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Imported intermediary inputs, R&D and Firm's Productivity: Evidence from Indian Manufacturing

Chandan Sharma[*]

Abstract

This paper examines dynamic as well as static effects of imported intermediary inputs and in-house R&D on productivity growth using firm-level panel data for Indian technology-intensive manufacturing industries for the period 2000-2009. For this purpose, the present study adopts two empirical frameworks: production function and growth accounting method. Although we do have some comprehensible evidence to conclude that imported inputs have positive and significant impact on the productivity of firms, but the overall findings are rather mixed. Specifically, the results from the production function framework suggest that impact of imported intermediary goods on output is reasonably sizable. Surprisingly, however, the role of R&D activities under this framework is found to be insignificant across industries in various estimation specifications. On the other hand, the analysis based on the growth accounting model some yields positive results, which suggest that TFP of firms are closely linked with import and R&D activities. Firms that engage in these activities have 8% to 12% higher TFP than other firms across the industries. However, labor productivity is found to be insulated from these activities.

Keyword: imported intermediary, R&D, Firms' productivity

JEL classification: D22, D24, F10, O30

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1. Introduction

International trade in general and import in particular is considered one of the key sources of the transmission and adoption of new technologies in the growth and development literature (e.g. see Romer, 1987, Coe and Helpman, 1995, Barro, 1997 and Frankel and Romer 1999). This channel is particularly important for developing economies where new technology is relatively scarce mainly because low level of per capita capital and poor institutions quality especially in the higher education and research. Now in a globalized competitive world, it is believed that firms of developing world highly dependent on high quality imported intermediate goods. Use of these goods has become an important channel of obtaining new technology, which finally leads to enhancement in productivity and income of these countries. Through adoption and simulation of technologies via import, developing countries can take advantage of research and development (R&D) of developed countries to improve the efficiency of domestic production. The growth models also suggest that imported intermediary inputs can potentially enhance productivity of domestic firms because of their better quality as well as through learning spillovers between foreign and domestic goods (e.g. Grossman and Helpman, 1991, Krugman, 1979 and Keller, 2004). However, empirical findings on this issue are very mixed. For example, recent studies of Amiti and Konings (2007), Kasahara and Rodrigue (2008), Goldberg et al. (2008), Jones (2008) and Halpern et al. (2009), have found a significant role of import or imported intermediary inputs. Contrary to this, Lawrence and Weinstein (1999), Van Biesebroeck (2003) and Muendler (2004) have shown insignificant or not very sizable impact of this activity.

On the other hand, the technological change through R&D activities and its impact on productivity is also well recognized in the growth models (e.g., see Solow, 1957, Grossman and Helpman, 1990; Smolny, 2000). Klette and Grilliches (1996) extended the edogenous growth theory for R&D and productivity linkage in the context of firm and presented the quality ladder model in a partial equilibrium framework. The model explains that R&D investment and innovations are the engine of growth. Thus, the theortical association between R&D activities and productivity of firms is well established in the literature. In the empirical literature too, there is no dearth of studies on R&D and firm's or plant's performance. Most of these studies are invariably found to have a significant and positive effect of R&D on the performance of firm. However, the estimated elasticity of productivity or output with respect to R&D varies widely in these studies (e.g. see Griliches, 1979, 1986, Griliches and Mairesse, 1990, Jaffe, 1986, and Griffith et al., 2006).

In this paper, we have taken up both of the issues (imported intermediary inputs and R&D) and attempt to investigate their role in technology-intensive industries in a developing and emerging economy- India. The Indian case is both interesting and relevant, because the country has witnessed a series of reform initiatives in the 1990's and the 2000's. As a part of this process, protection from import has decreased substantially as the rate of tariffs and non-tariff barriers (NTBs) were reduced considerable to at par with other developing economies. This has led to a surge in intermediate imports in the country[1]. More importantly, with more than two-thirds of the intermediate import growth occurring in new varieties (Goldberg et al. 2008). On the other side, to encourage firms for conducting R&D, the government has announced a series of fiscal incentives and financial support, which includes many new tax exemption schemes and most of the old such schemes were extended. And the recent data shows that government efforts in this direction have been reasonably successful as firms, at least in some industries, taking it more seriously and its intensity have shown dramatic improvements over the period.

Against this background, this paper aims to provide insight stemming from these different varieties of the literature and to provide evidence of whether the use of foreign intermediate goods and doing in-house R&D enhance firm's productivity, using a very recent panel data set on the Indian machinery manufacturing firms from 2000 to 2009. The dataset is rich and it provides heterogeneity in terms of import of intermediate inputs across firms and across time. It also provides information on yearly R&D expenditure of firms, which is obviously different across firms and years. We introduce three main novelties in empirical analysis in this paper. *First,* most of the previous studies have explained that imported inputs and R&D capital are important sources of productivity gain for firms. The related theories also explain that import and R&D are closely linked through various economic channels. However, in the standard literature both of the issues are tested separately on productivity. We move a step ahead and bring both issues together to test the impact of import and R&D in a single framework. The second novelty of this paper is to investigate the impact through variety of ways, which includes both static and dynamic analysis. The study also utilizes both the production function as well as the growth accounting methods to test the impact. Third, the

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[1] As a result of progressive reduction in customs duty rates and exemptions on various counts, customs duties as a proportion of imports have been falling quite rapidly in India. The customs duty was only 7.40 per cent of imports in 2008-09 compared to 21.88 per cent in 1999-2000. For intermediate imports only 738 number of tariff line are above 10%, while 6782 line are below 10 %(see Table A.1. and A. 2. of Appendix).
Source: International Trade, Economic Survey 2009-2010.
,http://indiabudget.nic.in/es2009-10/chapt2010/chapter07.pdf.

nature of the empirical analysis conducted in this study is, as generally expected, subject to endogeneity and the simultaneity problem. To overcome these problems therefore we utilize appropriate methodologies, i.e., the system Generalized Method of Moments (sys-GMM) (Blundell and Bond 1998, 1999) and Levinsohn and Petrin (2003) (LP hereafter) estimator to effectively account for these issues. More importantly, we depart from the existing literature and attempt to accommodate the R&D and intermediate imports in the production function. For this purpose, we modify the basic LP model.

