TECHNOLOGICAL DETERMINANTS OF COMPETITIVE ADVANTAGE IN THE INDIAN MACHINERY INDUSTRY

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Abstract

In the analytical framework of Resources Based View, competitive advantage is often defined in terms of a firm's superior efficiency, market share or financial performance in an industry. Adopting this framework, the study examines the technological determinants of firm-level competitive advantage, measured as technical efficiency, in the context of Indian machinery industry (IMI). To undertake this task, I first compute the firm- and year-specific technical efficiency by estimating a stochastic frontier production function with the help of an unbalanced panel of data on a sample of 178 firms for 7 years covering FY 2000/01 to FY 2006/07. Thereafter, I estimate a random-effect panel data model with Tobit specification for analysing the determinants of technical efficiency.

The study finds that a firm in IMI could improve its competitive advantage by enhancing its technological *resources and capabilities* through attraction of FDI, import of disembodied technology, in-house R&D, import of intermediate goods and use of capital intensive techniques of production. As a byproduct, the study also finds that the larger size firms to be more efficient (than smaller ones); firms deploying higher amount of owned fund as a ratio of its total liability, firms with higher product differentiation and based in less concentrated sub-industries of IMI to be more efficient.

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[1] This research paper is a revised chapter of author's doctoral thesis entitled "Comparative Performance of Foreign Controlled and Domestic Firms in the Indian Non-electrical Machinery Industry: A Micro-level Study" on which JNU, New Delhi has awarded Ph. D. in the year 2011. The author gratefully acknowledges the encouragements and comments provided by Prof. N. S. Siddharthan, MSE, Chennai while writing the thesis. The views expressed in this article are entirely personal and cannot be attributed to the organization (IDBI BANK) in which the author serves or the scholars who have given useful comments on the paper.

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1. Introduction

Indian Machinery Industry (IMI) represents *manufacture of machinery and equipment n.e.c.* that is the division 28 in National Industrial Classification: All Economic Activities-2008 (NIC-2008). It comprises two types of machinery producing industries, namely, general-purpose machinery (or group 281) and special purpose machinery (or group 282) at three digit level of NIC-2008. Following import substitution strategy of development, Government of India promoted this industry (notably special purpose machinery segment of this industry) through public investment, as an important part of capital goods sector. As a result, production capacities were built in important segments of this industry. There are some evidence based on industry/enterprise surveys and data pertaining to the post 1991 reform period that the major part of capital goods industry: i) has been unable to enhance its production capacity (in line with rising domestic demand); ii) lacks competitive advantage due to firm-specific factors like deficient technological capabilities, management and operational inefficiencies, inferior quality and finish of goods, lack of global market orientation as well as external factors such infrastructure bottlenecks, higher rate of interest, high incidence of indirect taxes etc. as compared to the competitors in China, Taiwan and Korea; iii) has failed to address the challenges arising from the increasing imports of finished goods (viz. second-hand machinery) by the user industries (CII 2007, EXIM Bank 2008). In post-WTO era, restricting imports is neither possible nor desirable. Therefore, the firms based in the IMI are required to develop additional production facilities with their due focus on achieving sustainable competitive advantage so as to check influx of imports. In this background, the present paper attempts to examine the firm-specific determinants of competitive advantage in IMI by using econometric methods.

Adopting resources based view (RBV), the study defines competitive advantage by its major dimension technical efficiency and thereby analyse its determinants. Among the probable determinants of technical efficiency, it focuses on the firm-specific technological factors.[2] The study is conducted in two stages. In the first stage, I compute the firm- and year-specific

[2] Efficiency performance of a firm in an industry is affected by external as well as internal factors. The study assumes that the external factors (e.g. demand and policy environment) affect all the firms in an industry in the same manner and the firms have little control over the external factors. However, it also examines the impact of some external factors, which are used as control variables such as sub-industry level characteristics, market concentration and time dimension, on the technical efficiency.

technical efficiency which is defined as the ratio of its mean output (conditional on given combination of input levels and firm effects) to the corresponding mean output represented by a stochastic frontier production function (SFPF) (i.e. when the firm could produce maximum output from the same combination of input levels) (Battese and Coelli 1992). In the second stage, I estimate a random-effect panel data model with Tobit specification for mainly examining the technological determinants of firm-level technical efficiency. These determinants include a set of proxy variables (viz. capital intensity, R&D intensity, firm's age, intensity to import intermediate goods, intensity to import disembodied technology, export propensity, foreign ownership) measuring technological capability and a set of control variables (e.g. firm-size, advertising and marketing intensity, networth, index of market concentration). I undertake these exercises with the help of an unbalanced panel of data, mainly drawn from PROWESS[3], on a sample of 178 firms belonging to the Indian Machinery Industry (IMI) covering 7 financial years 2000/01 to 2006/07.

The present study is noteworthy for the following reasons: First, this is the first firm-level study in IMI that examines the technological determinants of technical efficiency (competitive advantage) by estimating a panel data Tobit model for the post 1991 reform period of 2000/01 to 2006/07. Secondly, the Indian companies have adopted better accounting standards since 2000/01, which has made the presentations and descriptions of financial statements more detailed, transparent, accurate and uniform across the firms (Mukherjee 2008, Chapter 3). As our study uses firm-level data originally sourced from the annual reports of the companies containing audited financial statements, these developments add additional feature to our study against the studies that have used data pertaining to the period prior to the year 2000. Finaly, I select only one industry to reduce heterogeneity across industries and use panel data model to control firm-level hetrogeniety (which may arise due to firm-specific product profile, culture, routines, etc.) within the selected industry.

Rest of the study is organised in six sections. Section-2 explains status and characteristics of IMI. Section-3 briefly discusses the theoretical framework and formulates verifiable hypothesis regarding the relationship between technical efficiency and its various determinants. Section-4 discusses the sample, data sources and rationale for the selected period for the study. Section-5 explains the econometric models and procedures for deriving technical efficiency and analyzing the determinants of technical efficiency. Section-6 presents and discusses the findings of the empirical analysis. Section-7 offers summary and conclusions.

