Technological Capabilities and Exports: Evidence from Indian Manufacturing Firms

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India has witnessed a notable rise in the exports of technology-intensive manufacturing products in recent years. Such growth not only reflects greater production and global competitiveness but also generates positive spillovers for other sectors, contributing to industrial upgrading and long-term economic growth. This paper seeks to examine the drivers behind the expansion of India's technology-intensive exports and the processes enabling it. We argue that this surge is primarily attributable to the strengthening of firms' technological capabilities through investments in research and development (R&D), human capital formation, and access to advanced foreign technologies. To test this, we construct an unbalanced panel dataset comprising 2,334 firms and 21,718 observations, incorporating industry, firm, and region-specific characteristics from multiple sources. Employing Quasi-Maximum Likelihood Estimation (QMLE) as the primary empirical method, and Tobit estimation for robustness, we find that firms investing in in-house R&D and human resources, alongside imported technology, exhibit higher export intensity. These results highlight the critical role of indigenous capability building in enabling firms to absorb and utilize foreign technologies effectively, thereby enhancing export performance. By combining detailed firm-level data, advanced econometric techniques, and both aggregate and industry-level analysis, this study offers strong evidence with significant implications for innovation-led industrial and trade policy in India.

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Abstract

India has seen a surge in the exports of technology-intensive manufacturing products in recent years. Increased production and export of high technology commodities lead to spillovers into other sectors and upgradation of the country's industrial structure, fueling long term growth.

The purpose of this paper is to understand the process behind the growth of technology intensive exports from India and the factors driving it. We attribute this growth to the enhanced technological capabilities of Indian firms created through investments in research and development (R&D) and human capital, apart from import of advanced technologies. We consider an unbalanced panel data set of 2,334 firms and 21,718 observations for our study. Our dataset includes industry, firm and region-specific variables collected from different data sources.

We employ the Quasi-Maximum Likelihood Estimation (QMLE) model for empirical estimation. We also estimate the Tobit model to check the robustness of our results. Our estimates show that firms that invest in in-house R&D and building human resources, apart from imported technology, have a higher export intensity. This validates the argument that firms need to build indigenous capabilities to effectively utilize the knowledge involved in imported technology to perform better in the export market. This paper provides robust evidence on the significance of technological capability building for export performance of firms, taking the case of technology-intensive industries in India. The study uses detailed firm level data, advanced econometric methods and considers a recent time-period. The exercise has been carried out at the aggregate level as well as at the disaggregated industry levels, thereby giving wider scope for targeted policy implications.

Keywords: Technological capability-building, exports, Technology-intensive, Human capital, QMLE

JEL classification: F14, L6, O14

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1. Introduction

The significance of technology intensive exports for the growth of an economy cannot be stressed enough. Such exports are reflective of the economic complexity of the country which has a bearing on its global competitiveness and export performance (Lall, 2000; Erkan & Yildirimci, 2015). Countries specialized in these have been growing faster as they have greater income elasticities and scope for faster substitution of older products and generation of new demand (Lall, 2000). Moreover, they create spillovers which lead to the upgradation of the country's industrial structure and long-term growth (Hausmann et al, 2005; Falks, 2009; Shrawan, 2019)[1].

Even though the export of technology-intensive products is important for the industrial as well as economic growth of countries, many fail to enter and sell these products in the global market. As technology-intensive products require substantial investments in capital and know-how, a functioning innovation system, as well as continuous upgradation through R&D and product differentiation to keep up with the rapidly evolving market, only a few countries dominate the world market in the export of these products (UNIDO, 2002; Hout and Ghemawat 2010; UNCTAD, 2021). Data suggests that such countries belong to the high-income group[2].

Recent empirical evidence nonetheless indicates a rapid growth in the export of technology intensive products and an increasing presence of developing countries in it (Srholec, 2007). A pronounced shift from resource-based and low technology products to high technology goods has also been observed in the developing world, in the recent past (Lall, 2000; Anand et al., 2015). While some see this shift as a 'statistical illusion' - as these countries specialize in the labor intensive segments of technology intensive products which costs less to produce, others argue that it may be due to the catching up of developing economies on the technology ladder (see for instance, Lall, 2000; Mayer et al, 2003; Srholec, 2006).

India's experience is also similar to that of other developing countries. The export of technology intensive products grew significantly between 1990-91 to 2020-21 from USD 2.22 billion to USD 83.13 billion. The share of high technology (HT) products in the country's total manufacturing export also doubled during this period[3]. High technology (HT) here includes industries classified both as 'high technology' and as 'medium-high

[1] This is because firms engaged in HT exports often adopt advanced technologies and best practices, which can be diffused to other firms in the domestic economy. As a result, domestic firms are able to upgrade their production processes and become more competitive in the global market.

[2] For instance, in 2020 export of high and medium high technology products of high income countries contributed to more than 36 percent of the world manufacturing export.

[3] The share of HT export in total manufacturing exports of India increased from 16.05 percent in 1990-91 to 35.18 percent in 2020-21. The share of HTX of low and middle income countries in the world's manufacturing export increased from 3.5 percent in 1991 to 19.01 percent in 2020-21. These figures are based on the authors' calculation using data from WITS.

technology' by the OECD[4]. While the annual average growth rate of high-tech exports (HTX) in India's manufacturing exports was -4.41 per cent between 1990 and 2000, it increased to 8.75 percent in the 2000-2021 period. India's HTX as a proportion of the world's HTX as well as the world's total manufacturing exports have also been increasing continuously since 2000-01 and exponentially after 2008 (See Figure A1 in the appendix).

The objective of this study is to understand the process behind the increase in India's HTX from 2008 onwards. Grazzi et al. (2021) points out that the existing empirical literature on the drivers of HTX in developing countries is rather new and focuses on countries' participation in the cost-effective labor-intensive segments of HT products as a strategy to enter and sustain in the international market. However, we believe that technological upgradation may have a role to play in the HTX performance of emerging countries like India. We use firm level data of HT manufacturing industries for this purpose, as firms determine the volume of export of a country. Technological capability building of firms through investments in research and development (R&D) activities and human capital, apart from import of advanced technologies improves their competitiveness which enhances their export performance. Our empirical study finds evidence for this in the case of HT manufacturing firms in India. The results suggest that the higher export of HT products from India in recent years is the result of its firms learning from imported technologies as well as generating and managing indigenous capabilities by investing in R&D and human capital.

