International Trade and R&D Investment: Evidence from Manufacturing Firms in India

M. Parameswaran
Centre for Development Studies,
Prasanth Nagar Road, Ulloor,
Trivandrum – 695 011,
Kerala, India.
E-mail: parameswaran@cds.ac.in

Abstract

This paper investigates the effect of international trade on firms' R&D investment. It examines the impact of import competition, export and import of capital goods and disembodied technology on R&D investment. The theoretical predictions on the impact of trade through these channels are ambiguous and contingent on many industry and firm specific details. This makes an empirical analysis more significant. The study shows that export in general encourages investment in innovation, while R&D promoting effect of capital goods and disembodied technology import is not widespread. On the impact of import competition, the study found that it depends on domestic market structure. It promotes investment in R&D only when the market structure is highly concentrated otherwise it has negative effect. Thus the paper brings out the conditional nature of trade's impact on R&D investment. This result also supports the recent developments in the growth literature on the relationship between product market competition and innovation.

The issue of whether open trade policy regime accelerates technological progress and growth of an economy is one of the highly debated issues in the literature. It attracted wider intellectual attention not only because of the greater importance of trade in an economy, but also due to the ambiguity on the type of trade policy suitable for faster technological progress. The theoretical models examining various channels, through which trade can affect technological progress, though informative, are not unanimous in their predictions. Thus there are sound theoretical arguments supporting the move to more liberalised trade, but there are also equally sound theoretical arguments for protecting some industries from international competition; making the issue an important candidate for empirical analysis (Hallak and Levinsohn 2003).

A number of studies empirically examined the effect of trade openness on technological progress and economic growth[1]. This literature attempts to identify the empirical relationship between the degree of openness to international trade and economic performance using standard econometric methods on country level measures of these variables. Though the preferred choice of variables and the exact econometric techniques employed have improved considerably over time, this literature has not produced a set of results that provide informed and convincing recommendations for trade policy. The indicators of openness used by these studies are either problematic as a measure of trade barrier or are highly correlated with other sources of poor economic performance (see Rodriguez and Rodrik 2000). Further, it is also pointed out that trade affects technological progress through a variety of channels and is also conditional on the particular economic environment. Given this diversity of channels and state dependant nature of the relationship, it is virtually impossible for an econometric framework consisting of linear or log linear regression of a measure of growth on a simple measure of openness–and other controls–to uncover the relevant mechanism. Therefore, it has been widely recognised in the literature that focusing on the channels through which trade affects technological progress as well as uncovering the industry specific factors that condition the effect using micro level information is quite fruitful (Hallak and Levinsohn 2003; Rodriguez and Rodrik 2000 and Edwards 1993). The present study goes in this direction. It examines the impact of trade on manufacturing firms' investment in R&D in

[1] For a detailed review of these studies see Rodriguez and Rodrik (2000) and Edwards (1993).

India. In modern industrial world, firms' investment in R&D is an important source of technological progress. Investment in R&D is required not only for introducing innovations, but also for adapting and absorbing technology from outside sources (Cohen and Levinthal 1989). Further, policy makers are usually told that with the liberalisation of trade, firms would have no choice but to modernise their techniques and cut their costs in order to compete with the foreign producers[2] (Rodrik 1992). Empirical assessment of this argument is quite interesting. This study examines the effect of import competition, export and technology import on firms' R&D investment. It also shows the importance of domestic market structure in shaping the impact of import competition.

The paper is organised in following four sections. Section one, reviews the theoretical literature on various channels thorough which trade can affect R&D investment. The second section specifies the econometric model and describes the data and construction of variables. The third section discusses the results and the last one concludes the paper.

1. Trade and R&D Investment: The Theory

International trade can affect firms' R&D investment through a number of channels and these include import competition, export and technology import[3]. A brief review of the theoretical literature on each of these channels is given below.

<u>Import Competition</u>: A number of theoretical models have analysed the impact of import competition on innovation effort. Rodrik (1992) examines this under two market structures; one in which the domestic market structure is monopoly and another an oligopoly market. Under monopoly, the incentive to invest in R&D is greater, larger the scale of output[4]. In the first model, therefore import competition, which shrinks the market share of the domestic producer, reduces the incentive to do innovation. In the second one, where the domestic industry is an oligopoly behaving in Bertrand assumption, import competition stimulates R&D effort. Indeed the predictions, as in any oligopoly model, depend on the particular behavioural assumptions about the conduct of firms in the market. Smulders and Klundert (1995), while examining the impact of concentration on R&D investment within an endogenous growth framework, shows that

[2] For an emphasis of this argument in Indian context, see Ahluwalia (1996).

[3] Trade can also affect R&D by changing the relative price of factors employed in research sector. The present study, however, is not considering this channel.

[4] Since R&D investment is a fixed cost and its output, namely knowledge, is a non-rival commodity, the rate of return from research depends positively upon the scale of output on which the firm can spread the R&D cost.

import competition encourages R&D investment by simultaneously reducing the mark-up and increasing the level of domestic concentration through exit of inefficient firms and absorption of their market share by extant ones[5].

