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

Ruchita Manghnani
Abstract

The empirical evidence on within-firm productivity improvements from exports has largely been understated because the measures of revenue productivity used do not account for pricing heterogeneity across firms. Using a panel of Indian firms, the analysis in this paper controls for firm variation in prices and uses proxy methods to retrieve measures of productivity that reflect physical productivity. Within-firm productivity changes from export entry are computed using a difference-in-differences matching estimator. The findings show that, over a six-year period, the difference in productivity growth between export entrants and their non-exporter counterparts is about 11 percentage points. Thus, productivity improvements from selling in international markets have largely been understated in the export-productivity empirical literature. This difference in productivity growth is decomposed into two channels. About 15 percent of the difference in productivity growth is explained by higher imports of intermediate inputs, and about 85 percent is explained by investment in research and development. The evidence suggests that investment in research and development is an important source of within-firm productivity gains even in developing countries.
Exports and Productivity: The Role of Imported Inputs and Investment in R&D

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JEL Classification: D22, D24, F10, F14, L25, O30, O33

Key Words: Gains from Trade, Productivity, Pricing heterogeneity, Exports, Imports, R & D

*World Bank (email: rmanghnani@worldbank.org). I thank Patrick Conway, Tiago Pires, Helen Tauchen, Ivan Kandilov, Jonathan Williams and Simon Alder for their helpful comments and suggestions. All remaining errors are mine. The findings, interpretations, and conclusions expressed in this paper are entirely those of the author. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.
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 2,500 in 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 United States.\(^2\) 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., more productive firms will begin to export and becoming an exporter makes a firm more productive. Melitz (2003) models self-selection of more productive firms into export markets due to a fixed cost of entry into export markets, while Bustos (2011), 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 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. Several empirical papers have confirmed that more productive firms self select into export markets. For example, see Delgado et al. (2002) and Bernard and Jensen (1999). Girma et al. (2004) review 10 papers and find widespread evidence of the self selection hypothesis. Clerides et al. (1998), Arnold and Hussinger (2005) and Greenaway et al. (2005) find that exporting does not improve productivity. This also holds for evidence from 14 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). Previous work on India confirms the self-selection hypothesis but does not find evidence that exporting improves firm productivity (see Haidar (2012) and Sharma and Mishra (2011)).

One possible explanation for the lack of evidence (on firms becoming more productive after they begin exporting) found in the data could be that previous studies have usually estimated revenue productivity (i.e., the measure of output used in the production function uses industry level prices to deflate firm revenues rather than firm level prices). These studies assume common prices for all firms within an industry. If firms improve productivity and pass this on to consumers

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\(^1\)These numbers are based on public firms, which are legally required to report foreign exchange transactions.

in the form of lower prices, revenue-based measures using industry price deflators will not capture the improvements in productivity.\footnote{Foster et al. (2008) use data on physical quantities of a few homogeneous industries in the United States 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.} Recent work by Garcia-Marin and Voigtlnder (2019) 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.\footnote{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.}

This finding on Chile has highlighted the need to correct for biases that arise from revenue-based measures of productivity (that use industry rather than firm prices) to understand the relationship between exports and productivity. The data set 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.\footnote{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 an optimal price 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.} In this paper, I ask, do firms become more productive after they enter 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 not 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.

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 et al. (2006) 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 et al. (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. There is little known on the R & D-productivity link in developing countries. The evidence on the R & D productivity link in India is mixed. Sharma (2014) finds the role of R & D in overall manufacturing productivity growth to be insignificant using a production function framework, but finds some evidence of it using a growth accounting framework.

The results from the paper 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 describes the environment the firm operates in and the production technology of the firm. Section 3 presents the empirical production function where I discuss the measure of productivity that is used. Section 4 is on the estimation strategy employed. Section 5 describes the data. I discuss the findings in Section 6 and Section 7 concludes.

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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.

$$Q_{it} = e^{\omega_{it}} K_{it}^{\alpha_k} L_{it}^{\alpha_l} E_{it}^{\alpha_e} X_{it}^{\alpha_x}$$  (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). The input varieties are imperfect substitutes for each other and the aggregate input bundle is increasing in the number of varieties employed in production. The intermediate input bundle is a CES aggregator of a bundle of domestic intermediate inputs ($X_{dit}$) and a bundle of imported intermediate inputs ($X_{fit}$).

$$X_{it} = [X_{dit}^\rho + X_{fit}^\rho]^\frac{1}{\rho}$$  (2)

The elasticity of substitution between the domestic input bundle and the imported input bundle is given by $\frac{1}{1-\rho}$, where $0 < \rho < 1$. The domestic input bundle and the imported input bundle are again CES aggregators of domestically available varieties and imported varieties of intermediate inputs, respectively.

$$X_{dit} = \left[\sum_{h=1}^{H_t} d_{hit}^\theta \right]^\frac{1}{\theta}$$  (3)

$$X_{fit} = \left[\sum_{a=1}^{n_{it}} f_{ait}^\theta \right]^\frac{1}{\theta}$$  (4)

where $n_{it} \leq N_t$. 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 input varieties available domestically within the country, $N_t$ is the number of varieties available in the rest of the world and $n_{it}$ is the number of foreign inputs imported by firm $i$.

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

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7Intermediate inputs are commonly modeled as CES functions in the trade and growth literature. See Ethier (1982), Kasahara and Rodrigue (2008), Halpern et al. (2011) and Kasahara and Lapham (2013).

8An 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 data set 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 et al. (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.
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

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

where $\delta$ 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 et al. (2011). The firm can invest in R & D in period $t-1$ to improve productivity in $t$. In period $t-1$, the firm expects that its productivity in period $t$ will be $g(\omega_{it-1},d^k_{it-1})$ i.e.,

$$g(\omega_{it-1},d^k_{it-1}) = E(\omega_{it}|\omega_{it-1},d^k_{it-1})$$

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

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

The Markovian assumption implies that

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

In period $t$, the actual realized productivity is $\omega_{it}$ and it can be decomposed into expected productivity $g(\omega_{it-1},d^k_{it-1})$ and a random shock $\zeta_{it}$, 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 $\omega_{it-1}$ and $d^k_{it-1}$. I assume that

$$\omega_{it} = \gamma_1\omega_{it-1} + \gamma_2d^k_{it-1} + \gamma_3\omega_{it-1} * d^k_{it-1} + \zeta_{it}$$

I expect $\gamma_2$ 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 and $\zeta_{it}$ is the i.i.d. error term as mentioned above.

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9Recent 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 et al. (2015)
From the production technology specified, the marginal cost function is

$$MC_{it} = \left[ \frac{\beta}{\epsilon^\alpha K_{it}^{\alpha_k} Q_{it}^{1-\alpha_v} w_{it}^\alpha u_{it}^\alpha} \right]^{\frac{1}{\alpha_v}}$$

(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 ($P_{fit}$).

