Trade and plant level productivity gains: Role of Import Liberalisation, Technological Spillovers and Variety Growth in Indian Manufacturing

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Abstract

How does trade liberalization impact productivity at the micro level in the economy? Using a panel data of Indian manufacturing plants for the period 1998-99 to 2007-08 this study examines the mechanisms through which trade impacts productivity growth at the production level in the economy. These mechanisms include trade induced pro-competitive effect, technological spillovers and import & export variety growth. We use two estimation techniques and find significant impact of these mechanisms in driving plant level productivity growth. Our study also looks into the role of various plant level characteristics (like plant age, skill intensity & contract labour ratio) and state level institutional factors in influencing these micro level productivity gains.

1. Introduction

Does freer trade lead to productivity growth? The traditional neoclassical theory does not predict any implications of trade on productivity growth. However, the recent models of endogenous growth theory & new new trade theory identify several mechanisms through which trade can generate productivity gains to the producers in the domestic sector. First, trade liberalization increases competition in the market forcing the domestic producers to improve efficiency in order to retain market shares while forcing the least efficient ones to exit (Schmidt, 1997; Aghion et al, 2005; Melitz, 2003). This pro-competitive effect can induce productivity gains for domestic producers. Second, entry of foreign goods and foreign producers in the market can generate technology spillovers to domestic producers who get familiarized with superior technology and may adopt it in their production processes (Grossman & Helpman, 1991). Third, increased access to newer and larger varieties of intermediate inputs and expansion in output varieties produced by domestic producers can lead to gains in productivity levels in the domestic sector (Romer, 1990; Feenstra, 2004;

Goldberg et al, 2013). Fourth, participation of domestic firms in the export market may generate productivity gains through learning by doing effects (Baldwin & Gu 2004).

India initiated large scale trade reforms in 1991. In the above context, moving from import substitution policy to freer trade, it is expected that the long protected Indian producers would witness gains in productivity levels. However, the existing empirical studies analyzing the Indian manufacturing find a very mixed opinion pertaining to productivity growth in the post reform period.

Most of the descriptive studies analysing the first decade of liberalization (Trivedi et al. (2000), Unni et al (2001), Goldar (2004), Das & Kalita (2009), Rajesh & Mahapatra (2009)) find a deceleration in productivity growth in the 1990s as compared to the 1980s. While, the recent studies (Kathuria et al., 2010; Goldar, 2011; Hashim et al., 2009) covering the second decade of liberalization find evidence of productivity acceleration in the 2000s compared to the 1990s.

Econometric studies analysing the impact of trade reforms on productivity growth using various regression frameworks provide mixed evidence on trade reforms and productivity growth linkage. Studies by Krishna & Mitra (1998), Golar & Kumari (2003), Topalova (2004) find a positive impact of trade liberalization on productivity growth in the post reform period, while Balakrishnan et al (2000) and Bollard et al (2013) suggest no role of trade reforms in generating productivity gains in the Indian manufacturing. With varying growth trends and econometric evidence, role of trade in driving productivity growth remains a puzzling issue in the Indian context.

A key limitation of a large proportion of these studies is that they use aggregate industry level data and analyse the impact of trade policy changes using either dummy variable technique or trade policy variables like industry tariff rates, non-tariff barriers et cetra. [1]

While aggregate industry level data gets it right on average, it does not capture the direct impact of trade on the producers in the economy. As industries do not produce but plants do, some manufacturing plants may gain while others may lose as the result of changes in trade policy. Industry level data aggregates this effect making it impossible to understand the actual

[1] Studies by Trivedi et al. (2000), Unni et al (2001), Goldar (2004), Das & Kalita (2009), Rajesh & Mahapatra (2009), Golar & Kumari (2003), Goldar, 2011; Hashim et al., 2009 all use aggregate industry level data for analysis. Golar & Kumari (2003) use dummy variable for liberalization along with variables on effective rate of protection and non-tariff barriers. Krishna & Mitra (1998) & Topalova (2004) use industry tariff data in the regression analysis.

impact of trade on a heterogeneous set of plants operating within an industry. Aggregate level studies address the issue whether freer trade enhances productivity without asking the question how or why. To address the issue of 'how' requires analysing the exact mechanisms that lead to such gains at the level where production happens in the economy (Hallak & Lehvinson, 2004).

Coming to the analytical techniques, while data on tariff rates, non-tariff barriers have been used as instruments of trade policy in the regression equations, these outcome variables simply cover a single measure of openness in the industry. Changes in policy variable like industry tariff data may indicate changes in the competition structure of the industry thus accounting for the pro-competitive effect. However, there are several other channels through which trade impacts producer/micro level productivity. For example, gains from trade may vary for different sectors depending on their technological potential to absorb R&D spillovers from trading partners which tariff rate may fail to capture. Hence it seems inappropriate to answer the issue of trade and productivity linkage using a single policy measure of openness.

A study that explicitly measures & analyses the trade driven mechanisms in an integrated framework can correctly asses the trade-productivity linkage. This study aims to address this gap in literature by identifying, measuring and analysing the role of such mechanisms in driving productivity growth at the producer level.

A few micro level studies do exists that analyse the role of such mechanism like studies like Parmeshwaran (2009) & Goldberg et al (2010) analyse the impact of technology spillovers and import variety gains in the Indian context. However these studies address a single mechanisms in isolation and moreover rely on firm level data for analysis.

A limitation of using firm level data is that, it corresponds to company level balance sheet data on production, sales, profits et cetera. A firm may own several factories/ plants that operate under varied product lines and are spread over various geographical locations. Since firms do not produce but plants do, this data aggregates production data across plants and thus can lead to imprecise estimation of production function parameters. A detailed factory/plant level analysis can thus appropriately address this issue.

In this context two studies by Bollard et al (2012) & Harrison et al (2013) use plant level data of the Indian manufacturing, however, they either use a cross sectional data or pseudo panel for analysis which cannot exactly trace same plants year on year rendering the estimations imprecise.[2]

Our study uses a detailed plant level panel data that enables us to trace each plant of the manufacturing sector over the period 1998-99 to 2007-08 and measuring the impact of various mechanism namely pro-competitive effect, technology spillovers, gains from import & export variety and export growth on plant level productivities. Panel data framework allows us to precisely estimate production functions parameters and further run plant fixed effect regressions to control for any omitted variable bias.

Our study is important also for the period of analysis that it covers. Our study largely focuses on the second decade of liberalization covering the period 1998-99 to 2007-08. This period of analysis is important for analysis due to the following reasons.

While reforms of the first decade introduced large changes in the Indian trade policy, throughout the period India continued to remain a highly protected regime. Although the average tariffs rates fell massively from 82 % in 1990, a 33% rate by the end of 1990s was high enough to refer India as one of the most restricted regimes in the world. Tariff rates were substantially rationalized in the second decade to fall below an average 10% in 2009. Second, while the first decade only focused on capital and intermediate goods, the reforms of the second decade witnessed liberalization of trade policy for the long protected consumer sector.

That these policy changes had a substantial impact on trade participation reflects in the subsequent growth in trade. The import growth surged from an annual average growth rate 10.5% in 1990s to 24.3% in 2000s while the export growth rose from 9.4% in 1990s to 19.8% in 2000s. Thus analysing the period of 2000s is important to understand the impact of reforms on productivity growth which seems to be largely missing in the current studies.

To analyse the linkage between trade channels and plant level productivity growth in this study we firstly construct separate indices to measure each of these trade channels namely pro-competitive effect, technology spillovers, gains from import & export variety. Plant level productivity is estimated following the Lehvinshon & Petrin (2003) technique. And a regression model is estimated linking the dependant variable, plant level productivity growth

[2] Plant identifiers are not available for the whole data used by Harrison et al (2012) so they construct a pseudo panel dataset by matching individual firms from one year of the survey to the next. They match firms using beginning- and end-of-period information on capital and other types of stocks, supplemented with other identifying information. Moreover these studies analyse the role market share reallocations in driving aggregate productivity growth while our study analyses a different issue.

with the various mechanisms using a plant fixed effect model. To check for robustness of results we also undertake an alternate estimation technique closely following Fernandes (2007).

Our results remain same in both the cases. Our study finds a significant role of all these mechanisms in driving plant level productivity thus enabling us to attribute productivity gains to trade reforms. Our study also accounts for the role of state level institutional factors like physical infrastructure, financial markets and labour market conditions in generating productivity gains. Plants located in states with higher electricity generation, better credit availability and lesser labour market frictions are found to enjoy higher productivity gains.

We also analyse the interactive effect of policy reform variable, that is, tariff reduction on certain plant, industry and level characteristics. We find the gains to be higher for older plants, plants with higher intensity of skilled workers and lesser intensity of contract workers. Plants operating in export competing sectors are found to enjoy higher productivity gains vis-a-vis the others. And plants located in states with better credit availability gain higher as compared to its industry counterparts. This study allows us to provide micro level evidence pertaining to the positive impact of trade liberalization on productivity growth and access the differential role of various plant, industry and state level characteristics in benefitting from these trade policy reforms.

Rest of this paper is defined as follows. Section II discusses India's trade policy over the two decades; sections III and IV discuss related empirical literature and theoretical framework, section V discusses the model. Section VI discusses regression results and section VII concludes.

2. India's Trade Policy: Overview

India's trade policy till 1980s was an inward looking one which came from the long-standing distrust of markets in general and the fear that participation in international trade would hurt the much needed industrialization process (Srivinasan, 2000). With a comprehensive import licensing system, quantitative restrictions and prohibitions, imports of most of the products was effectively banned or were subject to stringent licensing regime. Only a small list of products in the OGL (Open General License) which included a few capital and intermediate goods that could not be supplied by the Indian manufacturers or were materials or components required by exporters could be freely imported till the end of 1980s (Pursell et al 2007)

The reforms of 1991 led to removal of licensing and quantitative restrictions on most imports except consumer goods. Average and weighted tariffs declined from 81.9% and 49.5% in 1990 to 57.4% and 27.8% in 1991 and further to 33% and 28.61% in 1999. The peak tariff which stood greater than 200% prior to reforms was reduced to 35% in 1999. The ERP declined from 125.9% in 1986-1990 to 80.2% in 1990-95 to further 40.4% in 1996-2000. In spite of these reforms it is argued that that protection to the manufacturing sector in the 1990s remained high.