The rest of the paper is organized as follows: Section 2 presents theoretical background and a brief review of related literature. Section 3 discusses data related issues, while section 4 presents empirical models and estimation techniques. Sectional 5 presents empirical results and discuss their implication. And finally section 6 provides conclusion and policy suggestions on the basis of the empirical findings.

2. The theoretical linkage and review of the related literature

A growing body of theoretical work, well supported by empirical studies in international economics suggests that foreign trade has large positive effects on income, output and productivity (Romer, 1987, Coe and Helpman, 1995, Barro, 1997 and Frankel and Romer 1999). Especially the role of imported intermediate inputs is understood to be vital and that is why in the recent years it has attracted considerable attention in the standard literature. How do intermediate goods affect productivity? Answering this question, the related literature has explained two important channels: the quality and complementarity mechanisms. One hand, imported inputs are considerably better in quality than their domestic counterparts, which often lead to better final products and higher productivity. This mechanism is well discussed and crucial in the endogenous growth literature (e.g., Grossman and Helpman, 1991). On the other hand, complementarity advantage is feasible through employing a combination of different intermediate inputs in the production that may cause gains that are more than the "sum of the parts". These gains could come from imperfect substitution across goods, as in the widely discussed love-of-variety framework of Krugman (1979) and Ethier (1982). It is also possible through Kremer's (1993) O-ring theory[2] of economic development. The knowledge spillovers between foreign and domestic goods could be another channel in this

[2] The O-ring theory of Kremer (1993) states that high-skill workers-those who make few mistakes-wills be matched together in equilibrium, and that wages and output will rise steeply in skill. The model has been proved to be consistent with large income differences between countries, the predominance of small firms in poor countries, and the positive correlation between the wages of workers in different occupations within enterprises. Furthermore, in the model, imperfect observability of skill leads to imperfect matching and thus to spillovers, strategic complementarity, and multiple equilibria in education.

process (e.g., Aitken et al. 1997, Keller, 2004). For the empirical validation, a recent study of Jones (2008) has shown that in equilibrium (through the income multiplier) these channels can work and potentially enhance the level of technology, which leads to significant improvement in productivity.

In the standard literature, the other key channel of productivity and income gain is considered to be innovation and research. In this concern, trade in general and import in particular is associated with these activities through various ways. More importantly, both channels of productivity gain are theoretical modeled together in the different growth frameworks. For example, total investment in R&D is often motivated by anticipated high profits that might further strengthen the expectation that international trade will reduce innovation and R&D activities in the import competing industries and increase it in the exporting sectors. And as a matter of fact, if the impact of import competition is visible in the form of return depressing in some industries, then it is reasonable to expect comparatively less spending and effort on innovation activities. However, as argued by Baldwin (1992), firms may have a motivation for not to innovate under the conditions of imperfect competition, if they are deriving reasonably high profits from the existing technologies. Therefore, in the condition the import competition could actually encourage innovation by reducing the monopoly profits derived from not innovating.

The endogenous growth models explain that R&D expenditures of individual firms contribute to productivity of an economy through their industry-wide spillover effect (Grossman and Helpman, 1990a; Grossman and Helpman, 1990b; Romer, 1986). In this framework, individual firms spend on innovation to obtain new technology that augments their productivity growth. This has significant implications for overall economy as private know-how of individual firms easily spills over to other firms of the same industry and latter to firms of other industries. This acts as an external effect in enhancing the productivity of all firms. With the spillover effect of R&D, a constant or decreasing returns to scale aggregate production function may demonstrate increasing returns to scale, and this would finally enhance output growth (Romer, 1986, Raut and Srinivasan, 1993). The implication of this argument would be that a developing economy can acquire technological know-how through import at a negligible cost. However, some others, for instance, Cohen and Levinthal (1989) argue that firms need to invest in in-house R&D to acquire the new technology which can be available in public domain through different modes including via import. Therefore, theoretically it is quite reasonable to argue that R&D and import can work as supplementary to each other in the production function.

Further, it is also argued that economies of scale often plays very crucial role in determining the returns from R&D spending in the light of the fact that research also involves a substantial fixed and sunk cost components. Therefore, in some sense the import competing sectors are expected to have less R&D investment that scale of activity is limited with that of trade. This can also be explained in the *learning – by – doing* framework of Lucas (1988), which explain why is trade is an important channel of the productivity growth of the involved sectors. Under this approach it is argued that sectors that produce on a larger scale are highly likely to grow faster than sectors the produce less. In other word, industries which have comparative advantage will witness an expansion in output and the expertise of firms and productivity of labor would improve considerably in producing particular product. But if this is the case, then the exporters may be net gainers while firms in import competing sectors may find themselves net losers.

Some recent studies have found a significant role of imported inputs in general and imported intermediate goods in particular. But overall findings in the literature on this issue are rather mixed. For example, Amiti and Konings (2007) find that the productivity gain from cutting tariffs on intermediate goods is twice as big as those from comparable cuts for final goods in Indonesia. Similarly, in case of India, Goldberg et al. (2008) have shown that access to new intermediate inputs produces substantial productivity gains in India. More recently, while discussing the importance of intermediate inputs for economic development, Jones (2008) concluded that they can help in explaining a large income difference across countries. Halpern et al. (2009) have found that imported inputs have large productivity effects: increasing the share of imported goods from 0 to 100 percent increases productivity by 11 percent for Hungarian firms. Similarly, in an important study, Kasahara and Rodrigue (2008) argued that through adoption and imitation of imported technologies, countries can take advantage of R&D abroad to improve the efficiency of domestic production. Their empirical analysis using plant-level Chilean manufacturing panel data clearly suggests that becoming an importer of foreign intermediates improves productivity.