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

(11)

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

$$P_{dt} = \left[ \sum_{h=1}^{H_t} p_{ht}^d \right]^{\frac{\theta - 1}{\theta}}$$

(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 $p_{at}^f$ is the price of foreign variety $a$. I assume that $p_{at}^f = p_{at}^i \forall a$ (similar to Gopinath and Neiman (2014)). This gives the price index of the imported intermediate bundle for firm $i$.

$$P_{fit} = p_{at}^f (n_{it})^{\frac{\theta - 1}{\theta}}$$

(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 (11), (12) and (13), the price index of the intermediate good bundle is

$$P_{xit} = \left[ P_{dt}^{\frac{\rho}{\rho - 1}} + (p_{at}^f (n_{it})^{\frac{\theta - 1}{\theta}})^{\frac{\rho - 1}{\rho}} \right]^{\frac{\rho - 1}{\rho}}$$

(14)

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

$$P_x(P_{dt}, p_{at}^f, n_{it}) - P_x(P_{dt}, p_{at}^f, n_{it} - 1) < 0$$

(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

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10 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.
number of input varieties used by the firm (since firms will access all domestic varieties) and lower
is the price index of the intermediate input bundle.\textsuperscript{11} From (10) and (15),
\[ MC(P_{dt}, p_{ft}^*, w_{t}, \omega_{it}, K_{it}, Q_{it}, n_{it}) - MC(P_{dt}, p_{ft}^*, w_{t}, \omega_{it}, K_{it}, Q_{it}, n_{it} - 1) < 0 \] (16)

From (10), it can also be seen that
\[ \frac{\partial MC(.,.)}{\partial \omega_{it}} < 0 \] (17)

Thus, for a given capital stock, firms with a larger number of imported varieties employed in
production (\( n_{it} \)) and higher productivity (\( \omega_{it} \)) 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 finds it worth-
while to undertake the fixed cost of investing in R & D and purchasing imported varieties of
intermediate inputs. 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. I also assume that the firm’s environment \( \Psi_{it} \), 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 similar to Boler et al. (2015). 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 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 in-
termediate input is higher for an exporter (\( d_{it}^x = 1 \)) compared to a non-exporter (\( d_{it}^x = 0 \)), everything
else being equal. It follows that the optimal number of imported varieties is non decreasing in export
status.

\[
\pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})|d_{it}^x = 1 > \pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})|d_{it}^x = 0
\] (18)
\[
n^*(\omega_{it}, \Psi_{it}|d_{it}^x = 1) \geq n^*(\omega_{it}, \Psi_{it}|d_{it}^x = 0)
\] (19)

Here, variable profits \( \pi_{it} \) are gross profits before deducting any fixed costs, \( n^*(.) \) refers to the optimal

\textsuperscript{11}This comes from the production technology specified and (2), (3) and (4).
number of varieties. The vector \( \Psi_{it} = (d^x_i, K_i, w_t, u_t, P_{dt}, p^f_i, f^o_i, \Phi^D_t, \Phi_t) \) represents the environment of the firm where \( f^o_i \) is the fixed cost of importing each foreign variety and \( \Phi^D_t \) and \( \Phi_t \) are industry aggregates (in domestic and foreign markets) and the other variables are as defined before.

**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. Thus, other things being equal, this would imply that an exporter will have a higher probability of doing R & D as compared to a non-exporter.

\[
\begin{align*}
[E(\pi_{it+1} | \omega_{it}, d^k_i = 1, \Psi_{it}) - E(\pi_{it+1} | \omega_{it}, d^k_i = 0, \Psi_{it})] | d^x_i = 1 > \frac{[E(\pi_{it+1} | \omega_{it}, d^k_i = 1, \Psi_{it}) - E(\pi_{it+1} | \omega_{it}, d^k_i = 0, \Psi_{it})] | d^x_i = 0}{d^x_i = 0} 
\end{align*}
\]

(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 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 controls 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>
<thead>
<tr>
<th>Table 1: Imports and R &amp; D by Export Status</th>
<th>R &amp; D Status</th>
<th>Import Status</th>
<th>Import Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.120***</td>
<td>0.265***</td>
<td>0.061***</td>
<td></td>
</tr>
<tr>
<td>(0.078)</td>
<td>(0.097)</td>
<td>(0.020)</td>
<td></td>
</tr>
</tbody>
</table>

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. *** \( p < 0.01 \), ** \( p < 0.05 \), * \( p < 0.1 \).

### 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 (1) and (2) to a specification which uses expenditure on intermediate inputs (domestic and foreign) as described in subsection 3.1. 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 3.2. This is in contrast to the literature which uses indus-
try 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.

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.)

\[
P_{xit} = P_{dt} \left( \frac{M_{it}}{M_{dit}} \right)^{\frac{\rho-1}{\rho}}
\]

(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 \( \frac{M_{it}}{P_{it}} \) in the expression for the production technology of the firm. From (1) and (21), the production function can thus be written as

\[
Q_{it} = e^{\omega_{it} K_{it}^{\alpha_k} L_{it}^{\alpha_l} F_{it}^{\alpha_e} \left( \frac{M_{it}}{P_{dt}} \right)^{\alpha_x} \left( \frac{M_{it}}{M_{dit}} \right)^{\alpha_x}}
\]

(22)

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

Usually, when production functions are estimated (including in the exports and productivity literature), the role of imports is ignored. The last term in (22) is not included and the general form of the production function estimated is

\[
Q_{it} = e^{\omega_{it} K_{it}^{\alpha_k} L_{it}^{\alpha_l} F_{it}^{\alpha_e} \left( \frac{M_{it}}{P_{dt}} \right)^{\alpha_x}}
\]

(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 materials inputs deflator). The term \( \left( \frac{M_{it}}{M_{dit}} \right)^{\alpha_x} \) gets subsumed in the estimate of productivity \( e^{\omega_{it}} \). If all firms purchased all their inputs domestically, \( \left( \frac{M_{it}}{M_{dit}} \right)^{\alpha_x} \) would disappear and (22) would reduce to (23).

However, for some firms, a portion of the expenditure on intermediate inputs is on inputs sourced from abroad. From (14) and (21),

\[
\frac{M_{it}}{M_{dit}} = 1 + \left[ \frac{p_{it}^f (n_{it})^\frac{\rho-1}{\rho}}{P_{dt}} \right]^{\frac{\rho}{\rho-1}}
\]

(24)

\( \frac{M_{it}}{M_{dit}} \) is increasing in \( n_{it} \) and \( \left( \frac{M_{it}}{M_{dit}} \right)^{\alpha_x} \) 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 $\omega_{it}$ having a lower marginal cost of production as seen in section 2. Analogously, firms with higher import intensity ($\frac{M_{it}}{M_{dit}}$) and higher $\omega_{it}$ are able to produce a higher level of output for a given level of inputs.

The natural log of the production function (22) of firm $i$ can be written as

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

(25)

The lowercase letters $q, l, k, e, m, \chi$ refer to the natural log of quantity, labor, capital, energy, expenditure on material inputs and import intensity ($\frac{M}{M_d}$) 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 $\omega_{it}$, is known to the firm when it makes its decisions on inputs but is not observed in the data. Lastly, $\epsilon_{it}$ represents measurement error and idiosyncratic shocks to production.