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[3] PROWESS is an electronic database containing financial statements and other information of more than 10000 Indian public, private, cooperative and joint sector companies, listed or otherwise. This database covers approximately 70 per cent of the economic activities of the country. The Indian researchers have been increasingly using this database [e.g. Driffield and Kambhampati (2003), Goldar et al. (2004)].

2. Indian Machinery Industry-The Focus of Study

The firms based in IMI are heterogeneous in terms of product profile, user groups, technological capability, size, ownership groups, etc. Yet, IMI falls into the group of production intensive *specialized suppliers* in terms of Pavit's (1984) classification based on the technological characteristics, requirements of the users and appropriability regime.

The IMI constitutes about 3.76 per cent weight in India's index of industrial production (base 2004/05) with approximately Rs.1 lakh crore of market size at current prices. In terms of its share in total imports and exports in 2006/06, IMI accounted for 8 per cent and 5.3 per cent respectively. Besides, IMI shared 5.1 per cent in cumulative amount of FDI and 16.6 per cent in cumulative number of approvals for foreign technological collaborations entered during August 1991 to July 2007 in the Indian manufacturing sector. Notably, IMI entered into the highest number of foreign technological collaborations but ranked only fifth among the industries receiving FDI in the Indian manufacturing sector (Keshari 2010, pp.63-66).

Machinery industry being a technology and skill intensive has potential for important source of innovations and higher value addition with higher margins and growth prospects as compared to the mature low-technology industries, in which intense competition has shrunk margins and lowered growth prospects. It can also generate significant intra-industry and inter-industry externalities due to its linkages with other sectors of the economy. As the machinery industry supports the other sectors of economy and holds strategic importance, the Indian policy makers, including those who laid the foundation for the import substitution industrialization in the early 1950s, considered the indigenous growth of machinery industry to be paramount importance for the country.

A firm in this industry builds technology based competitive advantage in the following manner: i) through product innovations including design and drawings (basic as well as detailed) capabilities, ii) through process innovation and production engineering including mastery of a range of manufacturing processes such as machining, welding, assembly and shop floor based problem solving related to the running, maintenance and repair of plants, iii) by improving performance of machines and their components in terms of reliability, precision, durability and finish.

Over 40 years' period during 1950/51-1990/91, IMI grew manifold and started producing a wide range of products needed in the country. The adoption of outward oriented growth strategy and economic reform measures implemented since the year 1991 have brought forth the weaknesses of IMI in terms of its lack of international competitiveness causing Indian firms to import finished goods rather than procure them domestically. The internal factors responsible for this phenomenon are identified as inadequate technological capability, management and operational inefficiencies, global marketing and customer orientations, etc. The Indian machinery manufacturing firms have developed adequate productionising capability. However, they lack expertise in regard to product designs and drawings-basic as well as detailed.

Firms are unable to produce quality products due to less expertise in precision measuring, material engineering and process control and lack of focus on maintaining aesthetic and finish of the final good. The defect rates of final products are quite high as about 20% firms use obsolete machinery and equipment. The operational efficiencies of firms in IMI are generally low. Most of the domestic firms do not use techno-managerial processes like just-in-time, total quality management, total production management, etc. for making their business processes like procurement, distribution, marketing and servicing more efficient. Except in a few product groups (e.g. earthmoving) quality consciousness is low in most of the product groups of IMI. Besides, most of the domestic companies spend inadequate resources on training their employees for achieving world-class bench marking in productivity and quality.

Indian firms invest less in marketing activities and have low customer orientation. Very little effort is made on branding. Investments in marketing, increased customer orientation and branding could act as entry barriers for foreign firms into the Indian market. The sale of machinery, particularly heavy machinery and equipment, is not a one-time transaction and is generally followed by technical support in transportation, erection, training, continuous service maintenance and periodical upgrade of technology. Trends in international market suggest that foreign firms are increasingly adopting solution-based approach to selling while Indian domestic firms continue to adopt a product-oriented approach towards their customers (CII 2007, EXIM Bank 2008).

Traditionally, USA, Germany and Japan have been the largest suppliers of IMI. Of late, Asian countries such as China, South Korea and Taiwan are also emerging as the important players in the production and export of IMI. Consumption of IMI has also increased substantially in the developing Asian countries due to their thrust on the value-added manufacturing. The shifting base of machinery and equipment production from the developed to developing countries is also providing major opportunities of production and exports from technologically advanced countries of the developing economies like China, India, South Korea, etc. In the year 2005, the countries like China and South Korea respectively shared 7 per cent and 4 per cent in the world's total production of IMI, while India's share was insignificant 1.4 per cent, indicating ample scope for expansion in its market share. (EXIM Bank 2008).

Despite various kinds of problems being faced by IMI, its low level of market share in the world production and exports and strategic importance of the industry for the entire economy, we do not find any econometric study exclusively focusing on the micro-level determinants of efficiency in IMI.

3. Analytical Framework, Explanatory Variables and Hypotheses

This study mainly utilises the Resource-based View of Firm (RBV) as the general framework for examining the technological determinants of competitive advantage measured as technical efficiency. The researchers subscribing RBV look for possible causes of sustainable competitive advantage mostly within the *resources and capabilities* of a firm, holding constant all external environmental factors. RBV is based on two major assumptions (Peteraf and Barney 2003): First, firms are fundamentally heterogeneous in terms of their bundle of resources and capabilities within an industry. Second, resource heterogeneity may persist over time because the resources used for acquiring competitive advantages are rare, valuable, imperfectly imitable, imperfectly substitutable and imperfectly mobile in strategic factor markets. The RBV provides an efficiency based explanation of performance. It suggest that a firm builds competitive advantage only through efficiency or effectiveness in use of its resources, i.e., by producing more economically from the set of resources it holds and by delivering greater benefits to its customers at a given cost (or the same benefits at a lower cost) (Peteraf and Barney (2003).