On the other side, Lawrence and Weinstein (1999) found that lower tariffs and higher import volumes would have been particularly beneficial for Japan during the period 1964 to 1973. However, their findings suggested that in the Japanese case the salutary impact of imports stems more from their contribution to competition than to intermediate inputs. Van Biesebroeck (2003) find that productivity improvements do not happen through the use of more advanced inputs in Columbia. Similarly, Muendler (2004) reached to the conclusion that there is only a small contribution of foreign materials and investment goods on output for Brazil.

On the other side, there is also a large volume of empirical literature focuses on R&D and firm's or plant's performance. Most of these studies are consistently found to have a significant and positive effect of R&D on the performance of firm. However, the estimated elasticity of productivity or output with respect to R&D found to varies widely in these studies. Considering the example from firm-level studies, Griliches (1979, 1986) found that the elasticity to R&D in the US manufacturing was around 0.07. In the case of France, it was found that the elasticity was larger than the US and it ranged between 0.09 and 0.33 (Cuneo and Mairesse, 1984; Mairesse and Cuneo, 1985). For USA, Jaffe (1986) estimated the elasticity around 0.20. For the same country, Griliches and Mairesse (1990) found it is ranging between 0.25 to 0.45, while in the same study, for Japanese manufacturing it was found to range between 0.20 to 0.50. However, for Taiwanese manufacturing firms, Wang and Tsai's (2003) estimation suggested it as 0.19. In a recent paper, Griffith et al. (2006) for the UK manufacturing firms found the size of the elasticity too low (ranging from 0.012 to 0.029). In the case of India, the elasticity with respect to value added was calculated to be 0.064 in the heavy industries, 0.357 in the light industries and 0.101 in the overall industries (Raut, 1995).

In the light of above discussion, three important issues are emerged. First, there is a strong theoretical linkage between Import, R&D and productivity. Second, empirical findings in this area are widely mixed and inconclusive. Finally, despite a voluminous research, hardly any study test the empirical linkage between these variables in a single framework and thus the issue is still its infancy. Therefore, it is both relevant as well as interesting to explore the issue further to find out that whether the linkage exists in the Indian manufacturing and if so, what is the direction of this linkage.

3. Data and Description

The dataset contains yearly information on Indian manufacturing firms from 2000 to 2009, obtained from Prowess database[3]. Our sample covers firms of three technology-intensive

[3] Prowess Database is online database provided by the Centre for Monitoring Indian Economy (CMIE). It is a database of large and medium Indian firms. It contains detailed information on over 23,000 firms. These comprise all companies traded on India's major stock exchanges and others including the central public sector enterprises. The companies covered in the database account for 75 per cent of all corporate taxes and over 95 per cent of excise duty collected by the Government of India. The financial data includes in the database are mostly the information that operating companies are required to disclose in their annual reports. The accepted

industries: Electrical (125 firms), Electronics (138 firms) and Non-Electrical (195 firms). These industries are part of 2digit Machinery manufacturing. We select the firms from these industries for our analysis on the basis of availability of data and firms with missing data of more than one year in the database are excluded from the study. The primary data series extracted from the company accounts are industrial sales, number of workers, gross value added, expenses incurred on raw materials and power, fuel and energy. Since our focus in this study is on R&D and import activities of firms, we also take these data series from the same database. Two capital related data series namely gross fixed capital and investment are also taken from the Prowess database. And to derive the series of capital, a real capital stock series is constructed using the perpetual inventory capital adjustment Method. We adhere to the construction process outlined by Levinsohn and Petrin (2003) since that is the methodology used in the TFP estimation process.[4] Our data series are deflated with appropriate deflators. Output related data are deflated by industry specific Wholesale Price indices (WPI). This deflator is obtained from Office of the Economic Adviser (OEA), the Ministry of Commerce & Industry of India (http://eaindustry.nic.in/), while raw materials series is deflated by the all commodities WPI, and the energy series is deflated using the Energy Price Index as provided by the OEA. The capital data is deflated by capital deflator, which is obtained from Handbook of Statistics on Indian Economy (RBI) (http://www.rbi.org.in). The details of data series, their definition and descriptive statistics are presented in Tables A.3 and A.5 of Appendix.

4. Empirical Models and Estimation Techniques

4.1. The Model of Production function Approach

In first stage, to examine the effect of imported intermediate inputs and firms' own R&D activities, we modify the traditional Cobb–Douglas production function. Broadly we follow a production function approach, *a la* Griliches (1980), Schankerman (1981) Bartelsman et al., (1996) Branstetter and Chen (2006), Acharya and Keller (2007) and Kasahara and Rodrigue (2008). And our specification also includes some additional variables which may potentially

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disclosure norms under the Indian Companies Act, 1956, make compulsory for companies to report all heads of income and expenditure, which account for more than 1% of their turnover.