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,

$$q_{it} = r_{it} - p_{it}$$

(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

$$\tilde{q}_{it} = r_{it} - p_{It}$$

(27)

Using (26) and (27), if we substitute for $\tilde{q}_{it} = q_{it} - (p_{it} - p_{It})$ into (25), the production function becomes

$$\tilde{q}_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_e e_{it} + \alpha_m m_{it} + \alpha_{\chi} \chi_{it} + \tilde{\omega}_{it} + \epsilon_{it}$$

(28)

where,

$$\tilde{\omega}_{it} = (p_{it} - p_{It}) + \omega_{it}$$

(29)
If firms operated in perfectly competitive markets where each firm was a price taker and charged the industry price (i.e., $p_{it} = p_{It}$), (25) and (28) 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 $\tilde{q}_{it}$ 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.\(^{12}\)

The second problem is specific to the export-productivity question when we try to estimate within-firm changes to total productivity from export entry (see Garcia-Marin and Voigtlnder (2013)). 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 $\omega_{it}$ rises. In this case, using estimates of productivity from (28) will underestimate gains to firms post export market entry.\(^{13}\)

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 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 data set.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage of Firms with Decline in Prices</th>
<th>Mean Reduction in Prices</th>
<th>Percentage of Firms with Increase in Prices</th>
<th>Average Increase in Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>37%</td>
<td>9%</td>
<td>63%</td>
<td>10%</td>
</tr>
</tbody>
</table>

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 3 percent increase in prices over the previous year. Deflating revenues by the industry deflator would underestimate the quantity changes for firms.

---

\(^{12}\)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.

\(^{13}\)Theoretical models of trade such as Melitz (2003) 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.
with price changes less than 3 percent and overestimate the quantity changes for firms with growth in prices over 3 percent. This would imply that productivity change is underestimated for firms that experience a change in price of less than 3 percent and overestimated for firms that experience a change in price greater than 3 percent.

Table 2: Price Changes in Transport Equipment Industry

<table>
<thead>
<tr>
<th>Year</th>
<th>% of Firms</th>
<th>Mean</th>
<th>% of Firms</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Industry Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>6.06</td>
<td>-0.21</td>
<td>93.94</td>
<td>0.13</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>1991</td>
<td>13.64</td>
<td>-0.07</td>
<td>86.36</td>
<td>0.11</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td>1992</td>
<td>6.06</td>
<td>-0.22</td>
<td>93.94</td>
<td>0.18</td>
<td>0.15</td>
<td>0.11</td>
</tr>
<tr>
<td>1993</td>
<td>7.77</td>
<td>-0.07</td>
<td>92.23</td>
<td>0.12</td>
<td>0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>1994</td>
<td>32.52</td>
<td>-0.07</td>
<td>67.48</td>
<td>0.09</td>
<td>0.12</td>
<td>0.03</td>
</tr>
<tr>
<td>1995</td>
<td>27.52</td>
<td>-0.12</td>
<td>72.48</td>
<td>0.13</td>
<td>0.17</td>
<td>0.07</td>
</tr>
<tr>
<td>1996</td>
<td>24.54</td>
<td>-0.11</td>
<td>75.46</td>
<td>0.13</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>1997</td>
<td>25.00</td>
<td>-0.11</td>
<td>75.00</td>
<td>0.11</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>1998</td>
<td>43.03</td>
<td>-0.10</td>
<td>56.97</td>
<td>0.09</td>
<td>0.14</td>
<td>0.04</td>
</tr>
<tr>
<td>1999</td>
<td>44.68</td>
<td>-0.09</td>
<td>55.32</td>
<td>0.09</td>
<td>0.14</td>
<td>0.03</td>
</tr>
<tr>
<td>2000</td>
<td>37.08</td>
<td>-0.09</td>
<td>62.92</td>
<td>0.10</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td>2001</td>
<td>36.86</td>
<td>-0.10</td>
<td>63.14</td>
<td>0.11</td>
<td>0.16</td>
<td>0.06</td>
</tr>
<tr>
<td>2002</td>
<td>52.80</td>
<td>-0.09</td>
<td>47.20</td>
<td>0.11</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>2003</td>
<td>43.80</td>
<td>-0.10</td>
<td>56.20</td>
<td>0.09</td>
<td>0.14</td>
<td>0.00</td>
</tr>
<tr>
<td>2004</td>
<td>42.69</td>
<td>-0.10</td>
<td>57.31</td>
<td>0.12</td>
<td>0.16</td>
<td>0.00</td>
</tr>
<tr>
<td>2005</td>
<td>32.02</td>
<td>-0.10</td>
<td>67.98</td>
<td>0.14</td>
<td>0.18</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Notes: Column (6) shows price change for the 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.

Information on prices allows me to estimate (25). 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 $\omega_{it}$ that do not suffer from the shortcomings discussed above.

4 Estimation Strategy

The empirical strategy involves two steps. First, I recover the parameters of the production function and estimates of total productivity ($\bar{\alpha}x_{it} + \bar{\omega}_{it}$). Next, I use difference-in-differences propensity score matching to examine the impact of starting to export on efficiency.
4.1 Recovering the Production Function Parameters

I estimate the parameters of (25) 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. (2006) who extends Olley and Pakes (1996) and Levinsohn and Petrin (2003).\footnote{Ackerberg et al. (2006) argue that the labor parameter cannot be consistently identified in the Olley and Pakes (1996) and Levinsohn and Petrin (2003) method.}

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.\footnote{See Hasan et al. (2007) for a discussion on labor market regulations and rigidities in India.} I assume like Ackerberg et al. (2006), that labor is not completely free 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.\footnote{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.}

The demand function for energy inputs is given by $e_{it} = h(k_{it}, l_{it}, m_{it}, \chi_{it}, \omega_{it})$. Under the monotonicity assumption (the demand for the variable input $h(k_{it}, l_{it}, m_{it}, \chi_{it}, \omega_{it})$ is strictly increasing in $\omega_{it}$), 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. (2006) method, no parameter is estimated in the first stage. The first stage is used to get a consistent estimate of expected output ($\hat{\phi}_{it}(.)$).

$$q_{it} = \phi_{it}(l_{it}, k_{it}, m_{it}, \chi_{it}, e_{it}) + \epsilon_{it} \quad (30)$$

where

$$\phi_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \alpha_e e_{it} + h^{-1}(k_{it}, l_{it}, m_{it}, \chi_{it}, e_{it}) \quad (31)$$

In addition to the firm variables in $h^{-1}(.)$, I also include year dummies to account for macro trends that could impact input demand. I use a full fifth degree polynomial in capital, labor, material inputs, labor and energy to get an estimate of $\hat{\phi}_{it}$. Once $\hat{\phi}_{it}(.)$ is estimated, for any candidate candidate values of the coefficients, productivity can be written as

$$\omega_{it}(\alpha) = \hat{\phi}_{it} - (\alpha_0 + \alpha_l l_{it} + \alpha_k k_{it} + \alpha_x m_{it} + \alpha_\chi \chi_{it} + \alpha_e e_{it}) \quad (32)$$

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

\[ \omega_{it} = \gamma_1 \omega_{it-1} + \gamma_2 d_{it-1}^k + \gamma_3 \omega_{it-1} * d_{it-1}^k + \zeta_{it} \]  

(33)

From (32) and (33), \( \zeta_{it} \) can be recovered for the candidate values of the coefficients. \( \omega_{it} \) is decomposed into two parts. The first part constitutes the conditional expectation of productivity based on the information set known in period \( t-1 \) and the second, \( \zeta_{it} \) is the deviation from the expectation. \( \zeta_{it} \) 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 coefficients through GMM using the moment conditions.

\[ E(\zeta_{it}(\alpha, \gamma) Z_{it}) = 0 \]  

(34)

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

### 4.2 Gains from Exporting

The measure of overall productivity is \( \hat{\alpha}_\chi \chi_{it} + \hat{\omega}_{it} \), which is constituted of two parts. The first is productivity due to imports of intermediate inputs and the second is the part that is due to investment in knowledge. 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).