The paper is organized into five sections, including the introduction. Section two reviews the existing theoretical and empirical literature pertaining to technological change and exports. Section three gives the source of the data, explains the model and the variables. The fourth section presents the issues in the estimation of the model and discusses the results. The last section concludes the study and highlights its implications.

2. Review of Literature

2.1. Theoretical literature

The differences in industrial performance between countries in terms of their ability to compete and sustain in the international markets is driven by their technological capabilities (Lee & Malerba, 2018). The significance of technological progress as the source of dynamic trade advantage has been advocated quite early on by the neo-technology theorists such as Posner, 1961 and Hufbauer, 1966. They highlighted

[4] The classification of Technology Intensive industries by OECD can be found here, see https://www.oecd.org/sti/ind/48350231.pdf .

different mechanisms of technological dissemination between a leader and follower countries (Hufbauer, 1966). This traditional understanding of technical change differentiates between innovation and diffusion and assumes that developing countries are mere consumers of the innovation undertaken by the early industrializers. For this reason, developing countries need not accumulate indigenous innovation capabilities. Technology here is viewed as codified knowledge which can be transferred easily through capital goods or blueprints. Further, the choice, acquisition and adaptation of technology are costless for developing countries.

The technological capability approach put forward by Lall (1992; 2000) suggests that the tacit knowledge embedded in technologies ensures that the ability to import technology is not the same as the ability to use it. The underlying idea being that technology cannot be reduced merely to capital goods or codified information. Explicit and tacit knowledge transferred from developed countries is utilized to varying extents by firms based on their existing knowledge base as well as their 'intensity of effort' (Cohen and Levinthal, 1990). The degree of utilization depends on the internal capabilities of the firm or their 'absorptive capacity' (Cohen & Levinthal, 1990). Therefore, firms in developing economies are not passive users of technology, but are involved actively in the process of technological progress through incremental innovations by cultivating competencies in the domains of production, investment and innovation (Bell and Pavitt, 1995; Kim, 1999).

Bell and Pavitt (1995) further delineate the role of technological capability in the process of economic catch up. They argue that technology entails 'complex bundles of information' which are only partially transferable. Once transferred, it needs to be adapted to suit the levels and specifications of individual firms. The modified technology further needs to be consistently monitored and managed to ensure that it meets the constantly evolving international efficiency standards. The dynamic capabilities framework which attempts to explain the potential for wealth creation of individual firms in a rapidly changing technological environment argues on similar lines. They underline that the success of the particular firm is dependent on its ability to refine its internal technological, organizational and managerial capabilities (for instance see Teece, Pisano & Shuen (1997)).

Experience or 'learning by doing' alone cannot guarantee economic catchup for latecomer firms in the global market (Bell & Pavitt, 1995). The sustained competitiveness of firms depends on the specialized resources at their disposal such as skilled labour. However, the nature and sources of technological accumulation conducive for different industries may be different. A mixed model involving imports of technology, coupled with indigenous R&D and employment of skilled labour may be relevant for science-based industries. (Pavitt, 1984).

2.2. Empirical review

High technology exports being an important factor influencing long-term economic growth, and many scholars have attempted to examine its determinants empirically. Most of the studies in this stream of literature are cross-country analyses which analyze the macro picture of why certain countries have higher high-tech exports than others. Our objective in this review is to scrutinize the factors impacting export capability at the firm level. Since firm-level exports make up countries' total exports and they are the actual players in the export market, it seems pertinent to examine the variation in their exports and the reasons for the same.

It is well established that innovative firms are more exportive in nature (Yi, et al., 2013; Forbes, N. 2022). Hence, most of the studies that examine the determinants of high-tech exports include the innovation potential of the firms as a key variable in their analysis. Innovation leads to the introduction of new products and processes which increases the firms' competitiveness in the export market (Becker and Egger, 2008).

Scholars like Zhang (2007) underline that the innovation potential of firms is directly related to their technological capabilities (TC). Technological capability-building takes place through two channels: the import of technology from advantaged countries and investment in in-house R&D which can help firms 'master and use' the imported technologies to their advantage. In the Indian context, a recent study by Grazzi et al. (2021) finds that R&D has a significant impact on both the probability as well as the intensity of export of manufacturing firms. However, studies such as Kumar and Siddharthan (1994), Aggarwal (2002), Bhat & Narayanan (2009), Srinivasan and Archana (2011), Goldar (2013) and Ghosh and Roy (2018) highlight the significance of the import of technology, apart from R&D expenditure in explaining firms' export performance.

Industry-specific studies on medium and high technology industries have also verified the relevance of technological capability-building through R&D and imported technology. Aggarwal (2002) supports the view that R&D and technology imports have a complementary relationship and that in technology-intensive sectors, firms' internal capabilities have a bearing on their export performance. On undertaking a disaggregated analysis based on the technological intensity of exporting firms, Aggarwal (2002) notes that investment in R&D significantly affects the export performance of medium-high tech industries. Bhat & Narayanan (2009) finds that for firms in the chemical industry who have entered the export market already, R&D and import of capital are very important to keep up and enhance their export competitiveness through continuous product innovation, quality enhancement and diversification. In the case of firms in the pharmaceutical industry in India, Goldar (2013) observes that in-house R&D efforts are associated with increased export intensity. This relationship is stronger in firms whose technical efficiency is high and who are closer to the technological frontier.

While undertaking a firm-level analysis of the export performance of Italian high-tech firms, D'Angelo (2012) notes that product innovation and external research collaborations with universities boost exports. Interestingly, he observes that innovation capabilities are embedded in human capital. He finds that while R&D employees impact export performance, R&D expenditure does not. The significance of skilled labour in making use of imported technology has also been highlighted by others. Since there is an underlying component of tacit knowledge involved in technology transfer, importing countries have to build "absorptive capacity" in order to effectively utilise it in the production process (Lall, 1992). This can be done by imparting training and improving the skill levels of the employees. According to Aggarwal (2002), there are two requirements to utilize the imported technology: "First, the firm must hire skilled persons and train them and two; the firms must organise to make use of employees' skills effectively". Joseph et al. (2021) highlights the significance of staff training as an important factor affecting the productivity of firms in India. However, few studies have highlighted the significance of skilling workers in firms' export performance.