The apprehension that domestic firms may not be able to compete with imported products kept protection high in many sectors. Tariff rates, especially for intermediate products and consumer goods were maintained high throughout this period. Tariff on capital goods was however reduced at a much faster pace with a view to enable domestic producers to get access to foreign capital and technology. Non tariff barriers like quantitative restrictions and licensing regime were prevalent in many sectors. While nominal tariff was reduced much in line with other goods it was particularly heavy import restrictions and quantitative restrictions that kept consumer sector largely protected. By the end of 1990s while the ERP for capital goods stood at 33%, it was much higher for intermediate goods and consumer goods sector at 40% and 48% respectively. Non Tariff barriers like import coverage ratio for capital goods stood at a low of 8%, while for intermediate and consumer goods it was as high as 28% and 33% respectively and quantitative restrictions still covered around 40% of total tariff lines in the sector (Das, 2003).

The beginning of 2000s witnessed further reduction in trade restrictions. After losing the WTO dispute against United States starting 1998, the general import licencing system was gradually dismantled and QRs were fully abolished in the year 2000. Apprehensive regarding the impact of these liberalization policies, the period also witnessed a few backtracking episodes of tightening between 1997 to 2001 when tariffs were increased through use of para-tariffs applied on top of customs duties to protect domestic producers from import competition.[3] (Pursell et al 2007).

[3] A “special duty” or “Surcharge” from 1997 to 2001 and a “Special Additional Duty” from March 1998 to March 2004. See World Bank (2004), Vol II, Table 3.6

Table 1: Average tariff for industrial products (1990-2008)

Tariff Year	Simple	Weighted	Peak Rate
1990	81.69	49.55	>200
1992	57.45	27.89	150
1997	30.08	19.92	85
1999	33.00	28.61	35
2001	31.06	24.76	30
2004	27.87	20.95	25
2005	15.38	11.97	15
2007	13.22	8.6	12.5
2008	9.1	5.91	10

Source: UNCTAD report: Twenty years of India's Liberalization, Experiences and Lessons

However, by 2001 it soon became apparent that the apprehensions regarding import competition were greatly exaggerated. The manufactured exports entered a new phase of rapid expansion and increased capital inflow bred new confidence in the economy leading to introduction of drastic reductions in industrial tariffs. For most industrial goods, abolition of special additional duty and a general reduction in maximum customs duty and abolition of para-tariffs led to large tariff reductions in 2004-05 (Pursell et al 2007). As the result the average and weighted tariff rate fell substantially from 27.8% and 20.9% in 2003-04 to 15.3% and 11.9% in 2004-05. This maximum customs duty limit was further reduced from 15% in 2005-06 to 12.5% in 2006-07. Compression of tariffs under lower ceiling led to lesser variance across industrial goods with 90% of the industrial tariffs falling below 12.5% in 2006-07. Even for the most protected sectors such as food and kindred products, textile mill products and apparel and related products where weighted tariff remained higher than 40% throughout the 1990s, cautious liberalization in 2000s brought down these tariff rates to around 10% by 2008.

Marking the end of second decade of reforms, the simple average tariff and weighted average tariff rates across board stood at as low as 9.4% and 7.2% respectively in 2009-10. As measured by ad volerem industrial tariffs, Indian manufacturing thus moved from being one of the worlds most protected sectors to low protection sector by world standards by this period (Pursell et al 2007).

Table 2: Product-wise tariff rates 1996-2008

Product Name	Simple Average			Weighted Average		
	1996	**2000**	**2008**	**1996**	**2000**	**2008**
Food and kindred products	54.2	37.7	37.7	41.2	38.9	11.7
Tobacco manufactures	52	35.6	35.6	52	38.5	32.3
Textile mill products	50.1	9.4	9.4	45.7	27.9	9.2
Apparel and related products	50.7	10	10	51.5	37.6	10
Lumber and wood products	26.7	9.0	9.0	13.7	7.7	5.6
Furniture and Fixtures	46.9	9.9	9.9	46	34.8	10
Paper and allied products	29.7	9.6	9.6	8.2	16.1	7.3
Printing, publishing, and allied	26.4	8.1	8.1	22.5	24.9	8.3
Chemicals and allied products	39.8	8.3	8.3	35.7	32.5	6.6
Petroleum refining and related	20.6	8.1	8.1	12.1	17.3	6.9

Source: UNCTAD report: Twenty years of India's Liberalization, Experiences and Lessons

Corresponding to this, the manufacturing sector witnessed stark rise in growth rate with steep rise in output, import and export growth. In this paper, we analyse this period of reforms beginning 1999-00 to 2007-08 when average rates fell from 33% to 9% and resultant export and import annual average growth surged as high as 20.2% and 24.2% respectively much higher than the earlier period of around 10% growth and the manufacturing sector growth was seen to touch 8%. We trace manufacturing plants over the entire period to analyse the impact of these trade reforms and corresponding increased trade participation on plant level productivity growth.

Table 3: India's Export and Import growth

Gross Exports (% growth)		**Gross Imports**(% growth)	
1990-1999	9.4	1990-1999	10.5
2000-2010	19.8	2000-2010	24.3
1990-2010	13.4	1990-2010	15.3
1999-2008	**20.2**	**1999-2008**	**24.2**

Source: World Bank

3. Review of Related Empirical Literature

Most of the early studies in the Indian context largely focused on analysing the trends in productivity. A detailed survey of studies by Goldar (2011) suggests that most of the studies find that growth rate of TFP in India's manufacturing sector in the post reform period of 1990s was lower than the pre reform period. Aggregate industry level studies by Golar & Kumari (2003), Das & Kalita (2009), Trivedi et al.(2000) find that for majority of the industries TFP growth in 1990s decelerated. Firm level studies by Srivastava et al. (2001), Balakrishnan et al. (2000) also find similar trends for this period of reforms. Deceleration of productivity growth in the post reform period initiated debates regarding the impact of trade reforms on productivity. Studies Goldar & Kumari (2003), Topalova (2004), Sivadasan (2009), Das (2006), Chanda & Sen (2002) find a positive impact of trade liberalization on productivity in the post reform period and suggest that the deceleration in productivity growth should not be attributed to trade liberalization but rather to gestation lags in investment projects, capacity underutilization and adverse agricultural growth.

On the other side, studies by Balakrishnan et al (2000), Bollard et al (2013) find no or negative impact of liberalization. Balakrishnan et al (2000) analysing the first decade of reforms argue that the expected productivity improvements which they find missing could either be due to the period of analysis was too close to the launching of reforms giving a small bandwidth for structural changes to appear or could be due to the fact that policy reforms undertaken have been inadequate to facilitate improvements. They suggest the need to address microeconomic foundations of productivity growth analysis which traces the exact channels/ mechanisms of this growth.

Studies by Virmani (2005), Hashim et al (2009) suggest a J-curve in aggregate productivity growth. Hashim et al (2009) breaks up the post reforms into the following three subperiods for a clearer understanding: 1992-93 to 1997-97; 1998-99 to 2001-02; and 2002-03 to 2005-06. They find productivity growth decelerated in the first sub-period because of the combined effects of the balance of payment shock and the J-curve effect arising from the dramatic import liberalization and exchange rate reforms of the early 1990s. In the late nineties-early 2000s, deepening of liberalization rendered certain types of capital obsolescent leading to deceleration in productivity. In the last sub-period as the dissemination of new technologies and products progressed from early adopters to others, productivity growth is found to accelerate sharply during the third subperiod.

Parmeswaran (2009) analyses role of technology spillovers in the Indian context and finds positive impact of these on firm level productivity gains. The study finds that rent spillovers through imported machinery have a significant effect on productivity in technology-intensive industries while impact of knowledge spillovers is significant in all cases with a greater effect on productivity in technology-intensive industries. Goldberg et al (2010) investigate the relationship between declines in trade costs, imports of intermediate inputs and domestic firm product scope and find lower input tariffs play a crucial role in introduction of new products by domestic firms which also forms a component of productivity. However, these studies only focus on the first decade of reforms, while the impact mechanism in the second decade of reforms remains largely unanalysed. In this study we try to measure analyse the role of all such mechanisms in an integrated framework for the second decade which to the best of our knowledge is still missing in literature.

4. Theoretical background

Our model draws from the literature of trade and endogenous growth theory. These models predict that trade liberalization can lead to productivity gains for plants in the domestic sector through various channels. Firstly, removal of trade restrictions leads to entry of foreign products and players in the domestic market. This induces a pro-competitive effect amongst domestic producers that are forced plants to increase efficiency by eliminating slack (Fernandes, 2007) and move down the average cost curves (Helpman & Krugman 1985). It may also lead to producers shifting production focus onto their core competency products and increasing innovation (Aghion et al 2005) to sustain market share. Increased competition can also alter plant's incentives to invest in productivity enhancing technology by reducing the opportunity cost of technological effort (Goh 2000) and resultant adoption of advanced production techniques could generate productivity gains to the producers.

The second channel of productivity growth is trade induced technology spillovers. Trade can lead to international technology diffusion as predicted by endogenous growth models of Grossman and Helpman (1991) and Rivera-batiz and Romer (1991). With trade liberalization, country's productivity depends on its access to capital goods produced around the world and its ability and willingness to make use of it. This channel can imply higher gains for developing countries since they are endowed with lesser technological stock and R&D activity is relatively expensive. In case of developing countries, interactions between buyers, sellers and products in the market can generate technology spillovers as imports from developed countries enables the domestic producers to get familiarized with superior technology which in turn gives them useful insights and ideas to improve their own products (Parmeswaran, 2009). Also, participation in export activity leads to interactions between domestic producers and foreign buyers where the latter provides technology updates and feedbacks to the former for product enhancement (Schmitz and Knorringa, 2000).

Technological spillovers can either arise from intermediate inputs or final products. In this study, we identify two kinds of technological spillovers enjoyed by domestic producers. Imports of advanced intermediate inputs leads to direct productivity gains to the domestic producers, which defined as rent spillovers arise from market competition when innovators are unable to charge the price that fully accounts for the technological improvement in the product. This underpriced quality change transfers the partial rent of innovation from innovator to the user in the form of productivity gains. The second kind of spillover, defined as knowledge spillover, are pure positive externalities enjoyed by the domestic producers from the imports of knowledge intensive intermediate and final goods in the domestic market. The competing firms in the domestic market, by way of imitation, adopt the advanced technology embodied in imported goods and enjoy productivity gains.

