Labor productivity, trade and R&D in the Electronics industry

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There is a rising concern in the recent times regarding the growth of Indian manufacturing sector and the sources of productivity growth. Recent trends indicate that growth is highly import intensive while both total and partial factor productivity growth is concentrated only in few subsectors. Using the prowess database from 2002-2012, the paper analyses the impact of trade and research and development on labor productivity in the Indian electronics industry. The paper finds that trade and R&D per se do not contribute to labor productivity, however, the joint impact of both these variables is positive and significant, suggesting strong complementarities between internal R&D and technology transfer in the Indian electronics industry.

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I. Introduction

There is a rising concern in the recent times regarding the growth of Indian manufacturing sector and the sources of productivity growth. Recent trends indicate that growth is highly import intensive while both total and partial factor productivity growth is concentrated only in few subsectors. This paper tries to understand the linkages between labor productivity, trade and research and development in a technology intensive industry, namely the electronics industry in India.

While total factor productivity has improved overall post 2000, in certain subsectors of manufacturing both total and partial factors of productivity, namely labor productivity, have declined. This is especially true for hi-technology sectors like Television, Radio and communication; accounting, office equipment and computing machinery[1]. There are also causes for concern that this sector has become highly import dependent[2]. These trends motivate one to explore the causes of declining labor productivity and the impact of increased import dependence. What is the role of research and development in improving labor productivity?

The objectives of this paper are two-fold. One, it seeks to measure the impact of trade on labor productivity of the electronics industry in India. Second, the paper analyzes the impact of research and development on labor productivity. Being knowledge based, electronics industry requires frequent innovations and in-house research to be globally competitive. There is also an increasing trend of outsourcing R&D to emerging economies, with the output of research aimed

[1] Post 2000, much of the output growth has come from capital (82%) followed by labor (12%) and productivity (6%). Virmani and Hashim (2011, 2009)

[2] The materials import intensity of Indian manufacturing almost doubled between 1998 and 2007 (Goldar, 2013).

at developed country markets. The role of technology transfer becomes very important because of research collaboration between foreign and domestic firms. Hence, the joint impact of research and development and imported inputs also becomes important. That is, in-house R&D may not directly enhance labor productivity but only when combined with imported inputs and equipment suppliers.

The paper uses the standard production function approach in the growth form to analyse the impact of labor, capital and knowledge inputs on the growth of firm productivity. Firm level data for the electronics industry is obtained for a period of 2002-2013 from PROWESS database. The paper is organized as follows. Section II presents literature review and broad trends, followed by methodology and data sources in section III. Section IV presents the results of empirical estimation and section V presents conclusions.

II. Literature review

Economic theory argues that there are two channels through which trade influences productivity growth: exports and imports. Although the causality can be two way, trade theory argues that firms learn about advanced technologies through exports and adopt them by learning by doing through imports, technology transfer agreements and licenses. Thus, trade is an important channel through which technological capabilities of the country can be enhanced. At the same time it can stunt the growth of domestic industries by making them import-dependent if there is no conscious effort or policies that support the growth of domestic technology capability building through entry barriers for selective components and categories. The example of Korean and Indian electronics industry provides a study in contrast.

Productivity is synonymous with growth in Total Factor productivity (TFP), as it measures the overall technical efficiency or the way a set of factors is combined to yield the best possible output. Labor productivity is a partial measure and captures only the contribution of labor, ignoring the changes in factor intensities and efficiency of capital. Increase in TFP need not imply an increase in labor productivity as well. For example, a substitution of capital for labor may increase labor productivity, but without any increase in productivity of capital or the overall TFP. On the other hand, productivity of capital may increase, without a concomitant increase in labor productivity if the absorptive capacity of labor is not sufficient. This is true in a developing country context, where unorganized sector comprises a large share in manufacturing. In this context, where, production processes are heterogeneous and highly labor intensive with small/medium firms facing shortages in the supply of skilled labor technology imports may not translate to very large increases in overall productivity because of decrease in labor productivity. Hence, an overall improvement in TFP may not suffice to capture the economic constraints faced by firms to improve labor productivity.

The importance of trade as well as research and development on improving total as well as partial factor productivity has been well documented. Empirical evidence on causality between exports, imports and productivity has been mixed (Hadad et al 1996, Pavcnik 2000). A recent study in the Indian context does not find support for the learning by exporting hypothesis for the manufacturing sector (Haider 2012). That is, while more productive firms enter the export market, reverse is not true. Moreover high export intensities in hi-tech industries need not be a consequence of their technological capability, but rather an international fragmentation of production, as reflected by rising import intensities as well (Shrolec, 2007). With respect to imports, while some studies have supported a positive impact of imports on TFP, others have shown contrary (Tybout 2000, Muendler 2004).