Another set of theoretical models, relevant in the present context, includes Aghion et al. (2001) and Aghion (2003). They examined the effect of product market competition on innovation. These models, assuming duopoly with Bertrand price competition[6], predict an inverted U shaped relationship between product market competition and innovation effort. In the extreme case of monopoly, profit is independent of monopolist's technological leadership and therefore, it has no incentive to invest in technological progress. On the other hand, at greater levels of competition firms find it difficult to appropriate rents from innovation and therefore, have lower incentive to be innovative[7]. In this framework, firms have greater incentive to invest in R&D when there is higher market concentration along with intense competitive pressure on them. Extending this logic to import competition, it would encourage R&D investment only in those industries where domestic competition is very low (or concentration is very high) and in industries, where competition is already higher import competition may discourage R&D effort.

<u>Export</u>: Export allows firms to produce on a large scale and thereby exploit increasing returns to scale, made possible by fixed investments like R&D. Hughes (1986) argues that export can have a positive effect on innovation effort because elasticity of foreign demand with respect to R&D is likely to be greater than that of the domestic demand. Several reasons can be extended to support this point. For instance, since export market usually consists of several segmented markets and each sub-market varies from others in terms of consumers' preferences, entry barriers and elasticities, the likelihood that R&D will increase demand in some of these markets is higher than that in the domestic market. Secondly, if R&D is leading to product differentiation or the development of a new product, likely to be preferred by a small group of consumers, then export enables the

[5] In this model when there is high domestic market concentration along with greater market power, there is lesser incentive for the firm to do R&D.

[6] Aghion (2003) extends the model to the case of three firms.

[7] In these models, innovation effort is at the maximum when there is an intense competition between neck-and-neck firms, that is, competition among a few firms having similar levels of productivity. In these situations firms try to escape competition by innovating.

firm to realise economies of scale in the production of this differentiated commodity. In this case, export possibilities allow the firm to make required R&D investment.

Technology Import: In an open trade policy regime, firms can import foreign technology. This can be either in the form of capital goods embodying recent technology or in disembodied form such as blue prints and designs. Technology import can affect the incentive of the firm to invest in in-house R&D. The relationship between the two, however, has been a subject of intense debate in the development literature (see Evenson and Westphal 1995). One view suggests that these two are substitutes to each other, implying that technology import would reduce R&D investment (Pillai 1979). An opposing view, on the other hand, considers them as complementary (Cohen and Levinthal 1989 and Bell and Pavitt 1997). It argues that, since most technologies consist of certain portion of tacit knowledge, absorption of imported technology requires some technological capability on the part of the firm and it can take the form of in-house R&D effort (Cohen and Levinthal 1989). Likewise, imported plants and machinery may also require adaptations and modifications to suit local conditions, raw materials and usage pattern, making some investment in in-house R&D necessary (Mani 1995 and Basant 1997). In this context, Kumar (1987) highlights mode of technology import and Subrahmanian (1991) emphasis policy environment as factors determining the relationship between technology import and local R&D effort.

2. Empirical Model, Data and Construction of Variables

Empirical Model

We use econometric method to examine the effect of various dimensions of trade on firms' R&D investment. In this, firms' R&D intensity (RDINS) is regressed on a set of explanatory variables. R&D intensity of a firm is defined as the ratio of R&D investment to its sales. Explanatory variables include those related to trade and other determinants of R&D. The variables related to trade are import penetration rate (IPR), export intensity (EXPOIN), disembodied technology import intensity (TECHIN) and capital good import intensity (CGOOD). The other determinants include size of the firm (SIZE), age of the firm (AGE), advertisement intensity (ADVTIN), rate of profit (ROP), share of value added in sales (VAS), domestic market concentration (MCON) and a dummy variable (D_FEP) that takes value one if the firm has foreign equity participation and otherwise zero. The selection of other determinants is based on previous studies in the context of Indian manufacturing industry.

The regression model for the i^{th} firm in j^{th} industry in year t is:

$$\begin{aligned} RDINS_{ijt} = {} & \beta_0 + \beta_1 SIZE_{ijt} + \beta_2 EXPOIN_{ijt} + \beta_3 TECHIN_{ijt} + \beta_4 ADVTIN_{ijt} + \beta_5 ROP_{ijt} + \\ & \beta_6 IPR_{jt} + \beta_7 MCON_{jt} + \beta_8 AGE_{ijt} + \beta_9 D\_FEP_{ijt} + \beta_{10} IPR_{jt} * MCON_{jt} + \\ & \beta_{11} CGOOD_{ijt} + \beta_{12} VAS_{ijt} + \boldsymbol{\delta' Z_{ijt}} + \varepsilon_{it} \end{aligned} \quad (1)$$

where $\boldsymbol{Z}$ is the matrix of industry specific dummy variables to capture the inter-industry variation in the innovation and adaptation opportunities and appropriability conditions and $\boldsymbol{\delta}$ is its coefficient vector.