Another channel of productivity growth is input and output variety growth of plants. The endogenous growth models by Romer (1990) and Grossman & Helpman (1991) view technological progress as R&D led variety growth. Trade raises productivity levels because producers gain access to new imported varieties which implies that firms can use larger number of intermediate inputs in production process and escape diminishing marginal product. Feenstra (2007) theoretically prove that assuming a CES production productivity can be defined as a function of the change in input variety and the elasticity of substitution, and assuming elasticity of substitution to be greater than one, any increases in input variety lead to increase in productivity. There is also an associated 'growth' effect as increase in the number of varieties drives down the cost of innovation and results in creation of even more varieties (Broda, Greenfield & Weinstein, 2006). Similarly, expansion in output variety by domestic producers can generate productivity gains as plants can move to a more efficient point on the production possibility frontier (Feenstra, 2007). The gains from increase in output variety emanate from the assumption of diminishing technical rate of substitution among the productive factors, which in turn results in concavity of the production possibility frontier. Therefore, producing more varieties leads to higher average marginal product per productive factor thus generating productivity gains [4]

[4] A formal proof of variety led productivity growth can be seen in Feenstra (1994) & Feenstra (1999)

In the following sections of this paper, we incorporate the role of these mechanisms in an econometric model and empirically examine their implications in the Indian context.

5. The Model

5.1 Hypothesis

To identify the role of these mechanisms we undertake a plant level regression analysis, with plant level productivity as the dependent variable and the mechanisms discussed above as the independent or explanatory variables to test the trade-productivity linkage. Our empirical study tests for the following hypothesis-

Tariff rate: Fall in tariff rate implies rise in market competition. The pro competitive effect thus induced is expected to raise plant level productivity. We expect a negative correlation between plant level productivity and tariff rate.

Import variety: Growth in intermediate input variety enables producers to escape diminishing marginal product. This would imply a positive correlation between import variety index and plant level productivity.

Export variety: Expansion in the export variety basket enables producers to escape diminishing rate of technical substitution. We expect a positive correlation between export variety index and plant level productivity.

Rent Spillover: Rise in rent spillover index would imply higher gains in productivity as market competition enables produces to acquire better technology at a price that is not fully indexed to equivalent technological context. We hence expect a positive correlation between rent spillover variable and plant level productivity.

Knowledge Spillover: Knowledge spillovers are pure positive externalities enjoyed by the producers as good with better technology enter the domestic market, hence similar as above we expect a positive correlation between knowledge spillover variable and plant level productivity.

5.2 Data

The data source for this study is the Annual Survey of Industries (ASI). We use plant level panel data that is annually collected in the ASI by the Central Statistical Organization which is a department in the Ministry of Statistics and Programme Implementation (MOSPI) of the Indian Government. The ASI is the principal source of industrial statistics in India and covers all the states of India.[5] The primary unit of enumeration in the survey is a plant/factory in the case of manufacturing Industries.[6] The ASI frame classifies industries into two sectors namely 'Census' sector and the 'Sample' sector. In the census sector, the data from all the factories employing 100 or more workers is collected on a complete enumeration basis.[7] The remaining factories fall under the sample sector for which data is collected by drawing a representative sample using sampling techniques.

This study covers only those plants that fall under the census sector since continuous data is only available for this set which can be successfully analyzed in a panel form. The data are an unbalanced panel and contains detailed information on production related variables like output, fixed assets, inventories, working capital, inputs, employment, labor costs, raw materials, electricity, power & fuel consumption, state location, ownership, year of incorporation et cetera. This data classifies each plant into industry categories which is available upto the 4-digit NIC level of disaggregation. Only plants operating in the manufacturing sector, that is,. belonging to NIC15-NIC36 two-digit industry groups have been included in the analysis.

While the ASI collects factory level information pertaining to production activity at plant level, it does not provide information on variables pertaining to trade participation of the plant like exporting products, net exports, and trading partners.[8] Such information is usually available at the firm level which comprises of group of plants under same ownership. However, since using firms level data leads to compromises on quality of production data as various products are clubbed in a single balance sheet. Studies that use firm level data attribute the total production value to the primary product of the firm however; it is an amalgamation of several products across various similar-dissimilar categories. To avoid this issue we resort to using the neat plant level production data for the analysis and data pertaining to trade participation is used at the most disaggregate industry level possible.

For data on trade variables we rely on industry level (at various levels of disaggregation) information. Data on trade variables, that is, imports and exports is at various levels of

[5] Except for the States of Arunachal Pradesh, Mizoram and Sikkim and the Union Territory of Lakshadweep
[6] The ASI covers all factories in India that are registered under Sections 2m(i) and 2m(ii) of the Factories Act, 1948 i.e. those factories employing 10 or more workers using power; and those employing 20 or more workers without using power.
[7] For years 1998-1999 and 1999-2000, census sector comprised of units with 200 or more workers.
[8] Information on imported intermediate goods is available for some plants; however detailed information pertaining to the geographical origin (country/port) is not available in the database which is required for analysis in this paper.

classifications is obtained from COMTRADE using the WITS software of the World Bank. Data on tariff rates was obtained from trade databases TRAINS of UNCTAD and the IDB database of the World Bank using the WITS software. Data pertaining to output, R&D and Input-Output tables of OECD countries was derived from OECD databases STAN and ANBERD. Data on Wholesale Price Index (WPI) and Input-Output tables for India were obtained from Database on Indian Economy (DBIE) –RBI's data warehouse and CSO respectively. Data on state level information regarding electricity, credit and labour markets was obtained from the CMIE publication on Energy, Money & banking and Ministry of Labour website respectively. Further details pertaining to data have been discussed in the next section on variable construction.

5.3 Measurement & Variable construction

5.3.1 Productivity Estimation: We pool all plants according to their 2-digit NIC industry groups and estimate a separate Cobb-Douglas production function for each industry group. Plant level total factor productivity (TFP) estimates are then obtained as the residual of the estimated production function. Following is the production function form for each two-digit NIC industry (j) used in the estimation

$$y_{it}^{j} = \beta_{l}^{j} l_{it} + \beta_{h}^{j} h_{it} + \beta_{k}^{j} k_{it} + \varepsilon_{it}^{j}$$

Here y is the log real value added, l is the log of number of production workers, i.e. the unskilled (blue collar) employees, h is the log of number of non-production employees i.e. the skilled (white collar) employees, k is the log of real capital employed and ε is the error term for plant (i) at time period (t). The error term, ε which measures productivity shock is split into two components such that

$$\varepsilon_{it}^{j} = \omega_{it}^{j} + \epsilon_{it}^{j}$$

Where ω is the unobserved TFP shock and the ϵ is the uncontrolled zero mean, random error which captures deviations from expected output due to measurement errors, machinery breakdown, natural calamities et cetera. The constant term is included in ω. However, estimating the TFP from the residual error of the production function poses an econometric challenge of endogeneity. Since the TFP is observed by the plant manager, the input choices made at the plant level are likely to be correlated with the plant TFP. Higher levels of observed TFP lead to greater employment of inputs. The OLS assumption of zero correlation between regressors and the error term (which includes the plant's TFP not observed by the econometrician) breaks down in this framework and renders the OLS estimates of the production function biased. To address the problem of endogeneity we adapt the two stage semi-parametric estimation by Lehvinshon & Petrin (2003); *LP henceforth*. We use electricity consumption by plant as a proxy for unobserved productivity. This intuitively implies we use the information on electricity consumption as a "control" for the unobserved productivity in the estimation. Using the LP technique, we hence obtain the production function estimates for each 2 digit NIC manufacturing industry, the residual difference between actual output and estimated output is the plant level productivity estimate.

Data on plant level real value added (y) is obtained as the difference of real output and real intermediate input. Relevant WPI has been used to deflate nominal output. Intermediate input deflators were created for each industry using Input –Output tables of the CSO and industry specific whole sale price indices. Plant level data on total number of production workers employed has been used to measure unskilled labour (l). Skilled workers (h) consist of supervisory & managerial staff. Capital stock (k) is estimated using the perpetual inventory method. The details of capital stock estimation have been discussed in the appendix A of the paper. The production function coefficient estimates for each 2 digit NIC industry group are displayed in appendix B.[9] This completes the discussion on estimation of plant level productivities which constitute the dependant variable of our econometric model.

We now move on to discuss the construction and measurement of the explanatory variables used in the model.

5.3.2 Trade variables

Tariff (t): We use the most disaggregate level tariff (Effectively Applied rates) data available, which corresponds to 4 digit level as per ISIC Revision 3.[10] To match this data with plant level ASI information, a concordance table has been drawn between 4 digit ISIC rev 3 and 4 digit NIC 1998.

Import variety Index (IV): This industry level variable is constructed closely following Feenstra (1994). The import variety index for industry j is defined as a weighted measure of

[9] The estimation has been undertaken using the LP program in STATA software.

[10] Primary data series was obtained from the TRAINS database, for years where tariff rate data was not available, data was obtained from the IDB database.

import variety indices of all intermediate inputs (i) used in production in industry j. The construction of this index thus involves to two stages. Firstly, estimating an import variety growth index for each industry i. And next, estimating a weighted measure of all import variety growth indices used as intermediate inputs in industry j. This index measures the rise in the variety of intermediate inputs/products available to an industry j for its production process.

The import variety growth index for each product (i) is defined as follows

$$Var\_In_{i,t,t-1} = \frac{\sum_{i\subset I_t} p_{it}x_{it} \ / \ \sum_{i\subset I} p_{it}x_{it}}{\sum_{i\subset I_{t-1}} p_{it-1}x_{it-1} \ / \sum_{i\subset I} p_{it-1}x_{it-1}}$$

Where I denotes the set of varieties available in both the periods $I \subset (I_t \cap I_{t-1})$, p denotes the price of product i, x denotes the quantity imported, t denotes the time. This index can be interpreted in the following manner. Consider a case where the set of input variety is growing over time, such that if I_{t-1}= (1,2,….. N_s) and I_t= (1,2….N_t), such that $N_s < N_t$ implying that all the varieties that were available in time period t-1 are atleast available in time period t in addition to new varieties in time period t. In this case the set of common variety $I=I_{t-1}$, hence making the denominator term equal to one. Since $I_t > I$, the numerator will be greater than one implying rise in variety.

