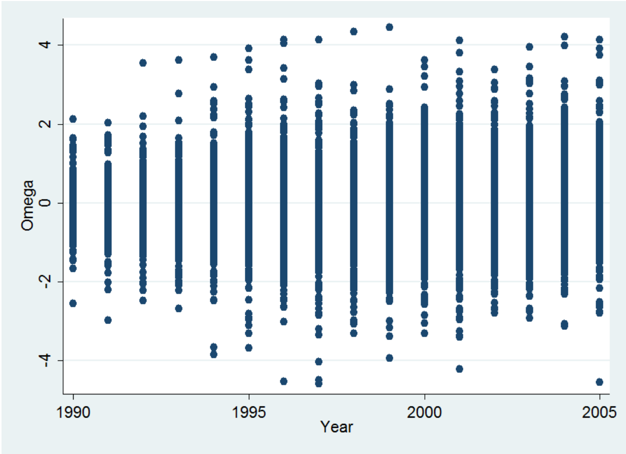


Figure A.2: Distribution of ω by year



A.3.1 Tables: Alternate Matching

Table A.2: Productivity Growth over Time from Export Entry: Matching Results

	Total Productivity	Imports	R & D
	$\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}}$	$\widehat{\alpha_\chi}\chi_{it}$	$\widehat{\omega_{it}}$
t+1	0.050*	0.002	0.048*
	(0.027)	(0.004)	(0.027)
t+2	0.063**	0.007	0.056*
	(0.028)	(0.005)	(0.029)
t+3	0.051	0.012***	0.039
	(0.035)	(0.004)	(0.034)
t+4	0.070**	0.017***	0.053
	(0.035)	(0.005)	(0.033)
t+5	0.081**	0.018***	0.063*
	(0.039)	(0.005)	(0.036)
t+6	0.094**	0.018***	0.076*
	(0.041)	(0.005)	(0.040)

Notes: Nearest Neighbor matching using five neighbors with replacement. The number of treated is 348. Block Bootstrap Standard errors given in parentheses (200 replications). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.3: Productivity Growth from Export Entry (All export entrants): Matching Results

	t+1	t+2	t+3	t+4	t+5	t+6
Total Productivity	0.063***	0.077***	0.084***	0.087***	0.107***	0.094***
$(\widehat{\alpha_\chi}\chi_{it} + \widehat{\omega_{it}})$	(0.024)	(0.023)	(0.031)	(0.032)	(0.032)	(0.036)
Imports	0.008***	0.013***	0.013***	0.018***	0.016***	0.015***
$(\widehat{\alpha_\chi}\chi_{it})$	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
R & D	0.055**	0.064***	0.070**	0.069**	0.092***	0.080**
$(\widehat{\omega_{it}})$	(0.024)	(0.024)	(0.031)	(0.032)	(0.032)	(0.038)

Notes: Nearest Neighbor matching using five neighbors with replacement. The number of treated varies by year (544 to 364). Block Bootstrap Standard errors given in parentheses (200 replications). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

APPENDIX B

APPENDIX FOR TRADE LIBERALIZATION AND INVESTMENT IN FOREIGN CAPITAL GOODS (CO-AUTHORED WITH IVAN T. KANDILOV AND ASLI LEBLEBICIOĞLU)

B.1 Euler Equation

F.O.C w.r.t I_{it} yields

$$1 + \frac{\partial G\left(K_{it-1}, I_{it}\right)}{\partial I_{it}} = \beta E_t \left[\frac{\partial V_{it+1}(k_{it})}{\partial K_{it}} \frac{\partial K_{it}}{\partial I_{it}}\right] \tag{B.1}$$

F.O.C using $V_{it+1}(K_{it})$ w.r.t K_{it} yields

$$\frac{\partial V_{it+1}(k_{it})}{\partial K_{it}} = \frac{\partial \Pi_{it+1}}{\partial K_{it}} - \frac{\partial G\left(K_{it}, I_{it+1}\right)}{\partial K_{it}} + \beta E_t \left[\frac{\partial V_{it+2}(k_{it+1})}{\partial K_{it+1}} \frac{\partial K_{it+1}}{\partial K_{it}}\right] \tag{B.2}$$

Substituting into equation (B.1) using

$$\frac{\partial V_{it+1}(k_{it})}{\partial K_{it}} = \frac{\partial \Pi_{it+1}}{\partial K_{it}} - \frac{\partial G\left(K_{it}, I_{it+1}\right)}{\partial K_{it}} + (1-\delta)\left[1 + \frac{\partial G\left(K_{it}, I_{it+1}\right)}{\partial I_{it+1}}\right] \tag{B.3}$$

we get equation (3.7) in the text.