[4] Specifically, we compute it as $K_t = (1-\delta)K_{t-1} + I_t$

where K is the capital stock, I is deflated gross investment, and δ is the rate of depreciation taken at 7%, consistent with similar studies for India (Unel, 2003 and Ghosh, 2009). *t* indicates for year. The initial capital stock equals the net book value of capital stock for 1994.

affect the firm's output through technological enhancement. Thus, the output can be described as

$$Q = K_{it}^{\propto} N_{it}^{\beta} M_{it}^{\gamma} IM_{it}^{\delta} RK_{it}^{\theta} A_{it}^{\vartheta} e^{\varepsilon_{it}} \ldots\ldots 1$$

taking the logs of both sides gives us

$$q = \alpha k_{it} + \beta n_{it} + \gamma dm_{it} + \delta im_{it} + \theta rk + \vartheta a_{it} + \varepsilon_{it} \ldots\ldots 2$$

where *Q* is output, *K* is capital, *N* is labor input, *M* is materials, *IM* is imported intermediary inputs, *RK* is the firm's own R&D stock, and *A* is the stock of technology. In the equation 2, lower case letter(s) indicate for logged value of variables. Unlike many of the previous studies that use dummies for intermediate inputs and R&D, which is static in nature, we use their actual size. This would make our analysis dynamic in nature that explains the role more effectively and practically. Estimating equation (2) using Ordinary Least Squares (OLS) with fixed or random effect usually provides estimates that are generally consistent with *a priori* knowledge of factor shares and constant returns to scale (Griliches and Mairesse, 1995). However, the equation is an augmented production function and a number of generic issues exist in the estimation of the capital and labor coefficients, and in the multivariate regression context any bias in them generally leads to biases in the other regression coefficients as well. A major econometric issue confronting production function estimation is the possibility that some of these inputs are unobserved. In that case, if the observed inputs are chosen as a function of the unobserved inputs, there is a problem of endogeneity, and OLS estimates of the coefficients of the observed inputs will be biased.

To tackle potential endogeneity and unobserved heterogeneity, we use the GMM technique, following Arellano and Bover (1995) and Blundell and Bond (1998,1999). The Blundell and Bond estimator, also called system GMM estimator, combines the regression expressed in first differences (lagged values of the variables in levels are used as instruments) with the original equation expressed in levels (this equation is instrumented with lagged differences of the variables) and allows to include some additional instrumental variables. We prefer this option to a fixed-effects estimator for two reasons. First, it allows us to take into account the unobserved time-invariant bilateral specific effects. Second, it can deal with the potential endogeneity arising from the inclusion of the lagged dependent variable and other potentially endogenous variables.

Alternatively, Olley and Pakes (1996) and Levinsohn and Petrin (2003) have developed two similar semi-parametric estimation procedures to overcome this problem. We prefer to apply

LP estimation technique for the estimation, which has been proved to be a superior method. This methodology explicitly recognizes the endogeneity that occurs since firms observes its productivity growth.

4.2. Modified Levinsohn and Petrin (2003) method

Original LP method does not allow direct inclusion of imported inputs R&D capital in the production function. Therefore, considering the aims of this research we modified this model to accommodate these important variables in the production specification.

The basic model of the LP procedure (gross revenue version) for a Cobb–Douglas production function is as follows:

$$q_t = \beta_0 + \beta_n n_t + \beta_k k_t + \beta_m m_t + \omega_t + \eta_t \quad (3)$$

$$= \beta_n n_t + \phi(k_t, m_t) + \eta_t \quad (4)$$

where $\phi(k_t, m_t) = \beta_0 + \beta_k k_t + \beta_m m_t + \omega_t(k_t, m_t)$

in the equation *q, n, k* and *m* are the firm's gross revenue, labor, capital and material, respectively (all variables are logged). In the model, error has two parts, first is ω, which represents the transmitted productivity component while η an error term that is not correlated with inputs. In the model material demand is assumed to be dependent on capital and ω.

We have modified the above model (3) and decomposed material and capital variables. Material is divided into domestically purchased (*dm*) and imported (*im*) material, while capital variable is decomposed into capital (*k*) and R&D capital (*rk*). Therefore, our specification is now as follows:

$$q_t = \beta_0 + \beta_n n_t + \beta_k k_t + \beta_{rk} rk_t + \beta_{dm} dm_t + \beta_{im} im_t + \omega_t + \eta_t \quad (5)$$

$$= \beta_n n_t + \phi(k_t, rk_t, dm_t, im_t) + \eta_t \quad (6)$$

where

$$\phi(k_t, rk_t, dm_t, im_t) = \beta_0 + \beta_k k_t + \beta_{rk} rk_t + \beta_{dm} dm_t + \beta_{im} im_t + \omega_t(k_t, rk_t, dm_t, im_t)$$

(7)

Using OLS for estimation with a third-order polynomial approximation in k_t, rk_t, dm_t and im_t in place of $\phi_t(k_t, rk_t, dm_t, im_t)$,and we estimate $\hat{\beta}_n$.

In next stage, for candidate values of $\beta_k{}^*, \beta_{rk}{}^*, \beta_{dm}{}^*$ and $\beta_{im}{}^*(for\ \beta_k, \beta_{rk}, \beta_{dm}$ and $\beta_{im})$, we estimate $\widehat{\omega}_t$ using

$$\widehat{\omega}_t = \hat{\phi}_t - \beta_k{}^* k_t - \beta_{rk}{}^* rk_t - \beta_{dm}{}^* dm_t - \beta_{im}{}^* im_t \quad (7)$$

Using the ω_t's for all *t,* we estimate $E(\widehat{\omega_t | \omega_{t-1}})$. Then residuals for $\beta_k{}^*, \beta_{rk}{}^*, \beta_{dm}{}^*$ and $\beta_{im}{}^*$ are computed as

$$\eta_t + \xi_t = q_t - \beta_n \widehat{n_t} - \beta_k{}^* k_t - \beta_{rk}{}^* rk_t - \beta_{dm}{}^* dm_t - \beta_{im}{}^* im_t - E(\widehat{\omega_t | \omega_{t-1}}) \quad (8)$$

