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Are Foreign Firms Allocatively Inefficient? : A study of selected manufacturing industries in India

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ABSTRACT

The study of efficiency gap between foreign and domestic firms and its implication for technology spillover has found that although foreign firms are generally found to be technically more efficient the evidence on technology spillover is less conclusive in developing countries. This could be due to the fact that foreign firms, whose parent companies are in the developed countries, are using a technology which may not be appropriate for the domestic firms. We examine this inappropriate technology hypothesis by estimating measures of allocative efficiency for both domestic and foreign firms in eleven 3-digit manufacturing industries of India during 1990-2000.

We use stochastic frontier (econometric approach) as well as Data Envelopment Analysis (DEA, linear programming) to measure efficiency of the firms. Assuming a Cobb-Douglas technology, we have estimated Stochastic Production Frontier and Stochastic Cost Frontier in each industry to measure technical efficiency and cost efficiency of each firm and get some inference on allocative efficiency. Using DEA we decompose total cost efficiency into technical and allocative efficiency. Our results indicate that generally foreign firms are technically more efficient but there is no conclusive evidence to suggest that these foreign firms are allocatively inefficient compared to the domestic firms.

***Keywords*:** Appropriate technology, allocative efficiency, Stochastic Frontier, DEA.
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1. Introduction

In the past decade, technology spillover from multinational affiliates to the local firms has received lot of attention. Technology spillover can occur through several channels as has been argued by Blomstrom et. al.,(1999). So far the empirical studies on technology spillover find a mixed effect from spillover in the developing country (Kathuria, (2001), Haddad and Harrison, (1993), Kokko, (1996), Aitken and Harrison, (1999)) and the conclusions remain inconclusive.

In this paper, we consider this issue from the perspective of "appropriate technology" within a developing country. Multinational affiliates, whose parent companies are in the developed countries, may be using the capital-intensive technology while the domestic firms use labour intensive technology in the host developing country. Hence it can be argued that the technology (measured as ratio of capital and labour) used by foreign firms may be "inappropriate" for the domestic firms. If the technology used by foreign firms is found to be "inappropriate" then there is less likely to be any technology spillover.

This idea of appropriate technology is not new and has been explored in the past by several authors in different contexts.[2] It is argued by some economists that the capital intensive technology from the developed world are not likely to be efficient (cost minimising) in the developing economies despite technical progress in the developed country since technological progress is mostly 'localised' in nature (Atkinson and Stiglitz, (1969)). According to this theory, a firm (or economy) learns over time to improve the productivity of the particular mix of capital and labour that it is currently using in production. This means that technical progress in a firm (country) might be 'localised' to a particular technique of production. Hence, unlike the standard Harrod-neutral view of technical progress where improvements in technology would increase the productivity of all the techniques of production (and shift the whole isoquant inward), localised progress will show as an improvement (in the isoquant) only at the point where the firm is currently producing. Since developing economies have different factor prices and firms are likely to be operating at quite different points on the isoquant, these firms are not going to benefit from the

[2] The concept of appropriate technology received lot of popularity in a book called "Small is beautiful" by Schumacher (Schumacher, (1973)). As the name suggests in this book, the idea on inappropriate technology was explained in terms of large and capital intensive technology in the developed countries compared to small and labour-intensive technology in the less developed country.

technological progress in developed countries. Recently, Basu and Weil (1998) have extended the above line of argument to study the issue of appropriate technology in the context of growth and technology spillover for countries with different absorption capabilities. They argue that a new technology is only appropriate for those countries that produce according to the technologies (particular mix of capital labour ratio) which are similar to the innovators' technology (developed country). Thus the countries which follow similar technologies as developed countries tend to gain in the form of spillover and converge in the long run. However, the developing countries which are producing at a different technology do not gain from spillover and their productivity diverges in the long run.

Los and Timmer, (2005) attempt an empirical investigation of Basu and Weil's model in a study of 53 countries during the period 1965 to 1990, by exploring whether there are any convergent or divergent patterns of different countries in the context of localised innovation and appropriate technology. They have decomposed labour productivity into three stages into which a country can be fitted depending on their stage of development and adaptability to spillover, -1) learning by doing for a specific technology (particular capital-labour ratio), 2) 'creating spillover potential' by shifting towards the frontier technology and 3) "localized innovation" or technical progress by shifts in the frontier for a specific technology. The study classifies India in the group 2 calling such countries as 'making a miracle'. For India, it finds that at the aggregate level, at first labour productivity in India invested more in creating the potential for technology spillover and thereafter in 1980's it was investing also in learning and innovation. Hence, for India it concludes that it has the desired capability to absorb the new technology of advanced countries and so foreign technology cannot be inappropriate for them.

We propose to give a precise meaning to this "in-appropriateness" by interpreting it as allocative inefficiency.[3] Allocative inefficiency is the degree to which a firm's choice of inputs differs from the cost minimising input choice given input prices. Allocative efficiency implies just the inverse of allocative inefficiency.

Technical inefficiency in a firm is the degree by which the actual output is deviating from the optimal production frontier and technical efficiency is just the

[3] There are some studies which have considered the issue of appropriateness of technology for foreign and domestic firms within a country. These studies too have found a mixed result. In a study on Brazilian manufacturing firms of similar size has found that foreign firms are using more capital intensive technology than domestic firms (Willmore, 1986).

inverse of former measure. There is evidence that foreign firms are technically more efficient compared to the domestic firms in the developing countries and hence change in technical efficiency (productive efficiency) has been used to measure productivity in the spillover studies while implicitly assuming allocative efficiency for all firms (Kathuria, (2001), Haddad and Harrison (1993)).We argue that the foreign firms may be technically more efficient compared to the domestic firms with a large efficiency gap but if the foreign firms are using an inappropriate technology, they may not be allocatively more efficient compared to the local firms and thus the total economic efficiency gap may not be large.