In-house Research and Development has been found to positively influence labor productivity, though with a higher impact in high-tech industries (Grilliches 1986, Mairesse, J. and M. Sassenou 1991, Tsai and Wang, 2004). More recent studies have found complementarity between in house and external (contracted) R&D; and a higher impact of R&D on productivity on industries engaged in product vis-à-vis process innovation (Lokshin, Rene Belderbos and Martin Carree 2008, Francesco Bogliacino and Mario Pianta 2009). In the Indian context, imports and R&D have been found to have a positive and significant impact on the total factor productivity of high tech industry as well as the output of overall manufacturing sector (Sharma 2010, Saxena 2011). Siddharthan (1992) analyzed the impact of technology transfer expenditures on R&D expenditures for a sample of private sector firms and found complementarities between R&D and technology transfer expenditures.

Few studies have however, analysed the joint impact of trade and R&D on labor productivity. For instance, Acharya and Keller (2009) argue, in the context of industrialized nations, that while R&D has a positive and significant impact on productivity, the contribution of international technology transfer often exceeds the effect of domestic R&D on productivity. They analyse the joint impact of R&D and trade by interacting the share of country's share in G6 imports with its domestic R&D and find that imports are crucial for technology transfer from Germany, France, and the United Kingdom. Industries where foreign technology has a strong impact on domestic productivity are radio, T.V, communication equipment, office, accounting, and computing machinery (72%) chemicals (39%), aircraft (26%), and drugs (15%).

In the context of the above findings, it would be interesting to analyse the impact of trade-related technology expenditures on the productivity of the electronics industry in India, which has witnessed a fall in productivity levels in the recent times.

II.1 Recent trends in imports and exports and labor productivity

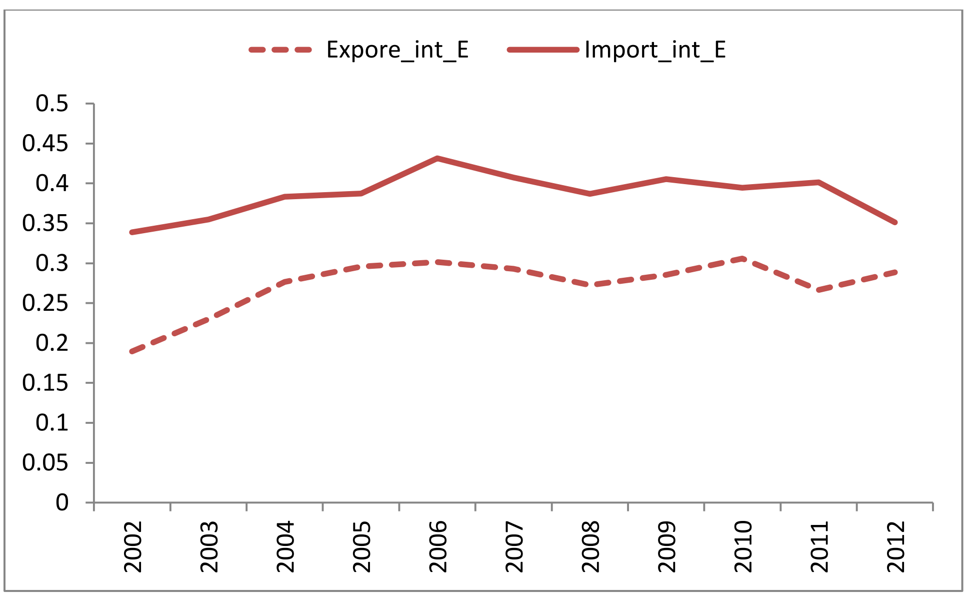
The two major items that account for one-third of manufactured exports from India are Mineral oil and Pearls & Precious stones. This is in contrast with China, where, electrical & electronics and machinery products constituted more than two-fifth of Chinese export in 2012. While the share of automobiles in Indian exports doubled from 2 to 4% during 2001-2012, electrical and electronics equipments marginally increased their export share.

Import of electronic items present a different picture. In general, the share of imports in Indian manufacturing has been rising rapidly since liberalization policies were introduced in 1991. In the electronics industry, there has been a rapid growth in imports since India became a member of the Information technology agreement (ITA) where in the participating countries agreed to bind and eliminate all customs and other duties and charges on information technology products by the year 2000. India eliminated tariffs on 38 per cent of the ITA products by 2000 and the rest by 2005. So the actual impact of the agreement on India was felt only by 2005 when the tariffs on 62 % of the total products were reduced to zero. Subsequently, there was a surge in import of electronics imports which grew at the rate of 18% during 1997-2000 and 38% from 2001-2005. The share of raw material imports in total sales increased from 5% in 1997 to 20% in 2004 (Kallumal and Francis, 2014). During 2001-2012, India's import of electrical & electronic items rose from 0.2 billion dollar to almost 30 billion dollars, out of which, the import of mobile phone & parts was almost 10 billion in 2012.