This residual must interact with at least two instruments to identify$\beta_k, \beta_{rk}, \beta_{dm}$ and β_{im}. In the model, period t's capital stock (k_t and rk_t) is determined by the previous *(t-1)* period's investment decisions, it does not respond to shocks to this period's(*t*) productivity innovation term ξ_t, providing the moment condition

$$E(\eta_t + \xi_t | k_t) = 0$$
$$E(\eta_t + \xi_t | rk_t) = 0$$

which is implicitly imposed in the objective function. An additional momencondition is needed to identify β_{dm} and β_{im} separately from β_k and β_{rk}. LP use the fact that the previous period's level of material usage β_{dm} and β_{im} are uncorrelated with this period's error, giving us the

moment condition

$$E(\eta_t + \xi_t | dm_{t-1}) = 0$$
$$E(\eta_t + \xi_t | im_{t-1}) = 0$$

Thus, with $Z_t \equiv (k_t, rk_t, dm_{t-1}, im_{t-1})$, one candidate estimator solves

$$\min\ (\beta_k{}^*, \beta_{rk}{}^*, \beta_{dm}{}^*\ \ \beta_{im}{}^*) \sum_h \left\{ \sum_t (\widehat{\eta_t + \xi_t}) Z_{ht} \right\}^2 \qquad (9)$$

with *h* indexing the elements of Z_t.

4.3. The Model of Growth Accounting Approach

To examine the effect directly on the productivity and indirectly on the output, as well as to check the robustness of the results of the production function approach, we follow a growth accounting method. Under this framework, we test the effect of imported intermediary inputs and R&D activates on firms' productivity i.e. TFP and labor productivity. We start our empirical modeling with the growth accounting framework. Under this approach we broadly follow Coe and Helpman (1995) and Atella and Quintieri (2001) and test firms' status in importing intermediary inputs and pursing in-house R&D. Our baseline empirical model to be estimated is as follows:

$$Z_{it} = \alpha + \beta\, import_{it} + \gamma \mathrm{R\&D}_{it} + \beta\, size_{it} + u_{it} \ldots\ldots\ldots\ldots\ldots\ldots 10$$

where Z is *TFP* or labor productivity (*NP*) of firm *i* in period *t.* import is import dummy (if import raw materials in period *t* then 1, otherwise 0) and R&D is R&D dummy (if R&D in period *t* then 1, otherwise 0) is dummy for firms status. These dummies would capture the effects regarding productivity of firms when they, for some exogenous reason, start importing or doing R&D. Size is modeled in the equation as a control variable, which is proxied by firm's capital stock in TFP equation) and capital labor ratio (ratio of capital divided by number of workers) in labor productivity model. In order to estimate equation 10, our first task is to compute TFP of firms. For this purpose, we utilize LP estimator and using firms' value added as output, we predict TFP of firms' (see Table A. 4. of Appendix for details). *NP* is computed as ratio of value of firm's sales divided by number of workers.

5. Empirical Results

5.1. Results of Production function Approach

The estimated results of production function using OLS-Fixed Effect estimator are presented in Table 1. Columns 1, 2 and 3 of the table provide results for Electrical, Electronics and Non-Electrical industry respectively. These results suggest that imported inputs are crucial for the productivity growth in two out of three industries. The results reveal that in Electrical and Non-Electrical industry the impact of imported inputs on the firms' output is positive and highly significant and it is found to be 3.4% and 5.4% respectively. This implies that firms which use imported intermediate inputs have higher productivity than those which use only domestically produced inputs. However, our other important variable, R&D capital is not found to be significant in all sample industries.

Table 1: Estimates of production function: OLS-Fixed Effect Method

Variables	Electrical (1)	Electronics (2)	Non-Electrical (3)
Capital (k)	0.050161** (0.0356882)	-0.0293907* (0.0518132)	0.0176241* (0.0160354)
Labor (n)	0.0949829** (0.0447031)	0.2860544** (0.0619723)	0.0545596** (0.0244808)
Imported Materials (im)	0.0343653** (0.0164002)	-0.0111357 (0.035426)	0.0545596** (.0244808)
R&D (rk)	0.0226709 (0.0188615)	-0.028858 (0.0283994)	0.0294172** (.0084999)
Materials (m)	0.9218663** (0.039649)	0.8337228** (0.0486729)	0.8223895** (0.0196193)
Const.	0.1917927** (0.0959105)	1.564908** (0.1641703)	0.424992** (0.064024)
R^2	0.9504	0.9274	0.9799

Notes:

1. Standard errors are in parenthesis.
2. 2. ** and * denote significant at the 5% and 10% level, respectively.

The OLS-fixed effect estimator is not designed to correct the problem of simultaneity between inputs and the persistent shock that varies within firm over time. To effectively account for the simultaneity and endogenity problem in panel data, we further estimate the equation by using sys –GMM estimator. Estimated results are reported in Columns 1, 2 and 3 of Table 2. Our estimation results suggest that only in Non-Electrical industry imported intermediary inputs have some impact (2.1%) on productivity. In other two industries the impact is found to be negligible as well as statistically insignificant at the conventional level. Consistent with the OLS results, we fail to find any role of R&D capital on firms' output in all of our sample industries. However, some other noticeable changes can be observed at this stage, i.e. the size of the coefficients of material have reduced in sys-GMM estimation, which is true for all industries.