Hence the aim of this paper is specifically to empirically examine whether foreign firms are allocatively inefficient compared to the domestic firms. Using a firm-level panel dataset for eleven manufacturing industries during the period 1990-2000, we estimate the technical, allocative and cost efficiency for each firm in an industry. We also examine whether there is convergence or divergence in the temporal patterns of total economic efficiency between foreign and domestic firms. If the total cost efficiency gap between foreign and domestic firms falls over time it implies that there is convergence. This convergence can be interpreted that there is likely to be technology spillover or potential for technology spillover.

To illustrate the conceptual framework we have adapted the figure given by Farrell (1957).

[Insert figure 1]

As shown in figure 1, CC and YY stand for the (minimum) isocost line and the isoquant respectively. K and L are the capital and labour inputs used by the firms. Suppose a foreign firm is producing at point F and a domestic firm is producing at A. The distance between the actual inputs and the input combination implied by the isoquant measures the technical inefficiency. Using this it is easy to see that ratio OB/OA and OD/OF will be the technical inefficiencies of the domestic and foreign firms respectively. The technical inefficiency of domestic firms given by the ratio OB/OA could be more than that of the foreign firms (OD/OF) due to the superior efficiencies of the latter.[4] But, note that while the domestic firms are using K and L in the exact proportion implied by the tangency of CC and YY, the foreign firms are relatively more capital intensive. The ratio OE/OD then would measure the allocative

[4] All the firms are assumed to be facing the same input price.

inefficiency among the foreign firms.[5] Hence, technical efficiency gap between foreign and domestic firms may be offset by the allocative efficiency gap and thus the total economic efficiency gap may be small.

The paper is organised as follows. Section 2 discusses the methodology and the sub-sections in it discuss different methodologies used for our purpose. Section 3 discusses data and variable construction, and the empirical results are examined in section 4. Section 5 presents the summary and conclusion.

2. Methodology

In this section, we outline two different methodologies – Stochastic Frontier (SF) and Data Envelopment Analysis (DEA) which are used to the study efficiency of firms. SF entails econometric techniques based on ordinary least squares regressions while DEA employs linear programming techniques. In DEA, a piece-wise linear convex hull around the data points is constructed to create a production (cost) frontier. Thus it is mainly a data driven approach and data points lying on the boundary of the hull represents the "best practice" production (cost) frontier and all the points lying within the hull are inefficient firms.

Both the techniques have their own strengths and weaknesses. In DEA any deviation from the frontier is considered to be technical (cost) inefficiencies and it does not take into consideration the statistical noise in the data. Besides, since DEA is a non-parametric technique, statistical hypothesis tests are difficult. In the SF a functional form needs to be imposed, while DEA has positive attribute that this is not required. However, we use both these methodologies to measure each firm's efficiency scores and this allows us to test the robustness of these measures in SF and DEA.

Within the SF framework, the technology is assumed to be Cobb-Douglas for both production and cost function. The advantage of choosing a Cobb-Douglas technology is its self-duality property which implies that the cost function has the same functional form as the production function [6](Berndt, 1999).

[5] However, it must be borne in mind that allocative inefficiency could arise because of other factors such as regulatory constraints and sluggish adjustment to price changes [Atkinson and Cornwell, (1994)]. In our case, in the period under study, most of these regulatory constraints have been phased out.

[6] Other functional forms which are self-dual are Constant elasticity of substitution (CES) production technology.

2.1 Empirical Model in Stochastic Production Frontier

To estimate the stochastic production and cost frontiers, we follow Battese and Coelli (1992) model which estimates technical and cost efficiency varying across firms as well as years. The advantage of this model over any other time-variant models is that the technical inefficiency can be separated from the technical change (Kumbhakar and Lovell, 2000).[7]

Hence, assuming a Cobb –Douglas technology specification, our model can be written as

$$\ln(y)_{it} = \alpha_0 + \alpha_l \ln(l)_{it} + \alpha_m \ln(m)_{it} + \alpha_k \ln(k)_{it} + \alpha_t \ln(t) + v_{it} - u_{it} \qquad (1)$$

where y_{it} stands for output of the firm i, i=1,2……N at time t=1, 2……T. The notation l, m and k stands for labour, materials (including energy) and capital stock as inputs used by each firm. Technology parameters α_l, α_m, α_k and α_t are the output elasticity for labour, materials (and energy), capital, and time-trend. The sum of the parameters for the inputs ($\alpha_l+\alpha_m+\alpha_k$) determines the returns to scale. Time-trend t is proxy for Hicks-neutral technical progress, which is common to all the firms. In equation (1), v_{it} is the random error associated with noise in the data and measurement errors in the output and other left out explanatory variables which could explain partially the level of output. The notation u_{it} is the one-sided random error associated with technical inefficiency. It is assumed to be distributed half-normally and is nonnegative.[8] Note that here the firm specific error term u_{it} is assumed to be time-variant. The time–variant technical (cost) inefficiency model can be written as

[7] There are other time-varying inefficiency models using traditional panel data approaches - fixed effect (or random effect) where time-varying inefficiency has more flexibility but it cannot be separated from the technical change term and requires more parameters to be estimated (Cornwell et. al. (1990) and Lee and Schmidt (1993)). Cornwell et. al. (1990) has specified that the intercept parameters for different firms in different time periods are a quadratic function of time and in this the time variables have firm-specific parameters. Lee and Schmidt (1993) have specified the time-variant inefficiency model as a product of individual firm and time effects.