Having obtained a measure of variety index for each product/intermediate input (i), Variety Index for each industry (j) that uses one or more of (i) is obtained using weights from Input-output tables and is defined as:

$$IV_{jt} = \sum_i Var\_I_{i,t,t-1} * \left(\frac{m_{ij}}{\sum_i m_{ij}}\right)$$

where m_{ij} is the imported intermediate input i used in industry j

In order to measure the variety growth within each 2 digit intermediate industry group we make use of finely disaggregated at the 6-digit level of Harmonised System (HS) trade data from UN-COMTRADE. Following Broda et al (2006) we define a product (i) as a 6 digit category of HS 1988 classification and a variety is defined as a 6 digit HS1988 product imported from a particular country.

Since the purpose of this index is to capture the growth in the intermediate input variety used in the industrial sector, the HS 6digit products are reclassified in groups based on Broad Economic Category (BEC) classification and only those categories are included which fall under the category of intermediate inputs.[11] This category of products (i) is then further matched with ISIC rev.3/ NIC 1998/2004 classification as index creation requires use of Input-output tables which classify data in ISIC rev.3/ NIC 1998/2004 classification at 2 digit industry level.

Export variety Index (EV): This index measures the rise in variety of exported products within a 2 digit industry classification (i), hence similar as input variety index is constructed for 2 digit industry level as per ISIC rev3 classification. A product is defined as a 6 digit category of HS 1988 classification. A variety is defined as a 6 digit HS1988 product exported to a particular country where I denotes the set of varieties available in both the periods $I \subset (I_t \cap I_{t-1})$. The interpretation of this index is same as discussed in the previous section and hence a rise in export variety will lead to a rise in index.

Rent Spillover (RS): This index closely follows Jacob & Meister (2010). We measure rent spillovers from trade in intermediate inputs with 16 OECD countries.[12] Since rent spillover arises from user-producer relationship, along with partner country R&D stock data this index uses Indian input output tables for construction. [13]

Firstly we construct R&D Intensity for each sector and each year for all the partner OECD countries. Then these sectoral R&D intensities are weighted using import data to get R&D intensity weighted value of goods imported by domestic country

$$RDI_{ij}(t) = RD_{ij}(t) * Imp_{ij}(t)$$

[11] This includes BEC codes 22, 322, 41, 42, 521 & 53

[12] Belgium, Canada, Czech Republic, France, Finland, Germany, Hungary, Italy, Japan, Korea, Mexico, Netherlands, Norway, Spain, USA, UK

[13] Data pertaining to R&D expenditure and sector GDP of OECD countries were extracted from STAN and ANBERD databases of OECD. Import data was obtained from WITS database of the World Bank. Input output tables of India were obtained from India's Ministry of Commerce website.

Here RDI_{ij} is the R&D intensity weighted value of imports for industry i, OECD country j. RD_{ij} is the R&D intensity of sector i, country j defined as the ratio of sector R&D stock to sector GDP of sector. Imp_{ij} are imports by India from sector i, country j. [14]

The RDI_{ij} entering the domestic market is further split across sectors in the domestic country using the Input-Output tables to get final RS_k index for sector k of domestic country.

$$RS_k(t) = \sum_j \sum_i RDI_{ij}(t) * w_{ik}$$

Here, w_{ik}, (which is obtained using input-output tables) is the share of imported intermediate input i used by industry k of the total intermediate input imported into the country. Mathematically defined as

$$w_{ik} = m_{ik} / \sum_k m_{ik}$$

where m_{ik} is the imported intermediate input i used in domestic industry k.[15]

Since data pertaining to R&D expenditures and Input-output tables is available at 2-digit industry levels, this index is created at the 2-digit industry level.

Knowledge Spillover (KS): Following Jacob & Meister (2010) this index is constructed by accounting for technological similarity between the home and the partner country. Greater technological congruence implies greater possible spillovers. This study measures spillovers across same sectors between India and partner countries.

To construct the index we start with RDI_{ij} which is the R&D intensity weighted value of imports for industry i, OECD country j. This represents the potential knowledge spillover that can be gained by the domestic country. However, gains in knowledge depend on the technological congruence of domestic and foreign we account for this using a vector $S_{ij}(t)$.

[14] Sectoral R&D stocks of each partner country are constructed using the perpetual inventory method using 1987 as the base year and 15% depreciation rate. Data on R&D expenditure and sectoral output were extracted in National currency constant prices with base year as 2000.

[15] not all plants buy foreign technology or intermediate input directly, however they may procure it from domestic traders who import the goods from international markets. Since we do not have information on the foreign content of intermediate inputs at plant level we apply the indirect approach of capturing rent spillovers at industry level and applying the same to each plant in a given industry.

Sij is a factor measuring the technological congruence of sector j of partner country j is measured as

$$S_{ij}(t) = \sum_{i} Min\ (A_{id}A_{ij})\ (t)$$

Where A_{id} and A_{ij} are column vectors representing the share in the column sum of input coefficient vector of industry i of domestic country and partner OECD country. S_{ij} takes the value 1 if the two sectors in two countries are perfectly similar and zero if perfectly dissimilar.[16]

$$KS_i(t) = RDI_{ij}(t) * S_{ij}(t)$$

Here, KS_i is knowledge stock (i.e. the knowledge spillover index for this study) for sector i.

Similar to rent spillover index this index is also constructed at 2 digit industry level due to availability of data.

Import penetration ratio: This index measures trade participation in terms of the proportion of domestic demand that is satisfied by imports. It is defined as ratio of imports to sum of total consumption C (where C= Q+M-X, Q is total domestic production/output, X is gross exports and M is gross imports). This variable has also been constructed at the 4 digit level as per ISIC Revision 3 classification. Data on gross imports and exports was obtained from COMTRADE.

Export intensity ratio: This index measures the share of exports in total domestic output of a product category. We construct this index at the 4 digit level as per ISIC Revision 3 classification. Data on gross exports was obtained from COMTRADE, output data was obtained from Ministry of Commerce, Government of India.

5.3.3 Plant level variables

Plant Size: Plant size is measured by the number of production workers employed.[17]

[16] Data pertaining Input output tables of OECD countries was extracted from STAN database of OECD.

[17] We also use plant output as plant size, the results of the regression remain the same

Plant Age: using the data on year of incorporation of the plant from the ASI we use to deduce plant age for each plant-year observation.

Skill Intensity: This is the ratio of total number of skilled labour (non production workers like managers & supervisors) employed in the plant per each production worker.

Contract labour Intensity: This is defined as the ratio of number of production workers employed through contractor to the total number of production workers in the plant,

5.3.4 Other Industry level variables

Export Competing Dummy: Literature has largely related exporting to productivity growth. This dummy captures the trade direction of the 2 digit industry in which the plant is operating to analyse the impact of trade orientation of industry on plant level productivity gains. Each 2 digit industry is classified based on trade intensities following Erlat (2000) on basis of a cut-off value of T, where T is defined as

$$T = \frac{C-Q}{C},$$

Where C =Q – X+ M. Sector with T <0 are defined as net exporting sectors. For sectors where T>0 , we decide a cutoff point of 0.40 such that sectors for which 0<T<0.40 are classified as import competing sectors and sectors for which T>0.40 are classified as non competing sectors. Export competing dummy hence allots 1 for each plant falling in a 2 digit industry in a given year with a T<0.

Labour Intensive sector Dummy: This dummy tests if plant productivity is dependent of the factor intensity of the industry the plant operates in. To classify industries on the basis of factor intensities we follow Hinlppen & Marreijk[18] which classifies 240 items, at the 3-digit SITC level, into five categories (number of items in each category in parentheses): primary (83), natural-resource intensive (21), unskilled-labor intensive (26), human capital-intensive (43), technology-intensive (62), and unclassified (5). Since ASI data classifies plants based on NIC categories, a concordance table between SITC 3 digit to NIC 3 digit is mapped to allot plant to various factor intensity categories. The labour intensive dummy in this study hence allots 1 to each plant that falls in the industry group ‘unskilled-labor intensive’.

[18] http://www2.econ.uu.nl/users/marrewijk/eta/intensity.htm, last visited July, 10 2013

5.3.5 State level institutional variables

We use three control variables to account for institutional differences across states which could impact productivity growth

Electricity: We calculate electricity (utilities only) generated per per 1000 persons for each state in India. Data on electricity generation was taken from CMIE publications on Energy while population estimates were obtained using Census data.

Credit: This variable accounts for financial infrastructure of the state. We calculate credit available for industrial purposes as a share of Gross state domestic product. Data on credit and GSDP were both obtained from CMIE publications on Money & Banking.

Mandays lost: This variable accounts for state of labor market in the state. We estimate an index named mandays lost in strikes and lockouts per industrial worker. Data on manday lost in each state due to strikes and lockouts was obtained from Labour Year book, Labour Bureau, Government of India.

5.4 Econometric Specification

We build an econometric model of the following baseline specification-

$$\omega_{ijt} = \beta_0 + \beta_j + \beta_t + \beta_\tau t_{i,t-1} + \beta_{ev}\mathrm{EV}_{it-1} + \beta_{iv}\mathrm{IV}_{it-1} + \beta_{rs}\mathrm{RS}_{it-1} + \beta_{ks}\mathrm{KS}_{it-1} + X'y + \eta_{ijt}$$

ω_{ijt} is the estimated TFP of plant i in industry j at time(year) t. β_0 is the common intercept, β_j and β_t are industry and year dummies. t, EV, IV, RS, KS are the trade variables tariff rate, export variety index, import variety index, rent spillover and knowledge spillover respectively. One year lagged values of these variables are used to measure impact on current year productivity. X is the vector of all other variables including plant, industry and state level characteristics. η_{ijt} is random error.

6. Regression Results

Our data comprises of 71,539 observations representing 13,945 manufacturing plants covering the period 1998-99 to 2007-08. The dependant variable in our regression analysis is plant level productivity. We run a plant level fixed effect model for the panel data which allows us to control for all the unchanging plant level characteristics over the time period.[19] The results of the regression analysis are displayed in Table 4. Model 1 provides the baseline results of the study. Tariff rate is found to be negative significant at 5% level implying that a fall in tariff rate is associated with rise in plant level productivity. Export variety and import variety variables are found to be positive and significant at 1% level. Rent spillover and knowledge spillover are also found to be positive and significant at 10% and 5% level respectively. Plant age is positive and significant at 1% level, plant size is found to be positive but insignificant. The model accounts for year and 2-digit industry dummies too. These baseline results are largely robust to various other model specifications, the sign and significance of estimated coefficients remains same for majority of cases.