Data

The study uses firm level data, covering the whole manufacturing industry, for the period 1994-95 to 1999-2000, obtained from the Centre for Monitoring Indian Economy's electronic database PROWESS. We are considering a period during which the Indian industry was operating in a more liberal trade policy regime. The data consist of 15181 observations on 3675 firms, organised in 92 four-digit industries of National Industrial Classification (NIC), 1998. This data set provides information on a number of variables such as firm's expenditure on R&D, technology import, capital goods import and advertisement, value of exports, extent of foreign equity participation and value of sales. We also use industry level output data obtained from Annual Survey of Industries (ASI) and import and export data of manufactured products collected from the World Bank compiled Trade and Production Database[8]. We have harmonised the classifications in different datasets using two concordance tables, one is between NIC 1986 and 1998 and the second is between NIC 1998 and ISIC rev 2. In this harmonisation process across

[8] Trade and Production database of the World Bank merges data on trade, production and tariff available from different sources into a common classification: the International Standard Industrial Classification (ISIC) revision 2. For more details on this database see Nicita and Olarreaga (2001).

different classifications[9], we have to merge some of the four-digit industries to get proper matching and finally we left with 59 industry groups[10].

Construction of Variables

The details on the construction of variables and their expected relationship with R&D intensity are explained below.

Import Penetration Rate (IPR): Import competition faced by an industry is measured using import penetration rate. It is an industry level variable. The import penetration rate of j^{th} industry in t^{th} year is defined as follows.

$$IPR_{jt} = \left(\frac{Import_{jt}}{Output_{jt} + Import_{jt} - Export_{jt}} \right)$$

where export and output respectively denote the export and output of industry j and import refers to the import of j^{th} industry's product[11]. The output data are taken from Annual Survey of Industries (ASI) and trade data are from World Bank Trade and Production Database.

Market Concentration (MCON): The relationship between market concentration and innovation effort is extensively analysed in the theoretical and empirical literature[12]. It is argued that a concentrated market might encourage innovation by allowing firms to differentiate their products as well as by improving the appropriability conditions. It is, however, also possible that greater market concentration may discourage R&D, as it allows firms to exercise monopoly power. In this study, concentration in the domestic market is measured using Herfindhal Index (HI^D). Herfindhal Index of domestic concentration of j^{th} industry in year t is:

[9] The concordance table between NIC 1998 and NIC 1988 is given in the National Industrial Classification-1998, Published by Central Statistical Organisation (CSO).

[10] In the 59 industry groups, a few groups are formed by aggregating two or three four-digit industries together and rest are the four-digit industries of NIC 1998.

[11] Since output figures are taken from ASI, which covers only the registered manufacturing sector, it should be noted that the denominator of this ratio provides only an approximate measure of domestic demand. Data on unregistered manufacturing output at this level of disaggregation are not available for the years of analysis.

[12] For a review of theoretical and empirical literature see Kumar and Siddharthan (1997) chapter 5.

where S_{ijt} is the share of i^{th} firm's domestic sale in the total domestic sales of n firms in industry j in year t. Sale in the domestic market is arrived at by subtracting exports from total sales of the firm[13].

The choice of Herfindhal index over other alternative measures of concentration is based on the following reasons[14]. First, it satisfies all the desirable properties required for a concentration index (see Chakravarty 1995). Second, it has good statistical distribution properties and hence, can be estimated from a sample of firms. Hart (1975) shows that, when the size distribution of firms follows log normal distribution, Herfindhal index is a function of the moments of the original and first moment distributions of the log of the size variable[15]. Third, it can be directly linked with oligopoly theory. For instance, for a given elasticity of demand one can show that the divergence between marginal cost and price (mark-up) is lower when the Herfindhal index is low (Chakravarty 1995). Indeed, in an open economy context, Herfindhal index of domestic concentration does not indicate the true market power of firms, for they are subjected to import competition. Here, price-marginal cost ratio, which reflects both domestic and foreign competition, is recommended as a better measure of market power (Aghion 2003). In the present study, however, one of the objectives is to examine how import competition is affecting innovation effort, given the domestic market structure. For this, we have to identify the two sources of competitive pressure on domestic firms, namely domestic concentration and import competition, separately.

*Interaction between Import Penetration Rate and Market Concentration (IPR*MCON)*: One of the objectives is to examine how the domestic market structure is shaping the effect of import competition. It is hypothesised that import competition encourages R&D in those industries that are more concentrated, implying that IPR and MCON not only have

[13] Domestic concentration is considered as a good indicator of the extent of concentration and market power, if the industry in question is involved in export. If exports constitute a larger portion of sales, index of concentration, which is based on firms' total sales, is a misleading indicator of their actual market power. This is because sale in the foreign market and sale in the domestic market must be distinguished, since the corresponding relevant markets are distinct. Producers are usually price takers in foreign markets. Hence, for that part of the production, which is exported, they are in a competitive market, facing an elastic demand. So export value must be subtracted from the total sales to assess the market power of the producers in the domestic market (Jacquemin et al. 1980).

[14] Several alternative measures of concentration are available. For review of these measures and their properties see Hart (1975) and Chakravarty (1995).

[15] Hart (1975) shows that "a wide variety of *ad hoc* measures of concentration or inequality are functions of the sample moments of the original and first moment distributions, so that information required may be obtained from a knowledge of the sample moment" (p. 430).

separate effects, but also have interactive effect. An interaction variable between import penetration rate (IPR) and market concentration (MCON) has been used to verify this hypothesis.