The incidence of high imports could have a negative impact on manufacturing. Further, because of quality standards and market access issues, the existing domestic producers may become domestic assemblers/traders in the IT products, rather than competitors in global value chain of electronics. This trend is supported by the results of the field survey interviews of small and medium firm belonging to the electronics industry in the city of Chennai, India.

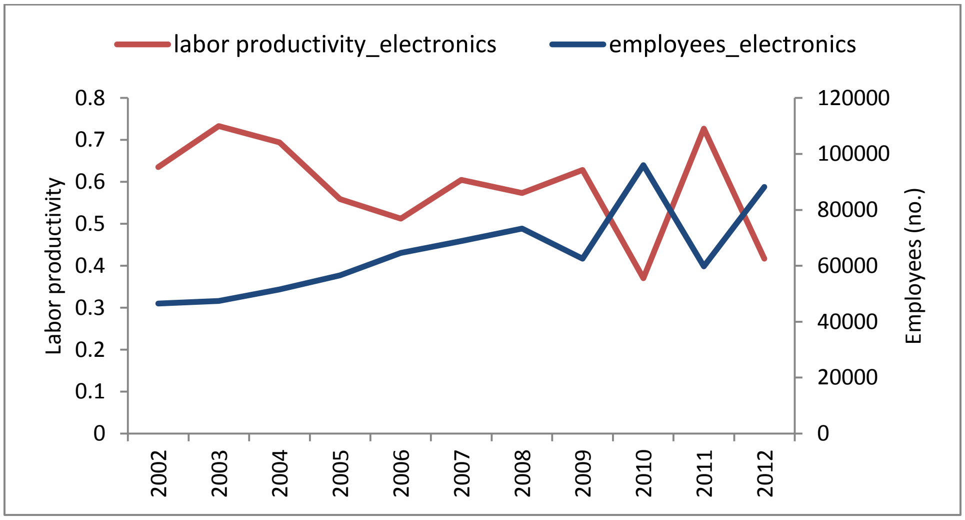
Figure 1 shows the trend in export and import intensities (value of imports/value of sales) for the electronics industry during 2002-2012. The import intensity is higher than export intensity, both of which are increasing at a decreasing rate. Figure 2 shows the labor productivity and employment trends in the electronics industry. Labor productivity is continuously falling till 2005 and exhibits volatility over 2005-12, while employment steadily rose upto 2008 and exhibits volatility afterwards.

Figure 1: Export and Import intensities in Electronics sector (2002-12)



Source: Prowess database, CMIE

Figure 2: Labor productivity in electronics sector



Source: Prowess database, CMIE

II.2 Impact of imports on growth of electronics industry: primary data analysis

The electronics industry consists of three segments as per the NIC classification: electronics components, communication equipment and computer peripherals. An analysis of the employment and output characteristics reveals that the electronics components segment is dominated by the formal sector (covered by ASI) whereas the informal segment dominates the other two segments (Institute for Human development studies, 2014). A comparison of the output and employment growth in the two sectors shows that the informal sector performed better than the formal sector in terms of employment and growth in units. During 2005-06 to 2011-12, while the formal sector output grew by 4 percent, informal sector output grew by 3 per cent. The growth in number of units and employment in the informal sector was 17 per cent and 11 percent as opposed to 8 per cent and 6 per cent in the formal sector. The relatively poor growth of formal sector is also evident from the increasing import competition that the formal sector is facing in the recent times.

Table 1: Growth in units, employment and output in the electronics sector: 2005-06 to 2011-12

NIC 2008 Code	DME			Factories			Total		
	Units	Output (crore)	Employ ment	Units	Output (crore)	Employ ment	Units	Output (crore)	Employ ment
Electronics									
261	22.7	10.9	35.1	13.7	5.4	9.5	18.9	5.5	12.4
262	26.1	-2.6	-8.6	-3.1	2	-2.3	15.9	1.9	-3.9
263	-21.8	-9.8	-20	0	3.4	3	-9.5	3.4	1.5
Total	17.3	3	11.4	8.3	3.9	5.9	13.5	3.9	6.7

Source: Different Rounds of Annual Survey of Industries and Unorganised Manufacturing Survey, NSS 62nd Round: July 2005 - June 2006, from IHDS report (2014)