Model 2 accounts for the role of state level institutional variables. State level electricity generation and credit availability is found to be positive and significant at 1% level. Mandays lost in strikes and lockouts reflecting labour market frictions are found to have a negative coefficient significant at 1% level. Thus plants that are located in states with better institutions enjoy higher gains vis-a-vis their counterparts.

In Model 3, instead of using tariff rate which is the policy variable, we use outcome variables namely import and export penetration rates.[20] These are negatively associated with industry tariff rates and are expected to rise as tariff rates are reduced. As expected, both the coefficients are found to be positive. Import penetration is highly significant at 1% level while export intensity is found to be positive but insignificant. Rest of the models analyse the interactive impact of the policy variable, i.e. tariff rate with various plant, industry and state level characteristics to assess how the impact of policy reforms vary across various scenarios.

In Model 4, we interact tariff with plant age. The coefficient is found to be negative and significant at 1% level suggesting that older plants enjoy higher productivity gains with tariff reduction. The direct impact of tariff is positive significant which is rather intuitive, suggesting that new plants with age less than zero suffer loss in productivity when market competition rises due to tariff reductions. The model suggests that plants older than 2.8 years

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[19] We notice plants in the panel switch across 2-digit NIC industries over the time period; hence 2-digit industry dummies have also been included in the models.

[20] Information on 4-digit industry was missing for a few plants hence total number of observations fall to 59,907

in the dataset are found to enjoy pro-competitive gains from tariff reduction.[21] Model 5 is interaction of tariff with all state level variables. Interaction of tariff rate with credit availability is found to be negative and significant suggesting better credit environment leads to higher plant level productivity gains. Plants that are located in states with better credit availability enjoy higher gains vis-a-vis its other counterparts.

Model 6 investigates the direct and interactive impact of exporting on productivity. Plants that belong to export competing sectors are significantly more productive than the rest. Moreover tariff reductions generate higher gains for these plants as compared to the others. In Model 7, we use a labor intensive sector dummy to segregate plants engaged in labour intensive sectors vis-a-vis the others. The labour intensive sector dummy is found to be negative however, neither the direct nor its interactive effect with tariff is found to be significant suggesting gains from tariff reduction are same across all sectors irrespective their industry's factor intensity.

Models 8 and 9 assess the impact of characteristics associated with labour employed at the plants.[22] Plants that have higher skilled labour intensity per worker enjoy higher gains from tariff reduction. Similarly, plants that employ higher proportions of contract labourers experience lesser gains from tariff reductions vis-a-vis its counterparts.

Alternate Estimation (Robustness checks)

We adopt an alternate method of estimation to check for robustness of the estimated results. This method addresses the issue of serial correlation raised by Fenandes (2007). However, due to requirement of higher degrees of freedom for estimation, this method does not give us the flexibility to estimate separate production function for each 2-digit industry group. A single production function is estimated for the whole manufacturing sector. In this technique productivity equation controls for lagged productivity and the production function estimation also includes trade variables (as state variable) as the regressors along with plant level input information on labour and capital. This approach uses the insight of Levinshon & Petrin (2003) method however the production function estimation technique closely follows Ackerberg, Caves and Frazer, (2006); ACF henceforth. The ACF technique provides the flexibility for adding additional state variables in the production function without having to

[21] -0.0852*2.8> 0.224, the LHS is the coefficient of plant age and tariff rate interaction multiplied with plant age, RHS is the direct impact of tariff. Refer Model 4

[22] Model 7 and Mode 8 use information on skill intensity and contract labor, which was found to be missing for some plants. The regression analysis only uses those plants for which information was not missing.

revisit the underlying dynamic model when considering modification to the original OP/LP setup. Like the LP technique, we use the material demand as a proxy for unobserved productivity. Here, the material demand (electricity in this case) is defined as a function of productivity, state variable k (whose current value is assumed to be uncorrelated with current productivity), labour l and all additional variables potentially affecting the optimal input demand choice.[23]

$$\mathrm{m_{it}} = \mathrm{m_{it}}(\,\omega_{\mathrm{it}}, \mathrm{l_{it}}, \mathrm{k_{it}}, \mathbf{Z}_{\mathrm{it}}) \qquad (2)$$

Z is the vector of all additional variables that are expected to influence plant level material demand decision, which in this study imply the trade orientation (tariff rates, knowledge spillover index, rent spillover index, import variety index, export variety index) of the industry and nature of state level institutional factors (electricity availability, credit availability and labour market conditions measured by mandays lost in strikes and lockouts) in which the plant is located. Assuming that a plant's material demand function is a monotonically increasing function in productivity, ω, we get an inverse demand function

$$\omega_{\mathrm{it}} = \mathrm{h_t}(\,\mathrm{m_{it}}, \mathrm{l_{it}}, \mathrm{k_{it}}, \mathbf{Z}_{\mathrm{it}}) \qquad (3)$$

This inverse function is plugged into the production function and the parameters are estimated using a semi-parametric approach discussed in the following section. We estimate a Cobb Douglas and a Translog production function to check for the robustness of our results. Assuming a Cobb Douglas production function and pooling plants across all industries and years, the empirical specification of our model is defined as[24]:

$$\mathrm{y_{it}} = \beta_{\mathrm{l}}\mathrm{l_{it}} + \beta_{\mathrm{k}}\mathrm{k_{it}} + \beta_{\tau}\mathrm{t_{it-1}} + \beta_{\mathrm{ev}}\mathrm{EV_{it-1}} + \beta_{iv}\mathrm{IV_{it-1}} + \beta_{\mathrm{rs}}\mathrm{RS_{it-1}} + \beta_{\mathrm{ks}}\mathrm{KS_{it-1}} + \beta_{\mathrm{es}}\mathrm{es_{it}} + \beta_{\mathrm{cs}}\mathrm{cs_{it}} + \beta_{\mathrm{ms}}\mathrm{ms_{it}} + \lambda_t + I^j + \omega_{\mathrm{it}} + \epsilon_{\mathrm{it}} \qquad (4)$$

Here y is the log real value added, l is the number of production workers employed, k is real capital employed , t is tariff rate, EV is the export variety index, IV is import variety index, KS is the knowledge spillover index, RS is the rent spillover index, es is electricity generated per capita in the state, cs is credit availability to industry per thousand capita, ms is mandays lost in strikes and workouts per thousand industrial workers in the state, λ is year dummy, I is

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[23] For ease of estimation, we use information on production workers only in this technique.

[24] Pooling plants across all industries is done to data problems, with small set of plant-year observations in individual industries, the estimation techniques leaves zero degrees of freedom thereby making it impossible for matrix inversion, discussed in detail later in the paper.

NIC-2 digit industry dummy, ω is the productivity and ε is the unpredictable and unobserved (by plant) zero mean shock for each firm i at time t. To avoid problem of endogeneity of trade policy, lagged values of trade variables have been used as regressors.

We perform a two-step estimation of (4) and like the ACF we do not estimate any parameter in stage one. In the first stage, we regress

$$y_{it} = \phi_t(m_{it}, l_{it}, k_{it}, \mathbf{Z}_{it}) + \epsilon_{it} \qquad (5)$$

Where, $\phi_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_t t_{it-1} + \beta_{ev} EV_{it-1} + \beta_{iv} IV_{it-1} + \beta_{rs} RS_{it-1} + \beta_{ks} KS_{it-1} + \beta_{es} es_{it} + \beta_{cs} cs_{it} + \beta_{ms} ms_{it} + \lambda_t + I^j + h_t(m_{it}, l_{it}, k_{it}, \mathbf{Z}_{it})$ (6)

And Z = $(t_{it-1}, iv_{it-1}, ev_{it-1}, sk_{it-1}, sr_{it-1}, es_{it}, cs_{it}, ms_{it})$

We estimate (5) by OLS using a third order polynomial in l, k, m and Z and obtain the estimate of expected output Φhat and the random error ε. Hence, the first stage eliminates the random error ε from the output and provides an estimate of expected output Φhat.

To estimate the parameters of regressors in (6), in the second stage, we assume that productivity follows a first –order markov process

$$\omega_{it} = g_t(\omega_{it-1}) + \xi(\beta)_{it}$$

This implies conditional on lagged productivity, current productivity should be a surprise. [25]

We now run an OLS on (1) and get candidate values of β, which are used to get an estimate of productivity using

$$\omega_{it} = \phi hat_{it} - \beta_l l_{it} - \beta_k k_{it} - \beta_t t_{it-1} - \beta_{ev} EV_{it-1} - \beta_{iv} IV_{it-1} - \beta_{rs} RS_{it-1} - \beta_{ks} KS_{it-1} - \beta_{es} es_{it} - \beta_{cs} cs_{it} - \beta_{ms} ms_{it}$$

Similar as above, we obtain ω_{it-1} and regressing ω_{it} on ω_{it-1} we recover the innovation term in productivity $\xi_{it}(\beta)$.The β vector is then estimated using GMM with the following moment conditions:

$E(\xi_{it} l_{it-1}) = 0$, $E(\xi_{it} k_{it}) = 0$, $E(\xi_{it} t_{it-1}) = 0$, $E(\xi_{it} IV_{it-1}) = 0$, $E(\xi_{it} EV_{it-1}) = 0$

[25] Apart from lagged productivity, current productivity term can also be expressed as a function of additional decision variables such as trade orientation, innovation etc faced by the firm. However, for simplicity we restrict to first order Markov assumption which has commonly been used in existing studies like Fernandes (2007), Parmeswaran (2009), DeLoecker and Warzynski (2012).

$E(\xi_{it}RS_{it-1}) = 0, E(\xi_{it}KS_{it-1}) = 0, E(\xi_{it}es_{it}) = 0, E(\xi_{it}cs_{it}) = 0, E(\xi_{it}ms_{it}) = 0$

The GMM procedure, estimates the β vector by setting the above moment conditions as close as possible to zero. The standard errors have been estimated using block bootstrapping. This involves sampling with replacement, where firm's id is randomly drawn and the entire time series of observations for that firm is placed in the bootstrapped sample.

Results of estimation are displayed in Table 5. Results are similar. Tariff is found to be negative significant at 1% level, rest of the channels namely export variety, import variety, rent spillover and knowledge spillover are positive and significant at 1% level.