Francis & Collins-Dodd (2000) argue that since high technology industries work under dynamic and turbulent market conditions with short technology cycles, firm-specific features including a strategic 'export orientation' and 'entrepreneurial management' which involve actively seeking out new markets, networks and relationships can positively affect export performance. For Indian manufacturing firms, Bhat & Narayanan (2009) Srinivasan and Archana (2011) and Ghosh and Roy (2018) underline the significance of effective distribution channels, as well as marketing and advertisement activities to gain traction in the international market.

Studies also indicate that firm-specific characteristics such as age, size and affiliation with multinational companies influence the export capabilities of firms (see Srinivasan and Archana, 2011; Ghosh and Roy, 2018; Bhat & Momaya, 2020; Anand, 2022). Location of firms also impacts their export capabilities. Firms located in a region or state with a conducive business environment with access to finance and knowledge partners are more likely to export (Cooke, 2001; Pradhan and Das, 2013).

The recent paper by Grazzi et al. (2021) which analyzes the probability and intensity of exports of manufacturing firms in India stands close to ours. However, their measures of firm innovation, R&D dummy and investment intensity do not account for technology transfers from advanced countries. This is a significant channel of technological capability-building for developing countries such as India, as indicated by previous studies such as

Aggarwal (2002), and Bhat & Narayanan (2009) among others. Moreover, Grazzi et al. (2021) consider manufacturing firms in all industries and the period of their analysis is between 1995 and 2011. However, the global export market has significantly changed in the last decade and there is a shift towards technology-intensive products (Mani, 2021). In our study, we use the most recent data and focus on the export performance of technology-intensive industries, as we believe that innovation and technological capability-building is more relevant for them.

We hypothesize that the technological capabilities of high-technology firms have a positive influence on their export performance. Firms situated in regions with greater innovation activity, ease of doing business and access to finance tend to do better in the export markets.

3. Model, Variables and Data

3.1. Econometric model

The review of empirical studies in the previous section informs us that firms spending on developing in-house R&D capabilities, import of capital goods and raw materials, and payments against the purchase of licenses and blueprint of foreign technology help in the process of technological catch-up, thus improving their export performance. Further, other firm-specific factors (Age, Size, expenses on promotional and distributional activities, domestic raw material intensity, outsourcing intensity, skill intensity and affiliation to MNEs) and locational advantages (Number of patents, size of knowledge-intensive firms, ease of doing business and availability of credit) also improves firms' competitiveness and export performance. Our empirical model tests the impacts of these variables on the intensity of export of the HT manufacturing firms. The model is presented below.

$$EXPIN_{ft} = \alpha + \beta_1 Technological_{ft} + \beta_2 Firmspecific_{ft} + \beta_3 Locationspecific_{rt} + \nu_i + \xi_t + \varepsilon_{ft} \quad (1)$$

Where,

$EXPIN_{ft}$: Export intensity of firm f in time t

ν_i: Industry specific dummy

ξ_t: Time dummy

$\varepsilon_{ft} \sim (0, \sigma^2)$: Random disturbance term with mean 0 and constant variance

The definition and construction of explanatory variables are explained in detail in the next subsection.

3.2. Construction of variables

The available theoretical and empirical literature indicates that technological investments have a bearing on the export performance of high technology firms in developing countries. Based on the insights from the literature, we have identified a set of explanatory variables which are defined in Table 1.

Table 1: Definition and construction of variables

Variables	Abbreviations	Definitions
Dependent variable: Export intensity	$EXPINT_{ft}$	Export/Sales
Firm-level Technological factors		
Research and development intensity	$RDINT_{ft}$	Spending on research and development/Sales
Capital goods import intensity	$CGIINT_{ft}$	Expenses on the import of capital goods/Sales
Raw material import intensity	$RMINT_{ft}$	Expenses on imported raw materials/Sales
Intensity of royalties payments	$RPINT_{ft}$	Payments on licencing and blueprints/Sales
Firm-specific factors		
Indigenous raw material intensity	$INDRMINT_{ft}$	Spending on the purchase of domestic raw material/Sales
Intensity of advertisement, marketing and distribution activities	$ADVINT_{ft}$	Advertisement, marketing and distribution expenses/Sales
Outsourcing intensity	$OUTINT_{ft}$	Payments on outsourcing manufacturing and professional activities/Sales
Intensity of staffs training	$STINT_{ft}$	Staff welfare & training expenses/Sales
Affiliation to MNEs	$MNEs_{f}$	Dummy variable with value 1 if firms' foreign equity share is more than 10 percent or a foreign owned firm
Firms' age	AGE_{ft}	Calculated from the year of incorporation
Firms' size	$SIZE_{ft}$	Log values of gross fixed assets
Location specific		
Number of patents in a region	$PATENT_{rt}$	Number of patents in a state
Number of knowledge intensive firms in a region	$KFIRMS_{rt}$	Number of knowledge intensive firms in a region
Ease of doing business	$EASE_{r}$	Rank of states bases on their average score for ease of doing business between 2015 and 2018.

Variables	Abbreviations	Definitions
Bank branches	$BANK_{rt}$	Number of bank branches in a state

3.3. Data

The data on HT manufacturing firms is obtained from the Prowess database hosted by the Centre for Monitoring Indian Economy (CMIE). This database provides detailed information about the balance sheet and various heads of income and expenditure of firms in the organised sector in India. The firms in the CMIE database account for more than 70% of the economic activity in the organized industrial sector of India. The data on manufacturing firms is collected for the period from 2008 to 2020. To clean the data, we first drop all those firms which do not report their sales figures during the period of study. Secondly, we remove firms that never entered the export market between 2008 and 2020 and also those firms that exported 100 per cent of their sales. The latter group of firms are known as 'born global' firms. Such firms export their full potential right from their inception and their exports are unlikely to be highly impacted by technological upgrading. In comparison to firms that export only a fraction of their sales, these firms are outliers and are thus removed from our data. We keep only those firms that are present at least thrice during the study period. Our final dataset is an unbalanced panel of 2,334 firms and 21,718 observations for the whole HT manufacturing industry. Information on the number of firms and observations for individual industries is given in the Table A1 of the Appendix.

In addition, we follow the same procedure to clean the data for individual industries too. Table A1 in the appendix explains the number of firms and observations for each of the HT industries considered.