Firm Size (SIZE): Several reasons can be put forward to expect a positive relationship between size of the firm and its innovation effort[16]. Since R&D cost is fixed, big firms can spread it over a greater amount of output than small ones. Firm size, therefore, is likely to exert a positive influence on the decision to innovate. Large firms are also in a favourable position, compared to small ones, regarding the financing of R&D. They usually have more internal resources at their disposal or they can easily mobilise funds from the capital market. Further, big firms often produce a variety of products, so they benefit more from their innovation activities, if these involve economies of scope. Following the earlier studies, firm's size is proxied by its sales[17].

Rate of Profit (ROP): One of the important sources to finance R&D expenditure is the profit of the firm. Higher profit can increase the internal resources of the firm and therefore, one can expect a positive relationship between profit and R&D investment. Kumar and Saqib (1996) and Pamukcu (2003), however, note that one can also expect a negative relationship between the two, if lower profit, which firms might view as a threat to their survival, forces them to be innovative to improve their competitiveness[18]. The rate of profit is taken as the ratio firm's net profit after tax to its sales.

Advertisement Intensity (ADVTIN): Firms usually advertise their products to increase their market share. The relationship between advertisement and innovation effort is ambiguous. Advertisement promotes R&D, if it enables the firm to increase its market share and thereby enhance the rate of return on R&D investment. If the firm, on the other hand, opts for investment in advertisement rather than in R&D to increase market share, one can expect a negative relationship between the two. In this case, both act as

[16] For a detailed review of the theoretical and empirical literature on firm size and innovative activity see chapter four of Kumar and Siddharthan (1997).

[17] Earlier studies using sales to proxy firms' size include Katrak (1997) and Basant (1997).

[18] It is to be noted that current investment in R&D affects firms' future profitability, as successful innovation improves productivity and leads to higher profit. It is usually taken in the literature that R&D investment takes time to produce results in terms of invention and innovation. Only at the stage of innovation, R&D shows up in profitability.

substitutes rather than complements to each other. In this study advertisement intensity is defined as the ratio of advertisement expenditure to sales.

Age of the Firm (AGE): If learning by doing exists in production and R&D activity, more experienced firms have accumulated stock of knowledge that gives them greater comparative advantage in research. Hence, experience of the firm is expected to affect the probability and intensity of R&D positively. It is proxied by age of the firm, which is calculated from the year of incorporation. Of course, for some firms the year of incorporation and the year of starting production may not coincide, however, this proxy has been used for want of a better alternative.

Value Added Share (VAS): Since information is a commodity having imperfect market, it is argued that firm could better appropriate the returns from knowledge production by internalising its use rather than selling it (Arrow 1962). On this basis, one can expect firms engaged in the larger part of the production chain of a product (higher vertical integration) have better opportunities for the internal application of knowledge and therefore, have higher probability of investing in R&D. In this study, following Kumar and Saqib (1996), share of value added in sales is taken as a proxy for the extent of vertical integration at the firm level. A positive relationship between *VAS* and *R&D intensity* is expected[19].

Foreign Equity Participation (D_FEP): The effect of foreign equity participation on innovation effort is not clear. It can have a negative impact, if foreign participation allows firms to have access to technological knowledge stock of the parent foreign company and thus avoids the need to do in-house R&D. On the other hand, it can have a positive influence, if technology, which is sourced from the parent firm, needs to be adapted to suit local factor prices, usage pattern and so on. It is argued that such innovation and adaptation activities are more likely to take place in joint ventures than in purely local firms, as joint ventures do not have to support the huge search cost of appropriate technologies in the world market, since such information can be provided by the head quarters of the foreign partner (Pack 1982). Dahlman et al. (1987) argue that

[19] It is also argued that value-added to sales ratio tends to be higher in consumer goods industries. Firms in these industries are also more likely to invest in R&D because of the better appropriability and differentiability conditions (Kumar and Saqib 1996). Since we are using industry specific dummies to control for the industry characteristics, we expect that VAS will capture what it intends to.

such positive effect on innovation is probable, if the local partner has the motivation and the ability to learn from the technological competence of the foreign partner. Further, in the context of globalisation of research activities of multinational firms, there is a higher probability that subsidiaries of foreign companies would start research units in India to take advantage of the low cost R&D personal available here. In the regression model, D_FEP is a dummy variable that takes value one if the firm has foreign equity participation, otherwise zero.

Export Intensity (EXPOIN): Firm's extent of involvement in export is measured by its export intensity. It is defined as the ratio of its export to its sales. However, it is to be noted that, while export can affect current year R&D through ways that we have already noted above, current R&D investment can improve export potential of the firm in future by increasing productivity.

Technology Import Intensity (TECHIN) and *Capital Goods Import Intensity (CGOOD)*: We use two variables to measure technology import intensity of the firm. The first one *TECHIN* captures the intensity of disembodied technology import through licensing, which is defined as the ratio of expenditure on disembodied technology import to sales. The second one, *CGOOD*, captures the intensity of capital goods import, which is defined as the ratio of expenditure on capital goods import to sales. We take these two variables separately, because we assume that they differ in their effects on R&D investment.