B.2 Demand for Imported Capital Goods

The firm's demand for domestic and imported capital goods is given by solving

$$Min\ P_{Dt} I_{Dit} + \tau_t^K P_{Mt} I_{Mit} \tag{B.4}$$

subject to

$$\left[(1-\mu_i)^{\frac{1}{\omega}} I_{Dit}^{\frac{\omega-1}{\omega}} + \mu_i^{\frac{1}{\omega}} I_{Mit}^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}} \geq I_{it}$$

The demand for imported capital goods is given by:

$$I_{Mit} = \mu_i (\tau_t^K P_{Mt})^{-\omega} I_{it} \left[(1-\mu_i) P_{Dt}^{1-\omega} + \mu_i (\tau_t^K P_{Mt})^{1-\omega}\right]^{\frac{\omega}{1-\omega}} \tag{B.5}$$

The price of the investment basket is a CES aggregator of domestic and imported capital goods:

$$P_{Iit} = \left[(1-\mu_i)P_{Dt}^{1-\omega} + \mu_i(\tau_t^K P_{Mt})^{1-\omega}\right]^{\frac{1}{1-\omega}} \tag{B.6}$$

Normalizing the price of the investment basket of the firm to 1 and using equation (B.5) yields equation (3.9) in the text.

B.3 The Marginal Profitability of Capital

Optimal behavior by the firm requires that the marginal cost of hiring domestic and foreign variable inputs equals their marginal revenue productivities.

$$\left(\frac{\theta-1}{\theta}\right) p_{it} \frac{\partial F}{\partial L_{it}} = w_t \tag{B.7}$$

$$\left(\frac{\theta-1}{\theta}\right) p_{it} \frac{\partial F}{\partial L_{it}^*} = \tau_t^I w_t^* \tag{B.8}$$

Since $F(.)$ is homogenous of degree 1, Euler's theorem implies that

$$\frac{\partial F}{\partial K_{it-1}} K_{it-1} + \frac{\partial F}{\partial L_{it}} L_{it} + \frac{\partial F}{\partial L_{it}^*} L_{it}^* = x_{it} \tag{B.9}$$

We differentiate equation (3.4) with respect to K_{it-1} to write the marginal profitability of capital as

$$\frac{\partial \Pi_{it}}{\partial K_{it-1}} = \left(\frac{\theta-1}{\theta}\right) p_{it} \frac{\partial F}{\partial K_{it-1}} \tag{B.10}$$

From equation (B.7), equation (B.8), equation (3.4), and equation (B.9) we get:

$$\frac{\Pi_{it}}{K_{it-1}} = \frac{p_{it}x_{it}}{K_{it-1}} + \left(\frac{\theta-1}{\theta}\right) p_{it} \frac{\partial F}{\partial K_{it-1}} - \left(\frac{\theta-1}{\theta}\right) \frac{p_{it}x_{it}}{K_{it-1}} \tag{B.11}$$

We substitute for $\frac{\partial F}{\partial K_{it-1}}$ from equation (B.11) into equation (B.10) and obtain equation (3.10) in the text.

B.4 Euler Equation, Taylor Expansion and Structural Parameters

We substitute the partial derivatives of the adjustment cost function in equation (3.12) into equation (3.7):

$$\left(1-\gamma\frac{\bar{I}}{K}\right)+\gamma\frac{I_{it}}{K_{it-1}}=\beta E_t\Bigg[\frac{\partial\Pi_{it+1}}{\partial K_{it}}+\frac{\gamma}{2}\left(\frac{I_{it+1}}{K_{it}}\right)^2 + (1-\delta)\gamma\frac{I_{it+1}}{K_{it}}+(1-\delta)\left(1-\gamma\frac{\bar{I}}{K}\right)-\frac{\gamma}{2}\left(\frac{\bar{I}}{K}\right)^2\Bigg] \tag{B.12}$$

To obtain the fully-parameterized non-linear investment equation for foregin capital goods, we substitute the marginal profitability of capital in equation (3.10), and the demand for imported capital goods in equation (3.9) into the Euler equation in equation (B.12).

$$\theta_1\left(\tau_t^K P_{Mt}\right)^{\omega}\frac{I_{Mit}}{K_{it-1}}+\theta_2=\beta E_t\Bigg[\frac{x_{it+1}p_{it+1}}{\psi K_{it}}-\frac{w_{t+1}L_{it+1}}{K_{it}}-\frac{\tau_{t+1}^I w_{t+1}^* L_{it+1}^*}{K_{it}} +\theta_3\left(\tau_{t+1}^K P_{Mt+1}\right)^{2\omega}\left(\frac{I_{Mit+1}}{K_{it}}\right)^2+\theta_4\left(\tau_{t+1}^K P_{Mt+1}\right)^{\omega}\frac{I_{Mit+1}}{K_{it}}+\theta_5\Bigg] \tag{B.13}$$

where $\theta_1=\frac{\gamma}{\mu}$

$\theta_2=1-\frac{\gamma}{\mu}\left(\tau^K P_M\right)^{\omega}\frac{I_M}{K}$

$\theta_3=\frac{\gamma}{2\mu^2}$

$\theta_4=(1-\delta)\frac{\gamma}{\mu}$

$\theta_5=(1-\delta)\left[1-\frac{\gamma}{\mu}\left(\tau^K P_M\right)^{\omega}\frac{I_M}{K}\right]-\frac{\gamma}{2\mu^2}\left(\tau^K P_M\right)^{2\omega}\left(\frac{I_M}{K}\right)^2$