The RBV divides resources into two major heads, namely *tangible resources* and *intangible resources* (or *assets*). The tangible resources include financial, physical and human capital. These resources possess fixed long-run capacity and properties of ownership and are relatively easy to be measured, traded and duplicated (Fahy and Smithee 1999). Intangible resources (or assets) consist of intellectual property rights (e.g. trademarks, patents, copyrights, registered designs, and brands), contracts (viz. agency agreements, license agreements, property lease), organizational and marketing expertise, trade secrets, reputation or goodwill and networks with customers, suppliers, government organizations, research institutes, etc. (Fahy and Smithee 1999). In comparison to tangible resources, *intangible assets* do not diminish by extra use; they are relatively resistant to duplication and difficult to be measured, valued and traded (Fahy and Smithee 1999, Barney 2001). Thus, the intangible resources are more important source of heterogeneity and divergence in competitive advantage and performance across firms.

The capability is defined as a capacity to perform some task or activity by effective cooperation and coordination of team of resources for maximizing efficiency (or profit). Examples of a firm's capability include highly reliable services, repeated process or product innovation, manufacturing flexibility, responsiveness to market trends, and short product development cycles [Fahy and Smithee (1999)]. Capabilities can also be thought of as intermediate goods generated by a firm to provide enhanced productivity of its resources as well as flexibility and protection for its final product or service through information-based capabilities (e.g. brand names).

RBV gives paramount important to efficiency enhancing technological resources and capability. A firm in IMI may develop technological resources and capabilities in the following ways: a) foreign affiliation through FDI; b) import of disembodied technology in an arm's length transaction; c) import of intermediate goods (raw material, spare parts and capital goods) involving embodied technology; d) by employing capital intensive technologies; e) exposure to international market through exports and imports; e) in-house research and development; f) learning by doing or experience. It is therefore predicted that technological resources and capabilities obtained through each avenue shall improve the firm level technical efficiency.

Foreign affiliation through FDI: FDI may play a major role in enhancing the efficiency of a firm in industry in a host economy for the following reasons (Dunning 2000): First, foreign affiliated firms (FAFs) through FDI, may have access to efficiency enhancing *technology* and skills from their corresponding Multinational Enterprise (MNE) network; secondly, FAFs may also identify, evaluate and harness technology and skills present in the host country and combine these with their internal technological *capabilities* for maximizing the benefits of innovation, learning and accumulated knowledge. First and second together may lead to higher level of efficiency for FAFs in relation to the existing domestic firms (DFs) in the industry. Besides, when FAFs with their superior *resources and capabilities* interact, transact and compete with DFs for a reasonable length of time in an industry, the latter group may also realize efficiency gains, mainly through two channels: the competition effects and knowledge spillovers[4] generated by demonstration/imitation effects and movement of employees with superior skill set from FAs to DFs (Smeets 2008). It is also possible that less efficient DFs may not withstand competition generated by FAFs and thereby quit the industry. In both the cases, efficiency level of IMI shall improve. IMI is a heterogeneous industry in which some segments of the industry may be more attractive for FDI than others. Therefore, the efficiency gains realized by a sub-industry due to the presence FAFs may vary among sub-industries of IMI. I test two hypothesise that: i) FAFs are more efficient than DFs and ii) a firm operating in a sub-industry with higher share of FAFs output will be more efficient than a sub-industry with lower share of FAFs' output.

***Intensity to Import Disembodied Technology* (IMDT):** Arms length import of disembodied technology fills the gap (e.g. the lack of basic or/and detailed designs and drawings capabilities in IMI) in domestically available technology. By using imported disembodied

[4] Knowledge externalities or spillovers at firm level is defined as the diffusion of knowledge created by one firm or a group of firms (e.g. FAs) to the other firm or group of firms (e.g. DFs in our case) without the latter (fully) compensating to the former (Smeets 2008). The knowledge spillovers differ from knowledge transfer or technology transfer in the sense that the latter involves voluntary diffusion or transfer of knowledge creating no externality (Smeets 2008).

technology a firm may either introduce a new or improved version of a product in the market or increase efficiency in the use of resources in the plant. In the former cases, the firm's revenue earning capacity may increase while in the latter case, the firm may save on its resources. Thus, I expect a positive relationship between TE and IMDT.

Capital Intensity **(CAPI):** Being a medium and high technology producer goods industry, the goods produced in IMI are required to have high level of precision, performance, finish, quality, etc. Therefore, the efficiency enhancing efforts of a firm may require higher use of information and communication technology, greater automation and frequent modernisation of its plant and machinery. Besides, as the opportunity cost of unused plant and machinery could be very high, firms shall be under pressure to use their machinery and equipment efficiently. Technical efficiency is expected to be positively related to CAPI.

Intensity to Import Intermediate Goods **(IMIG):** The import of intermediate goods, including raw material, capital goods, spare parts and stores, may add to the technological strength of a firm and fulfill the special quality or production requirements of the final goods that cannot be met through the domestically available inputs (in some cases relevant inputs may not be domestically available at all). Therefore, a firm with higher intensity to import intermediate goods may produce output with greater value addition or produce the same output with savings on the resources. I hypothesize a positive relationship between technical efficiency and IMIG.

Export Intensity **(XD):** Export activity makes a firm more efficient on account of knowledge spillovers from its competitors and customers besides its exposure to more competitive (and sometimes advance) international market (Wagner 2007). Global value chains (GVCs) approach emphasises the importance of export activity in enhancing the technological capabilities (i.e. learning by exporting) of a firm. GVCs are increasing present in IMI due to the liberalization of national and international regulatory framework (Pietrobelli 2007). Thus, I expect firms undertaking export activity to be more technically efficient than those with no exports.

Research and Development Intensity **(RDI):** The most of the existing firms in IMI invest in R&D mainly to develop *in-house technological capabilities* in the form of production engineering, which include operating existing plants and machineries more efficiently; assimilating, absorbing and adapting (to local conditions) the imported embodied and disembodied technology; shop-floor based problem solving related to running, maintainance and repair of plants (CII 2007, EXIM Bank 2008). As most of these activities are efficiency enhancing, the higher R&D expenditures by firms in IMI may lead to higher technical efficiency. I therefore expect a positive relationship between TE and RDI.

***Firm's Age* (AGE):** The firm's age acts as a proxy measure for its maturity, accumulated experience or learning. Thus, it may also capture the technological capability acquired by a firm over the years in various areas of execution, operations, maintenance of plant and machinery. it is expected to have a favourable impact on TE. On the contrary, if a firm's age reflects the plant vintage and/or rigidity in outlook or inflexibility towards the changing market conditions, it is expected to have negative influence on TE. Thus, the relationship between TE and firm's age cannot be predicted on *a priori* basis.