<u>Sectoral Classification of Industries</u>

There exists significant intersectoral variation in the process of innovation and technological progress mainly due to the differences in incentive structures and opportunities for innovation. To accommodate this intersectoral variation in the extent of appropriability and opportunities for innovation, this study classifies industries into four sectors on the basis of the taxonomy developed by Pavitt (1984). Pavitt's sectoral typology has been one of the widely used taxonomies in the innovation and R&D literature[20]. It classifies industries into four sectors using three criteria, namely sources of technology, user's needs and means of appropriating the benefits[21]. The four sectors are

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[20] For instance, see Greenhalgh and Rogers (2006) and Vossan (1998).

[21] Pavitt's taxonomy has been recently updated by Tidd et al (2001) by adding one more sector called *information intensive sector*, which include firms in finance, retail and publishing. For a review of various taxonomies of patterns of innovation see de Jong and Marsili (2006).

(1) Supplier dominated sector, (2) Scale Intensive Sector, (3) Specialised Suppliers, and (4) Science based Sector. The important features of these sectors and their constituent industries are briefly explained below[22].

In the supplier dominated sector, innovations are mainly process innovations through the use of improved capital equipment and intermediate inputs. Thus, in this sector, the process of innovation is primarily a process of diffusion of best practice capital goods and innovative intermediate inputs and R&D expenditure is limited due to the lack of endogenously generated opportunities. The industries belonging to this sector include textiles, leather, wood and furniture, paper and printing. In the specialised suppliers sector, innovation activities relate primarily to product innovation that enters most other sectors as capital inputs. Firms in this sector usually operate in close contact with their users and embody specialised and partly tacit knowledge in design and equipment building. Opportunities for innovation are generally abundant, but they are often exploited through "informal" activities of design improvement and formal R&D is often rather low. Idiosyncratic and cumulative skills make for a relatively high appropriability of innovation. This sector includes industries manufacturing machinery, instruments and optical goods. In the scale intensive sector, innovation consists of both process and product innovation and firms often devote a relatively high proportion of resources to innovation. Firms usually have well equipped production and process engineering departments and they form an important source of process technology. Firms maintain their technological lead through know-how secrecy around process innovation and through inevitable technical lags in imitation as well as through patent protection. Scale intensive sector include industries such as food beverages and tobacco, oil, rubber and plastics, building materials, earthenware and glass, metal and metal products and transport equipment. In the science based sector, innovation is directly linked to new technological paradigm made possible by the advancements in the underlying science. Technological opportunities are higher and innovation activities are formalised in R&D laboratories. Firms appropriate their innovation leads through a mix of methods, i.e. patents, secrecy, natural technical lags and firm specific skills (see Pavitt 1984 and Dosi 1988). This sector includes chemicals and electrical and electronic goods.

[22] Our division of industries into various sectors is very much similar to Vossan (1998).

Table 1

[Goes about here]

3. Estimation and Results

Estimation

For the majority of observations, the dependant variable in our regression model takes value zero and therefore ordinary least square (OLS) is not appropriate for estimation as it leads to biased estimates (Amemiya 1984). Therefore, we estimate model (1) using pooled tobit as discussed in Wooldridge (2002)[23]. Since the estimated coefficients of the tobit model are not the marginal effects of explanatory variables as in the case of linear OLS regression, we also estimate marginal effects of explanatory variables. Estimation of marginal effects allows us to find out the change in the independent variable due to a small change in the explanatory variable. More importantly, as we shall see below, the sign and statistical significance of the marginal effect of an interaction variable can be different from those of the corresponding coefficient. So it is important to compute marginal effects for correct inference.

Marginal effects (ME) of variables, except that of IPR, MCON, and IPR*MCON, are estimated as follows[24],

M E of k^{th} variable = $F\left(\frac{\hat{\boldsymbol{\beta}}'\boldsymbol{X}}{\hat{\sigma}}\right)\hat{\beta}_k$

Where $\hat{\boldsymbol{\beta}}$ is the vector of estimated coefficients of tobit regression, $\boldsymbol{\beta}_k$ is the coefficient of k^{th} explanatory variable, $\hat{\sigma}$ is the standard deviation of the random error term and $F(.)$ is the cumulative normal distribution function.

Marginal effects of IPR, MCON and the interaction between the two in model (1) are:

M E of IPR =

M E of MCON =

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[23] Another method to estimate tobit regression from panel data is random effect tobit model. However, random effect tobit model assumes strict exogeneity of regressors that is not valid in the present context as current year R&D affects future export and profit. Pooled tobit can accommodate explanatory variables that are not strictly exogenous (see Wooldridge (2002).

[24] See Greene (2000, p.910)

M E of IPR*MCON= $F\left(\frac{\hat{\boldsymbol{\beta}}'\boldsymbol{X}}{\hat{\sigma}}\right)\hat{\beta}_{10} + \frac{1}{\hat{\sigma}}\left[f\left(\frac{\hat{\boldsymbol{\beta}}'\boldsymbol{X}}{\hat{\sigma}}\right)(\hat{\beta}_6 + \hat{\beta}_{10}MCON)(\hat{\beta}_7 + \hat{\beta}_{10}IPR)\right]$

Marginal effects and their standard errors are estimated for each observation and averages are reported[25]. The standard errors of the marginal effects are estimated using delta method[26]. Since sign and statistical significance of the marginal effects of IPR, MCON and IPR*MCON can vary from one observation to another, an average may not be a good representative of the effect of these variables (Ai and Norton 2003). So, while making inference on the effect of these variables, we also utilise the distribution of the marginal effects and their *t* values (test statistics).