[8] One can make other distributional assumptions such as truncated normal distribution and gamma distribution, but such distributions could be computationally difficult. Some authors consider that there is cost to assume flexible distribution for inefficiency because the log-likelihood is quite ill-behaved when μ is unrestricted (Greene, 1997). When a nonzero μ is assumed the estimation of the stochastic frontier model often inflates the standard errors of the other parameters considerably, sometimes attains extreme values of other parameters and sometimes prevents convergence of the iterations.

$$u_{it}=u_i[\exp(-\eta(t-T))] \quad (2)$$

where u_i is firm-specific, time-invariant inefficiency effects, t is the time trend and η is the unknown scalar parameter to be estimated, T is the last period of the sample. The function $\exp(-\eta(t-T))$ is always greater than equal to zero and its value depends on the parameter η.

If $\eta=0$ it implies then $u_{it}=u_i$. This means that function $\exp(-\eta(t-T))$ is equal to1, whatever the value of t. This implies that the efficiency of all the firms is time-invariant. If $\eta>0$ then $du_{it}/dt = -\eta u_i[e^{-\eta(t-T)}] <0$ and $u_{it} < u_{iT,}$ for every t<T. Hence, inefficiency (u_{it}) of all firms is decreasing over time. If $\eta<0$ then $du_{it}/dt >0$ and $u_{it} >u_i$. It implies that inefficiency (u_{it}) of all firms is increasing over time. In this inefficiency model the ranking of the firms remains same throughout the period. In other words, the temporal pattern remains same for all the firms and efficiency either increases or decreases exponentially. Hence, although this model has the advantage of keeping technical (cost) inefficiency error term (u) separated from the technical change (t), it has an intrinsic drawback that for productivity purposes, this model is not adequate especially in within the framework of a Cobb-Douglas technology where technical change is not varying across firms and years.

Technical efficiency (TE): The technical efficiency score of the i^{th} firm at time t is defined as

$$TE_{it}=\exp(-u_{it}) \quad (3)$$

where $\exp(-u_{it})$ is conditional upon the observed values of the entire composed error term $\varepsilon_{it,}$ where $\varepsilon_{it} = (\nu_{it}-u_{it})$ in equation (1). The technical efficiency score is the ratio of the actual output of the firm to its frontier output. Frontier output is the maximum potential output a firm can produce. So the technical efficiency equals one only if the firm has an inefficiency effect equal to zero, otherwise it is less than one. A firm with a value close to one is considered to be close to the frontier and more efficient.

2.2. Empirical Model in Stochastic Cost Frontier

The stochastic cost frontier can estimate cost efficiency when the price data for the inputs are also available along with input quantities and output. In any cost function the total cost must be linearly homogenous in the input prices. To impose homogeneity of degree one in input prices, both cost and input prices are normalised by capital price. So using input prices for labour capital and material, the same model in equation (1) can be in the form of

$$\ln\left(\frac{C}{kp}\right)_{it} = \beta o + \beta_l \ln\left(\frac{lp}{kp}\right)_{it} + \beta_m \ln\left(\frac{mp}{kp}\right)_{it} + \beta_y \ln(y)_{it} + \beta_t(t) + w_{it} + z_{it} \tag{4}$$

In equation (4) C_{it} is total cost of production for i^{th} firm at time t; lp_{it} is labour price, mp_{it} is the material price, kp_{it} is capital price, y_{it} is the gross output and t is the time-trend. β_l, β_m, β_y, β_t are technology parameters for cost elasticity for labour price, material price, output and time-trend. The returns to scale can be explained by parameter $1/\beta_y$. Here, time-trend t is proxy for the Hicks-neutral technical progress as given in the production function. The $w_{it's}$ are random noise errors assumed to be identically and independently determined and have normal distribution as $N(0,\sigma_w^2)$. The z_{its} are nonnegative one-sided random errors, which are associated with cost inefficiency effects in the model. These errors are distributed independently from noise v_{its} and the regressors and is half-normally distributed as $N^+(0,\sigma_z^2)$. The cost inefficiency error term, z_{it} includes both costs of technical inefficiency as well as cost of allocative inefficiency. As noted before, cost inefficiency measures the minimum inputs required to optimize the output given the input prices and output.

Denoting $\left(\frac{lp}{kp}\right) = Lp$, and $\left(\frac{mp}{kp}\right) = Mp$, and $\left(\frac{C}{kp}\right) = c$ the above can be written as

$$\ln(c)_{it} = \beta_o + \beta_l \ln(Lp)_{it} + \beta_m \ln(Mp)_{it} + \beta_y \ln(y)_{it} + \beta_t(t) + w_{it} + z_{it} \tag{5}$$

Cost efficiency (CE): Cost efficiency score of i^{th} firm is defined as follows

$$CE_{it} = \exp\left(-\hat{z}_{it}\right) \tag{6}$$

This is conditional upon the observed values of entire composed error term ε_{it} where ε_{it} is equal to $(z_{it}+w_{it})$. Cost efficiency score is the ratio of the actual cost of the firm to its frontier cost and is bounded from above ranging between 1 and 0. CE_{it} equals to 1 only if firm is on the frontier and inefficiency effect equals to zero, otherwise it is more than 1.