We also modify the production function specification to a more general form of a Translog function and replicate the estimation. The production function is defined as[26]:

$$y_{it} = \beta_l l_{it} + \beta_{ll} {l_{it}}^2 + \beta_k k_{it} + \beta_{kk} {k_{it}}^2 + \beta_{lk} l_{it} k_{it} + \beta_t t_{it-1} + \beta_{ev} EV_{it-1} + \beta_{iv} IV_{it-1} + \beta_{rs} RS_{it-1} + \beta_{ks} KS_{it-1} + \beta_{es} es_{it} + \beta_{cs} cs_{it} + \beta_{ms} ms_{it} + \lambda_t + I^j + \omega_{it} + \epsilon_{it}$$

The functional form of optimal input demand choice remains same. Φhat is estimated in the first stage by separating the random error term . With the assumption of first-order markov process with respect productivity evolution, innovation term $\xi_{it}(\beta)$ is recovered. And the The β vector is then estimated using GMM with additional moment conditions:

$$E(\xi_{it} l_{it-1}) = 0, \quad E(\xi_{it} {l_{it-1}}^2) = 0, \quad E(\xi_{it} k_{it}) = 0, \quad E(\xi_{it} {k_{it}}^2) = 0, \quad E(\xi_{it} k_{it} l_{it-1}) = 0,$$
$$E(\xi_{it} t_{it-1}) = 0, \quad E(\xi_{it} IV_{it-1}) = 0, \quad E(\xi_{it} EV_{it-1}) = 0, E(\xi_{it} RS_{it-1}) = 0, \quad E(\xi_{it} KS_{it-1}) = 0,$$
$$E(\xi_{it} es_{it}) = 0, E(\xi_{it} cs_{it}) = 0, E(\xi_{it} ms_{it}) = 0$$

The GMM procedure, estimates the β vector by setting the above moment conditions as close as possible to zero. The standard errors have been estimated using block bootstrapping. Our results remain the same (Table 6). [27] The average output elasticity of labour across the panel is 0.52 and output elasticity of capital is 0.49. Estimated coefficients of all trade facilitated channels are found to be significant at 1% confidence level.

[26] Pooling plants across all industries is done to enable estimation using this technique. With small set of plant-year observations in individual industries, the estimation techniques leaves zero degrees of freedom thereby making it impossible for matrix inversion

[27] This estimation starts with 71, 539 observations, for 13,945 plants. Since this estimation one year lagged productivity as regressor, first year observations are dropped for all plants, total number of observations falls to 57,094.

We find the results to be robust to various estimation techniques and specifications. The ACF technique however gets tedious and lengthy adding variables to productivity equation leads to expansion of moment conditions. Estimating a higher order polynomial for semi-parametric estimation with many state variables considerably reduces the degrees of freedom rendering estimation impossible for each 2 digit industry. Moreover, analysing the impact of various plant, industry and state level factors and their interactions with bootstrapping of standard errors gets very lengthy, and in cases impossible. As baselines results are similar for both the methods this study relies on the first method of two stage estimation as the primary method of analysis.

7. Conclusion

This paper provides micro-level evidence on productivity gains from trade participation in the Indian context. We identify, measure and analyse the mechanisms through which trade is envisaged to generate productivity gains. These mechanisms are pro-competitive effect due to import liberalization, technology spillovers from imports and variety growth of import and export products. Pro- competitive effect is measured by change in tariff rates across industries. Technology spillovers are distinguished into two types, rent spillovers and knowledge spillovers. We create an index to measure each of the spillover variables. Similarly, growth in import and export variety is measured by constructing relevant indices.

We use a production function framework for our analysis and we find that all the mechanisms play a significant role in generating plant level productivity gains. The effect of tariff reduction is found to be strongly associated with plant level productivity gains. Gains from technology spillovers and variety growth are also found be positive & significant across most of the specifications. This study identifies the growth channels and provides detailed micro level evidence on the trade and productivity growth linkage.

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Table 4: Regression results

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6	(7) Model 7	(8) Model 8	(9) Model 9
Plant_Size	0.00965	0.00880	0.00145	0.0103	0.00933	0.00897	0.00874	-0.0193**	0.0305**
	(0.00768)	(0.00768)	(0.00940)	(0.00768)	(0.00768)	(0.00768)	(0.00768)	(0.00960)	(0.0151)
Plant_Age	0.126***	0.126***	0.129***	0.478***	0.130***	0.124***	0.126***	0.118***	0.126***
	(0.0162)	(0.0162)	(0.0201)	(0.0464)	(0.0163)	(0.0163)	(0.0163)	(0.0185)	(0.0304)
t	-0.0268**	-0.0238*		0.224***	0.0116	-0.00410	-0.0249**	-0.0593***	-0.132***
	(0.0124)	(0.0124)		(0.0330)	(0.0243)	(0.0141)	(0.0126)	(0.0193)	(0.0352)
EV	0.240**	0.231**	0.357***	0.249**	0.231**	0.210*	0.234**	0.239**	0.421**
	(0.109)	(0.109)	(0.125)	(0.109)	(0.109)	(0.109)	(0.109)	(0.115)	(0.185)
IV	0.316***	0.329***	0.458***	0.313***	0.328***	0.340***	0.329***	0.206*	0.422**
	(0.108)	(0.108)	(0.130)	(0.108)	(0.108)	(0.108)	(0.108)	(0.108)	(0.170)
RS	0.0425*	0.0382	-0.209***	0.0320	0.0374	0.0305	0.0384	0.0557**	0.117**
	(0.0245)	(0.0245)	(0.0240)	(0.0245)	(0.0245)	(0.0246)	(0.0245)	(0.0275)	(0.0458)
KS	0.00406**	0.00402**	0.00370	0.00361*	0.00398**	0.00352*	0.00395**	0.00346*	0.00258
	(0.00199)	(0.00199)	(0.00245)	(0.00199)	(0.00199)	(0.00200)	(0.00200)	(0.00199)	(0.00309)
Electricity(es)		0.408***	0.398***	0.389***	0.361*	0.387***	0.413***	0.189	0.0689
		(0.124)	(0.148)	(0.124)	(0.203)	(0.124)	(0.124)	(0.135)	(0.214)
Credit (cs)		0.0824***	0.0775**	0.0792***	0.240***	0.0837***	0.0826***	0.0853***	0.0884*
		(0.0284)	(0.0347)	(0.0284)	(0.0716)	(0.0284)	(0.0284)	(0.0308)	(0.0478)
Mandayslost (ms)		-0.0276***	-0.0318***	-0.0269***	0.00871	-0.0276***	-0.0276***	-0.0377***	-0.0223
		(0.00910)	(0.0106)	(0.00910)	(0.0272)	(0.00910)	(0.00910)	(0.00997)	(0.0169)
EI			0.000156						
			(0.0816)						
IP			0.298***						
			(0.0809)						
Plant_Age X t				-0.0852***					
				(0.0105)					
Electricity X t					0.0223				
					(0.0513)				
Credit X t					-0.0518**				
					(0.0212)				
Mandayslost X t					-0.0115				
					(0.00792)				
Exportdummy						1.179***			
						(0.428)			
Exportdummy X t						-0.0473***			
						(0.0160)			
labordummy							-0.0795		
							(0.102)		
Labordummy X t							0.0100		
							(0.0222)		
Skill_intensity								0.0507**	
								(0.0227)	
Skill_intensity X t								-0.0262***	
								(0.00685)	
contractlabor									-0.777***
									(0.218)
Contractlabor X t									0.228***
									(0.0644)
Industry Dummy	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.765***	3.664***	10.18***	2.781***	3.546***	2.707***	3.662***	10.25***	5.011***
	(0.555)	(0.556)	(0.366)	(0.567)	(0.560)	(0.418)	(0.556)	(0.479)	(0.762)
Observations	71,539	71,539	59,907	71,539	71,539	71,539	71,539	63,635	27,071
R-squared	0.154	0.154	0.008	0.155	0.154	0.154	0.154	0.141	0.120
Number of plants	13,945	13,945	12,270	13,945	13,945	13,945	13,945	13,797	7,550

Dependent Variable: log total factor productivity, t=tariff,EV=export variety index, IV=import variety index, KS=knowledge spillover index, RS=rent spillover index, es= electricity availability per capita in state, cs= industrial credit availability per state domestic product, ms= mandays lost in strikes and lockouts per 1000 industrial workers. EI=export intensity, IP=import penetration, Exportdummy=1 if plant if plant operates in net exporting industry, labordummy=1 is plant is locates in state with flexible labour laws. Skill intensity= number of skilled labour per worker. Crontractlabor=ratio of contract labourer to total workers. All values are in logarithms. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5: Cobb-Douglas production function estimates (Alternate Estimation)

	All Industries
	(1)
l	0.585***
	(0.016)
k	0.456***
	(0.010)
t	-0.147***
	(0.008)
EV	0.624***
	(0.052)
IV	0.096
	(0.075)
KS	0.023***
	(0.001)
RS	0.061***
	(0.006)
es	0.232***
	(0.041)
cs	0.023
	(0.037)
ms	-0.045***
	(0 .005)

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
l=labour, k=capital, t=tariff,EV=export variety index, IV=import variety index, KS=knowledge spillover index, RS=rent spillover index, es= electricity availability per capita in state, cs= industrial credit availability per state domestic product, ms= mandays lost in strikes and lockouts per 1000 industrial workers. All values are in logarithms.

Table 6: Translog production function estimates (Alternate Estimation)

	All Industries
l	1.501 ***
	(0.002)
k	-0.733***
	(0.003)
l2	0.052***
	(0.005)
k2	0.045***
	(.000)
lk	-0.082***
	(0.002)
t	-0.179***
	(0.003)
EV	1.401***
	(0 .003)
IV	0.168***
	(0.003)
KS	0.047***
	(0.007)
RS	0.067***
	(0.002)
es	0.248***
	(0 .003)
cs	0.020***
	(0 .003)
ms	-0.040***
	(0.003)

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
l=labour, k=capital, t=tariff,EV=export variety index, IV=import variety index, KS=knowledge spillover index, RS=rent spillover index, es= electricity availability per capita in state, cs= industrial credit availability per state domestic product, ms= mandays lost in strikes and lockouts per 1000 industrial workers. All values are in logarithms.