Table 2: Estimates of production function: sys-GMM Method

Variables	Electrical	Electronics	Non-Electrical
Output lag 1(q_{t-1})	0.4695624** (0.03769)	0.2541608** (.0389974)	0.2674425** (.0391009)
Capital (k)	0.1970341** (0.0345295)	0.0353609* (.0598483)	0.038836* (0.0237644)
Labor (n)	0.0150492* (0.0477412)	0.236663** (.0558817)	0.0061497* (.0369877)
Imported Materials (im)	0.0044729 (0.0164402)	-0.0186227 (.0324156)	0.021651** (0.0129099)
R&D (rk)	0.0133995 (0.0180928)	0.0155522 (.0251258)	0.010629 (.0144718)
Materials (m)	0.716367** (0.0418642)	0.7706053** (.0583683)	0.6610974** (.0323655)
Const.	0.1911468** (0.1030421)	1.213107** (0.1592218)	0.3812155** (0.085117)
Sargan (p-value)	0.18	0.23	0.09

Notes:

1. Standard errors are in parenthesis.
2. ** and * denote significant at the 5% and 10% level, respectively.
3. Sargan is the Sargan (1958) test of over-identifying restrictions.

In the order to correct for the simultaneity problem, we next apply the modified LP method (as explained in 4.2) and the estimated results are report in Table 3. It is noteworthy that the size of coefficients for the imported intermediary has now improved in comparison with sys-GMM estimation. In Electrical and Non-electrical industry the elasticity is estimated to be 4% and 5%, respectively and they are highly significant. In Electronic industries again the impact of this variable is found to be weak as well as insignificant. Consistent with previous results here too we fail to find any impact of in-house R&D capital on the productivity. Results also indicate for a wide variation in estimated elasticity of other inputs as well.

Table 3: Estimates of production function: LP Method

Variables	Electrical	Electronics	Non-Electrical
Capital (k)	0.0315154* (.1396067)	0.181126** (0.082058)	0.00127 (0.039206)
Labor (n)	0.1365191* (0.0768081)	0.2225017** (0.0677643)	0.172844** (0.0242392)
Imported Materials (im)	0.0400799** (0.015478)	0.0008105 (0.0272435)	0.050162** (0.011833)

R&D (rk)	-0.0046667 (0.0303901)	-0.0143926 (0.0160265)	0.0237034 (.014944)
Materials (m)	0.9736731** (0.1380239)	0.7941083** (0.1293793)	0.7698142** (0.114241)
Wald test (P-Value)	1.47 (0.2251)	1.47 (0.2246)	0.02 (0.8909)

1. Standard errors are in parenthesis.
2. ** and * denote significant at the 5% and 10% level, respectively.
3. Wald test is Wald test of constant returns to scale.

One might wonder why the estimates for import coefficient from the sys-GMM and LP estimators are substantially different than the OLS-fixed effect estimates. In a multivariate context, however, even if R&D and import variables are positively correlated with contemporary shocks, the OLS estimates for both variables could be downwardly biased when R&D and import are less responsive to a shock than other inputs (e.g., see Levinsohn and Petrin, 2003). This may probably be the case as R&D and imported inputs are persistent over time in the data.

Not surprisingly, however, the estimated capital and labor coefficient from the LP estimation are largely different than the OLS-fixed effect estimates perhaps because LP estimators has corrected the biasness in OLS estimated coefficients. But relative to the general specification, our specification includes two additional variables—imported inputs and R&D capitals, which may positively correlated with capital and, consequently, it is difficult to estimate the direction of OLS bias especially in estimation of capital coefficient in our case.

Results of estimation in this section broadly indicate that imported intermediary inputs have some impact in at least two industries of our sample. This is consistent with endogenous growth theories, which consider '*learning by importing*' as an important channel of productivity growth. Our findings regarding R&D also make sense as the Indian manufacturing traditionally has very low intensity in this, therefore, lowering the tariff on imports have perhaps made the imported intermediary inputs as an attractive substitute of in-house R&D activities. Thus, intermediate inputs may enhance productivity by providing domestic firms with access to technologies that are embodied in foreign capital goods that are not available domestically. Therefore, it is reasonable to argue that for technical improvement and productivity enhancement, Indian firms are more dependent on imported inputs rather than doing their own R&D activities. In other words, it can be convincingly argued foreign R&D is proved to be more crucial in the Indian case, which avoids high fixed and sunk cost from in-house R&D.

5.2. ***Results of Growth Accounting Approach***

We estimate equation 10 using OLS-fixed effect method. In Table 4, we present result of the estimation in which TFP is modeled as dependent variables. Columns 1, 3 and 5 of the table report results in which import and R&D dummies are tested. To investigate TFP difference for firms which engage in both import as well as R&D, we interact dummies of both and their results report in columns 2,4 and 6 of the table. The results suggest that importing has sizable, positive and statistically significant impact on TFP of firms across our sample industries. This can be interpreted as importing firms are 14%, 8% and 9.5% more productive than non-productive firms in Electrical, Electronics and Non-Electrical industry, respectively. Our results also confirm positive and significant impact of R&D pursuing firms. They indicate that firms that engage in this activity have 8%, 0.3% and 14% higher TFP in Electrical, Electronics and Non-Electrical industry, respectively. This result also suggests that TFP of Non-electrical firms are very sensitive towards the R&D activity. In the alternative specification, we test the impact on TFP of firms that engage in both import and R&D. Results suggest that firms in Electrical and Non-Electrical industry are 7.9% and 11% more productive than the rest of firms, respectively. Overall, these results suggest that unlike the output, TFP of firms across the sample industries are highly sensitive to both the activities. Our variable for size-capital is found to be statistically significant and sizable across the industries and various specifications.