The stochastic production frontier and cost frontier models given in equations 1 and 5 were estimated using maximum likelihood estimation techniques.[9] We have used the Frontier Program given by Coelli, (1996). The two variance parameters of the composed error term (ε), σ_u^2 and σ_v^2 are re-parameterised to $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$ as suggested in the program to facilitate the convergence in maximum likelihood estimation. The parameter, γ, must lie between 0 and 1. *Frontier Program* reports the values of these parameters along with the technology parameters and value of η parameter.

2.3. DEA Method and the Empirical Model

Following Coelli et al. (2002), we estimate the efficiency scores using variable returns to scale, cost minimising model.[10] This model is used to decompose cost efficiency into technical and allocative efficiency.

Cost VRS Model: The cost efficiency can be obtained by solving the following dual cost minimisation linear programming problem.

$$\begin{aligned} &\underset{\lambda, x_i^*}{Min} \quad \rho_i = w_i x_i^* \\ &s.t \\ &-y_i + Y\lambda \geq 0, \\ &x_i^* - X\lambda \geq 0, \\ &e\lambda = 1, \quad \lambda \geq 0 \end{aligned} \tag{7}$$

Where w_i is a vector of input prices for the i^{th} firm (i=1…N) and x_i^* (which is calculated by linear programming) is the cost minimizing vector of input quantities for the i^{th} firm given input prices w_i and the output levels y_i. λ is N*1 vector of

[9] MLE techniques have more appeal in these frontier estimations because they are shown to be more asymptotically efficient than Least squares dummy variable or Generalised Least Square estimator (Greene (1993), Kumbhakar (2001)). This is because it exploits the distributional information of the inefficiency error term that other methods do not apply.

[10] A constant return to scale is appropriate when the firms are operating at the optimum scale while variable returns to scale model allows firms which are not operating at optimum scale and the model can calculate technical efficiency separated from scale efficiency.

constant weights which defines a linear combination of peers for the i^{th} firm.[11] The value of ρ_i obtained will be the cost efficiency score for the i^{th} firm which is always $0<\rho_i\leq 1$. If the ρ_i is equal to 1 the firm is on the frontier and efficient, while if $\rho<1$ the firm is inefficient. Since, we have one output and three inputs,

$Y = [y_1, y_2, \ldots y_N]$ and

$$X = \begin{bmatrix} x_{11}, x_{12}, \ldots x_{1N} \\ x_{21}, x_{22}, \ldots\ldots x_{2N} \\ x_{31}, x_{32}, \ldots\ldots x_{3N} \end{bmatrix}$$

e stands for (N*1) vector of ones. The total cost efficiency (CE) or economic efficiency of the i^{th} firm is calculated as ratio of minimum cost to observed cost as given below.

$$CE_i = \frac{w_i x_i^*}{w_i x_i} \qquad (8)$$

The allocative efficiency can be then calculated implicitly as

$$AE_i = \frac{CE_i}{TE_i} \qquad (9)$$

The above model allows for technical change by estimating separate frontier for each year.

In DEA, besides calculating the mean allocative efficiency one can further investigate which inputs are being overused or underused. Cost minimizing DEA model (equation 7) gives the cost efficient input quantities (x_i^*). The technically efficient input quantities can be obtained by solving the production maximising DEA model. Thus one can specify by how much a firm is over using or under using an input by taking the ratios of technically efficient input level to cost efficient input level for each firm. If the ratio is greater than unity it indicates that input is being overused. If the ratio is less than 1 it implies the input is being underused and if the ratio is 1 it implies that they are using inputs optimally.

[11] A peer is a firm which is operating on the frontier and fully efficient.

In DEA the software program by Coelli (1996), DEAP Version 2.1 program has been used to estimate the technical, cost and allocative efficiency and the input use ratios.

3. Data

The data set used in this paper is based on a panel of Indian manufacturing companies and covers the financial period from 1990-91 to 1999-2000.[12] Our firm-level database is obtained from the *Prowes*s database of *Centre for Monitoring Indian Economy* (CMIE) which includes listed as well as unlisted companies. Other industry-level data sources were obtained from Annual Survey of Industries (ASI, 2001) and Input-Output Transaction Table, (Government of India, (1997).

From the original dataset we selected eleven manufacturing industries where our selection is mainly based on high market share of foreign firms in the total sales of the industry and the number of foreign firms (Table 1).

[*Insert Table1*]

Since we are interested in the comparative study of foreign and domestic firms, we have not included industries with very low market share by foreign firms or industries with no foreign firms. We classified the 3-digit manufacturing industries into scientific and non-scientific based on Basant and Fikkert (1996) and Hasan (2002). For our investigation we have considered only scientific industries because generally most of the foreign direct investment goes into these industries. Besides, some studies have found that there is no technology spillover in the scientific industries (Kathuria, 2001). The Prowess industry classification is different than National Industrial Classification of India. Since the data from other sources have also been used in this study, the industries obtained from Prowess were matched to the 3-digit industrial classification based on National Industrial Classification of India.