Control Variables

***Advertising and Marketing Intensity* (AMI):** Advertising and marketing is used as an important means for creating product differentiation by promoting corporate image, brand equity and customer loyalty. Hence, higher AMI may lead to higher sales.

***Firm Size* (SZ):** Major factors differentiating a small size firm from a large size firm are the latter's command over a large amount of resources and its diverse capabilities (e.g. risk bearing and innovatory capability), benefits of economies of scale and scope in production and bargaining power in accessing financial resources and factors of production from the market. Based on some these benefits of large size, Hirsch and Adler (1974) suggest a positive relationship between firm-size and efficiency. A negative relationship between firm size and efficiency may also exist due to the following reasons: a) the larger firms are generally afflicted by complex bureaucratic rules causing lack of human relationship and motivation to work, therefore, they may suffer more technical inefficiency than the smaller ones (van den Broeck 1988); b) the large size may confer higher degree of market power to a firm (Shepherd 1972), therefore, the bigger firms may feel reduced necessity for gaining competitiveness through efficient utilization (and allocation) of their resources. Thus, the net outcome of the positive and negative factors associated with the larger size firms shall determine the outcome of the relationship between technical efficiency and SZ.

Networth Intensity (NWI): Companies with higher networth (owned fund) may have greater involvement of promoters in improving the performance of the company. Besides, networth also acts as a cushion for undertaking expansion or modernisation of its plants and risk taking activities like R&D and exports. Thus, NWI, a ratio of net worth to total liability, is expected positively affect technical efficiency.

***Index of Market Concentration* (IMC):** Existence of monopoly power or market concentration leads to slack or lack of efforts on the part of managers and workers of a company. Besides, the market leaders in concentrated market structure may prevent entry of superior firms and thereby delay the diffusion of information, technical knowledge and experience-sharing. Thus, the industries with concentrated market structure may adversely affect firm-level efficiency. IMI consists of many sub-industries with varying levels of market (sellers) concentration. I construct a firm-specific index of market concentration (IMC) which is expected to affect technical efficiency negatively.

Year-specific Dummy **(YD):** TE of the firms are expected to be influenced by year to year changes in external factors such as changes in industrial policy, competitive conditions, supply and demand conditions, etc. To account for such factors, I employ 6 additive year-specific dichotomous dummy variables (YD), corresponding to the 6 year of the study covering the 2001/02 to 2006/7 with reference to the year 2000/2001. Table-1 presents the explanatory variables used in the model, their measurements and expected relationship between technical efficiency and the explanatory variable.

Table-1

Variable	Definition	Expected relationship with technical efficiency
FCD	FCD is a dichotomous additive dummy variable which takes the value 1 for FAFs and 0 for DFs. A firm is defined as a FAF (or DF) if a foreign promoter holds at least 26 per cent (or less than 26 per cent) share in the paid-up capital of the company[5].	**Positive**
DFO	As a firm may operate in multiple sub-industries of IMI, I construct a firm-specific index of degree of foreign ownership (DFO). DFO is computed as the weighted average of FAFs' share in gross sales of each of the sub-industries of IMI in which the firm operates. For this purpose, IMI is categorized into 8 sub-industries including prime movers, engines, boilers and turbines; fluid power equipment, pumps, compressors, taps and valves; bearings, gears, gearing and driving elements; agricultural and forestry machinery; metal forming machinery and machine tools; machinery for lifting and handling goods/humans, earthmoving, mining, quarrying, construction; machinery for food, beverages and tobacco processing; machinery for textiles apparel and leather production. A minimum 51 per cent of gross sales made up from a sub-industry in a particular financial year is used as the norm for this reclassification.	**Positive**
IMDT	Ratio of a firm's expenditure on payments of royalty and	**Positive**

[5]The adoption of this criterion is justified on two grounds: First, a foreign promoter can effectively control an Indian company with a minimum of 26 per cent equity holdings in the paid up capital of a public limited company since the Indian Company Act 1957 gives to a single entity (or a group of shareholders) with 26 per cent equity the power to block special resolution, involving several important proposals and diversified nature of equity holding in the Indian companies (Majumdar 2007). Similar studies on India have adopted various criterions for defining FAFs ranging from 10 per cent foreign share-holding to 51 per cent. Secondly, the sharing of resources and cross-border value adding activities can take place in a firm even with MNE affiliation involving minority percentage of equity holding (Narula and Dunning 2010).

	technical fees for the import of disembodied technology	
IMIG	Ratio of a firm's combined expenditure on import of raw material, components, spare parts and capital goods to net sales.	**Positive**
CAPI	Ratio of a firm's original cost of plant and machinery to its wage bill.	**Positive**
XD	Dummy variable takes value 1 for exporting firm and 0 for non-exporting ones.	**Positive**
RDI	Ratio of R&D expenditure to net sales.	**Positive**
AGE	Age of a firm is measured by the difference between its year of presence in the sample and its year of incorporation. As every year of operation may not add significantly to the experience (or plant vintage), I use natural logarithm of firm's age (AGE) to reduce the variability.	**?**
AMI	Ratio of a firm's expenditure on advertising and marketing to net sales and expect TE to be positively related to AMI.	**Positive**
SZ	Natural logarithmic value of net sales of a firm in a year. This measure of firm size reduces degree of variability in size across firms and thereby avoids the problem of heteroskedasticity in the estimation of a regression equation.	**?**
NWI	Rratio of net worth (equity capital plus reserves excluding revaluation reserves) to total liability.	**Positive**
IMC	Sales weighted average of an index of four-firm seller concentration ratio (SCR4) of each of the sub-industries of IMI in which a firm operates.	**Negative**

4. Sample and Data Sources

Empirical analysis in this study employ a sample of 178 firms (including 43 FAFs) belonging to IMI, with 940 observations spread over 7 year's period (2000/01 to 2006/07). I include all those firms in the sample for which data on each of the variables used for the study are available in PROWESS for at least 2 years of the study. Besides, I do not include sick companies, i.e., the companies with negative networth in a financial year, mainly with a view to remove probable outlier effect on the empirical analysis. Thus, the number of firms included in the sample being used in the study is smaller than that covered in the PROWESS database. In the PROWESS database of IMI, the sample firms shared 68 per cent of sales turnover, 85 per cent of net worth, 74 per cent of gross fixed assets, 69 per cent of total assets, 66 per cent of exports and 74 per cent of imports; where data on each variable is aggregated over 2000/01 to 2006/07. Considering the fact that PROWESS covers almost entire corporate sector and 70 per cent of the manufacturing activity, this sample with such shares can be considered as the good representative of the IMI.