The literature indicates that apart from firm-specific factors, location-specific variables can also impact the export performance of firms. Innovative regions are more likely to have firms that export more. The innovation potential of individual states reflected in the number of patent applications filed in a year is collected from the publications of the Office of the Controller General of Patents, Designs and Trademarks, Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce & Industry. The state-level 'ease of doing business scores' (calculated by DPIIT) were taken from the Handbook of Statistics on the Indian States brought out by the Reserve Bank of India (RBI). Other variables including the number of bank branches and denoting access to finance were also taken from RBI's Handbook of Statistics on the Indian States. The data on the number of knowledge-intensive firms was taken from CMIE's Prowess database[5]. A table with the descriptive statistics of the variables, Table A2, is given in the appendix.

4.Estimation and Results

4.1. Estimation of the model

The relationship between technological capability and the export performance of firms is specified in Equation 1. A major challenge in estimating this model is related to the nature of the dependent variable. Export intensity (EXPINT) in our data is obtained by dividing firms' exports by their sales. Firms either abstain from the foreign market or export a part of their sales. For this reason, EXPINT varies from 0 to 1. In our data, out of 21,718 observations, 6,479 have zero values for EXPINT and its maximum value is 0.99. Our dependent variable is thus fractional in nature with a larger number of observations clustered at zero, i.e. $0 \leq EXPINT < 1$. Given the fractional nature of the dependent variable and accumulation of observations at one end of the distribution, the standard least square method is not appropriate. OLS does not guarantee that the predicted values of EXPINT, E(EXPINT|X), falls within the unit interval (Papke & Wooldridge,1996, 2008; Ramalho et al. 2011). This results in inconsistent estimates of β.

A number of methods have been developed for the consistent estimation of the parameters when the dependent variable is of bounded nature. Log-odds ratio, beta distribution, two-limit Tobit model and Quasi Maximum Likelihood Estimators (QMLE) are important among those (Papke & Wooldridge 1996 and Ramalho et al. 2011). QMLE method for the fractional dependent variable was proposed in the seminal work of Papke & Wooldridge (1996). This estimation procedure (1) does not require any ad-hoc transformation of data like the log odds ratio, (2) it can be applied even if observations are not clustered at both ends of the distribution which is essential for two limits Tobit model and (3) lastly, it is not based on the idea that each observation of the dependent variable, from 0 to 1, is taken with probability zero, which is the case for the beta distribution.

The QMLE is defined as

$$E(EXPINT|x) = G(x\beta) \tag{2}$$

Where $G(\cdot)$ is a nonlinear function and $0 \leq G(\cdot) \leq 1$. This is necessary for $E(EXPINT|x)$ to be in the unit interval.

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[5] Eurostat, the statistical office of the European Union identifies certain industries to be 'Knowledge Intensive Activities' based on the level of tertiary educated persons in sectors of economic activity. We map the same into the National Industries Classification and identify corresponding industries to be knowledge-intensive. From CMIE's Prowess database, we find the number of firms belonging to knowledge-intensive industries in each state and use that for our analysis.

In Papke & Wooldridge (1996), $G(\cdot)$ is a cumulative distribution function (cdf) and expressed

$$\text{as } G(\cdot) = \frac{exp(\cdot)}{[1 + exp(\cdot)]} \text{ or } G(\cdot) = \phi(\cdot).$$

Here,
ϕ is the standard normal cdf.

In equation 2, β can be estimated consistently through nonlinear least squares (NLS). NLS is used more frequently because it directly estimates $E(y|x)$, even though its estimators suffer through a number of limitations (See Papke & Wooldridge,1996).
However, β in QMLE is estimated in the following way

$$\widehat{\beta} = aggmax_{\beta} \sum_{i=1}^{N} LL_i (b) \qquad (3)$$

Where $LL_i(b)$ is Bernoulli log-likelihood function and it is given by

$$LL_i(b) = y_i log[G(x_i b)] + (1 - y_i) \log[1 - G(x_i b)] \qquad (4)$$

The estimated value of β in equation 3, irrespective of the distribution of y, is consistent and asymptotically normal.

Using the QMLE procedure, the final model we estimate is given below:

$$EXPINT_{ft} = \alpha_{ft} + \beta_1 RDINT_{ft} + \beta_2 CGINT_{ft} + \beta_3 RMINT_{ft} + \beta_4 RPINT_{ft} + \beta_5 INDRMINT_{ft} + \beta_6 ADVINT_{ft} + \beta_7 OUTINT_{ft} + \beta_8 STINT_{ft} + \beta_9 MNES_{ft} + \beta_{10} AGE_f + \beta_{11} SIZE_{ft} + \beta_{12} PATENT_{rt} + \beta_{13} KFIRM_{rt} + \beta_{14} EASE_{rt} + \beta_{15} BANK_{rt} + \nu_i + \xi_t + \varepsilon_{ft} \qquad (5)$$

The equation 4 is used to find out the export determinants of HT industries as a whole. For the individual industries, we estimate the same model by removing the industry-fixed effect, ξ_t, from the equation[6]. We also estimate the Tobit model as a robustness check.

[6] Note that, in equation 4 we have not considered firm level fixed effects, which includes for example the risk taking attitude of the managers and may affect firms export. Recently, Ramahlo et al (2016) proposed an exponential fractional response fixed effect model (EFRM) to address the issues. The fixed effects in their model are captured either by including industry specific dummies or by mean differencing the variables. Both the options in our case are not applicable because (1) given the micro panel with 2,334 number of firms, estimating the model with a very large number of dummies is not feasible; (2) mean differencing is not appropriate when variables involve a large number of zero observations. Though our model consider time and industry specific fixed effects, it fails to capture firm specific fixed effects.

4.2. Results

The results of QMLE models for the whole HT industry are presented in Table 1, along with the results of Tobit models. In Table 2, the values for the Wald and F statistics are significant suggesting that the models are properly fit. The results of individual HT industries are presented in Table 3 and Table 4. While Table 3 explains the coefficients of the Tobit model, Table 4 presents the results of QMLE. The F and Wald statistics in these two models are also significant. Given the nature of our dependent variable, QMLE approach is more appropriate. Hence, this section explains the coefficients of QMLE models in Table 2 and Table 4.