In the context of this paper, treatment (W) is the entry into export markets and the outcome of interest \( (Y_{is}) \) is efficiency 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

\[ P(W_{it} = 1) = \Phi \left( f(\omega_{it-1}, k_{it-1}, l_{it-1}, d_{it-1}^k, \chi_{it-1}) \right) \]  

(35)

where \( P(W_{it} = 1) \) is the probability of the firm starting to export at period \( t \), \( \Phi \) is the cumulative

\[ \text{15} \]
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 nonparticipant analogue for each participant. 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., \( E(Y_t^0 - Y_{t-1}^0|P, W = 1) = E(Y_t^0 - Y_{t-1}^0|P, W = 0) \). 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 \( (Y_t^0 - Y_{t-1}^0) \) denotes the change in the outcome of interest between the two periods in the untreated state.

The treatment on the treated is given by

\[
\delta^T = \frac{1}{N} \left( \sum_{i \in T} (Y_{it'}^1 - Y_{it-1}^1) - \sum_{j \in C} w_{ij} (Y_{jt'}^c - Y_{jt-1}^c) \right)
\]

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 \( i \). \( Y_{it'}^1 - Y_{it-1}^1 \) is the change in the outcome variable for the export entrant between \( t' \) and \( t - 1 \) and \( Y_{jt'}^c - Y_{jt-1}^c \) is the change in the outcome variable for the control firms between \( t' \) and \( t - 1 \).

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

5 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 data set 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).

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

The measure of quantity I use is the firm sales revenue deflated by the firm specific price 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 4.2.

The data set 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. Among the firms, 1,658 are single-product firms throughout the period while the remaining firms sell two or more products at least at 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 et al. (2004), Eslava et al. (2010), Ornaghi (2008) and 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.3). 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.

\[19I\ exclude\ minor\ industries\ such\ as\ printing,\ coke\ and\ petroleum\ products\ etc.,\ where\ the\ number\ of\ firm-year\ observations\ is\ too\ few\ to\ allow\ for\ estimation\ of\ the\ production\ function\ parameters.\]
Table 3: Summary Statistics

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

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.

6 Results

I begin by estimating the parameters of the production function (25) and the endogenous productivity evolution process (33) as described in subsection 4.1. The estimates are presented in subsection 6.1. In subsection 6.2, 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 6.3, I present results from robustness checks.

6.1 Production Function Parameters: Imports and R & D

Tables 4, 5 and 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 4 reports the estimation results for the production function parameters for 13 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 magnitudes of these parameters are reasonable across industries for these different inputs.

Table 5 presents the estimates of the imported inputs term in the production function. \(\alpha_\chi\) is the estimate on the import intensity term (\(\chi\)) in the production function where \(\chi\) takes a value 0 if the firm does not import from abroad (since in that case, \(M_{it} = M_{dit}\) and \(\chi\) is the natural log of \(\frac{M_{it}}{M_{dit}}\)). \(\chi\) is increasing in the expenditure share on imported intermediate inputs. The coefficient \((\alpha_\chi)\) is positive in all 13 industries. Everything else held equal, firms that import a larger share of
Table 4: Production Function Coefficients

<table>
<thead>
<tr>
<th>Industry</th>
<th>$\alpha_0$</th>
<th>$\alpha_l$</th>
<th>$\alpha_k$</th>
<th>$\alpha_x$</th>
<th>$\alpha_e$</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food &amp; Beverages</td>
<td>2.130***</td>
<td>0.241***</td>
<td>0.035**</td>
<td>0.525***</td>
<td>0.125***</td>
<td>5,340</td>
</tr>
<tr>
<td></td>
<td>(0.098)</td>
<td>(0.012)</td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.014)</td>
<td></td>
</tr>
<tr>
<td>Textiles &amp; Apparel</td>
<td>1.329***</td>
<td>0.069***</td>
<td>0.105***</td>
<td>0.704***</td>
<td>0.031**</td>
<td>5,471</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(0.013)</td>
<td>(0.012)</td>
<td>(0.020)</td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>Paper &amp; Products</td>
<td>1.196***</td>
<td>0.088**</td>
<td>0.114***</td>
<td>0.723***</td>
<td>0.031*</td>
<td>1,464</td>
</tr>
<tr>
<td></td>
<td>(0.110)</td>
<td>(0.045)</td>
<td>(0.024)</td>
<td>(0.047)</td>
<td>(0.016)</td>
<td></td>
</tr>
<tr>
<td>Basic Chemicals</td>
<td>1.890***</td>
<td>0.215***</td>
<td>0.164***</td>
<td>0.520***</td>
<td>0.015</td>
<td>3,518</td>
</tr>
<tr>
<td></td>
<td>(0.126)</td>
<td>(0.052)</td>
<td>(0.052)</td>
<td>(0.046)</td>
<td>(0.050)</td>
<td></td>
</tr>
<tr>
<td>Chemical Products</td>
<td>1.514***</td>
<td>0.436***</td>
<td>0.053</td>
<td>0.660***</td>
<td>-0.166*</td>
<td>1,469</td>
</tr>
<tr>
<td></td>
<td>(0.243)</td>
<td>(0.115)</td>
<td>(0.049)</td>
<td>(0.083)</td>
<td>(0.088)</td>
<td></td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>1.621***</td>
<td>0.315***</td>
<td>0.057**</td>
<td>0.619***</td>
<td>0.014</td>
<td>2,538</td>
</tr>
<tr>
<td></td>
<td>(0.114)</td>
<td>(0.041)</td>
<td>(0.028)</td>
<td>(0.054)</td>
<td>(0.039)</td>
<td></td>
</tr>
<tr>
<td>Rubber &amp; Plastic</td>
<td>2.019***</td>
<td>0.125**</td>
<td>0.220***</td>
<td>0.435***</td>
<td>0.189**</td>
<td>2,438</td>
</tr>
<tr>
<td></td>
<td>(0.212)</td>
<td>(0.051)</td>
<td>(0.061)</td>
<td>(0.080)</td>
<td>(0.095)</td>
<td></td>
</tr>
<tr>
<td>Mineral Products</td>
<td>1.348***</td>
<td>0.091*</td>
<td>0.127***</td>
<td>0.575***</td>
<td>0.251***</td>
<td>1,811</td>
</tr>
<tr>
<td></td>
<td>(0.098)</td>
<td>(0.051)</td>
<td>(0.033)</td>
<td>(0.047)</td>
<td>(0.046)</td>
<td></td>
</tr>
<tr>
<td>Basic Metals &amp; Products</td>
<td>1.403***</td>
<td>0.064***</td>
<td>0.090***</td>
<td>0.726***</td>
<td>0.073**</td>
<td>4,896</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.017)</td>
<td>(0.023)</td>
<td>(0.019)</td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Computer &amp; Electronics</td>
<td>0.977***</td>
<td>0.180***</td>
<td>0.072</td>
<td>0.864***</td>
<td>-0.034</td>
<td>1,485</td>
</tr>
<tr>
<td></td>
<td>(0.146)</td>
<td>(0.059)</td>
<td>(0.063)</td>
<td>(0.060)</td>
<td>(0.061)</td>
<td></td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>1.150***</td>
<td>0.132***</td>
<td>0.127***</td>
<td>0.774***</td>
<td>-0.041</td>
<td>2,246</td>
</tr>
<tr>
<td></td>
<td>(0.088)</td>
<td>(0.034)</td>
<td>(0.019)</td>
<td>(0.029)</td>
<td>(0.028)</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>1.303***</td>
<td>0.118**</td>
<td>0.042</td>
<td>0.722***</td>
<td>0.162**</td>
<td>2,353</td>
</tr>
<tr>
<td></td>
<td>(0.196)</td>
<td>(0.060)</td>
<td>(0.052)</td>
<td>(0.042)</td>
<td>(0.066)</td>
<td></td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>1.151***</td>
<td>0.142***</td>
<td>0.094***</td>
<td>0.693***</td>
<td>0.052*</td>
<td>2,493</td>
</tr>
<tr>
<td></td>
<td>(0.116)</td>
<td>(0.041)</td>
<td>(0.036)</td>
<td>(0.047)</td>
<td>(0.029)</td>
<td></td>
</tr>
</tbody>
</table>