The study sources major portion of the basic data for designing several variables from the PROWESS itself. The PROWESS database, however, provides inadequate data on the foreign promoter's equity participation in a firm. I supplemented the same from other databases (viz. *Bombay Stock Exchange Directory* and *Capital Line Ole* -another electronic database) and *Annual Reports* of some companies. I also acquired data from *Industry Market Size and Share* published by the Centre for Monitoring Economy chiefly for constructing the variable IMC. Data on price deflators for each year of analysis is collected from various publications of the Government of India (GoI). I use relevant product/industry-wise data on *Wholesale Price Index* (base year 1993-94) from the WPI series published by the Office of Economic Advisor (OEA) and data on the *All India Consumer Price Index Numbers (General) for Industrial Worker* (base year 1982) from the Labour Bureau. With the help of compiled data, I design appropriate firm-level and sub-industry level indicators as discussed in the last section.

Table-2 reports the descriptive statistics of individual variables used in the study. Matrix of correlation coefficients of variables, as summarized in Table-3, and presentation on computations on variance inflation factor and tolerance factor in Table-4 reveal no serious multicolinearity problem either in terms of the rule of thumb for the pair-wise correlation coefficients between two regressors (> 0.80) or the rule of thumb for the variance inflation factor (>10) for the individual regressors.

5. Econometric Models and Procedure

5.1 Computing Technical Efficiency through SFPF

To study the efficiency gains from FDI, I require firm and year specific technical efficiency. For this purpose, I prefer to employ Battese and Coelli's (1992) formulation of SFPF model and its estimation by readily available software FRONTIER 4.1.[6] Some comparable studies (e.g. Driffield and Kambhampati 2003 and Goldar et. al 2004 in the case of India) have been using this model (or its simple variants) and software for computing technical efficiency and examining the determinants of technical efficiency including foreign ownership. To empirically estimate a SFPF model, I select a Cobb-Douglas form of production function for its simplicity[7] and estimate its log linear form. The model is defined by:

$$\ln Y_{jt} = b_0 + b_1 \ln M_{jt} + b_2 \ln L_{jt} + b_3 \ln K_{jt} + V_{jt} - U_{jt} \qquad (1)$$

[6] The software FRONTIER 4.1 estimates SFPF as well as gives the estimates of firm- and year specific technical efficiency even in the case of unbalanced panel data (Coelli 1996). The software and literature on the same is available on internet as free download.
[7] Researchers (e.g. Driffield and Kambhampati 2003) do not report significant differences in the estimation results obtained either Cobb-Douglas or an alternative form trans-log specification.

$U_{jt} = \exp\{-\eta(t-T)\}.U_j;$ (2)

The Y, M, L and K represent output, material input, labour input and capital input respectively. Construction and measurement of these variables are discussed in Appendix. The subscript j (j = 1,..., N) refers to the j-th sample firm (or group); t (t = 1,…,T) represent year of operation. The ln symbolises natural logarithm; b_0, b_1, b_2, b_3 are unknown coefficients to be estimated; random error V_{jt}, assumed to be independently and identically distributed (iid) as $N(0, \sigma_v^2)$, reflect two-side "statistical noise" component that accounts for the effect of random factors such as the measurement error, luck, machine performance, etc.; V_{jt} are also assumed to be independent of U_{jt} and the input vector; U_j are non-negative random variables and are assumed to be iid as truncations as zero of the $N(\mu, \sigma_u^2)$ distribution; U_j are assumed to capture technical inefficiency in production, since the non-negative assumption of U ensures that the firm's actual production point lies beneath the stochastic frontier. Eta (η) is an unknown scalar parameter to be estimated.

Given the model (1) – (2), Battese and Coelli's (1992) defines operational (minimum-mean-squared-error) predictor of technical efficiency of firm j for the year t (i.e. TE_{jt}) as:

$$E[\exp(-U_{jt})|\, W_j] = \frac{1 - f[\eta_{jt}\,\sigma_j^* - (\mu_j^*/\sigma_j^*)]}{1 - f(-\mu_j^*/\sigma_j^*)} \exp[-\eta_{jt}\,\mu_j^* + (1/2)\,\eta^2_{jt}\,\sigma_j^{*2}] \quad (3)$$

where W_j represents the (T_j X 1) vector of W_{jt} associated with the time periods observed for the j^{th} firm, where $W_{jt} \equiv V_{jt} - U_j$;

$$\mu_j^* = [\mu\,\sigma_v - \eta_j' W_j\,\sigma^2] / [\sigma_v^2 + \eta_j'\eta_j\,\sigma^2] \quad (4)$$

$$\sigma_j^{*2} = [\sigma_v^2\,\sigma^2] / [\sigma_v^2 + \eta_j'\eta_j\,\sigma^2] \quad (5)$$

where η_j represents the (T_j X 1) vector of η_{jt} associated with the time periods observed for the j^{th} firm. The function f (.) denotes the probability distribution function (pdf) for the standard normal variable. The SFPF model, defined by equations (1) and (2), contains four b-parameters and 4 additional parameters (σ^2, γ, η and μ) associated with the distributions of the V_{jt} and U_{jt}. By using FRONTIER 4.1, I obtain maximum likelihood estimates of these parameters as well as the operational predictor of TE_{jt} by substituting the relevant parameters by their maximum likelihood estimates in equation (3).