Table 4: Determinants of TFP: discrete variables with the control variable

Variables	Electrical		Electronics		Non-Electrical	
	1	2	3	4	5	6
R&D Dummy	0.0843395** (0.0266647)		0.0033852** (0.0156459)		0.1447293* (0.0418966)	
Import Dummy	0.1416604** (0.0298868)		0.0818501** (0.024626)		0.0958881** (0.0436655)	
R&D Dummy* Import Dummy		0.0791011** (0.0268055)		0.0007386 (0.0158723)		0.1164645** (0.043683)
Size (k)	0.1146176** (0.0363326)	0.1325962** (0.0365582)	0.0135609** (0.0202279)	0.0221698** (0.0201663)	0.0654592** (0.0388705)	0.0683725* (0.038985)
Const.	0.7197804** (0.050495)	0.8217608** (0.0467379)	0.5472462** (0.028405)	0.6107535 (0.0213508)	1.165745** (0.0569005)	1.255574** (0.0442811)
R^2	0.0861	0.2630	0.0379	0.0281	0.3025	0.2953

1. Standard errors are in parenthesis.
2. ** and * denote significant at the 5% and 10% level, respectively.

After estimating the effect of importing and R&D on TFP, we now intend to investigate the role of these activities on labor productivity of firms for our sample industries. The estimated results of equation 3 for *NP* are reported in Table 5. Results are indeed surprising as the estimated coefficient suggests that both importing and R&D don't have any significant impact on labor productivity of firms across the sample industries (see columns 1, 3 and 5). Furthermore, the results also suggest that firms which engage in both of the activities do not have any superiority in labor productivity over other firms as the interaction variable is not found to be significant in any of the industries. The hypothesis of endogenous models that workers can acquire the knowledge to unbundle the new embodied technology through use imports of intermediary goods, which finally convert into higher labor productivity is not looking true in the Indian case.

Table 5: Determinants of *NP*: discrete variables with the control variable

Variables	Electrical		Electronics		Non-Electrical	
	1	2	3	4	5	6
R&D Dummy	0.0148286 (0.1022795)		0.0158567 (0.1243676)		0.0148286 (0.1022795)	
Import Dummy	0.0658908 (0.1068353)		-0.2867931 (0.1949212)		0.0658908 (0.1068353)	
R&D Dummy* Import Dummy		0.0329431 (0.0222594)		0.0088462 (0.1256226)		-0.0042221 (0.1062981)
size(k/n)	1.155297** (0.0536087)	-0.488901** (0.0491253)	-0.0902295* (0.0515696)	-0.0956673* (0.0514673)	1.155297** (0.0536087)	1.155206** (0.0535971)
Const.	-0.0766274 (0.1017393)	0.8025466 (0.0273003)	0.6620087** (0.1778478)	0.4174344** (0.0580874)	-0.0766274 (0.1017393)	-0.0147769 (0.0488609)
R^2	0.2239	0.0891	0.0388	0.0627	0.2239	0.2181

1. Standard errors are in parenthesis.
2. ** and * denote significant at the 5% and 10% level, respectively.

6. Conclusion

In this paper, we have examined the relationship between imported intermediary inputs, in-house R&D and productivity using firm-level longitudinal panel data for Indian *technology-intensive* manufacturing industries (Electrical, Electronics and Non-Electrical machinery) from 2000 to 2009. To test the linkage, this study follows two empirical frameworks: production function and growth accounting method. Further, to effectively overcome the problems of potential endogeneity, simultaneity and unobserved heterogeneity in the analysis, which are highly likely in the estimation of production function, we use the sys-GMM technique and modified Levinsohn and Petrin (2003) estimators along with the traditional methods of panel data. The study also attempts to test both dynamic as well as static effects of both of the activities. Although we do have some evidence to conclude that imported inputs have positive and significant impact on the productivity of firms, but the overall findings are rather mixed. Estimation results of the production function framework suggest that the impact of imported intermediary goods on output is reasonably sizable (2%-5%) on

Non-Electrical firms, slightly lower (0.4%-4%) on Electrical firms and negligible in the Electronic industry across various specifications. These findings are much lower than that of Kasahara and Rodrigue (2008) for the Chilean manufacturing. Surprisingly, the role of R&D under this framework is found to be insignificant across the industries and estimation specifications. Nevertheless, results regarding both these variables are somewhat on the expected line. As despite considerable policy liberalization in the external sector of the economy in the recent years, the share of imported intermediary inputs in international trade has still not reached to a level like many other developing countries to have a strong impact on the productivity. Further, the results are highly dismal in the case of R&D activities and productivity growth in India. The results suggest that despite significant efforts and incentives, the scale of R&D is still too low to have any significant impact on the overall productivity of the firms. Also, over the period, the impact of R&D has not improved substantially, as findings of Raut (1995) for 1975-1986 showed similar elasticity. The situation, therefore, requires immediate policy attention to increase the scale of R&D and technology innovation which is considered to be one of the main sources of productivity growth. Furthermore, the underling linkages are especially weak in Electronic industry. It seems that this industry has not been able to cope up with changing market dynamic as the Chinese products are dominating in this industry.

On the other hand, the analysis based on the growth accounting model has offered some positive and encouraging results. In fact under this approach, we attempt to test the static effects of both of activities. Our findings suggest that TFP of firms in all three industries are closely linked with import and R&D activities. Firms that engage in these activities have 8% to 12% higher TFP than other firms across the industries. However, labor productivity is found to be completely independent from these activities in all sample industries, which is indeed a surprising result. In the light of these findings, we can conclude that the hypothesis of unbundling of new technology through the use of imported intermediary goods and in-house R&D is found to be true for TFP of firms. However, this acquired knowledge does not seem to be converting into higher labor productivity, which could be a serious concern for the policy makers. Overall, results of the present study have strong policy implications for the productivity enhancement strategies and international trade policy in India. Also, the results may help indirectly in formulating some other policies, i.e. exchange rate and taxation, to boost up the import intensity and R&D activities to such a level where technological spillover and innovation can perform a crucial role in augmenting productivity growth.