The selected scientific industries have a sales share of 22 percent in the total sales of the manufacturing sector. Besides, in these industries foreign sales share is 46 percent of the total foreign sales in the manufacturing sector. We have an unbalanced panel dataset with 6008 observations and 768 firms spread over 4-10 years.

[12] Major reforms and liberalisation efforts started in the year 1991. So our time period captures the post-liberalisation period.

We have defined the foreign firms based on Prowess ownership classification given in CMIE. It considers both equity share holding and corporate governance issues such as the identity of the controlling share holder, the composition of the board of directors and management control.[13] Based on the Prowess ownership classification we have generated a dummy variable called foreign, which contains all the firms classified as "Private foreign companies" by Prowess and also joint venture companies. We have included joint venture firms into the foreign group since the joint venture firms may be using a technology similar to the foreign firms.

3.1 Construction of the variables

Variables used in the cost frontier estimation

Total cost (c): The total cost of production is the sum of the cost of raw materials, energy expense, wages and cost of capital.

Output (y): We have used the gross value of output and it was deflated by wholesale price index (WPI) for the respective industries with base year 1993-94.[14]

Capital Price (kp): Construction of the capital price index follows Jorgenson and Griliches (1996), the price of capital (K_p) is given by

$$K_p = q\,(\delta + r - i), \tag{10}$$

where q is price of equipment, δ is rate of depreciation and r is the rate of interest and i is inflation rate. For equipment price, we have used the wholesale price index of machinery goods (Mongia et al, (1999)). For interest rate r, we have used the prime lending rates of the Industrial Development Bank of India (IDBI) given as percent per annum.

Rate of depreciation, for each firm was constructed as following:

$$\delta_{it} = 0.06[\text{pltmach}/(\text{pltmach}+\text{lndbuil})] + 0.02\,[\text{lndbuil}/(\text{pltmach}+\text{lndbuil})] \tag{11}$$

[13] Some of the earlier studies on India have defined a company as "foreign" if the equity share holding of foreign entities in that particular company is 25% or more (Kathuria, (2001), Aggarwal, (2001)).

[14] For the years, 1990, 1991, 1992, WPI was with base year, 1981-1982 and they had to be converted to base year 1993-94 in order to match with the rest.

where 6% is rate of depreciation for plant and machinery (pltmach) and 2% is the rate of depreciation for land and building(lndbuil). The measure of δ_{it} is used in equation 10 to get the rental value of capital price index.

Labour price (lp):

Since the firm total cost of labour is available but not the wage rate we constructed wage rate for each 3-digit industry (*Annual Survey of industries of India (ASI) databse*). Hence each of the prowess industries was matched with the 3-digit industries from ASI. The wage rate was constructed using the total emoluments (Rs lakhs=Rs100, 000) divided by number of mandays (in thousands). So, industry specific labour price (Rupees per mandays) is given by[15],

$$lp_d = (\text{total emoluments}_d/\text{mandays}_d) \tag{12}$$

Material Price (mp):

Since firm level material price index is not available, we have constructed industry-specific composite price index by combining price indices of different input components of total materials and energy consumed by each industry. The input components are classified according to the availability of wholesale price indices of different input components (Government of India, WPI, various years). This was done at the most disaggregated level since WPI for most of the input components were available. The weights are calculated from the I*nput-Output Transaction Table 1989-90,* (Government of India, 1997).

Material and energy price (mp)[16] of a firm is given by

$$mp_d = \sum\left[p_d * \left(\frac{a_{jd}}{\sum a_{jd}}\right)\right] \tag{13}$$

where, p_d is wholesale price index of input j, a_{jd} is input output coefficient for the input j in the d^{th} industry.

Variables used in Production Frontier:

Besides output (y) we have other variables in the production frontier.

[15] Since ASI did not give the data for the years 1998-99 & 1999-00, we have extrapolated the labour wage rate for these two years using wholesale price index and time trend for each industry.

[16] We have included the energy price index here.

Labour (l): We constructed labour as total cost of labour for each firm divided by the industry-specific wage rate (lp).

Material (m): We constructed material as total cost of material and energy for each firm divided by industry specific material and energy price index (mp).

Physical Capital Stock (k): For constructing the net capital stock at the replacement cost we have followed the commonly used Perpetual Inventory Method (PIM) (Basant and Fikkert, (1996)).

Net capital stock according to the PIM is

$$K_{it}=I_{it}+(1-\delta)K_{it-1} \tag{14}$$

Where K_{it} is capital stock for each firm at time (t=1….T), I_{it} is the real investment and δ is the constant rate of depreciation. Using this method, firm's historical values for physical capital stock (gross fixed assets) were converted into net capital stocks expressed in constant 1990-91 prices.

Assuming that it takes 16 years for full depreciation of capital, the average age of each firm in the base year is calculated as

$$\text{Average age (AA)}=(AD_0/GFA_0)*16 \tag{15}$$

where GFA_0 is the initial year (base year) gross fixed assets, AD_0 is the accumulated depreciation in the initial year. The average age was used to construct the implicit deflator for the capital stock in the year 1990-91. The implicit price deflator[17] for replacement cost of capital stock in the initial year (CD_0) was compiled from the year (base year–age) to the base year of the sample. Then assuming a 6% rate of economic depreciation the net capital stock for a firm in the base year period is

$$K_0=(GFA_0/CD_0)*(1-\delta)^{AA} \tag{16}$$

where K_0 is the net capital stock in the base year, GFA_0 is gross capital in the base year, and δ is rate of constant depreciation , AA is average age and CD_0 is capital price deflator for base year. Real gross investment,

[17] For the capital price deflator we have used implicit deflator constructed using current values of gross fixed capital formation and constant values of gross fixed capital formation. We have obtained it from National Account statistics (GOI). It was available for the base year 1993-94==100 and we have rebased it to 1990-91=100.