A survey of 35 electronic units (out of 300 units) in Chennai in 2014 showed that majority of units in Chennai manufacture or trade in electronic components (261 NIC code) and very few are engaged in communications equipments. Hardly any manufacturer of computer and peripherals was located in Chennai. Only one third were registered and covered by ASI, while rest come under the informal sector. These units were at the low end of the supply chain and involved mostly in design and assembly of printed circuit boards for automobile electronic components, medical equipment, display boards and vending machines, assembly of electronic testing equipment and manufacturers of transformers. The import intensity (import of raw materials as % of sales) was 21 percent and export intensity was 17 per cent. Only 43 percent of firms were exporting outside India whereas 80 percent of firms were importing raw material. The average share of raw material imports in total imports was 36 percent with one-third firms importing 80-90 percent of raw materials from abroad.

A preliminary analysis of the primary data reveals the following facts: one is the declining growth in output and employment in formal vis-a-vis informal sector, indicating a rise in subcontracting in the electronics industry. A second fact is the rising import intensity of exports.

II.3 Complementarities between technology transfer and nature of R&D

The supply chain of electronics sector in India is dualistic in nature. The capabilities in the electronics supply chain consist of assembly at the low end to designing and research and development at the high end, without any manufacturing capability. Both these segments are highly import dependent with important implications for labor productivity.

A preliminary analysis of the firm –level data from Prowess database shows 126 categories of product classification in the electronics industry. It ranges from small parts and components like printed circuit boards, switches and connectors to more high value products like solar photovoltaic cells, integrated circuits and computer terminals. There are also end-end (from designing to development and installation) solution providers for industrial process automation and defence industries, who need not manufacture any specific product. For example, firms engaged in industrial process automation design the factory automation process, buy the imported hardware components from companies like Siemens or ABB; and assemble and install the machinery at the industrial premises of the client. The R&D carried out by these firms is relatively low but import of raw material and capital goods is very high. Table A.1 shows the average import intensity of firms by different product categories and finds that import intensity is highest in case of control instrumentation and industrial electronics, suppliers to defence industry, solar appliances, and components for telecom industry, integrated circuits and computer terminals.

For these firms, the direct impact of R&D on labor productivity is low because of its low magnitude. However, the import of technology complements the R&D and may generate a positive impact on labor productivity.

At the other end, there are firms with high R&D capabilities. Post 2000, India has emerged as the global R&D outsourcing hub for IT solutions in all hi-tech industries ranging from telecom, automobiles to aerospace. MNCs like Motorola and QuEST global have set up R&D hubs in India for new product development in various areas. A survey of conventional and new technology industries[3] (Reddy 2010) was carried out to find the motive behind R&D in these industries. Availability of personnel and low cost of R&D were the main reasons for setting up such R&D hubs in emerging economies. Two important conclusions emerged from the survey: (a) there is less need for product or process adaptation to the local market; (b) proximity to manufacturing facilities and the Indian market were not considered as important suggesting that R&D could be geographically delinked from manufacturing facilities.

The research and development undertaken by the firms in global value chain has weak linkages with the domestic manufacturing capability and is highly dependent on disembodied technology transfer through import of raw materials and capital goods. Hence, there are strong complementarities between R&D and technology imports. What does this imply for labor productivity? In essence, we can expect that compared to standalone imports or R&D, the interaction between the two would have a higher impact on labor productivity.

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[3] The new technology industries included electronics, bio technology and solar energy companies. Firms engaged in R&D were classified into four categories: technology transfer unit, Indigenous technology unit, global technology unit and corporate technology unit. Results of the survey showed that all the global technology unit (GTU) and corporate technology unit (CTU) types of R&D units belonged to new technologies firms, with 50 percent of new technologies firms carrying out GTU and 12.5 percent performing CTU types of R&D.

III. Data Methodology

The following section analyzes the impact of trade and R&D on labor productivity. The study utilizes a sample of 266 electronics over the time period of 2002-2012 from the Prowess database. The study uses the standard production function approach whereby ouput is expressed as a function of inputs in an augmented Cobb-Dougals production function[4] for firm i at time t:

$Y_{it} = \alpha_{it} L_{it}^{\beta} K_{it}^{\delta} R_{it}^{\gamma} e_{it}^{\sigma it}$……………………………………………………(1)

Where Y is the output, L is labor, K is physical capital stock value and R is knowledge stock. The parameter σ is firm specific efficiency parameter. The knowledge stock is captured by in-house research and development and import of technological know-how through royalty payments and import of raw materials/capital goods.