<u>Results</u>

Table 2 and Table 3 respectively present the estimated tobit coefficients and marginal effects of model (1) for the four sectors. The row LLF in Table 1 reports maximised value of the log likelihood function. LR test reports the results of the likelihood ratio test of the null hypothesis that all the slope coefficients are equal to zero, which is rejected in every case. The Table 3 shows that in all the sectors marginal effect of size variable is significant and positive. This supports the theoretical hypothesis of a positive effect of firm's size on innovation effort. Advertisement intensity has a significant positive effect in all sectors except in specialised suppliers sector. It may be suggesting a complementary relationship between R&D and advertisement. Advertisement may be helping firms to enhance their product market and thereby increasing the rate of return on innovation.

[Table 2 and Table 3 go about here]

Rate of profit (ROF) has significant positive effect in two sectors, where investment in in-house R&D is important for technological progress, namely scale intensive and science based sectors. The value added share in output, a proxy for the extent of vertical integration at the firm level is significant in all except in scale intensive sector. However, in the specialised supplier sector, it has negative effect, implying that greater vertical integration at the firm level is reducing R&D investment. Age of the firm, a proxy for its

[25] One can compute marginal effects by evaluating the expression at the sample means or at every observation and use sample average of the individual marginal effects. Since the functions are continuous, the theorem of Convergence in Quadratic Means (the Slutsky theorem) applies and in large samples both approaches give same result. But in small or in moderate sized samples this is not applicable. Current practice favours averaging the individual marginal effects when it is possible to do so (Greene, 2000, p.816).

[26] For delta method of computing standard errors of non-linear combination of parameters, see Greene (2000), p. 357-358.

accumulated experience, has significant positive effect in all sectors. It may be indicating that firms' accumulated knowledge through production experience is increasing R&D productivity and thereby enhancing the incentive to invest. Foreign equity participation dummy (D_FEP) is positive and significant in all, except in supplier dominated sector. One of the possible reasons for the positive effect of foreign equity participation can be the setting up of R&D centres in India by the subsidiaries of multinational firms in their attempt to take advantage of low cost R&D personal available here. The intersectoral variation in the effect of foreign equity participation may be due to the importance of R&D in these sectors. For instance, in supplier dominated sector investment in R&D may not be as important as in science based sector to bring about technological progress.

Average marginal effect of market concentration is not significant in any of the sectors (see Table 3). Here, we also look at the distribution of the marginal effects and that of test statistic, as the sign and statistical significance of the marginal effect may vary from one observation to another. Table 4 presents the distribution of marginal effects and *t* values of MCON, IPR and IPR*MCON. It shows that in supplier dominated and science based sectors, respectively 69 and 66 per cent of the marginal effects are negative and significant, indicating that in these two sectors, market concentration in general has negative impact on R&D investment. This may be suggesting that in these two sectors the negative effect of market concentration may be outweighing its positive effect through better appropriability conditions.

[Table 4 goes about here]

Export intensity has significant positive effect on R&D investment in all the sectors, except in specialised suppliers. This result, as argued in the theoretical literature, suggests that export promotion encourages innovation effort. Disembodied technology import intensity (TECHIN) and capital good import intensity (CGOOD) are found to be promoting R&D investment only in supplier dominated industries. The confinement of R&D promoting effect of technology import to supplier dominated industries may be due to the lower technological and engineering capability of firms in this sector, so they have to invest in R&D to absorb imported technology.

Regarding the effect of import competition on R&D investment, Table 3 shows that its average marginal effect is negative and significant only in science based sector.

However, the distribution of its marginal effects presented in Table 4 shows that 60 and 78 per cent of them are negative and significant in supplier dominated and science based sectors respectively. One important objective of the present paper is to examine the role of domestic market structure in shaping the impact of import competition. For this, we have included an interaction variable between import penetration rate and market concentration. Its average marginal effect is positive and significant in all except in scale intensive sector. The distribution shows that in supplier dominated sector 83.77 per cent of them are positive and significant and the corresponding figures for specialised suppliers and science based sectors are respectively 61.35 and 98.32 per cent. This result suggests that the effect of import competition depends on the domestic market structure. Import competition promotes R&D investment in those industries where domestic market structure is more concentrated.

[Figure 1, Figure 2 and Figure 3 go about here]

To further understand the variation in the impact of import competition with the level of concentration, we have computed its marginal effects keeping all other variables except IPR and MCON, at their mean values for three sectors, where the interaction variable is significant. These estimates are plotted in Figures 1, 2 and 3 for three sectors. The figures show that at a lower level of concentration, i.e. the Herfindhal index below the vertical line, the marginal effect of import competition is negative. The results, thus, suggest that in a situation of greater market concentration, import competition would reduce the market power of firms, leaving them without any option other than investing in productivity enhancing activities like R&D to increase profit. Further, in this case, greater market concentration and large scale of output due to lesser number of firms may be making investment in R&D a feasible option. On the other hand, in those industries, where the domestic concentration is already lower (competition is higher), import may be further intensifying the competitive pressure, and thereby reducing the incentive of the firm to invest in R&D. The result seems to be supporting the theoretical argument that both too much competition and too little competition are not conducive for innovation and growth. When there is too little competition in the domestic industry liberal import policy is an option that can be used to discipline the firms and thereby induce them to make productivity enhancing investments. This result has important implications for aligning trade and industrial policy for achieving faster technological progress.