Table 2: Results: Overall HT manufacturing

VARIABLES	Tobit (Model 1)	Tobit (Model 2)	QMLE (Model 1)	QMLE (Model 2)
LRDINT	0.212**	0.209**	1.169**	1.168**
	(2.334)	(2.300)	(2.374)	(2.356)
LIRMINT	0.273***	0.271***	1.801***	1.786***
	(19.84)	(19.71)	(22.32)	(22.13)
LCGINT	0.138**	0.143**	0.784**	0.818***
	(2.478)	(2.558)	(2.513)	(2.604)
LRPINT	-0.552**	-0.562***	-5.075**	-5.245**
	(-2.565)	(-2.595)	(-1.984)	(-2.031)
LSTINT	0.317	0.286	2.616*	2.386*
	(1.568)	(1.423)	(1.878)	(1.710)
INDRMINT	0.041***	0.042***	0.382***	0.390***
	(5.887)	(5.985)	(6.634)	(6.749)
ADVINT	-0.096***	-0.098***	-0.762***	-0.784***
	(-3.248)	(-3.337)	(-2.895)	(-2.964)
OUTINT	-0.0250	-0.032	-0.267	-0.335
	(-0.628)	(-0.820)	(-0.721)	(-0.890)
AGE	-0.001***	-0.001***	-0.010***	-0.010***
	(-13.91)	(-14.33)	(-13.28)	(-13.71)
SIZE	0.0005	0.0006	0.005	0.005
	(0.548)	(0.604)	(0.636)	(0.704)
MNC	0.0006	0.0002	0.0228	0.0205
	(0.124)	(0.050)	(0.515)	(0.464)
KFIRMS		2.85e-05		0.0002
		(1.356)		(1.152)
PATENT		-4.97e-06		-3.73e-05
		(-1.385)		(-1.173)
EASE		-0.0001		-0.0006
		(-0.357)		(-0.204)
BANK		3.42e-06***		2.84e-05***
		(3.028)		(3.141)
Constant	0.0682***	0.051***	-2.493***	-2.652***
	(7.240)	(4.153)	(-28.86)	(-24.44)
Observations	18,773	18,773	18,773	18,773
Industry FE	YES	YES	YES	YES
Time FE	YES	NO	YES	YES

VARIABLES	Tobit (Model 1)	Tobit (Model 2)	QMLE (Model 1)	QMLE (Model 2)
Pseudo R-squared	-2.330	-2.374		
Log pseudolikelihood	367.5	367.5	-6365.23	-6358.28
wald Ch2			1626.93(0.00)	1634.46 (0.00)
F-stat	55.79 (0.00)	49.15 (0.00)		

Note: Figure in the parenthesis are robust t statistics, except for the chi2 test. For F and chi2 tests parentheses present probability values.
*** < 0.01, **< 0.05 and * < 0

It can be seen from the three tables that the coefficients estimated by the QMLE model have a higher explanatory power than those of the Tobit model. R&D intensity is observed to be positive and highly significant for the hi-tech industry. A unit change in R&D intensity leads to a 1.17 unit increase in the export intensity of firms. There are two channels through which R&D affects export performance. It is an indicator of innovation which directly affects the firm's competitiveness (Sharma, 2012; Joseph et al, 2021; Sahoo et al, 2021) In-house R&D expenditure is also necessary to build 'absorptive capacity' which helps firms to utilize the knowledge embedded in imported technology (Cohen & Levinthal, 1990). Our results show that the import of technology through the import of capital goods and raw materials is positively significant. While export intensity increases by 1.8 units with a unit increase in import of raw materials, it increases by 0.8 units in the case of capital goods. Reading these together, we can infer that R&D expenditure is contributing to enhancing the absorptive capacity of firms. However, expenditure on R&D alone is not enough. As is evident from the literature, skilled workers capable of utilizing the knowledge embedded in imported technology are essential to building technological capability in firms (Pavitt, 1984; Lall, 1992). This is clear from the positive and significant coefficient of the expenditure on staff training (LSTINT). However, we see that the import of disembodied technology (LRPINT), which is also an important factor that contributes to capability-building, is detrimental to the export competitiveness of high-tech manufacturing firms in India. In fact, the coefficient seems to be negative and significant; a unit increase in LRPINT causing a decline of 5.24 units in export intensity. It is interesting to note that this is however driven by a particular industry.

The coefficient for LRPINT for the Chemical industry (NIC 20) is very high and negatively significant. This is in line with the findings of Bhat & Narayanan (2009) whose study on the Chemical industry shows that a unit increase in payments on disembodied technology dampens firms' export intensity by -118.13 units. Firms in the chemical industry constitute 31.15% of our total observations, the largest share among all HT industries, which may have disproportionately affected the LRPINT coefficient in Table 4.