Dividing by labor on both sides and taking logs, value added is expressed as a function of labor, capital and other variables affecting firm output:

$y_{it} = \propto + (1-\beta) lit + \delta kit + \gamma\, rit + + \sigma iteit,$ …………………………………………..(2)

where, letters in small case denote logs of the variables. Taking first difference, we arrive at the growth equation

$\Delta y_{it-1} = \propto + (1-\beta)\Delta lit + \delta \Delta kit + \gamma\, \Delta rit + + \Delta\sigma it$……………………………………….(3)

Change in firm-specific efficiency levels is assumed as a function of past productivity, in order to allow for a gradual convergence in efficiency levels between firms, where, θ is the convergence parameter that lies between -1 and 0:

$\Delta\sigma it = \theta \mathrm{yit} - 1 + \varepsilon it$...(4)

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[4] Lokshin et al (2008)

To allow unobserved firm-level heterogeneity in efficiency growth and an impact of common macroeconomic efficiency shocks, the error term in equation above includes firm-specific fixed effects μi and year-specific intercepts λt in addition to serially uncorrelated measurement errors vit.

III.1 Expressing change in knowledge stock as a function of technology expenditures

The study assumes that change in knowledge stock is a function of past research and development[5], disembodied technology transfer in the form of import of technical know-how, raw material and capital goods imports and learning from exports of goods and services. Import of technical know-how is captured through royalty expenditures and technical licensing fees. It is also captured through import of raw materials and capital goods, where a lot of know-how is transferred through specialized equipment suppliers.

In addition to the R&D and technology transfer variables, the study also introduces an interaction term between the two to analyze complementarities between the two variables. This is especially important in the context of emerging economies which are witnessing an increasing trend in outsourcing of R&D along with transfer of technology, where such R&D needs to be applied. Taking the lagged output on the right hand side of the equation and substituting (4) into (3) the dynamic panel equation is:

$$yit = (1+\theta)\ y_{it-1} + (1-\beta_0)\Delta l + \delta\Delta k + \gamma\ \Delta rit + \mu i + \lambda t + vit \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

[5] The knowledge stock can be transformed as follows: $= \gamma \Delta r_{it} = \frac{\partial y}{\partial x}\frac{R_{it-1}}{Y_{it-1}}\ \frac{\Delta R_{it-1}}{R_{it-1}} = \varphi \frac{R_{it-1}}{Y_{it-1}}$
which gives change in knowledge stock as a function of past investments in research and development (Lokshin et al 2008).

III.2 Description of variables and expected coefficient signs

The study uses data of gross value added of the firms as a measure of output and it is 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. Value added is arrived by subtracting the expenditure on raw materials, stores and spares form the gross value of sales.

Prowess database does not provide number of workers information, but it does provide data on salaries and wages .The number of workers is computed for each firm by dividing the salaries and wages reported in Prowess data base by the average wage rate for the electronics industry for various years. The average wage rate is obtained from the industry ASI database computed as total emoluments in the industry divided by employees in the industry. For capital, each firm's net fixed asset data is deflated by the capital deflator (WPI for capital and machinery).

Other independent variables used in the study include Import of raw materials, import of capital goods, exports of goods and services, Research and development expenditure on current and capital account and expenditure on royalty payments.

Empirically, the equation to be estimated is as follows:

$$y_{it} = \propto + \beta 0 y_{it-1} + \beta 1 \Delta l + \beta 2 \Delta k + \beta 3\ R\&Dint + \beta 4\ Royaltyint + \beta 5\ Expint + \beta 6\ Impint + \beta 7\ Imp * RDint + e$$

where Δl is growth in employment, Δk is growth in capital-labor ratio, R&Dint= Research and development expenditures divided by net sales, Royaltyint is expenditure on royalty payments and technology license fees, divided by net sales, Expint is exports divided by net sales, Impint is import of raw materials, capital goods and finished goods divided by net sales. The last variable is an interaction term between imports and R&D.

The coefficient for lagged productivity $\beta 0 = 1+ \theta$, as per the model specification. If θ is zero, then change in firm specific efficiencies are not dependent on past productivities and there is no convergence in efficiency levels between firms with high and low productivity. The opposite would hold true if $\theta = -1$. The coefficient on lagged labor productivity is expected to lie between 0 and 1. Growth of employment is expected to have a positive impact on productivity. The coefficient of labor growth is β-1, implying that $\beta>0$.

As per economic theory, R&D intensity is expected to influence labor productivity positively. However, in the context of the current sample of electronics industry, R&D intensity is very low and hence it is not expected to be significant in the study. Also, a threshold R&D intensity may be necessary before firms can benefit from it through improvements in productivity. A negative coefficient sign would mean that the returns to R&D are diminishing for the industry.