4. Concluding remarks

This paper examined the effect of international trade on manufacturing firms' R&D investment. Trade can affect innovation effort of domestic firms through import competition, export and technology import. However, theoretical predictions on the impact of trade through these channels are ambiguous and conditional on many industry and firm specific factors. The present paper, drawing upon the theoretical literature, hypothesised that the impact of import competition on R&D investment depends upon domestic market structure.

The empirical analysis shows that export in general has a positive effect R&D investment; supporting the argument that an export promoting trade strategy encourages innovation and technological progress. Technology import is found to have positive effect only in supplier dominated sector-a sector having relatively lower level of engineering and technological capability. This result is in line with the view that firms having lower level of engineering and technological capability need to undertake in-house R&D to effectively absorb imported technology. The results on the impact of import competition indicate that it is shaped by the domestic market structure. Import competition encourages R&D investment only in those industries, where the domestic market structure is highly concentrated. When the domestic market is less concentrated, import competition has a negative effect on R&D. This evidence goes well with the argument of some of the new growth models that both too much competition and too little competition are not conducive for innovation and growth. If there is too little competition in the domestic industry, liberal import policy is an option that can be adopted to encourage the firms to be innovative. The study also shows that there exists significant intersectoral variation in the effect of various determinants of R&D investment, including those related to trade.

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Table 1. Summary measures of variables

	Supplier Dominated	Scale Intensive	Specialised Suppliers	Science based
RDINS	0.0007 (0.008)	0.0014 (0.009)	0.0034 (0.008)	0.0044 (0.018)
IPR	0.0736 (0.143)	0.0909 (0.131)	0.3582 (0.158)	0.2249 (0.239)
MCON	0.0950 (0.146)	0.1172 (0.087)	0.1932 (0.175)	0.0571 (0.044)
SIZE	67.19 (134.40)	246.38 (2044.35)	138.23 (462.78)	111.91 (258.28)
EXPOIN	0.223 (0.319)	0.0796 (0.181)	0.0835 (0.168)	0.1055 (0.199)
TECHIN	0.0007 (0.006)	0.0015 (0.011)	0.0033 (0.011)	0.002 (0.012)
CGOOD	0.0330 (0.133)	0.0176 (0.094)	0.014 (0.059)	0.0164 (0.090)
ADVTIN	0.0045 (0.016)	0.0053 (0.018)	0.0078 (0.020)	0.0069 (0.021)
ROP	-0.0656 (0.382)	-0.0370 (0.322)	-0.0095 (0.309)	-0.0185 (0.305)
VAS	0.3097	0.2920	0.3974	0.3094

	(0.332)	(0.329)	(0.397)	(0.2856)
AGE	21.81 (22.60)	22.46 (18.84)	23.39 (17.80)	20.876 (17.86)
Number of Observation having R&D investment	390	1386	310	1706
Number of observations having foreign equity participation	311	1045	293	1005
Number of Observations	2914	6407	903	4927

Note: All values except those in last three rows are mean over observations and standard deviation is reported in parenthesis.

Table 2. Estimated Coefficients of Tobit regression

	Supplier Dominated	Scale Intensive	Specialised Suppliers	Science based
Constant	-0.041* (-16.96)	-0.034* (-19.30)	-0.006 (-1.13)	-0.029* (-5.07)
IPR	-0.034* (-2.80)	0.001 (0.07)	-0.021 (-1.92)	-0.028* (-5.45)
MCON	-0.044* (-3.60)	0.008 (0.94)	-0.033* (-1.98)	-0.087* (-5.45)
IPR*MCON	0.214* (4.97)	0.018 (0.29)	0.090* (2.14)	0.248* (3.81)
SIZE	0.00003* (7.70)	7.36e-07* (4.97)	4.92e-06* (3.52)	0.00001* (5.09)
EXPOIN	0.009* (3.39)	0.005* (2.23)	0.003 (0.53)	0.026* (8.64)
TECHIN	0.354* (3.57)	0.062* (1.73)	0.058 (0.84)	0.069 (1.57)
CGOOD	0.011* (2.20)	0.002 (0.50)	-0.031 (-1.59)	-0.007 (-0.88)

ADVTIN	0.130* (2.35)	0.067* (3.57)	0.073* (1.97)	0.134* (5.16)
ROP	0.001 (0.39)	0.005* (2.97)	0.006 (1.69)	0.009* (3.59)
VAS	0.005* (2.55)	-0.002 (-1.07)	-0.009* (-2.74)	0.005* (2.13)
AGE	0.0001* (4.09)	0.0003* (13.31)	0.0003* (6.11)	0.0003* (9.47)
D_FEP	0.002 (0.93)	0.009* (9.02)	0.007* (4.48)	0.013* (8.62)
LLF	371.53	1850.41	570.22	2037.32
LR test	5352*	9781*	788*	6313*
Number of Observations	2914	6407	903	4927

Notes:

(1) t values are given in parentheses. For LR test Chi-square values are reported.
(2) All regressions include industry dummies at two digit level of NIC 1998.
(3) * Indicates significant at five per cent level.