Table 3: Tobit results of Individual HT Industries

VARIABLES	NIC 20		NIC 21		NIC 26		NIC 27		NIC 28		NIC 29	
	Tobit (Model 1)	Tobit (Model 2)	Tobit (Model 1)	Tobit (Model 2)	Tobit (Model 1)	Tobit (Model 2)	Tobit (Model 1)	Tobit (Model 2)	Tobit (Model 1)	Tobit (Model 2)	Tobit (Model 1)	Tobit (Model 2)
L.RDINT	1.071***	0.982***	0.406**	0.409**	-0.531***	-0.536***	0.551	0.573	-0.862**	-0.810**	-0.476***	-0.484***
	(3.173)	(2.835)	(2.353)	(2.426)	(-4.435)	(-4.592)	(0.983)	(1.044)	(-2.164)	(-2.026)	(-5.670)	(-5.617)
L.IRMINT	0.217***	0.209***	0.471***	0.491***	0.331***	0.333***	0.465***	0.457***	0.201***	0.202***	0.0102	0.0101
	(9.224)	(9.002)	(9.966)	(10.20)	(8.950)	(8.985)	(12.76)	(12.65)	(6.076)	(6.102)	(0.377)	(0.376)
LCGINT	-0.0703	0.0527	0.105	0.121	0.310	0.314	0.249	0.245	0.267***	0.254**	0.0801	0.0896
	(-0.880)	(0.634)	(0.634)	(0.721)	(1.263)	(1.320)	(1.393)	(1.386)	(2.614)	(2.501)	(0.895)	(1.001)
LRPINT	-1.601***	-1.758***	-0.390	-0.798	0.681*	0.690*	0.154	0.0902	-0.392*	-0.441**	0.0718	0.0657
	(-4.981)	(-5.315)	(-0.429)	(-0.868)	(1.774)	(1.829)	(0.248)	(0.148)	(-1.830)	(-2.009)	(0.478)	(0.433)
LSTINT	-0.818*	-0.484	-1.238***	-1.332***	2.596**	2.245**	3.116***	2.648***	0.188	0.319	-0.271	-0.284
	(-1.898)	(-1.111)	(-3.629)	(-3.532)	(2.556)	(2.350)	(4.126)	(3.514)	(0.550)	(0.919)	(-0.703)	(-0.704)
INDRMINT	0.0777***	0.0761***	0.229***	0.225***	0.0457	0.0522*	-0.0629***	-0.0620***	0.0259**	0.0215	0.0409***	0.0410***
	(4.955)	(4.855)	(6.791)	(6.595)	(1.630)	(1.852)	(-4.639)	(-4.569)	(1.966)	(1.634)	(2.954)	(2.975)
ADVINT	-0.158***	-0.176***	0.0734	0.0222	-0.269	-0.194	-0.215***	-0.223***	0.0656	0.0465	1.035***	1.054***
	(-4.268)	(-4.755)	(0.873)	(0.266)	(-1.522)	(-1.133)	(-4.571)	(-4.651)	(0.675)	(0.474)	(6.967)	(7.042)
OUTINT	-0.0216	-0.0340	-0.125	-0.107	0.0468	0.0390	-0.00428	0.0188	-0.0144	0.000192	0.204	0.221
	(-0.282)	(-0.467)	(-1.528)	(-1.358)	(0.444)	(0.357)	(-0.0397)	(0.171)	(-0.205)	(0.00273)	(1.337)	(1.431)
AGE	-0.001***	-0.001***	-0.002***	-0.003***	-0.002***	-0.002***	-0.0002	-0.0002	-0.001***	-0.001***	-0.0002	-0.0002
	(-5.829)	(-6.908)	(-11.37)	(-11.97)	(-5.368)	(-4.961)	(-1.089)	(-0.997)	(-8.197)	(-8.584)	(-1.174)	(-1.171)
SIZE	-0.00436**	-0.00347*	0.0254***	0.0258***	0.0129***	0.0134***	-0.0120***	-0.0112***	0.00237	0.00296	-0.0064***	-0.0068***
	(-2.380)	(-1.913)	(6.542)	(6.448)	(3.310)	(3.376)	(-4.686)	(-4.430)	(1.176)	(1.485)	(-2.602)	(-2.781)
MNC	-0.0445***	-0.043***	0.0385**	0.0327*	0.0873***	0.0808***	0.0110	0.00992	0.0238**	0.0268***	-0.0277***	-0.0275***
	(-4.116)	(-4.033)	(2.057)	(1.717)	(3.744)	(3.481)	(0.756)	(0.687)	(2.536)	(2.858)	(-3.724)	(-3.673)
KFIRMS		9.97e-05**		0.000113		-0.000183**		-6.58e-05		0.000177***		-7.36e-05*
		(2.180)		(1.270)		(-2.265)		(-1.387)		(4.409)		(-1.770)
PATENT		-9.05e-06		-3.30e-06		3.56e-06		-2.05e-06		-3.64e-05***		2.23e-05***
		(-1.312)		(-0.270)		(0.282)		(-0.267)		(-4.644)		(2.590)
EASE		-0.003***		0.00467***		0.00161		0.00216**		0.00185**		-0.000597
		(-3.846)		(3.970)		(1.055)		(2.571)		(2.225)		(-0.697)
BANK		5.31e-06**		3.75e-06		9.53e-06***		5.43e-06**		7.16e-06***		-5.37e-06**
		(2.289)		(1.227)		(2.877)		(2.203)		(2.595)		(-2.003)
Constant	0.175***	0.164***	0.0468	-0.0348	0.0807***	-0.00674	0.115***	0.0571**	0.106***	0.0931***	0.107***	0.110***
	(10.70)	(6.887)	(1.518)	(-0.872)	(2.672)	(-0.149)	(6.126)	(2.233)	(6.803)	(4.087)	(4.982)	(4.203)
Observations	4,988	4,988	2,235	2,235	1,614	1,614	2,722	2,722	4,330	4,330	2,884	2,884
Industry FE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	2.045	2.556	0.534	0.579	0.772	0.824	-1.004	-1.025	-0.272	-0.301	-0.0812	-0.0854
Log pseudolikelihood	-86.24	-86.24	-379.6	-379.6	-161.5	-161.5	286.6	286.6	426.7	426.7	937.6	937.6
F-stat	23.07(0.0)	22.55(0.0)	23.67(0.0)	20.82(0.0)	9.611(0.0)	9.088(0.0)	12.80(0.0)	11.03(0.0)	9.417(0.0)	9.33(0.0)	6.381	5.615

Note: Figure in the parenthesis are robust t statistics, except for the chi2 test. For chi2 test parentheses present probability values.
*** < 0.01, **< 0.05 and * < 0.1