5.2 <u>Model for Determinants of Technical Efficiency</u>

We employ random effect panel data regression model with Tobit specification to analyse the determinants of TE. Use of Tobit model is necessitated by the fact that the technical efficiency estimates range between zero and one. Thus, the distribution of efficiency is truncated above unity. If the OLS (or GLS) method is applied in this case, then the parameter estimates will be biased. The usual way of handling this problem is to use a limited dependent variable models such as Tobit. The use of panel data improves the efficiency of econometric estimates on account of larger number of observation compared to the individual data set of cross-section or time series. Besides improving the efficiency the application of panel data model in this study shall enable us to control for time invariant firm-specific heterogeneity in TE arising from the unobserved firm-specific characteristics such business practices and culture, routine, trade secrets, preferences, etc. The empirical form of the model is symbolically represented by the following equation:

$$TE_{jt} = b_0 + b_1\ FCD_{jt} + b_2\ DFO_{jt} + b_3\ IMDT_{jt} + b_4\ CAPI_{jt} + b_5\ IMIG_{jt} + b_6\ XD_{jt} + b_7\ RDI_{jt} + b_8\ AGE_{jt}\ b_9\ AMI_{jt} + b_{10}\ SZ_{jt} + b_{11}\ NWI_{jt} + b_{12}\ IMC_{jt} + b_{13} YD02 + \ldots + b_{18}\ YD07 + u_j + v_{jt};$$

$$j = 1, \ldots ,178 \text{ and } t = 1, \ldots ,7;\ \ TE_{jt} = TE_{jt}^{*} \text{ if } TE_{jt}^{*} > 0;\ TE_{jt} = 0 \text{ if } TE_{jt}^{*} \le 0 \ \ldots\ldots\ldots \ (6)$$

Where the term u_j are unobserved stochastic heterogeneity varying across groups but not over time while error term v_{jt} vary across groups and over times and $v_{it} \sim IID\ (0, \sigma_v^2)$. The term u_j are assumed to be uncorrelated with explanatory variables in equations (6).

6. Results and Discussions

6.1 SFPF and Technical Efficiency

Table-3 presents the results of the maximum likelihood estimates of parameters of SFPF. The results show that the ML estimates of coefficients, signifying elasticity of output with respect to material, labour and capital input, are statistically significant. Elasticity of output with respect to material input (0.71) is the highest and substantial, followed by elasticity of output with respect to labour (0.14) and capital input (0.10) respectively. Although the value of the coefficient associated with material input is substantial, it is much less than the unity which justifies the use of three input production function. Notably, when one uses two input production function, ignoring raw material, one implicitly assumes that the coefficient associated with material input is close to unity. Further, return to scale, measured as a sum total of these elasticities (0.95), is close to unity, indicating that the production technology is characterised by constant returns to scale.

The analysis of data on the firm specific and year-specific TE_{jt} suggests that: (a) the mean value of TE works out to 71 per cent with higher between variation (0.084) than the within variation (0.003) as measured by standard deviation; (b) group of FAFs with mean TE of 74 per cent is more efficient than the DFs with mean TE of 70 per cent; c) the most technically efficient firm with mean TE of 99.3 per cent belongs to the group of FAFs whereas the least technically efficient firm with mean TE of 55.5 per cent belongs to the group of DFs; d) five most technically efficient firms in the sample includes two FAFs, each one with mean TE of 99 per cent and 97 per cent, and three DFs, each one with mean TE of 96 per cent; e) five least efficient firms belong to the group of DFs which include two firms with 58 per cent, one with 56 per cent and two with 55 per cent technical efficiency.

6.2 The determinants of Technical Efficiency

Table-6 presents the results obtained from the Tobit estimates of the equation (6). It shows that Wald chi^2 statistics corresponding to the estimated equation is quite high and significant, suggesting that the equation enjoy significant explanatory power in terms of the independent variables used for explaining TE. I now discuss the results in respect of each explanatory as presented in Table-6.

The coefficients of FCD and DFO are statistically significant and positive. These results imply that the FAFs on an average are more technically efficient than the DFs and sub-industries with higher presence of FDI are also more efficient, even after controlling for observed and unobserved factors including firm-specific heterogeneity, industry segment effect and year wise effect in data. This result is in line with our hypothesis and the findings of several studies, notably the one comparable study on Indian engineering firms by Goldar et al. (2004).

In line with the findings of some Indian studies (e.g. Banga 2004, Ray 2006), the coefficient of IMDT turn out to be significant. Thus, the firms in IMI are able to purchase foreign disembodied technologies capable of enhancing their efficiency in resource use or even providing value added items. The estimated coefficient of RDI turns out to be significant and positive, indicating that the in-house R&D contributes in achieving higher level of efficiency. In other words, R&D efforts aimed at adapting the technology, inputs of production or customization of products are benefiting firms in IMI in producing higher level of output. Contrary to this finding, most of the Indian studies report RDI having no impact on firm level productivity/efficiency.[8] AGE of the firm has negative impact on TE, indicating the association of age with vintage technology, plant and machinery and inflexible attitude of the employee. The results on CAPI indicate that the use of more capital intensive firms enjoy greater technical efficiency. Indian studies report industry-specific relationship between productivity/efficiency and CAPI.[9] Coefficient of XD is insignificant, indicating exports activity do not offer significant efficiency enhancing benefits to the firms in IMI. This may be because firms in IMI are mostly oriented towards domestic market and consider exporting as the residual activity. The relationship between TE and IMIG is found significantly positive, implying that the greater use of imported input improves the TE in general. This endorses the findings of Goldar et al. (2004)

[8] Refer to Driffield and Kambhampati (2003) for machine tools industry, Goldar et al. (2004) for engineering industry and Ray (2006) for manufacturing sector.

[9] Banga (2004) finds that CAPI has no impact on total factor productivity growth in the case of Indian automobile, chemical and electrical industries. Driffield and Kambhampati (2003) find CAPI to be positively related to TE in the chemicals, metal products and transport equipment industry but negatively related in the food and beverages and machine tools.

and Ray (2006) who suggests that the import liberalisation aimed at providing easy access to imported raw material and capital goods has efficiency enhancing effect.