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


their intermediate inputs from abroad are able to produce higher output with the given inputs.

To illustrate, in the transport equipment industry, a 10% increase in the $\frac{M_i}{M_{di}}$ ratio (which is approximately a 9% 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 5.2% increase in total output.

The table also presents the implied values for $\rho$ which are calculated from the estimates of $\alpha_x$ and $\alpha_\chi$ 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 $\rho$ to be between 0 and 1. The implied values for $\rho$ for all the 13 industry groups falls within this range.

Table 5: Imports in the Production Function

<table>
<thead>
<tr>
<th>Imports</th>
<th>$\alpha_\chi$</th>
<th>$\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food &amp; Beverages</td>
<td>0.467***</td>
<td>0.529</td>
</tr>
<tr>
<td>Textiles &amp; Apparel</td>
<td>0.386***</td>
<td>0.646</td>
</tr>
<tr>
<td>Paper &amp; Products</td>
<td>0.078</td>
<td>0.903</td>
</tr>
<tr>
<td>Basic Chemicals</td>
<td>0.258*</td>
<td>0.668</td>
</tr>
<tr>
<td>Chemical Products</td>
<td>0.298</td>
<td>0.689</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>0.137</td>
<td>0.819</td>
</tr>
<tr>
<td>Rubber &amp; Plastic</td>
<td>0.096</td>
<td>0.819</td>
</tr>
<tr>
<td>Mineral Products</td>
<td>0.144</td>
<td>0.800</td>
</tr>
<tr>
<td>Basic Metals &amp; Products</td>
<td>0.234*</td>
<td>0.756</td>
</tr>
<tr>
<td>Computer &amp; Electronics</td>
<td>0.066</td>
<td>0.929</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>0.351*</td>
<td>0.688</td>
</tr>
<tr>
<td>Machinery</td>
<td>0.318</td>
<td>0.694</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>0.540***</td>
<td>0.562</td>
</tr>
</tbody>
</table>

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

Table 6 presents the estimates of the endogenous productivity process. The coefficient $\gamma_1$ measures the impact of previous period firm productivity on current productivity and is positive
Table 6: Productivity Evolution: Past Productivity and Investment in R & D

<table>
<thead>
<tr>
<th>Category</th>
<th>$\omega_{t-1}$</th>
<th>$d^k_{t-1}$</th>
<th>$\omega_{t-1}X_{d^k_{t-1}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma_1$</td>
<td>$\gamma_2$</td>
<td>$\gamma_3$</td>
</tr>
<tr>
<td>Food &amp; Beverages</td>
<td>0.052</td>
<td>0.016*</td>
<td>0.697***</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.009)</td>
<td>(0.087)</td>
</tr>
<tr>
<td>Textiles &amp; Apparel</td>
<td>0.321**</td>
<td>0.025***</td>
<td>0.500***</td>
</tr>
<tr>
<td></td>
<td>(0.144)</td>
<td>(0.007)</td>
<td>(0.161)</td>
</tr>
<tr>
<td>Paper &amp; Products</td>
<td>0.422***</td>
<td>0.046*</td>
<td>0.095</td>
</tr>
<tr>
<td></td>
<td>(0.095)</td>
<td>(0.024)</td>
<td>(0.309)</td>
</tr>
<tr>
<td>Basic Chemicals</td>
<td>0.762***</td>
<td>0.000</td>
<td>-0.391***</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.028)</td>
<td>(0.139)</td>
</tr>
<tr>
<td>Chemical Products</td>
<td>0.662***</td>
<td>0.024**</td>
<td>0.354**</td>
</tr>
<tr>
<td></td>
<td>(0.096)</td>
<td>(0.012)</td>
<td>(0.165)</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>0.565***</td>
<td>0.032***</td>
<td>0.322**</td>
</tr>
<tr>
<td></td>
<td>(0.081)</td>
<td>(0.009)</td>
<td>(0.140)</td>
</tr>
<tr>
<td>Rubber &amp; Plastic</td>
<td>0.778***</td>
<td>0.024**</td>
<td>0.151*</td>
</tr>
<tr>
<td></td>
<td>(0.039)</td>
<td>(0.011)</td>
<td>(0.081)</td>
</tr>
<tr>
<td>Mineral Products</td>
<td>0.094</td>
<td>0.042***</td>
<td>0.960***</td>
</tr>
<tr>
<td></td>
<td>(0.331)</td>
<td>(0.008)</td>
<td>(0.333)</td>
</tr>
<tr>
<td>Basic Metals &amp; Products</td>
<td>0.694***</td>
<td>0.024***</td>
<td>0.273***</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.005)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Computer &amp; Electronics</td>
<td>0.224</td>
<td>0.011</td>
<td>0.432*</td>
</tr>
<tr>
<td></td>
<td>(0.164)</td>
<td>(0.023)</td>
<td>(0.238)</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>0.001</td>
<td>0.035***</td>
<td>0.845***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.010)</td>
<td>(0.087)</td>
</tr>
<tr>
<td>Machinery</td>
<td>0.317</td>
<td>0.033***</td>
<td>0.994**</td>
</tr>
<tr>
<td></td>
<td>(0.241)</td>
<td>(0.012)</td>
<td>(0.415)</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>0.521***</td>
<td>0.022***</td>
<td>0.397*</td>
</tr>
<tr>
<td></td>
<td>(0.123)</td>
<td>(0.005)</td>
<td>(0.240)</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses are clustered at firm level. *** p<0.01, ** p<0.05, * p<0.1.
in all industries. The coefficient $\gamma_2$ 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 4 percent higher productivity than firms that do not.