$I_t = (GFA_t - GFA_{t-1})/CD_t$ (17)

Similarly, for the rest of the years we compute the net capital stock series (net of depreciation) and at constant 1990-91 price. For example: For the year 1991 we have $K_{91} = K_0(1-\delta)+(GFA_{91}-GFA_{90})/CD_{91}$,

where the second term is investment, which is difference of capital stock in a year and the lagged value of that capital stock, CD is the capital price deflator for that year. Similarly, we have computed net capital stock for other years.

3.2. Descriptive Statistics

In this section we provide the descriptive statistics for mean capital intensity, labour productivity and capital productivity for the two ownership groups- foreign and domestic firms (Table2).

[Insert Table 2]

Average capital intensity is measured as average of capital-labour ratio over the sample period. Similarly, labour productivity and capital productivity is measured as average of output–labour ratio and average of output-capital ratio. Capital-labour ratios are in units of Rupees per man day. Contrary to the general belief, foreign firms are found to be using more capital intensive technology than local firms in *only* two industries General Purpose Machinery and Automobiles. Foreign firms are found to have higher labour productivity in selected industries, General Purpose Machinery, Industrial Machinery, Automobiles and Fertiliser and Pesticides. Hence the capital intensity and the labour productivity figures are broadly consistent with the notion that higher capital intensity would be reflected in greater output per labour. While average capital productivity suggests that foreign firms are generally found to have higher capital productivity ratio compared to domestic firms. [18]

The observation that foreign firms are not more capital intensive across the board is somewhat striking. Even though this is not commonly expected, a mixed pattern has been observed in other cases studies (Lindsey, 1994). A study of four industries in Hong Kong found that, with the possible exception in one industry foreign firms did not use more capital-intensive technologies (Chen, (1983)). In contrast, a study on Brazilian manufacturing firms has used 282 matched pairs of

[18] We also tried to measure the capital-labour ratios after weighting them by sales measure, but the pattern of results was not affected.

equal size firms and industry found that foreign firms are using more capital intensive technology than domestic firms (Willmore, (1986)). They found that *inter-alias* foreign firms use greater capital intensive techniques for their production with significant mean difference. So far there is no clear evidence to show that foreign firms use more capital intensive technology by the foreign firms. This result could vary across countries and industries.

4. Empirical Results

4.1. Stochastic Frontier Estimates

The technology parameters (α_l, α_m, α_k and α_t) estimated in production function are output elasticity of labour, material, capital and time (Table 3a). In the stochastic production frontier the elasticity estimates for all the inputs are found to be significant. The low capital elasticity may reflect that output is not constrained by capacity shortage. The coefficient of time which is proxy for technical change is generally found to be positive and statistically significant indicting that there is generally a positive technical change. While technology parameters estimated in the cost function (β_l, β_m, β_y and β_t) are cost elasticity for normalised labour price, normalised material price, output and technical progress (Table3b).[19] There is an inconsistency in the technology parameters between stochastic production frontier and cost frontier and hence they should be interpreted with caution. The cost elasticity of outputs is high and significant in all the industries implying changes in output of these firms could make a significant positive impact on the total cost of these firms. The cost elasticity of input prices in some of the industries does not give plausible results.
[*Insert Table 3a and 3b*]

In Table 3a the estimate of γ parameter is high and ranging from 0.53 to 0.94 and statistically significant in all the industries indicating that contribution of inefficiency variance is more than noise variance in the total composed error term. However, these estimates are not entirely indicative of large contribution of noise element in the total composed error except for few industries. This indicates that perhaps the deterministic frontier or similar approach where the noise is not captured in the model may not be inappropriate for the efficiency analysis. In the cost side too the γ parameter is generally high and statistically significant.

[19] Due to the homogeneity restriction imposed earlier, the parameter for capital price can be derived from these estimated parameters ($1-\beta_l-\beta_m$).

The η parameter indicates the rate at which efficiency is increasing or decreasing for all firms. In table 3a this parameter is generally negative and statistically significant, implying that the inefficient firms are lagging behind and are unable to keep up with the best practice firms, while as noted earlier the output elasticity for time trend (technical change) is generally positive and significant indicating there is upward shift in the frontier. This pattern is more evident in case of industries which are subject to rapid technical change at the frontier and one cannot expect the inefficient firms to keep up with the best practice firms (Kumbhakar et. al., 1997). In table 3b, the value of η is showing a mixed pattern. The η parameter is negative and significant for both production and cost frontier in 3 industries (Machine Tools, Paints and Dyes and Electrical Appliances) indicating that both technical and cost efficiency for all the firms has been falling over time in these industries.

Specification test

Before analyzing the efficiency scores we have carried out some specification tests. To that effect we compare our specification with another a restricted specification. For this we have used generalized likelihood ratio (LR) statistics as

$$\lambda=-2\ (LLF_{UR}-LLF_{R})$$

where LLF_{UR} is log likelihood function for an unrestricted specification and LLF_{R} is the log likelihood function for a restricted specification. If this test statistics is greater than the critical value than we reject the null hypothesis (the restricted specification). Firstly, we test for the null hypothesis that the inefficiency error term is zero (u=0) or variance of inefficiency, σ_u is zero (γ=0). This specification test is conducted using restricted (ie OLS model) and unrestricted specification (MLE model) log-likelihood function.