Appendix A

Capital Stock Estimation

For capital stock estimation we closely follow Balakrishnan et al (2000). ASI data contains information on gross opening & closing capital and depreciation for each factory. An investment series is generated by taking differences between gross closing and opening stock for each year.

Estimation of base year capital stock is the next step in estimation. We choose 2008 as the base year due to availability of greater number of observations. Following Balakrishnan et al (2000) it is assumed that for the existing capital stock in 2008, the earliest vintage dates at most 20 years old to 1988. If the factory is incorporated in a year after 1988 then the year of incorporation is taken to be the earliest vintage year for capital. Using revaluation factor, the historic value of the base year capital is then converted to replacement cost of capital at current prices by multiplying base year capital values with RG , where

$$R^G = \frac{[(1+g)^{\tau+1}-1]\,(1+\pi)^{\tau}\,[(1+g)(1+\pi)-1]}{g([(1+g)(1+\pi)]^{\tau+1} - 1)}$$

τ is the number of vintage years, π is the rate at which price of capital changes such that $1+\pi = Pt/Pt\text{-}1$. Pt. This is obtained from CSO's data on gross fixed capital formation published in various issues of the National Accounts Statistics (NAS). Similarly, it is assumed that investment also changes at a constant rate $1+g = It/It\text{-}1$. The growth of fixed capital formation at 1993-94 prices, taken from various issues of NAS, is applied in the case of all the firms. The replacement cost of capital at current prices is then deflated using price index for machinery and machine tools. This provides the replacement value of base year capital stock at constant prices. Next, with information on base year replacement value of capital stock at constant prices, the subsequent stocks of capital have been estimated using the following PIM formula

$$P_0K_t = (1-\delta)P_0\,K_{t-1} + P_0\,I_t$$

Where P_0K_t is the real capital in time period t, P_0K_{t-1} is real capital in time period t-1 and P_0I_t is the real investment in time period t. δ is the rate of economic depreciation, however we use gross values instead of net as economic rates of depreciation were not available.

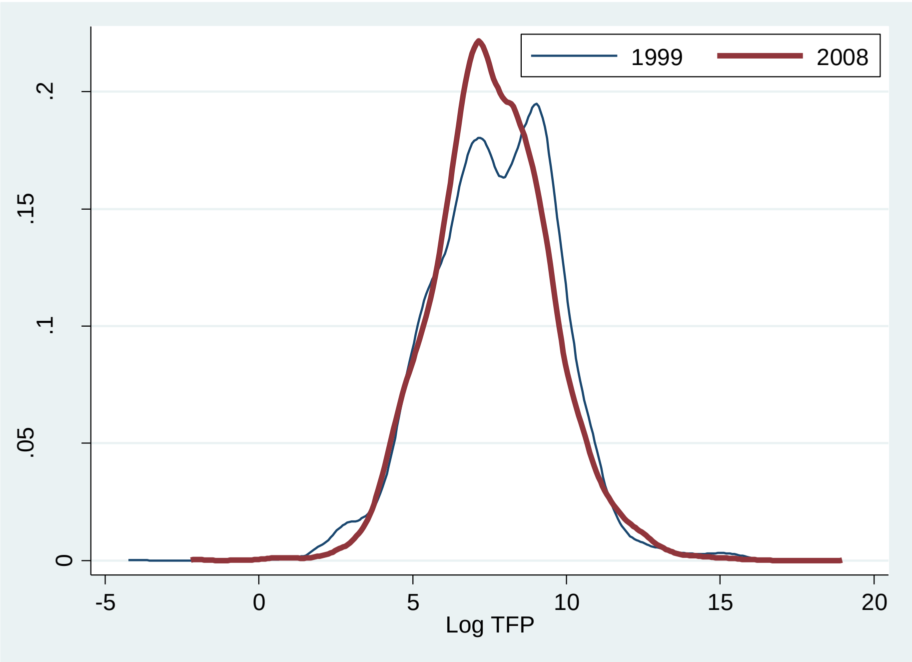
Table 7: Estimated Production Function coefficients

NIC Industry	LP Coefficient Estimates	Standard Errors
NIC 15: Food products & Beverages		
Capital	0.27***	0.02
Unskilled Labour	0.27***	0.02
Skilled Labour	0.22***	0.02
NIC 16: Tobacco		
Capital	0.50	0.20
Unskilled Labour	0.52***	0.05
Skilled Labour	0.15	0.11
NIC 17: Textile		
Capital	0.37***	0.07
Unskilled Labour	0.38***	0.02
Skilled Labour	0.22***	0.03
NIC 18: Wearing Apparel		
Capital	0.27***	0.03
Unskilled Labour	0.36***	0.02
Skilled Labour	0.38***	0.05
NIC 19: Leather		
Capital	0.31***	0.10
Unskilled Labour	0.53***	0.04
Skilled Labour	0.20***	0.04
NIC 20: Wood		
Capital	0.38***	0.10
Unskilled Labour	0.47***	0.07
Skilled Labour	0.27***	0.09
NIC 21: Paper		
Capital	0.51***	0.11
Unskilled Labour	0.29***	0.04
Skilled Labour	0.33***	0.05
NIC 22: Publishing		
Capital	0.45***	0.08
Unskilled Labour	0.23***	0.06
Skilled Labour	0.42***	0.05
NIC 23: Coke, refined petroleum prod.		
Capital	0.13	0.21
Unskilled Labour	0.23***	0.08
Skilled Labour	0.29***	0.09
NIC 24: Chemicals		
Capital	0.35***	0.05
Unskilled Labour	**0.35*** **	**0.02**
Skilled Labour	0.24***	0.03
NIC 25: Rubber		
Capital	0.26***	0.08
Unskilled Labour	0.38***	0.03
Skilled Labour	0.30***	0.04
NIC 26: Non Metallic Mineral Products		
Capital	0.36***	0.04
Unskilled Labour	0.36***	0.03
Skilled Labour	0.28***	0.03
NIC 27: Basic Metals		
Capital	0.22***	0.07
Unskilled Labour	0.35***	0.02
Skilled Labour	0.22***	0.03
NIC 28: Fabricated Metal Products		
Capital	0.30***	0.07
Unskilled Labour	0.39***	0.04
Skilled Labour	0.38***	0.03
NIC 29: Machinery & Equipment		
Capital	0.42***	0.07
Unskilled Labour	0.36***	0.03
Skilled Labour	0.37***	0.02
NIC 30: Office, Accounting & Computer Machinery		
Capital	0.62***	0.27
Unskilled Labour	0.22	0.15
Skilled Labour	0.24***	0.10
NIC 31: Electrical Machinery		
Capital	0.43***	0.11
Unskilled Labour	0.44***	0.04
Skilled Labour	0.33***	0.04
NIC 32: Radio, TV & Communication Equip		
Capital	0.16	0.19
Unskilled Labour	0.36***	0.06
Skilled Labour	0.42***	0.06
NIC 33: Medical, Precision & Optical Instruments		
Capital	0.41***	0.11
Unskilled Labour	0.18***	0.07
Skilled Labour	0.51***	0.06
NIC 34: Motor Vehicles		
Capital	0.45***	0.11
Unskilled Labour	0.51***	0.03
Skilled Labour	0.26***	0.03
NIC 35: Transport Equip		
Capital	0.49***	0.11
Unskilled Labour	0.30***	0.04
Skilled Labour	0.39***	0.06
NIC 36: Furniture		
Capital	0.39***	0.09
Unskilled Labour	0.38***	0.04
Skilled Labour	0.38***	0.04

Table 8: Data: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Unskilled labour[28]	314.622	850.249	0	37261
Skilled labour	95.0149	307.764	1	27273
Capital Stock (estimated) (in Rs 10000)	54600	417000	100.7	37700000
Value added (in Rs 10000)	11800	90100	264.5	9890000

Fig 1: Kernel density plot of log TFP



[28] The study analyses only the census sector plants of the ASI for which continuous data is available. This sector corresponds to the large manufacturing plants employing >100 workers.

Table 8: Data source for variable construction

Data	Source	Remark
Plant level production data	Annual Survey of Industries conducted by Central Statistical organization, India	Plants only under the census sector have been included in the study
Tariff rate	TRAINS, IDB	Using WITS software of the World bank
Import data	COMTRADE,	Using WITS software of the World bank
Export data	COMTRADE	Using WITS software of the World bank
OECD R&D	STAN database	OECD
Sector GDP	STAN database	OECD
I-O table OECD	ANBERD database	OECD
I-O table India	Database of Indian Economy	Reserve Bank of India
WPI	Central Statistical organization	
Electricity generation	CMIE publication- ENEGRY	
Credit	CMIE publication- Money & Banking	
Mandays lost in strikes & lockouts	Ministry of labour	
State population	Census of India 2001	
Gross state domestic product	CMIE publication- Money & Banking	
State-wise Industrial workers	Annual Survey of Industries	
Capital stock deflator	Price index of machinery and machine tools obtained from Office of economic advisor	For capital stock estimation

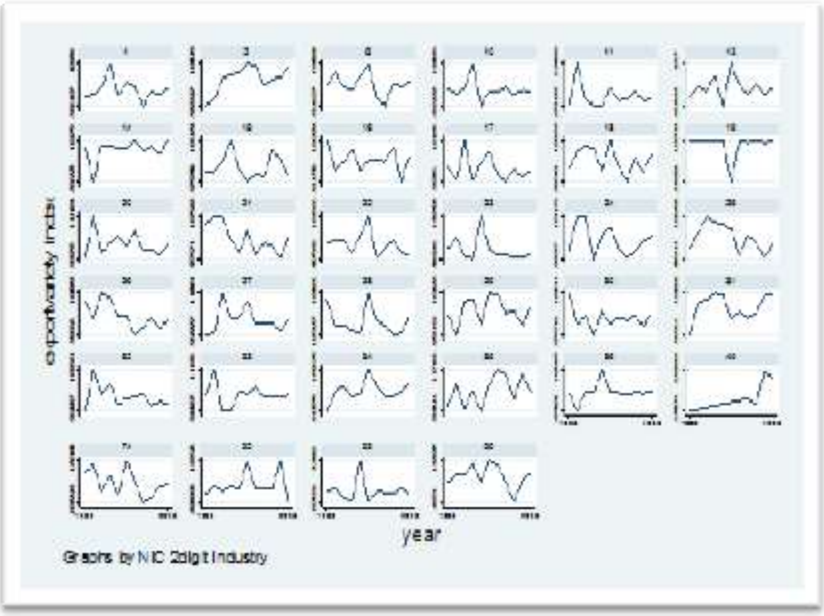
Table 9: Industry-wise technological congruence index of India with OECD countries