Imports and exports are assumed to have a positive impact if the firms have the sufficient absorptive capacity in terms of higher R&D and skilled labor. In the absence of both, it may be insignificant or even negative. The coefficient for technology expenditures or royalty expenditures is assumed to follow a similar argument. In the study, R&D expenditures are combined with royalty expenditures together as technology expenditures. This also solved the problem of too few observations related to royalty payments.

The interaction term between technology expenditures and imports is expected to be positive because of the earlier arguments related to complementarities between the two variables. This is one of the crucial arguments proposed by the study in the context of an emerging economy where firms are increasingly becoming a part of the global value chain for hi-tech industries resulting in technical collaborations and technology transfers through different channels.

However, this will have a positive impact on labor productivity only if the firms have sufficient absorptive capacity and relevant R&D capabilities in the sense that firms with higher R&D also benefit more from technology transfer. In the current context, in-house R&D can be too low to have positive impact on labor productivity. Technology transfers may enable firms to benefit from such R&D. On the flip side, even when firms are undertaking high R&D, it may not be directed towards domestic market demand, thus not having a significant impact on productivity, unless they also undertake technology transfers for applying the R&D.

Table 2 shows the descriptive statistics for the period under study for all the variables used.

Table 2 Descriptive statistics

	Electronics Industry	
	Mean	Standard Deviation
Labor Productivity	0.70	0.72
R&D intensity	0.01	0.05
Royalty intensity	0.01	0.02
Export intensity	0.27	0.33
Import intensity K goods	0.32	0.29
Import intensity Raw material	0.07	0.30
K-labor ratio	8.34	17.85

Source: Prowess database

The average export intensity for the period under study is 0.27, whereas, import intensity of capital goods is 0.32 and that of raw materials is 0.07. Capital labor ratio is 8.34, with a high standard deviation, suggesting varying levels of labor intensity in the electronics industry. R&D intensity is very low in the sample under study. Out of 266 firms 19 are private foreign firms, 160 are private Indian firms and rest are owned by individual business groups. There might be underreporting of R&D by privately owned foreign firms, resulting in the low R&D figure (table

2A) whereas it is mandatory to report R&D expenditure by central government enterprises like BEL Optronic devices, Bharat dynamics and Bharat electronics.

Table 2A: Average R&D expenditure during 2002-2012

Ownership type	Average R&D intensity
Business group	1%
Private Foreign	0%
Private Indian	1%
State/Central	4%

Source: Prowess database

IV. Results

Three specifications are estimated: specification one estimates the equation in levels and without royalty (technology transfer) expenditures. Specification two estimates the difference equation, again without the technology transfer expenditures. Specification three combines R&D expenditures along with technology transfer expenditures and estimates complementarities between the overall technology expenditures and imports. Lagged variables are used as instruments in the dynamic panel data model.

Table 3 reports the results from panel data estimation for variables in levels and without royalty expenditures. Tests for serial correlation and heteroskedasticity in panels show to be significant and hence a generalized least square model was estimated that uses panel corrected standard errors and AR(1) process. However, as Hausman test shows that fixed-effects is the appropriate model, using a GLS corrected for heteroskedasticity and autocorrelation does not solve the problem. For the dynamic panel data, 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 endogeniety problem in panel data, the paper uses the GMM technique, following Arellano and Bover (1995) and Blundell and Bond (1998). The Blundell and Bond estimator, also called system GMM estimator, uses moment conditions in which lagged differences are used as instruments for the level equation in addition to the moment conditions of lagged levels as instruments for the differenced equation. Instruments in the difference GMM model are twice-lagged values of the level of the dependent variable and the lagged-level values of the labour, capital-labor ratio and R&D variables. The extra lag reduces the number of observations considerably. Instruments in system GMM estimation for equations in levels are differenced values of the other right-handside variables, i.e. twice-lagged change in productivity and lagged changes in employment and capital-labor ratio, and R&D.

Table 3: Fixed and random effects model for electronics panel data (variables in logs)

	FE	RE	GLS (corrected for heteroskedasticity and AR1)
Dependent variable= log productivity	Coeff	Coeff	Coeff
Employment	`-1.005*** (0.04)	`-0.98*** (0.04)	`-0.91*** (0.016)
K-L ratio	0.04 (0.03)	0.018 (0.025)	0.017 (0.010)
R&D current exp	`-1.001*** (0.035)	`-0.96*** (0.031)	`-0.90*** (0.0154)
Imports	`-1.092*** (0.045)	`-1.05*** (0.042)	`-0.94*** (0.02)
Exports	`-0.028 (0.011)	`-0.03 (0.010)	`-0.024** (0.006)
R&D *Imports	1.005*** (0.037)	0.97*** (0.033)	0.90*** (0.016)
_cons	`-0.84*** (0.22)	`-0.77*** (0.18)	`-0.68*** (0.04)
N	353	353	345
Groups	64	64	56
R Sq (overall)	0.78	0.78	

prob >chi2	0	0	0
Hausman	Prob>chi2 = 0.053		
Figures in parentheses are standard errors. ***, **, * denote significance at 1%, 5% and 10% levels.			