First we take a first-order Taylor approximation of the non-linear equation above around the steady state values of the variables. Second we define total sales as S_{it}=$x_{it+1}p_{it+1}$; total costs as $Z_{it+1}=w_{t+1}L_{it+1}$; and the cost of imported inputs as $Z_{it+1}^*=\tau_{t+1}^I w_{t+1}^* L_{it+1}^*$. Rewriting the sales and the cost variables in terms of S_{it}, Z_{it+1} and Z_{it+1}^*, we obtain equation (3.13) in the text:

$$\frac{I_{Mit}}{K_{it-1}}=E_t\left[\phi_0+\phi_1\frac{I_{Mit+1}}{K_{it}}+\phi_2\frac{S_{it+1}}{K_{it}}-\phi_3\frac{Z_{it+1}}{K_{it}}-\phi_4\frac{Z_{it+1}^*}{K_{it}}+\phi_5\left(\tau_{t+1}^K P_{Mt+1}\right)-\phi_6\left(\tau_t^K P_{Mt}\right)\right]$$

The expressions for the coefficients in terms of the structural parameters and the steady-state values of the variables are:

$\phi_0 = \frac{S}{\psi} - Z - Z^* + (1-\delta) - \frac{1}{\beta}$
$\phi_1 = \frac{\left(\tau^K P_M\right)^\omega}{\mu} \frac{I_M}{K} + (1-\delta)$
$\phi_2 = \frac{\mu}{\gamma\psi} \left(\tau^K P_M\right)^{-\omega}$
$\phi_3 = \phi_4 = \frac{\mu}{\gamma} \left(\tau^K P_M\right)^{-\omega}$
$\phi_5 = \frac{\omega}{\mu} \left(\frac{I_M}{K}\right)^2 \left(\tau^K P_M\right)^{\omega-1} + (1-\delta)\omega \frac{I_M}{K} \left(\tau^K P_M\right)^{-1}$
$\phi_6 = \frac{\omega \frac{I_M}{K}}{\tau^K P_M}$.

B.5 Input Tariffs

Matrix 1 of the Input-Output Transaction Table (1993-94) is the Absorption matrix which gives for each Industry k,

Intermediate Inputs at Factor cost + Capital Inputs at Factor cost + Services Inputs + Net Indirect Taxes + Value Added = Gross Value of Output

Matrix 3 of the Input - Output Transaction Table (1993-94) gives the above in terms of coefficients or share in output by dividing by Gross value of output. We use the information directly from the coefficient matrix i.e., Matrix 3

Share of Intermediate inputs + Share of Capital Inputs + Share of Service Inputs + Share of Net Indirect Taxes + Share of Value Added = 1

For each industry k,

$\sum_s c_{sk}^{Intermediate}$ + $\sum_s c_{sk}^{Capital}$ + $\sum_s c_{sk}^{Services}$ + Share of Net Indirect Taxes + Share of Value Added = 1

Intermediate Inputs constitute sectors: $s = 1-76$, $85-86$ and $97-98$
Capital Inputs constitute sectors: $s = 77-84$ and $87-96$
Service Inputs constitute sectors: $s = 99-115$

Since we don't have tariffs on services and are interested in constructing separate tariffs on intermediate inputs and capital inputs we rescale the coefficients such that for each industry k,

$w_{sk}^{Intermediate} = \frac{c_{sk}^{Intermediate}}{\sum_s c_{sk}^{Intermediate}}$ for each s and $\sum_s w_{sk}^{Intermediate} = 1$
$w_{sk}^{Capital} = \frac{c_{sk}^{Capital}}{\sum_s c_{sk}^{Capital}}$ for each s and $\sum_s w_{sk}^{Capital} = 1$

The intermediate input and capital input tariffs for each industry k are then calculated as:

$$\tau_{kt}^{Intermediate} = \sum_{s} w_{sk}^{Intermediate} \tau_{st}$$

where $w_{sk}^{Intermediate}$ is the weight of the intermediate input industry s in output of industry k and τ_{st} is the tariff of industry s in time t.

$$\tau_{kt}^{Capital} = \sum_{s} w_{sk}^{Capital} \tau_{st}$$

where $w_{sk}^{Capital}$ is the weight of the Capital input industry s in output of industry k and τ_{st} is the tariff of industry s in time t

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