NIC/ Country	1516*	20	2122*	23	24	25	26	27	28	29	30	31	32	33	34	35	3637*
Australia	0.724	0.760	0.853	0.711	0.914	0.850	0.425	0.840	0.723	0.701	0.297	0.584	0.580	0.580	0.590	0.419	0.396
Austria	0.809	0.753	0.845	0.760	0.850	0.839	0.581	0.870	0.586	0.541	0.242	0.491	0.493	0.480	0.487	0.416	0.360
Belgium	0.780	0.792	0.865	0.696	0.904	0.788	0.579	0.861	0.655	0.493	0.181	0.456	0.389	0.400	0.477	0.391	0.471
Canada	0.740	0.857	0.872	0.712	0.927	0.780	0.549	0.915	0.734	0.616	0.050	0.327	0.217	0.300	0.483	0.337	0.451
Czech Republic	0.801	0.766	0.782	0.707	0.801	0.712	0.597	0.871	0.569	0.618	0.204	0.400	0.445	0.500	0.600	0.353	0.276
Denmark	0.782	0.765	0.757	0.443	0.822	0.674	0.630	0.681	0.555	0.588	0.255	0.383	0.444	0.500	0.745	0.448	0.266
Estonia	0.838	0.830	0.798	0.593	0.883	0.633	0.545	0.562	0.626	0.800	0.227	0.280	0.323	0.500	0.709	0.566	0.281
Finland	0.752	0.802	0.898	0.472	0.803	0.811	0.555	0.836	0.728	0.594	0.159	0.442	0.376	0.500	0.658	0.351	0.352
France	0.794	0.731	0.823	0.578	0.866	0.797	0.532	0.906	0.549	0.566	0.205	0.471	0.471	0.500	0.647	0.305	0.367
Germany	0.797	0.785	0.762	0.431	0.891	0.723	0.531	0.854	0.498	0.521	0.203	0.337	0.493	0.550	0.597	0.422	0.230
Greece	0.866	0.791	0.810	0.429	0.921	0.869	0.481	0.816	0.919	0.844	0.502	0.865	0.475	0.500	0.602	0.642	0.481
Hungary	0.893	0.868	0.816	0.745	0.713	0.766	0.661	0.899	0.744	0.721	0.147	0.248	0.278	0.350	0.457	0.446	0.302
Ireland	0.808	0.726	0.803	0.820	0.859	0.772	0.546	0.590	0.835	0.576	0.157	0.300	0.347	0.450	0.559	0.260	0.321
Italy	0.787	0.734	0.867	0.645	0.843	0.713	0.611	0.693	0.595	0.561	0.204	0.519	0.463	0.550	0.621	0.426	0.377
Japan	0.775	0.825	0.830	0.533	0.818	0.662	0.623	0.795	0.830	0.626	0.291	0.529	0.504	0.480	0.464	0.538	0.345
Korea, Dem. Rep.	0.783	0.756	0.798	0.665	0.797	0.853	0.599	0.795	0.816	0.660	0.183	0.399	0.359	0.450	0.566	0.524	0.386
NZ	0.677	0.874	0.807	0.650	0.551	0.496	0.575	0.628	0.541	0.565	0.500	0.500	0.500	0.500	0.551	0.500	0.244
Netherlands	0.735	0.727	0.767	0.468	0.815	0.792	0.556	0.716	0.551	0.508	0.212	0.469	0.442	0.500	0.543	0.329	0.324
Norway	0.742	0.790	0.787	0.528	0.703	0.735	0.566	0.847	0.712	0.621	0.152	0.585	0.398	0.500	0.867	0.442	0.445
Poland	0.811	0.816	0.810	0.803	0.831	0.624	0.665	0.790	0.632	0.672	0.437	0.633	0.400	0.500	0.598	0.506	0.314
Spain	0.773	0.763	0.826	0.454	0.793	0.649	0.589	0.456	0.841	0.631	0.350	0.641	0.461	0.500	0.595	0.456	0.336
Sweden	0.765	0.747	0.842	0.687	0.829	0.650	0.724	0.855	0.552	0.558	0.361	0.553	0.468	0.500	0.573	0.411	0.428
Switzerland	0.749	0.699	0.888	0.500	0.875	0.901	0.554	0.693	0.713	0.516	0.500	0.432	0.497	0.500	0.482	0.463	0.284
Turkey	0.848	0.673	0.897	0.605	0.924	0.756	0.603	0.824	0.819	0.838	0.205	0.718	0.329	0.500	0.652	0.646	0.687
United Kingdom	0.786	0.758	0.812	0.814	0.877	0.607	0.548	0.695	0.667	0.654	0.252	0.453	0.406	0.550	0.695	0.351	0.421
United States	0.754	0.725	0.830	0.538	0.843	0.812	0.514	0.846	0.654	0.593	0.255	0.593	0.580	0.580	0.586	0.380	0.339

*Sectors clubbed together for index construction as R&D investments data for these industries in the OECD database was clubbed together due to close technological relations between sectors.

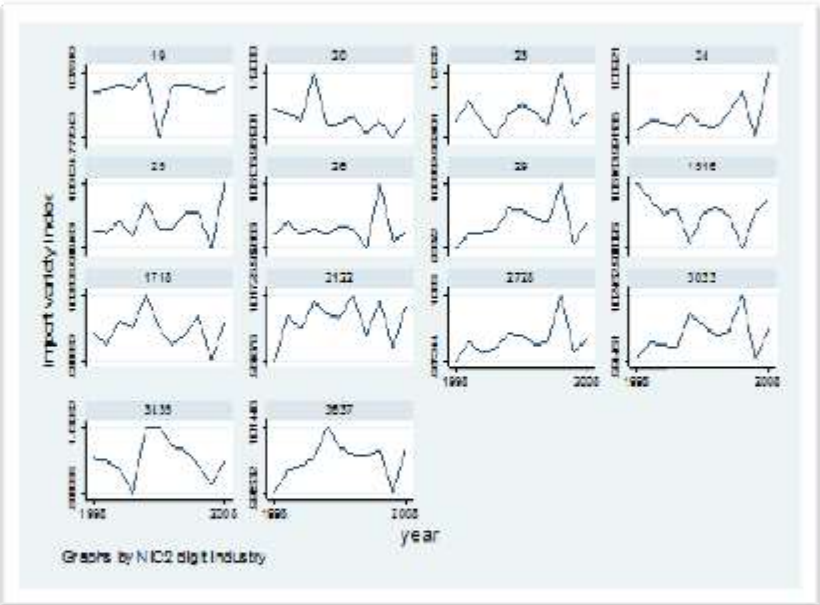
Source: Authors' estimates

Graph 1: Export variety Index



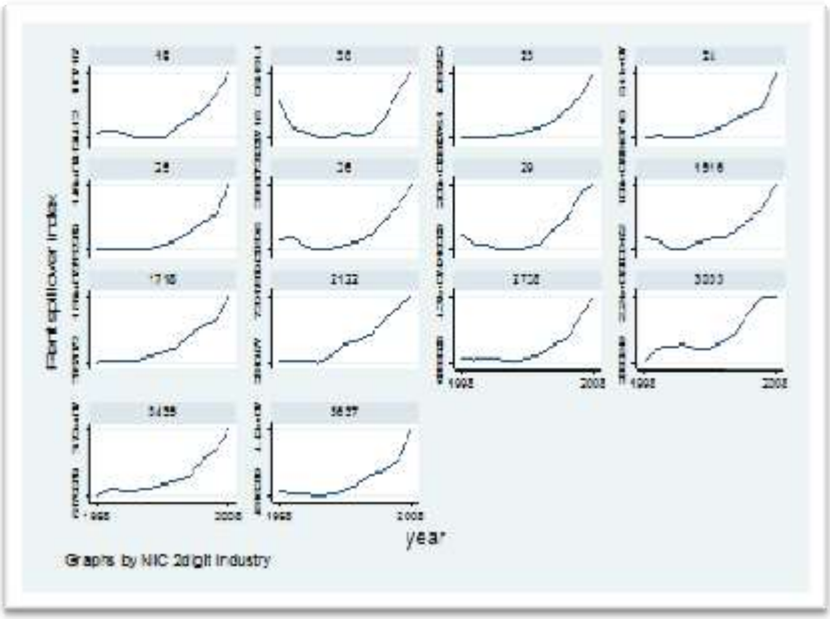
Source: Authors' estimates

Graph 2: Import variety Index



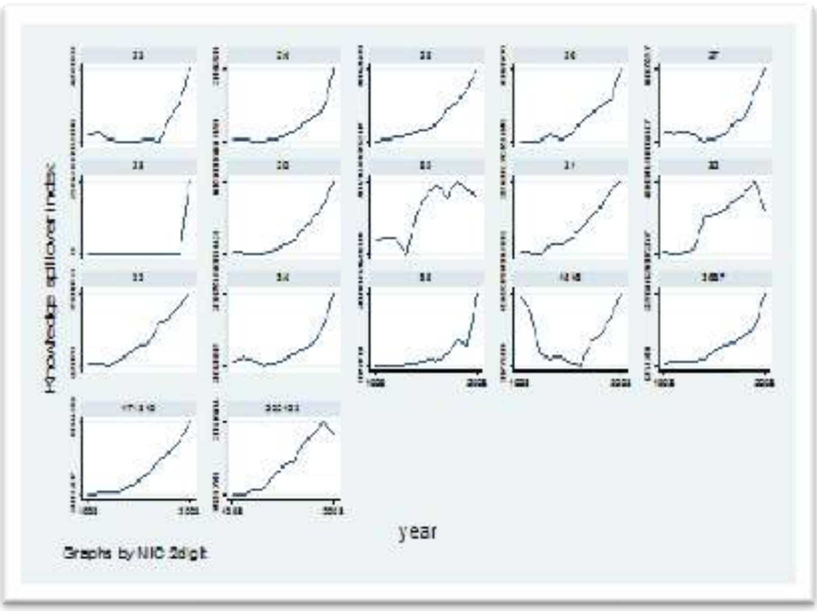
Source: Authors' estimates

Graph 3: Rent Spillover Index



Source: Authors' estimates

Graph 4: Knowledge Spillover Index



Source: Authors' estimates