Tables 4 and 5 report the results from dynamic panel data estimation, with and without royalty payments. Lagged value added is positive and significant. The convergence factor θ ranges from -0.64 to -0.75. Growth in employment is also positive and significant as expected ranging from 0.25 to 0.5. A one percent increase in labor increases labor productivity by 0.25 to 0.5 per cent. Capital-labor ratio is not significant and does not have any influence on labor productivity. Exports also do not turn out to be significant. Imports and R&D are negative and significant at 1% level of significance, implying that in-house R&D does not improve labor productivity. However, the interaction term between R&D and imports is positive and highly significant. A 1 per cent joint increase in R&D and imports results in a gain of 0.5 per cent in labor productivity. What this means is that firms engaged in R&D per se do not find any improvement in labor productivity. However, R&D *along with* technology transfers through imports increases labor productivity significantly. The coefficient magnitude increases when research and development expenditures are combined with technology transfer (royalty) expenditures.

Table 4: Dynamic panel data estimation (Only R&D current expenditures)

	Difference GMM estimator	System estimator
	Coeff	Coeff
Value added (lag1)	0.29** (0.12)	0.46* (0.11)
Employment (growth)	`-0.61*** (0.16)	`-0.75* (0.14)
Capital-labor (growth)	`-0.092 (0.088)	`-0.018 (0.86)
R&D current expenses	`-0.56*** (0.18)	`-0.63*** (0.12)

Imports	\`-0.66*** (0.19)	\`-0.61*** (0.18)
Exports	\`-0.058 (0.046)	0.001 (0.03)
R&D current*Imports	0.56*** (0.19)	0.59*** (0.11)
time	\`-0.03 (0.04)	\`-0.03* (0.015)
constant		\`-4.3*** (0.76)
No. of obs	203	311
No. of groups	45	60
No. of instruments	47	52
Prob > F /chi2	0	0

Figures in parentheses are standard errors. ***, **, * denote significance at 1%, 5% and 10% levels.

Table 5: Dynamic panel data estimation (combining R&D and royalty expenditures)

	Difference GMM estimator	System estimator
Value added	Coeff	Coeff
Value added (lag1)	0.25** (0.12)	0.41*** (0.12)
Employment (growth)	\`-0.49*** (0.18)	\`-0.54*** (0.16)
Capital-labor (growth)	\`-0.04 (0.098)	0.012 (0.11)
R&D current & royallty expenses	\`-0.59*** (0.14)	\`-0.65*** (0.10)
Imports	\`-0.71*** (0.14)	\`-0.72*** (0.11)
Exports	\`-0.036 (0.053)	0.02 (0.03)
Tecnology expenditures*Imports	0.61*** (0.15)	0.66*** (0.09)
time	0.02 (0.05)	\`-0.04*** (0.016)
constant		\`-4.5*** (0.68)
No. of obs	272	422
No. of groups	59	82
No. of instruments	47	52
Prob > F /chi2	0	0

Figures in parentheses are standard errors. ***, **, * denote significance at 1%, 5% and 10% levels.

V. Conclusions

The study analyses the impact of trade on labor productivity and finds that while imports and R&D both have a negative impact on labor productivity, the interaction of R&D and imports has a positive impact on labor productivity. The negative coefficient on R&D and imports suggests the lack of a domestic manufacturing capability of electronic components and absence of linkages between R&D and domestic market demand. On the positive side, a positive coefficient of the interaction terms suggests the contractual nature of R&D and role of technology transfer in the global value chain of electronics industry.

The results point towards the lop-sided development of Indian manufacturing, whereby, domestic manufacturing capability has not developed alongside research and development capabilities in the electronics sector. Further, the free trade regime in electronics components has discouraged manufacturing and led to import intensive manufacturing and prevalence of trading opportunities. Policy steps need to be taken to encourage indigenous manufacturing capability and provide incentives for research and development that directly contributes to product development in domestic markets.