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Appendix

Table A. 1. Peak duty reductions, customs duty collection and import values

Year	Peak duties (per cent)	Customs duty collections (INR, Million)	Imports (INR, Million)	Customs duty as a percentage of imports
1999-00	40	47,0910	2,15,2370	21.88
2000-01	38.5	49,0660	2,30,8730	21.25
2001-02	35	42,2560	2,45,2000	17.23
2002-03	30	44,6100	2,97,2060	15
2003-04	25	48,8570	3,59,1080	13.6
2004-05	20	55,4700	5,01,0650	11.08
2005-06	15	63,6560	6,60,4090	9.64
2006-07	12	81,0150	8,40,5060	9.64
2007-08	10	97,6910	10,12,3120	9.65
2008-09	10	1,01,7100	13,74,4360	7.4

Source: Economic survey-2009-10 (chap-7, pp-172, http://indiabudget.nic.in/es200910/chapt2010/chapter07.pdf

Table A. 2. Tariff, imports and notional duties in 2008-2009

Basic Duty	Capital goods			Intermediate Goods		
	Total no. of tariff lines	Imports (INR, Million	Notional duty (INR, Million)	Total no. of tariff lines	Imports (INR, Million)	Notional duty (INR, Million)
7.5% or	1079	1,64,1980	383580	3353	8,96,4590	890460
Less 10%	334	337450	100820	3429	2,14,8160	641810
Above 10%	15	150	90	738	245910	58420
Total	1428	1,97,9740	48,4490	7520	11,35,8606	1,59,0690

Source: Economic survey-2009-10 (chap-7, pp-172, http://indiabudget.nic.in/es200910/chapt2010/chapter07.pdf

Table A.3. Variables Definition and their Source (s), 2000-2009

Variable	Definition	Data source
Output(Q)	Industrial sales and Gross value added of firms	Prowess
Gross value added (GVD)	Gross value added of firms	Prowess
Labour (N)	Number of workers	Prowess

Physical capital (K)	Computed as follows: $K_t = (1-\delta)K_{t-1} + I_t$ where K is the capital stock, I is deflated gross investment, and δ is the rate of depreciation taken at 7%.	Prowess and Authors' calculation
*R&D (*RD)	Annual expenditure on R&D of firms	Prowess
*Imported intermediary inputs (*IM)	Imported intermediary inputs of firms.	Prowess
Raw materials(R)	Expenditure on raw materials of firms	Prowess
Size	Proxied by Physical capital (K)	Prowess
TFP	Total factor productivity (estimated by value added method)	Authors' estimation
Labor Productivity (LP)	Output(Q)divided by Labour (N)	Prowess and Authors' calculation
Capital Labor ratio(KN)	Capital (K) divided by Labour (N)	Prowess and Authors' calculation

Note: all series are deflated with appropriate deflator before any econometrics treatment.

Table A. 4. TFP Estimation using value added method

Estimates of production function: LP Method
Dependent variable: Gross value added

Variables	Electrical	Electronics	Non-Electrical
Ln(K)	0.2518023 (0.1265212)	0.4054239 (.1205553)	0.3266794 (0.0367995)
Ln(N)	0.5137311 (0.038732)	0.5456492 (0.0510856)	0.3266794 (0.0367995)
Wald test	3.78	0.16	13.44

1. Standard errors are in parenthesis.
2. ** and * denote significant at the 5% and 10% level, respectively.
3. Wald test is Wald test of constant returns to scale.

Table A. 5. Appendix

Descriptive Statistics on Indian Manufacturing Firms, 2000-2009

	Mean	Standard Deviation.	Minimum	Maximum
Electrical Manufacturing				
lnQ	1.680009	0.8280601	-2.159145	3.75077
lnK	1.191061	0.6919384	-0.820011	3.045306
lnN	2.285204	0.69529	0.69529	4.033888
lnR	1.414774	0.8228378	-2.082814	3.200642
TFP	1.013122	0.3528041	0.0995918	3.240328
lnIM	0.6865067	0.9595876	0.9595876	3.042615
lnRD	-0.3632071	0.7569779	0.7569779	1.920906
lnGVA	1.37175	0.8108224	-1.69897	3.796108
LP	0.5671659	0.3823772	-4.378668	1.041266
KL	0.5154342	0.313055	-0.9409554	4.418177
Electronics Manufacturing				
lnQ	1.351401	0.995058	-2.034039	3.845397
lnK	0.9954211	0.8483159	-1.889778	3.591072
lnN	2.12473	0.7938263	-.3684542	4.395881
lnR	-0.9330774	1.009954	-4.190808	1.559456
TFP	0.6334645	0.2259976	.0364906	1.731408

lnIM	0.7779548	1.037277	-2	3.341808
lnRD	-0.1149879	0.9443334	-2	2.386196
lnGVA	1.026984	0.9481932	-2.159145	3.698652
LP	0.3840375	1.293154	-14.29298	25.39355
KL	0.3744812	1.046504	-15.73373	5.196716
Non-Electrical Machinery Manufacturing				
lnQ	1.580324	0.8735048	-2.103935	5.037267
lnK	1.046852	0.7225934	-1.324855	3.237757
lnN	2.363582	0.7643323	-0.3916407	5.037267
lnR	1.284801	0.8768178	-1.889778	4.000258
TFP	1.371177	0.5944866	0.0873015	4.498017
lnIM	0.5700625	0.999707	-2	3.529764
lnRD	-0.0831359	0.8480057	-2	2.838855
lnGVA	1.327047	0.8613421	-2	4.093714
LP	0.4447523	1.14853	-29.23825	2.671072
KL	0.3938466	0.4885851	-9.837888	4.607168