Table 4: *QMLE results of Individual HT Industries*

VARIABLES	NIC 20		NIC 21		NIC 26		NIC 27		NIC 28		NIC 29	
	QMLE (Model 1)	QMLE (Model 2)	QMLE (Model 1)	QMLE (Model 2)	QMLE (Model 1)	QMLE (Model 2)	QMLE (Model 1)	QMLE (Model 2)	QMLE (Model 1)	QMLE (Model 2)	QMLE (Model 1)	QMLE (Model 2)
LRDINT	6.751***	6.314***	2.288***	2.494***	-8.450***	-8.779***	7.049	7.212	-7.470*	-6.996*	-5.78***	-5.853***
	(4.213)	(3.819)	(2.968)	(3.195)	(-5.710)	(-5.594)	(1.494)	(1.570)	(-1.927)	(-1.819)	(-5.029)	(-4.884)
L.IRMINT	1.439***	1.403***	2.371***	2.504***	2.116***	2.115***	3.271***	3.190***	1.357***	1.371***	0.136	0.131
	(10.21)	(9.886)	(10.39)	(10.55)	(9.933)	(9.919)	(14.99)	(14.59)	(6.803)	(6.842)	(0.472)	(0.463)
LCGINT	-0.750	0.319	0.661	0.761	1.448	1.405	1.361	1.352	1.444***	1.326**	0.850	0.954
	(-1.071)	(0.490)	(0.738)	(0.787)	(1.186)	(1.218)	(1.562)	(1.594)	(2.691)	(2.489)	(1.083)	(1.219)
LRPINT	-25.90***	-27.08***	-0.517	-3.048	3.691*	3.886**	4.707	3.829	-3.361	-3.842*	0.512	0.410
	(-3.254)	(-3.387)	(-0.0938)	(-0.538)	(1.956)	(2.089)	(0.779)	(0.637)	(-1.606)	(-1.819)	(0.319)	(0.248)
LSTINT	-6.139	-3.453	-15.52***	-18.37***	16.59**	14.18**	25.88***	22.09***	1.460	2.696	-3.576	-3.687
	(-1.402)	(-0.803)	(-3.260)	(-3.503)	(2.287)	(2.251)	(4.405)	(3.709)	(0.524)	(0.945)	(-0.748)	(-0.738)
INDRMINT	0.566***	0.558***	1.343***	1.333***	0.460**	0.487**	-0.597***	-0.582***	0.236**	0.203*	0.475***	0.481***
	(5.211)	(5.071)	(7.329)	(7.073)	(2.112)	(2.217)	(-3.609)	(-3.521)	(2.109)	(1.831)	(3.137)	(3.187)
ADVINT	-2.094***	-2.129***	0.475	0.119	-2.277	-1.638	-2.593***	-2.660***	0.449	0.258	9.041***	9.229***
	(-4.835)	(-4.896)	(0.911)	(0.220)	(-1.644)	(-1.250)	(-3.499)	(-3.534)	(0.649)	(0.365)	(8.445)	(8.529)
OUTINT	-0.219	-0.362	-1.271	-1.107	0.0944	0.0606	0.110	0.367	-0.168	-0.0200	1.196	1.360
	(-0.317)	(-0.502)	(-1.405)	(-1.291)	(0.0956)	(0.0609)	(0.113)	(0.387)	(-0.247)	(-0.0295)	(1.397)	(1.505)
AGE	-0.00937***	-0.011***	-0.0196***	-0.022***	-0.0204***	-0.019***	-0.00248	-0.00207	-0.01***	-0.0114***	-0.00243	-0.00243
	(-5.656)	(-6.581)	(-9.956)	(-10.63)	(-5.022)	(-4.636)	(-1.009)	(-0.847)	(-7.796)	(-8.310)	(-0.973)	(-0.969)
SIZE	-0.0327**	-0.0243*	0.160***	0.161***	0.103***	0.108***	-0.107***	-0.096***	0.0227	0.0282*	-0.07***	-0.0770***
	(-2.363)	(-1.759)	(7.307)	(7.112)	(3.578)	(3.690)	(-4.019)	(-3.601)	(1.338)	(1.680)	(-2.715)	(-2.891)
MNC	-0.393***	-0.386***	0.249**	0.238**	0.599***	0.542***	0.113	0.0888	0.209***	0.240***	-0.33***	-0.337***
	(-3.693)	(-3.631)	(2.318)	(2.160)	(4.328)	(3.922)	(0.820)	(0.653)	(2.874)	(3.288)	(-3.428)	(-3.362)
KFIRMS		0.000611		0.000751		-0.00111*		-0.000807		0.00168***		-0.00091*
		(1.518)		(1.271)		(-1.951)		(-1.611)		(4.475)		(-1.887)
PATENT		-5.03e-05		-4.00e-07		-1.01e-05		2.72e-05		-0.0003***		0.0002***
		(-0.794)		(-0.004)		(-0.111)		(0.319)		(-4.719)		(2.63)
EASE		-0.023***		0.024***		0.0113		0.0178**		0.0168**		-0.00725
		(-3.786)		(3.293)		(1.026)		(2.088)		(2.435)		(-0.787)
BANK		4.3e-05**		1.59e-05		7.0e-05***		4.23e-05		6.58e-05***		-6.04e-05**
		(2.228)		(0.749)		(2.960)		(1.640)		(2.821)		(-2.078)
Constant	-1.521***	-1.697***	-2.328***	-2.778***	-2.258***	-2.846***	-2.211***	-2.781***	-2.12***	-2.242***	-2.12***	-2.135***
	(-11.10)	(-8.796)	(-11.31)	(-10.48)	(-9.186)	(-8.358)	(-10.25)	(-9.255)	(-14.71)	(-11.32)	(-8.607)	(-7.016)
Observations	4,988	4,988	2,235	2,235	1,614	1,614	2,722	2,722	4,330	4,330	2,884	2,884
Industry FE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Time FE	Yes	YES	Yes	YES	Yes	YES	Yes	YES	Yes	YES	Yes	YES
Log pseudolikelihood	-1799	-1780	-922.9	-915.3	-582.3	-579	-734.2	-732.3	-1411	-1406	-755.4	-754.1
Wald Ch2	372.1(0.0)	445.9(0.0)	438.9(0.0)	442.8(0.0)	233.3(0.0)	266.2(0.0)	403.2(0.0)	409.5(0.0)	229.9(0.0)	258.4(0.0)	162.9(0.0)	169.3(0.0)

Note: Figure in the parenthesis are robust t statistics, except for the chi2 test. For chi2 test parentheses present probability values.
*** < 0.01, **< 0.05 and * < 0.1

Interestingly, the coefficient of LRPINT is positively significant only for the Computer and Electronics industry (NIC 26). This is not surprising as the proportion of royalties to net sales, profit and capital employed in the electronics industry has increased exponentially after 2006 (Damodaran & Marippan, 2018). In this industry, we also find that the import of raw materials (LIRMINT) and staff training (LSTINT) is also positive and significant, which implies that the recent surge in India's electronics exports can be attributed to technological capability building through the import of technology. A similar process of capacity building is visible in the electrical equipment industry (NIC 27) as well. On the other hand, the technological capability-building in industries like Chemical (NIC 20) and Pharmaceutical (NIC 21) seems to be driven by investments in in-house R&D and the import of raw materials.

However, these processes of technological capability building are not enhancing the firms' export competitiveness in the Automobile industry (NIC 29). Interestingly, export intensity in this industry is affected mainly by firms' expenditure on Advertisement, Marketing and Distribution. Another peculiar case is that of the Machinery and Equipment industry (NIC 28). For this industry, the import of raw materials and capital goods are significantly contributing to firms' export intensity. However, R&D intensity and expenditure on staff training, two important components for building absorptive capacity are negative or insignificant.