Table 3. Estimated Marginal effects of Tobit regression

	Supplier Dominated	Scale Intensive	Specialised Suppliers	Science based
IPR	-0.001 (-0.95)	0.0005 (0.47)	-0.001 (-0.41)	-0.004* (-3.21)
MCON	-0.002 (-1.55)	0.002 (1.08)	-0.0003 (-0.12)	-0.011 (-1.83)
IPR*MCON	0.029* (2.93)	0.004 (0.32)	0.027* (1.96)	0.074* (3.92)
SIZE	3.70e-06* (5.35)	1.29e-07* (4.91)	1.54e-06* (2.84)	3.06e-06* (4.58)
EXPOIN	0.001* (2.88)	0.0009* (2.17)	0.001 (0.52)	0.007* (7.44)
TECHIN	0.038* (2.94)	0.011 (1.70)	0.018 (0.83)	0.019 (1.56)
CGOOD	0.001*	0.0004	-0.009	-0.002

	(2.02)	(0.50)	(-1.53)	(-0.88)
ADVTIN	0.014* (2.15)	0.012* (3.34)	0.23 (1.88)	0.038* (4.87)
ROP	0.0001 (0.57)	0.0009* (2.84)	0.002 (1.62)	0.003* (3.47)
VAS	0.0006* (2.30)	-0.0003 (-1.07)	-0.003* (-2.49)	0.001* (2.11)
AGE	0.00001* (3.31)	0.00005* (8.41)	0.0001* (4.45)	0.0001* (8.15)
D_FEP	0.0002 (0.91)	0.002* (6.71)	0.002* (3.67)	0.004* (7.46)

Notes:

(1) t values are given in parentheses.

(2) * Indicates significant at five per cent level.

Table 4. Distribution of Marginal Effects and Test Statistics
(The figures are percentages of total observations in each sector)

Supplier Dominated firms

Variable	Marginal Effect		Test Statistic	
	% of ME<0	% of ME>0	% of t<-1.96	% of t>1.96
IPR	83.63	16.37	60.22	10.50
MCON	87.13	12.87	68.84	2.30
IPR*MCON	3.67	96.33	0.00	83.77

Scale Intensive

Variable	Marginal Effect	Test Statistic

	% of ME<0	% of ME>0	% of t<-1.96	% of t>1.96
IPR	0.00	100.00	0.00	0.00
MCON	0.00	100.00	0.00	0.00
IPR*MCON	0.00	100.00	0.00	0.00

Specialised Suppliers

Variable	Marginal Effect		Test Statistic	
	% of ME<0	% of ME>0	% of t<-1.96	% of t>1.96
IPR	78.63	21.37	0.00	4.98
MCON	52.16	47.84	4.54	0.55
IPR*MCON	0.44	99.56	0.00	61.35

Science Based

Variable	Marginal Effect		Test Statistic	
	% of ME<0	% of ME>0	% of t<-1.96	% of t>1.96
IPR	84.96	15.04	77.69	2.44
MCON	78.16	21.83	65.90	1.73
IPR*MCON	0.00	100.00	0.00	98.32

Figure 1. Marginal Effect of Import Competition at various levels of Herfindhal Index

Figure 2. Specialised Suppliers

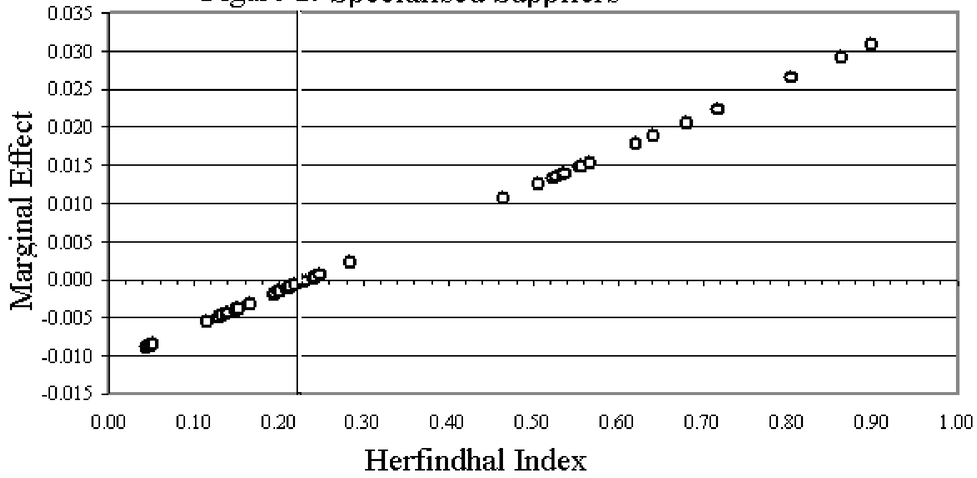

Figure 3. Science based