Table A.1 Firms classified by type of electronic products

industry	total_imports (millions Rs)	Sales_def (millions Rs)	Average Import intensity (2002-12)	Import intensity_2012	No. of firms in 2012
Analytical instruments	92	453	20%	0%	1
Antennae for TVs	0	0			0
Antennae for radios & TVs	125	514	24%	4%	1
Batteries incl. Ni-Cd batteries	33	212	15%		0
Blowers, portable	3	158	2%		0
CR tubes	41	146	28%		0
Capacitors	107	248	43%		0
Ceramic capacitors	21	65	32%	43%	1
Coils	2	50	3%		0
Communication & broadcasting equipment	30	251	12%	55%	1
Compact Discs	19	83	23%		0
Computer peripherals	237	619	38%	53%	2
Computer systems	258	1153	22%	8%	3
Computer terminals (VXL instruments, thin client computing technology)	458	577	79%	98%	1
Connectors	331	636	52%	61%	2
Control instrumentation & industrial electronics (print solutions, real time dashboards, motion control, industrial electronics)	205	609	34%	180%	2
Control panels	124	552	23%	39%	2
Control valve actuators	21	732	3%		0
Control valves	15	255	6%	8%	1
Crystals	1	26	4%	4%	1
Data storage, memory systems (real time tech solutions, defence)	328	361	91%	56%	1
Defence communication equipment	201	1980	10%	4%	2
Diagnostic equipment	1157	4003	29%		0
Diodes	17	40	41%		0
Electro cardio graphics	565	2997	19%	60%	1
Electrolytic capacitors	40	63	64%	94%	1
Electronic balances	0	18	3%	1%	1
Electronic components	35	325	11%	3%	5
Electronic relays	106	397	27%		0
Electronic test & measuring instruments	50	422	12%	6%	1
Electronic transformers	0	14	0%		0
Electronics	491	1793	27%	54%	5

Filters	17	89	19%	14%	2
Floppy disks	9006	15133	60%	33%	2
Fuses & fuse holders	12	35	33%		0
Industrial electronics & automation equipment	6	46	12%		0
Industrial fans, blowers, etc.	5	58	9%	31%	1
Industrial fans, etc.	23	354	7%		0
Industrial power supplies	16	379	4%	0%	1
Industrial ultrasonic equipment	31	158	20%	16%	1
Instrument cooling fans	34	137	25%	37%	1
Integrated circuits	120	182	66%	82%	1
Integrated circuits, nec	39	80	49%	44%	0
Inverters	5	116	4%		0
LED displays	164	1225	13%	7%	1
LED lamps	6	19	31%	10%	1
Laminates	12	35	34%		0
Level controllers	8	19	41%	40%	1
Line printers	511	1181	43%	41%	1
Medical electronic equipment, nec	9	112	8%	3%	1
Medical equipment	78	144	54%	19%	3
Microwave passive components	149	446	33%	37%	2
Miscellaneous components, nec	19	232	8%	9%	1
Miscellaneous electronic equipment	1234	3989	31%	55%	1
Mosquito repellers, insect killers	16	216	7%		0
Moulding compounds in electronics	1	32	3%	3%	1
Other automation electronics equipment	152	1087	14%	0%	1
Other communication equipment, nec	217	862	25%	0%	1
Other diodes & transitors	1761	2276	77%	67%	1
Other electronic components	150	220	68%		0
Other electronic equipment	21	188	11%	28%	1
Other electronic equipment, nec	46	124	37%		0
Other parts of lamps, nec	82	115	72%	96%	1
Other testing & measuring instruments	404	1125	36%	54%	1
Other transmission equipment	73	368	20%		0
Pacemakers	14	44	33%	29%	1
Photovoltaic power modules	1916	2126	90%	69%	3
Piezo electric elements (centum rakon, defence)	223	177	126%	79%	1
Power line carrier communication equip.	103	636	16%		0
Printed circuit boards	81	152	53%	72%	8
Process control equipment	447	1375	33%	37%	2
Process controllers	0	1	20%	0%	1

Rack & panel connectors	91	842	11%	11%	1
Reed switches	25	49	51%	70%	2
Resistors	2	8	27%		0
Rotary switches	6	169	4%	4%	1
Satellite communication equipment	0	4	3%		0
Security electronics equipment	2	6	36%		0
Semiconductor devices	174	437	40%	32%	1
Servo components	6	4	139%		0
Soft ferrites	17	111	15%	27%	2
Solar appliances	218	228	96%	103%	5
Solar modules	532	900	59%	57%	5
Stepper motors	319	592	54%		0
Surgical equipment	39	116	33%	15%	2
Switch mode power supply systems	42	434	10%	0%	3
Switching systems	335	619	54%		0
TV picture tubes colour	877	3516	25%	23%	2
Telephone components	2777	3115	89%	90%	1
Temperature controllers	7	193	3%	10%	1
Therapy equipment	4	453	1%	1%	1
Thermal analysis equipment	6	33	18%	26%	1
Thyristor power convertors	53	90	58%		0
Transmission equipment	323	1171	28%	48%	0
Uninterrupted power supplies	267	710	38%	79%	2
Voltage stabilisers / regulators	10	77	12%		0

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