The result on AMI shows that the firms spending more on advertising and marketing as a ratio of sales enjoy greater TE. Thus the product differentiation advantages created through expenditure on advertising and marketing is helping the firms in realizing higher value for their products. This result is in line with the finding of Goldar et al. (2004) for the Indian engineering firms. The result pertaining to SZ indicates that the larger size firms are more efficient. Thus, augmenting the scale of operation helps firms in IMI to perform better. The coefficient of NWI indicates that firms using higher amount of internal funds are more technically efficient. As expected, IMC has negative impact on TE, suggesting competition to be good for improving efficiency in IMI. This result is in line with of the findings of other studies (viz. Driffield and Kambhampati 2003). The results on the coefficients of YD variables indicate realization of higher efficiency in FY04, FY05, FY06, FY07 with reference to FY01.

7. Summary and Conclusions

Adopting the framework of resource based view of firm, this study empirically examines the technological determinants of technical efficiency in the context of Indian machinery industry. To undertake this task, we first compute the firm- and year-specific technical efficiency by estimating a stochastic frontier production function with the help of an unbalanced panel of data with 940 observations on a sample of 178 firms for 7 years covering FY 2000/01 to FY 2006/07. Thereafter, we estimate a random-effect panel data model with Tobit specification for analysing the technological determinants of technical efficiency.

The most important findings of the study is that technological capability and knowledge base built through alternative channels, such as FDI, import of disembodied technology, research and development, use of more capital intensive techniques of production and import of intermediate goods have efficiency enhancing effects on the firms in Indian machinery industry. Thus, given the current policy of Indian Government for 100 per cent equity participation through FDI, no restrictions on import of intermediate goods and technology and fiscal concessions on R&D expenditure, the firms desiring to expand their base in this industry (nationally or internationally) must built their competitive advantage through these channels of technological capability building. To improve their efficiency levels, the companies may also focus on building product differentiation advantage through higher advertising and marketing expenditure, enlargement in their size and financing expansion through internal resources than borrowed fund

Table-2: Descriptive Statistics of Variables, 2000/01-2006/07

Variable		Mean	Std. Dev.	Min	Max	Observations
FCD	overall	0.2788	0.4487	0.0000	1.0000	N = 940
	between		0.4301	0.0000	1.0000	n = 178
	within		0.0000	0.2788	0.2788	T-bar = 5.28814
TE	overall	0.7096	0.0816	0.5377	0.9934	N = 940
	between		0.0838	0.5447	0.9932	n = 178
	within		0.0028	0.7025	0.7156	T-bar = 5.28814
SZ	overall	3.4278	1.6245	-0.1372	8.8828	N = 940
	between		1.5575	0.2772	8.5254	n = 178
	within		0.2773	2.1015	4.9944	T-bar = 5.28814
AGE	overall	3.1944	0.7298	0.0000	4.6250	N = 940
	between		0.7373	0.8959	4.6000	n = 178
	within		0.1266	2.0978	3.8896	T-bar = 5.28814
CAPI	overall	4.7216	5.0334	0.2844	50.0000	N = 940
	between		5.0590	0.3259	39.5469	n = 178
	within		1.2665	-4.5606	15.1747	T-bar = 5.28814
AMI	overall	0.0309	0.0333	0.0000	0.2506	N = 940
	between		0.0314	0.0000	0.2197	n = 178
	within		0.0127	-0.0548	0.1597	T-bar = 5.28814
IMDT	overall	0.0031	0.0074	0.0000	0.0743	N = 940
	between		0.0060	0.0000	0.0372	n = 178
	within		0.0040	-0.0215	0.0547	T-bar = 5.28814
RDI	overall	0.0035	0.0060	0.0000	0.0398	N = 940
	between		0.0053	0.0000	0.0284	n = 178
	within		0.0027	-0.0093	0.0260	T-bar = 5.28814
NWI	overall	0.3338	0.2526	0.0000	0.9863	N = 940
	between		0.2432	0.0000	0.9577	n = 178
	within		0.1070	-0.1947	0.7288	T-bar = 5.28814
IMIG	overall	0.0930	0.1027	0.0000	0.5823	N = 940
	between		0.0918	0.0000	0.4633	n = 178
	within		0.0455	-0.1904	0.4421	T-bar = 5.28814
IMC	overall	0.4038	0.1596	0.1256	0.8955	N = 940
	between		0.1523	0.1580	0.7762	n = 178
	within		0.0568	-0.0171	0.6845	T-bar = 5.28814

Table-3

	FCD	DOF	SZ	AGE	CAPI	AMI	IMDT	RDI	NWI	XD	MI	IMC	NICD	YD02	YD03	YD04	YD05	YD06
FCD	1.00																	
DOF	0.40	1.00																
SZ	-0.10	0.09	1.00															
AGE	0.04	0.04	-0.24	1.00														
CAPI	0.03	0.10	0.20	0.04	1.00													
AMI	0.11	0.05	0.00	0.06	-0.04	1.00												
IMDT	-0.26	0.07	-0.01	0.02	0.01	0.09	1.00											
RDI	0.01	-0.08	-0.33	-0.08	0.08	0.05	0.04	1.00										
NWI	0.16	0.07	0.06	0.00	0.10	-0.01	-0.03	0.08	1.00									
XD	-0.10	0.0	-0.09	-0.09	0.07	-0.03	-0.10	0.05	0.04	1.00								
IMI	-0.27	-0.09	-0.21	0.12	-0.23	-0.15	-0.06	-0.07	0.01	-0.05	1.00							
IMC	0.05	0.32	-0.20	0.16	-0.05	-0.01	-0.02	-0.04	0.09	0.17	0.08	1.00						
YD02	0.01	0.08	0.01	0.00	-0.01	-0.01	0.00	0.00	0.01	-0.04	0.02	-0.01	0.01	1.00				
YD03	0.00	-0.03	0.02	-0.02	-0.02	-0.01	0.02	-0.02	0.04	-0.05	0.04	0.00	0.01	0.52	1.00			
YD04	0.01	0.03	0.03	-0.04	0.01	-0.04	0.01	-0.03	0.07	-0.05	0.02	0.02	0.00	0.51	0.52	1.00		
YD05	0.02	0.07	0.01	-0.06	0.02	-0.05	0.02	0.00	0.09	-0.07	-0.01	0.05	-0.01	0.51	0.52	0.52	1.00	
YD06	0.01	0.03	-0.04	-0.07	0.01	-0.05	0.04	0.04	0.09	-0.04	-0.02	0.06	-0.04	0.50	0.51	0.50	0.51	1.00
YD07	0.01	0.02	-0.05	-0.09	0.03	-0.03	0.05	0.08	0.11	-0.03	-0.04	0.01	-0.02	0.50	0.50	0.50	0.51	0.51
CONS	-0.11	-0.13	-0.17	-0.63	-0.24	-0.12	-0.04	0.09	-0.34	-0.10	-0.07	-0.42	-0.12	-0.28	-0.29	-0.28	-0.27	-0.24