[*Insert Table 4*]

Table 4 reports the Likelihood ratio (LR) test statistics for stochastic production frontiers (SPF) and for stochastic cost frontiers (SCF). The null hypothesis that γ is zero does not have a chi-square distribution because the restriction defines a point on the boundary of parameter space (Coelli, 1995). Hence, the critical value is taken from Kodde and Palm (1986) which gives a table of mixed chi-square distribution. In this case the LR statistics follows a mixed chi-square distribution with degree of freedom equal to number of restrictions (which is equal to 2 in our case). The critical value at 5% significance level is 5.14 and critical value at 1% significance is 8.27. Since in all the industries the LR statistics is very large than the critical value at 1% significance level we reject the null hypothesis that there is no effect of inefficiency on the cost and production function.

Another null hypothesis stating that inefficiency error term is time-invariant ie $\eta=0$ (or $u_{it}=u_i$) is also tested. This was tested using the restricted and unrestricted specifications of the SPF and SCF model. The LR test statistics value is much higher than the critical value at 5% significance level in all the industries except in Industrial Machinery and General Purpose Machinery. For the cost function, high values for this statistic were observed in most of the industries except Industrial Machinery, Drugs and Pharmaceuticals, and Fertiliser and Pesticides. Hence, we consider the time-variant specification to be the appropriate one.

Efficiency Scores

The mean cost efficiency and technical efficiency scores for foreign and domestic firms are calculated over period 1990-91 to 1999-2000 (Table 5). This table also provides the standard error of the mean values (se) and standard error of the mean difference (se mean-difference). Means of cost efficiency and technical efficiency in both groups of firms, within each industry are statistically significant at 5% significance level. Our result shows that the mean difference for technical efficiency between the two groups is statistically significant in all the industries. While the mean difference for cost efficiency between foreign and domestic firms is not statistically significant in all the industries.

[*Insert Table 5*]

The mean cost efficiency scores and technical efficiency scores for the two ownership groups in each industry show the following broad patterns. 1) Foreign firms are significantly more cost efficient as well as technically efficient than domestic firms in only two industries: *Machine Tools and Paints and Dyes.* This suggests that foreign firms in these industries are performing well on both fronts. This could be due to the huge research and development (R&D) investments made by foreign firms in these sectors. We found that in Paints and Dyes, foreign firms have more R&D intensity (measured as total expenses on R&D/sales) than domestic firms (foreign firms using 0.07% of their sales and domestic firms with 0.02% of their sales) while in Machine Tools foreign firms have 0.07% R&D intensity and domestic firms have 0.06%. The correlation coefficient for technical efficiency and R&D intensity for foreign group is highly correlated but not so for the domestic firms. 2) In the second set of industries, domestic firms are relatively more cost efficient as well as technically efficient: *General Purpose Machinery and Chemicals*. Here average performance of domestic (Indian) firms is better than foreign firms. 3) In the third set of industries, foreign firms are technically more efficient than the domestic firms but when mean cost efficiency scores are compared there is no significant mean difference between the foreign and domestic firms. These industries are *Industrial Machinery, Cosmetics and Toiletries, Electrical Appliances and Fertiliser and Pesticides*. 4) In *Automobiles* domestic firms are relatively technically more efficient compared to foreign firms and with a statistically significant mean difference. However from the cost perspective, domestic firms are performing well but the mean difference is not statistically significant. This may indicate that in this industry there is a strong competition between the two groups and domestic firms are performing well. The latter's performance could be due to more investment in research and development, re-engineered process technology and spillover. 5) In *Automobile Ancillaries*, domestic firms are more technically efficient but the mean difference is not statistically significant. But the domestic firms are more cost efficient than the foreign firms and the mean difference is significant. 6*) Drugs and Pharmaceuticals* is the only industry where foreign firms are cost inefficient and technically more efficient than domestic firms.

Thus there is generally indication for foreign firms to be more technically efficient than the domestic firms except few exceptions. The cost efficiency scores show a mixed pattern depending on the industries. If a firm is technically more efficient but not cost efficient it can be interpreted that the firm might be allocatively inefficient. Thus differences in cost and technical efficiencies in above set of industries (3) and (6) could be interpreted as evidence of allocative efficiency. Based on our pattern of results, it can be argued that foreign firms may be allocatively inefficient in Drugs and Pharmaceuticals and possibly in two other industries (Fertiliser and Pesticides, Cosmetics and Toiletries). However a direct measure of allocative efficiency is required to shed more light into this aspect.

Efficiency Gap

In these stochastic frontier results the efficiency gap between the foreign and domestic firms tend to be very small especially for mean cost efficiency scores (Table 5) thus suggesting more competition between the two groups of firms. The gap between foreign and domestic firms is relatively large for mean technical efficiency and of smaller magnitude for mean cost efficiency. This is plausible since cost efficiency scores include both technical and allocative efficiency and reflects that there is some contribution for allocative efficiency in the cost efficiency gap. However foreign firms in two industries which are in above pattern of industries in set 1 and set 3, Machine Tools and Cosmetics and Toiletries are technically more efficient and the gap is extremely large. Foreign firms in these industries are performing better possibly due to more R&D and low working capital which raises their internal cash flow and affects their efficiency too. Besides both foreign and domestic firms could be operating in different market segments. For example in Cosmetic and Toiletries the domestic firms could be producing more for the poor class while foreign firms could be producing for the richer class where brand names, quality are more in feature and involves research and development and reverse-engineering process. [20]

4.2. DEA Results

Efficiency Scores:

Using DEA techniques, we obtain the mean cost, technical and allocative efficiencies for each firm and year. We calculate the mean over the whole period for the two groups consisting of foreign and domestic firms.