However, the impact of doing R & D on productivity varies depending on the firm’s initial productivity level. The coefficient on the interaction term, $\gamma_3$ captures the idea that the productivity effects from investing in R & D depends on the firm’s initial productivity level. In 12 of the 13 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, a median productivity firm in the transport industry can increase its productivity by 1.9 % in $t + 1$ by engaging in R & D in period $t$ while a firm in the 90th percentile of productivity can increase its productivity by 18.6 % in $t + 1$ by engaging in R & D in period $t$.

6.2 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 1 depicts the productivity trajectory for the export entrant using measures of revenue productivity as well as physical productivity. 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 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, I graph how the productivity trajectory of an export entrant compares with a non exporter control firm. 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

\[\text{Median productivity of a firm in the transport industry equals } -0.008 \text{ while a 90th percentile firm has productivity which equals } 0.414. \text{ The parameters of the productivity process in the transport industry are } \gamma_1 = 0.521, \gamma_2 = 0.022 \text{ and } \gamma_3 = 0.397.\]

\[\text{These productivity trajectories are based on 348 export entrants for which data are available for the entire period under consideration.}\]

\[\text{The control firm was chosen as described in subsection 4.2 using nearest neighbor matching techniques.}\]

\[\text{20}\]
similar trajectories prior to export entry. However, after the firm begins to export, their trajectories diverge and the gap between them widens over time.

Figure 1: Productivity Trajectory for Export Entrant (Revenue vs. Physical Productivity)
Average Firm Specific Total Productivity

![Figure 1](image)

Figure 2: Productivity Trajectory for Export Starter vs. Non Exporter Counterpart
Average Firm Specific Total Productivity (From Imports and R & D)

![Figure 2](image)

In Table 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. The firm begins exporting in

23 For example, if an export entrant experienced 15% productivity growth and a non exporter counterpart experienced a 5% productivity growth, the coefficient on $\delta^T$ would be .10 which reflects that export entrants productivity
period \( t \) and \( t + i \) where \( i = 1, 2, \ldots \) refers to the time period \( i \) years after the firm enters the export market.

Table 7: Productivity Growth over Time from Export Entry: Matching Results

<table>
<thead>
<tr>
<th></th>
<th>Total Productivity</th>
<th>Imports</th>
<th>R &amp; D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \hat{\alpha}<em>X \chi</em>{it} + \hat{\omega}_{it} )</td>
<td>( \hat{\alpha}<em>X \chi</em>{it} )</td>
<td>( \hat{\omega}_{it} )</td>
</tr>
<tr>
<td>( t+1 )</td>
<td>0.063** (0.028)</td>
<td>0.001 (0.004)</td>
<td>0.061** (0.029)</td>
</tr>
<tr>
<td>( t+2 )</td>
<td>0.072*** (0.024)</td>
<td>0.008 (0.006)</td>
<td>0.065** (0.027)</td>
</tr>
<tr>
<td>( t+3 )</td>
<td>0.067* (0.035)</td>
<td>0.011* (0.006)</td>
<td>0.055* (0.033)</td>
</tr>
<tr>
<td>( t+4 )</td>
<td>0.081** (0.033)</td>
<td>0.017*** (0.006)</td>
<td>0.065* (0.035)</td>
</tr>
<tr>
<td>( t+5 )</td>
<td>0.092** (0.036)</td>
<td>0.019*** (0.005)</td>
<td>0.074** (0.035)</td>
</tr>
<tr>
<td>( t+6 )</td>
<td>0.103*** (0.038)</td>
<td>0.017*** (0.005)</td>
<td>0.087** (0.039)</td>
</tr>
</tbody>
</table>

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 \( \delta^\tau \) for overall productivity \( \hat{\alpha}_X \chi_{it} + \hat{\omega}_{it} \). 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 \( \delta^\tau \) is significant for every time period for the six years.

Column 2 of Table 7 presents the estimates of the coefficients \( \delta^\tau \) for the component of productivity attributable to imports \( \hat{\alpha}_X \chi_{it} \) and column 3 presents the coefficients \( \delta^\tau \) for component of productivity attributable to firm investment in R & D \( \hat{\omega}_{it} \). While the coefficients are positive and significant for both components, they are much larger in magnitude for the R & D component. The estimates of \( \delta^\tau \) 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.

---

growth rate was 10 percentage points higher.
The coefficients in Table 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 4.2. 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 data ends at 2005. The results from the unrestricted sample are presented in Table 8.

The first row shows the \( \delta^T \) for total productivity and the second and third rows shows the estimates of \( \delta^T \) 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 \( \delta^T \) for total productivity, productivity from imports and productivity from R & D are 0.056 (0.026), 0.008 (0.003) 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 an 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 higher.

| Table 8: Productivity Growth from Export Entry (All export entrants): Matching Results |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                | \( \hat{\alpha}_{\chi} + \hat{\omega}_{it} \) | \( \hat{\alpha}_{\chi} \) | \( \hat{\omega}_{it} \) |
| Total Productivity                              | 0.056**         | 0.079***        | 0.079**         | 0.098***        | 0.117***        | 0.112**         |
| \( \hat{\alpha}_{\chi} + \hat{\omega}_{it} \) | (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***        |
| \( \hat{\alpha}_{\chi} \)                     | (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**         |
| \( \hat{\omega}_{it} \)                        | (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

6.3 Robustness Checks

I verify whether the results from subsection 6.2 are robust to concerns about foreign firms possibly driving the productivity growth of exporters, the possibility of export entrants having different growth rates than their non exporter counterparts prior to export entry in anticipation of
6.3.1 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). 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 9 presents the results for the sample of domestic firms. The estimate of $\delta^*$ 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.

Table 9: Productivity Growth over Time from Export Entry (Domestic Firms): Matching Results

<table>
<thead>
<tr>
<th></th>
<th>Total Productivity</th>
<th>Imports</th>
<th>R &amp; D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\hat{\alpha}<em>X^{\chi</em>{it}} + \hat{\omega}_{it}$</td>
<td>$\hat{\alpha}<em>X^{\chi</em>{it}}$</td>
<td>$\hat{\omega}_{it}$</td>
</tr>
<tr>
<td>$t+1$</td>
<td>0.063**</td>
<td>0.003</td>
<td>0.060**</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.004)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>$t+2$</td>
<td>0.081***</td>
<td>0.009</td>
<td>0.071**</td>
</tr>
<tr>
<td></td>
<td>(0.029)</td>
<td>(0.006)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>$t+3$</td>
<td>0.091***</td>
<td>0.013**</td>
<td>0.078**</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.006)</td>
<td>(0.036)</td>
</tr>
<tr>
<td>$t+4$</td>
<td>0.105***</td>
<td>0.018***</td>
<td>0.087**</td>
</tr>
<tr>
<td></td>
<td>(0.037)</td>
<td>(0.006)</td>
<td>(0.037)</td>
</tr>
<tr>
<td>$t+5$</td>
<td>0.107***</td>
<td>0.020***</td>
<td>0.087**</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.006)</td>
<td>(0.040)</td>
</tr>
<tr>
<td>$t+6$</td>
<td>0.115***</td>
<td>0.018***</td>
<td>0.097**</td>
</tr>
<tr>
<td></td>
<td>(0.041)</td>
<td>(0.005)</td>
<td>(0.044)</td>
</tr>
</tbody>
</table>

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

Table 9 presents the results for the sample of domestic firms. The estimate of $\delta^*$ 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.