When it comes to firm-specific factors, we find only age to be statistically significant for the high-tech manufacturing industry in India. This is in line with the existing studies such as Goldar et al. (2017). An increase in firm's age by one year reduces its exports by 0.001 units, implying that younger firms tend to export more. We find similar results for individual industries as well. However, other firm-specific variables such as Size and MNE affiliation are significant with varying signs for individual industries, even though they are insignificant for all high-tech manufacturing. Our results partially support the common explanation that firms in developing countries adopt cost-effective strategies to improve export performance. The use of domestic raw materials has a positive and significant impact on the export intensity of firms in overall as well as individual specifications. However, outsourcing manufacturing jobs and professional services does not seem to significantly affect export. Our results indicate that region-specific factors except for access to finance (BANK) are insignificant in explaining firms' export intensity for HT firms. Even though 'ease of doing business' (EASE) and BANK are significant for a few individual industries, their coefficients are very small and hence have less explanatory power.

From the above discussion, we can summarize that firms' technological capabilities play a major role in determining their export intensity.

5. Conclusion

The last two decades have seen a phenomenal growth in high-tech exports from developing countries. India's case is no different as we see its exports of technology-intensive manufacturing products have grown exponentially in the period after 2008. The literature points out that this is a 'statistical illusion' as developing countries' high-tech exports are driven by their participation in the low-cost segments of high-tech products. However, we believe that technological upgradation also has a role to play in explaining India's high-tech export growth. We show this using firm-level data of the high-tech manufacturing industry in India for the period 2008 to 2020. Technological upgradation at the firm level happens through capability-building using the purchase of foreign technology, together with in-house R&D and skill development of workers. Investment in R&D and human capital not only improves firm export directly but also creates the absorptive capacity required for the effective utilization of imported technology (Lall, 1992; 1999; Cohen & Levinthal, 1990). Our results indicate that all the above technological factors have a positive and significant impact on firms' export intensity in the high-tech manufacturing industries. However, at the individual industry level, expenditure on R&D is relevant in explaining the capability building and export intensity of the Chemical (NIC 20) and Pharmaceutical (NIC 21) industries, staff training expenditure is significant for Electronics (NIC 26) and Electrical (NIC 27) industries. Both these processes of technological capability building are absent in the Motor Vehicle Industry (NIC 29) where export seems to be driven by advertising, marketing and distribution expenditure (ADVINT). Our results also partially support the hypothesis that firms opting for low-cost strategies have higher export intensity, as indicated by the positive and significant coefficient of domestic raw material intensity.

Our study shows that to sustain in the dynamic and competitive export market, firms should continuously build their in-house capabilities through investments in R&D and human capital, apart from purchasing frontier technology from advanced countries. The current R&D tax credit system incentivizes large firms to invest in capacity building. However, smaller firms may not be able to afford this. Government should support such firms through specialized technical skilling initiatives and dedicated R&D grants.

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Appendix

Table A1: Number of firms and observations

Industry Name and its NIC code	Number of firms	Number of observations
Manufacture of Chemicals and Chemical Products (NIC 20)	594	5,743
Manufacture of Pharmaceuticals & Medicinal Chemicals (NIC 21)	266	2,580
Manufacture of Computer & Electronic (NIC 26)	223	1,909
Manufacture of Electrical Equipment (NIC 27)	340	3,155
Machinery & Equipment (NIC 28)	573	5,046
Manufacture of Motor Vehicles (NIC 29)	338	3,285

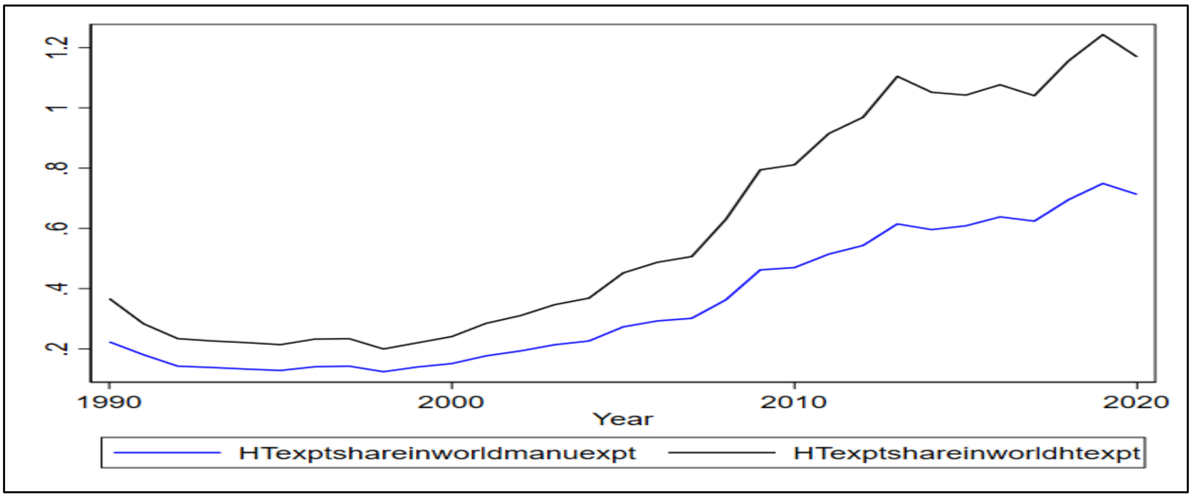
Table A2: Descriptive statistics of all HT industries

Variables	Observations	Mean	Std. Dev.	Min	Max
EXPINT	21,718	0.16	0.24	0.00	0.99
RDINT	21,718	0.01	0.03	0.00	0.90
IRMINT	21,718	0.10	0.16	0.00	0.99
CGIINT	21,718	0.01	0.04	0.00	0.89
RPINT	21,718	0.00	0.01	0.00	0.57
STINT	21,718	0.01	0.01	0.00	0.39
INDRMINT	21,718	0.22	0.24	0.00	1.00

Variables	Observations	Mean	Std. Dev.	Min	Max
ADVINT	21,718	0.04	0.05	0.00	0.90
OUTINT	21,718	0.01	0.05	0.00	0.95
AGE	21,713	32.34	17.36	3.00	141.00
SIZE	21,718	6.31	1.77	-2.38	13.03
MNC	21,718	0.13	0.33	0.00	1.00
KFIRMS	21,718	222.44	169.35	0.00	533.00
PATENT	21,718	1847.03	1472.04	0.00	5225.00
EASE	21,718	11.03	5.57	1.00	26.00
BANK	21,718	7671.96	3496.75	18.00	17902.00

Source: Author's Computation

Figure A1: Share of India's HT export in Worlds' manufacturing export and World's HT export.



Source: Author's Computation

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