Table-4: Indicators of Multicolinearity: Variance Inflation Factors

Variable	VIF	TOL (1/VIF)
FCD	1.37	0.73
DOF	2.53	0.39
AMI	1.07	0.93
AGE	1.19	0.84
NWI	1.11	0.90
IMIG	1.34	0.75
IMDT	1.15	0.87
CAPI	1.16	0.86
RDI	1.26	0.80
SZ	1.64	0.61
IMC	1.25	0.80
XD05	1.14	0.88
YD02	1.78	0.56
YD03	1.80	0.56
YD04	1.75	0.57
YD05	1.80	0.56
YD06	1.76	0.57
YD07	1.77	0.56
Mean VIF	1.42	

Table-5
Maximum Likelihood Estimates of Parameters of SFPF

Variable/Parameters	Coefficient	t-ratio
Ln M	0.71	85.68*
Ln W	0.14	8.13*
Ln C	0.10	6.83*
Constant	1.20	29.17*
Sigma-squared (σ_s^2) $\equiv \sigma_v^2 + \sigma^2$	0.032	5.62*
Gama (γ) = σ^2 / σ_s^2	0.777	32.13*
Mu (μ)	0.313	9.44*
Eta (η)	0.006	0.84
Log likelihood function	705.57	
LR test of the one-sided error	462.36	
Number of iterations	10	
Number of cross-section	178	
Number of Years	7	
Number of Observations	940	
Number of Observations not in the panel	306	

Note: * shows that the coefficient is significant at one per cent level.

Table-6: Technological Determinants of Technical Efficiency

Explanatory Variable	Coefficient	Standard Error	z-stat
FCD	0.023	0.001	15.87*
DFO	0.026	0.005	5.78*
IMDT	0.462	0.081	5.72*
CAPI	0.002	0.000	20.53*
IMIG	0.018	0.006	3.17*
XD	0.001	0.001	0.81
RDI	0.402	0.097	4.16*
AGE	-0.002	0.001	-2.67*
AMI	0.380	0.018	21.01*
SZ	0.002	0.000	5.7*
NWI	0.050	0.003	18.23*
IMC	-0.028	0.003	-7.94*
YD02	0.001	0.002	0.57
YD03	0.003	0.002	1.78
YD04	0.005	0.002	2.45*
YD05	0.004	0.002	2.22**
YD06	0.007	0.002	4.01*
YD07	0.010	0.002	5.44*
Cons	0.645	0.004	174.12*
Sigma u	0.057	0.0004	141.29*
Sigma e	0.014	0.0003	43.04*
Rho	0.941	0.0027	
Log likelihood	2310.03		
Wald chi square (18)	2866.8*		
No. of observations	940		
No. of groups	178		

Note:
1. *, ** denote level of significance at 1 per cent and 5 per cent respectively.
2. Z-value corresponding to the coefficient of each variable presented in the tables is obtained from dividing the value of an estimated coefficient of each independent variable by corresponding heteroskedastic panel corrected standard error.

Appendix

Construction of Variables used for the Estimation of SFPF

Output (Y): Wholesale Price Index (WPI) deflated Value of Production (VoP) represents the output (Y) of a firm in our study. To deflate VoP, I have used year-wise data on WPI for a firm's major product group. In this regard, the major product group of each company was matched with the WPI classification, and the matching price series was chosen for the deflation. If the appropriate deflator was not available, the deflator corresponding to the nearest product group is utilized for the purpose. For a few diversified companies operating in various segments of IMI, I have used WPI of IMI as the deflator. The value of production, instead of value added, is employed to measure the output because: (i) the use of the former facilitates the inclusion of material input as another important input of production, that can also be used efficiently (or inefficiently) along with the labour and capital, (ii) the use of value added as a measure of output can yield misleading results if there is imperfect competition or increasing returns to scale (Basu and Fernald 1995). Many Indian studies in recent years have estimated production function with material input as an important independent variable (see e.g. Driffield and Kambhampati 2003 and Banga 2004).

Material Inputs (M): Materials inputs (M) constitute one of the important constituents of production in the business. To remove the effect of year-to-year change in prices, M in this study is deflated by WPI corresponding to the main product group to which M belonged. For this purpose, M of each company was divided into various categories and matched with the WPI classification, and the best available price series was chosen for deflation.

Labour Input (L): The study approximates L by total wage bill of a firm deflated by the Consumer Price Index of Industrial Workers (CPI). I employ wage bill instead of number of employee for the following reasons: a) Indian firms rarely report this information in their annual reports, since the Indian Company Law does not make it mandatory; b) the payments made to outsourced satff are included in the wage bill of the firm but the workers employed through the outsourced agencies are not included in the payroll of the firm; c) wage bill reflects the skill composition of employees at firm level, therefore some Indian researchers in recent years have preferred to use wage bill as the measure for labour input in their respective studies (e.g. Ray 2006).

Capital Input (K): The study captures K by the original cost of plant and machinery (or gross fixed stock of capital or plant and machinery as reported in the balance sheet). Thus, I exclude cost of land and building from the gross fixed assets. I do not use data on net fixed cost of plant and machinery because many Indian companies manipulate data on depreciation and machineries are used even beyond their life span. The measure used in this study has limitation since K should be ideally be measured by the current replacement cost of the fixed assets of a firm. To derive current replacement cost sometimes scholars (e.g. Goldar et al. 2004) use *perpetual inventory* method, which requires detailed information on the age structure of capital assets, a long time series of data on gross fixed capital stock, the benchmark capital value, etc. In the absence of such data, these researchers have made unrealistic assumptions. Hence, I do not use perpetual inventory method, despite the limitation of the method selected for this study.

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