---

24 This is an time invariant firm specific variable.
6.3.2 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 or they 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 10. The average growth rates for export entrants and their non-exporter counterparts prior to entry into export markets are not different from each other.

Table 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|

6.3.3 Alternate Matching

Finally, I check whether the results are robust to alternate matching estimators. The main results presented in section 6.2 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 11 and 12 in appendix A.4 presents the results from the using five neighbors. The results are very similar to the ones presented in Tables 7 and 8 in section 6.2.

7 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 has been driving this non result. I revisit the export-productivity question where I retrieve firm-level physical productivity measures that account for firm pricing heterogeneity.

I find evidence that firm productivity grows faster after they 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 in 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 markups of exporters after they begin selling in international markets.

References


A Appendices

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 complementarity that is 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 (2003)). The demand functions of the firm in the domestic ($Q_{Dit}$) and export ($Q_{Xit}$) markets are given by

$$Q_{Dit} = Q_{IDt} \left( \frac{P_{Dit}}{P_{IDt}} \right)^{-\sigma} = \Phi_{D}^{D}(P_{Dit})^{-\sigma} \quad (37)$$

$$Q_{Xit} = Q_{IXt} \left( \frac{P_{Xit}}{P_{IXt}} \right)^{-\sigma} = \Phi_{X}^{X}(P_{Xit})^{-\sigma} \quad (38)$$

$P_{Dit}$ and $P_{Xit}$ are prices of the firm in the domestic and export markets, $Q_{IDt}$, $Q_{IXt}$, $P_{IDt}$ and $P_{IXt}$ are the industry output and price indices in the two markets, $\sigma > 1$ is the constant elasticity of demand, $\Phi_{D}^{D}$ and $\Phi_{X}^{X}$ 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 $\pi_{it}$ in period $t$ is given by:

$$\pi_{it}(d^x = 0) = \frac{\lambda}{\sigma} \left[ \Phi_{D}^{D} \left( \frac{\sigma}{\sigma - 1} \right)^{(1-\lambda)\alpha_v} \left( \frac{e^{\omega_{it} K_{Ut}^{\alpha_k}}}{\beta \lambda \eta_{it}^{\alpha_k} \omega_{it}^{\alpha_e} P_{xit}^{\alpha_e}} \right)^{\sigma-1} \right]^{\frac{1}{\lambda}} \quad (39)$$

$$\pi_{it}(d^x = 1) = \frac{\lambda}{\sigma} \left[ (1 + \Phi_{it}) \Phi_{D}^{D} \left( \frac{\sigma}{\sigma - 1} \right)^{(1-\lambda)\alpha_v} \left( \frac{e^{\omega_{it} K_{Uit}^{\alpha_k}}}{\beta \lambda \eta_{it}^{\alpha_k} \omega_{it}^{\alpha_e} P_{xit}^{\alpha_e}} \right)^{\sigma-1} \right]^{\frac{1}{\lambda}} \quad (40)$$

where $\pi_{it}$, 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, $\Phi_{it} = \frac{\Phi_{X}^{X}}{\Phi_{D}^{D}}$, $\beta = \alpha_l^{-\alpha_l} \alpha_e^{-\alpha_e} \alpha_x^{-\alpha_x}$, $\alpha_v = \alpha_l + \alpha_e + \alpha_x$ and $\lambda = 1 + (1 - \alpha_v)(\sigma - 1) \geq 1$. In the specific case of constant marginal cost where $\alpha_v = 1$, $\lambda$ will take the value 1.
A.1.2 Import and R & D Decision

The firm’s environment is represented by the vector $\Psi_{it} = (d^x_i, K_i, w_t, u_t, P_{dt}, p^f_t, f^n_i, \Phi^D_t, \Phi_t)$. Here $f^n_i$ 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 (2003). 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 ($f^n_i$) and chooses the number of varieties ($n_{it}$) to maximize net profits.

$$\Pi(\omega_{it}, \Psi_{it}) = \text{Max}_{n_{it}} \pi_{it}(\omega_{it}, d^x_i, K_i, w_t, u_t, P_{dt}, p^f_t, \Phi^D_t, \Phi_t, n_{it}) - n_{it} f^n_i$$ (41)

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 $f^n_i$.

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

$$V(\omega_{it}; \Psi_{it}) = \Pi(\omega_{it}; \Psi_{it}) + \text{Max}_{d^x_{it}} \left\{ \delta E[V(\omega_{it+1}|\omega_{it}, d^x_{it+1} = 1; \Psi_{it}) - f^k_t], \delta E[V(\omega_{it+1}|\omega_{it}, d^x_{it+1} = 0; \Psi_{it})] \right\}$$ (42)

I assume that the firm’s environment $\Psi_{it} = (d^x_i, K_i, w_t, u_t, P_{dt}, p^f_t, f^n_i, \Phi^D_t, \Phi_t)$ is constant over time.
\( (\Psi_{it} = \Psi_{it+1}) \) and firm has perfect foresight about it. This is a simplifying assumption to isolate the impact of R & D. Investment in R & D in \( t-1 \) impacts \( \omega_{it} \) in \( t \). The firm invests in R & D in \( t \) if

\[
E[V(\omega_{it+1}|\omega_{it}, d_{it}^k = 1; \Psi_{it})] - f_{it}^k > E[V(\omega_{it+1}|\omega_{it}, d_{it}^k = 0; \Psi_{it})]
\]

(43)

### A.1.3 Comparative Statics by Export Status

From (39) and (40), the change in variable profits (gross) from importing an additional variety is given by:

\[
\pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1}) = \frac{\lambda}{\sigma} \left[ (1 + \Phi_t d_i^F) \Phi_t^D \left( \frac{\sigma}{\sigma - 1} \right)^{(1-\lambda)u_v} \left( \frac{e^{\omega_{it} K_i^s_k}}{\beta^i u_t^\omega \alpha^v} \right)^{\sigma - 1} \right] \Delta_{it}
\]

(44)

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

\[
\Delta_{it} = \left[ \left( \frac{1}{P_x(P_{dt}, p_f^t, n_{it})} \right)^{\frac{\sigma - 1}{\lambda}} - \left( \frac{1}{P_x(P_{dt}, p_f^t, n_{it-1})} \right)^{\frac{\sigma - 1}{\lambda}} \right]
\]

(45)

From (15) and (45) 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

\[
\pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})\mid d_i^x = 1 > \pi_{it}(., n_{it}) - \pi_{it}(., n_{it-1})\mid d_i^x = 0
\]

(46)

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.,

\[
n^*(\omega_{it}, \Psi_{it}|d_i^x = 1) \geq n^*(\omega_{it}, \Psi_{it}|d_i^x = 0)
\]

(47)

Next, I move to investment in R & D. First, from (39) and (40), it is straightforward to see that variable profits are increasing in \( \omega_{it} \) for both exporters and non-exporters, i.e.,

\[
\frac{\partial \pi_{it}(.)}{\partial \omega_{it}} = \frac{\sigma - 1}{\lambda} \pi_{it}(.) > 0
\]

(48)

Furthermore, since \( 1 + \Phi_t > 1 \) and \( \frac{\sigma - 1}{\lambda} > 0 \), it follows from (39), (40) and (48) that everything else being equal, this increase is greater for exporters as compared to non-exporters.

\[
\frac{\partial \pi_{it}(.)}{\partial \omega_{it}}\mid d_i^x = 1 > \frac{\partial \pi_{it}(.)}{\partial \omega_{it}}\mid d_i^x = 0
\]

(49)
From (7) and (49),

\[
[E(\pi_{it+1}|\omega_{it}, d^k_i = 1, \Psi_{it}) - E(\pi_{it+1}|\omega_{it}, d^k_i = 0, \Psi_{it})]|d^p_i = 1 > \]
\[
[E(\pi_{it+1}|\omega_{it}, d^k_i = 1, \Psi_{it}) - E(\pi_{it+1}|\omega_{it}, d^k_i = 0, \Psi_{it})]|d^p_i = 0
\] (50)

Investment in R & D in time \(t\) 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 (1) and (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

\[
\text{Min } P_{dit}X_{dit} + P_{fit}X_{fit}
\] (51)
\[
s.t \left[\frac{X_{dit}^{\rho}}{X_{fit}^{\rho}}\right]^{\frac{1}{\rho}} \geq X_{it}
\]

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

\[
X_{dit} = \left[\frac{P_{dit}}{P_{xit}}\right]^{\frac{1}{\rho - 1}} X_{it}
\] (52)
\[
X_{fit} = \left[\frac{P_{fit}}{P_{xit}}\right]^{\frac{1}{\rho - 1}} X_{it}
\] (53)

Here the demand for the intermediate input bundle \(X_{it}\) is the input demand function for the Cobb Douglas technology specified in (1).

\[
X_{it} = \frac{\alpha_x}{P_{xit}} \left[\frac{Q_{it}}{e^{\omega_{it} K_{it}^{\alpha_k}}} \right]^{\frac{1}{\alpha_l + \alpha_e + \alpha_x}} \left[\frac{w_{it}}{\alpha_l}\right]^{\frac{\alpha_l}{\alpha_l + \alpha_e + \alpha_x}} \left[\frac{p_{fit}^{\rho}}{\alpha_e}\right]^{\frac{\alpha_e}{\alpha_l + \alpha_e + \alpha_x}} \left[\frac{P_{xit}}{\alpha_x}\right]^{\frac{\alpha_x}{\alpha_l + \alpha_e + \alpha_x}}
\] (54)

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

\[
P_{xit} = \left[\frac{P_{dit}^{\rho}}{P_{fit}^{\rho}}\right]^{\frac{1}{\rho - 1}}
\] (55)

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 \(M_{dit} = P_{dit}X_{dit}\) where \(X_{dit}\) is the optimal demand for the domestic
intermediate input bundle. From (2), (52), (53), and (55),

\[
\frac{M_{it}}{M_{dit}} = \left[ \frac{P_{xit}}{P_{dit}} \right]^{\frac{\rho}{\rho - 1}}
\]  

(56)

Rearranging the terms of (56) gives (21) in subsection 3.1 in the text.

A.3 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.

\[
\Delta P_{it} = \sum_{h=1}^{H} \overline{s}_{hit} \Delta \ln(P_{hit})
\]

(57)

where

\[
\Delta \ln(P_{hit}) = \ln(P_{hit}) - \ln(P_{hit-1})
\]

(58)

and

\[
\overline{s}_{hit} = \frac{s_{hit} + s_{hit-1}}{2}
\]

(59)

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 were 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,

\[
\Delta P_{it} = P_{it-1} + \Delta \ln(P_{it-1})
\]

(60)

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.4 Tables: Alternate Matching

#### Table 11: Productivity Growth over Time from Export Entry: Matching Results

<table>
<thead>
<tr>
<th></th>
<th>Total Productivity</th>
<th>Imports</th>
<th>R &amp; D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \hat{\alpha} \chi_{it} + \hat{\omega}_{it} )</td>
<td>( \hat{\alpha} \chi_{it} )</td>
<td>( \hat{\omega}_{it} )</td>
</tr>
<tr>
<td>t+1</td>
<td>0.050* (0.027)</td>
<td>0.002 (0.004)</td>
<td>0.048* (0.027)</td>
</tr>
<tr>
<td>t+2</td>
<td>0.063** (0.028)</td>
<td>0.007 (0.005)</td>
<td>0.056* (0.029)</td>
</tr>
<tr>
<td>t+3</td>
<td>0.051 (0.035)</td>
<td>0.012*** (0.004)</td>
<td>0.039 (0.034)</td>
</tr>
<tr>
<td>t+4</td>
<td>0.070** (0.035)</td>
<td>0.017*** (0.005)</td>
<td>0.053 (0.033)</td>
</tr>
<tr>
<td>t+5</td>
<td>0.081** (0.039)</td>
<td>0.018*** (0.005)</td>
<td>0.063* (0.036)</td>
</tr>
<tr>
<td>t+6</td>
<td>0.094** (0.041)</td>
<td>0.018*** (0.005)</td>
<td>0.076* (0.040)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>t+1</th>
<th>t+2</th>
<th>t+3</th>
<th>t+4</th>
<th>t+5</th>
<th>t+6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Productivity ( (\hat{\alpha} \chi_{it} + \hat{\omega}_{it}) )</td>
<td>0.063*** (0.024)</td>
<td>0.077*** (0.023)</td>
<td>0.084*** (0.031)</td>
<td>0.087*** (0.032)</td>
<td>0.107*** (0.032)</td>
<td>0.094*** (0.036)</td>
</tr>
<tr>
<td>Imports ( (\hat{\alpha} \chi_{it}) )</td>
<td>0.008*** (0.003)</td>
<td>0.013*** (0.004)</td>
<td>0.013*** (0.004)</td>
<td>0.018*** (0.004)</td>
<td>0.016*** (0.005)</td>
<td>0.015*** (0.005)</td>
</tr>
<tr>
<td>R &amp; D ( (\hat{\omega}_{it}) )</td>
<td>0.055** (0.024)</td>
<td>0.064*** (0.024)</td>
<td>0.070** (0.031)</td>
<td>0.069** (0.032)</td>
<td>0.092*** (0.032)</td>
<td>0.080** (0.038)</td>
</tr>
</tbody>
</table>

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