[*Insert Table 6*]

Our results show that the foreign firms are technically more efficient on average than the domestic firms but the mean difference is statistically significant in five out of eleven industries (Industrial Machinery, Machine Tools, Drugs and Pharmaceuticals, Cosmetics Toiletries and Fertiliser and Pesticides) (see Table 6). These results are similar in pattern to that of stochastic production frontier in these

[20] It has been noted that in such industries with segmented markets there is less scope for technology spillovers (Kokko (1996)).

same industries. Electrical Appliances is one industry where domestic firms are technically more efficient and the mean difference is statistically significant.

From the perspective of average cost efficiency scores foreign firms are more cost efficient in eight out of eleven industries (Industrial Machinery, Machine Tools, Automobile Ancillaries, Chemicals, Drugs and Pharmaceuticals, Paints and Dyes, Cosmetics and Toiletries and Fertilisers and Pesticides) with a significant mean difference. This indicates that the foreign firms are performing better in terms of cost efficiency also.

With regard to allocative efficiency the Stochastic Frontier results showed that there could be some prospect for foreign firms to be allocatively *less efficient* compared to their domestic counterparts especially in three industries – Drugs and Pharmaceuticals, Cosmetics and Toiletries and Fertiliser and Pesticides. However, our results in DEA indicate that generally the foreign firms are allocatively *more efficient* than domestic firms, although the mean difference is statistically significant in some of the industries (Industrial Machinery, Automobile Ancillaries, Chemicals, Paints and Dyes, Electrical Appliances and Cosmetics and Toiletries). In some of these industries there is a large gap in allocative efficiency (Paints and Dyes, Cosmetics and Toiletries and Automobile Ancillaries). This indicates that foreign firms are generally able to use more optimal input combination than the domestic firms in Indian environment. Fertiliser and Pesticides is the only industry where domestic firms are allocatively more efficient and also statistically significant. It seems from these results that foreign firms are allocatively efficient and hence using technology appropriately. This observation is further supported by our analyses of the input use ratios.

Input mix ratios

Input use ratios were obtained for each firm in each year. Table **7** provides mean input use of capital, labour and materials for two groups: foreign and domestic in the selected industries. Here average input use ratios for foreign and domestic firms are based on geometric mean rather than arithmetic mean. This is because when the arithmetic mean is used the input use ratios especially in the domestic firms gives a highly skewed and long tail of input use ratios. If a firm has input ratio (eg. k/k^*, where k^* is the optimal capital use) equal to 1, it means that the firm is using the input in the optimal way. If it is greater (less) than 1 it means it is over (under) using that input relative to the optimal use.

[*Insert Table 7*]

Generally capital use ratios for domestic firms were found to be higher than the foreign firms and significant in some of the industries (Automobile Ancillaries, Chemicals, Drugs and Pharmaceuticals, and Fertiliser and Pesticides) with a significant mean difference. This reflects that on average domestic firms are significantly overusing capital in these industries.

The labour use ratios indicate that domestic firms are relatively using more labour compared to foreign firms in only *few* industries (Industrial Machinery, Automobiles and Chemicals). While in few other selected industries foreign firms are using more labour than domestic firms (Paints and Dyes, Electrical Appliances, and Cosmetics and Toiletries).

Foreign firms are found to be over using materials in some of the industries (General Purpose Machinery, Automobiles, Automobile Ancillaries, Chemicals and Fertilisers and Pesticides).

4.3. Analysis of Efficiency

The pattern of capital use seen in the input use ratios (Table 7) could be explained by the historical reasons – as India followed an inward-looking import substituting development strategy during 1960, 70's when there was heavy emphasis on self- sufficiency and rapid industrialisation, specifically the creation of domestic heavy industries which produced capital goods compared to other developing countries (Kochar et. al.(2006)). This highly protective regime allowed lot of capital investment in order to improve the productivity of these industries, although used capital inefficiently. This is the reason, why even after liberalisation there is more accumulated capital in the Indian-owned firms. Recently, in a study on India's pattern of development, it is noted that during the pre-liberalisation period India emphasised more capital-intensive production and highly skill-intensive production within manufacturing sectors compared to other developing countries (Kochar, et. al. 2006).

The labour use pattern is also interesting since it is normally considered that domestic firms in a developing country tend to be more labour intensive. This could be partly due to the nature of the industry. For example, Paints and Dyes, Machine Tools, and Industrial Machinery are some of the industries which are predominantly more capital intensive and hence there may not necessarily be a wide difference in use of labour in foreign and domestic firms. Secondly, the low cost nature of labour could be partly illusionary because of stringent labour laws in India. This is further highlighted by the propensity of Indian firms to use contract labour in place of regular employment. The difficulties faced by firms in firing labour and the pro-labour nature of laws have been debated in the Indian context (Besley and Burgess (2004), Kochar et.al.(2006)).

While the stochastic frontier results show a mixed pattern, DEA results overwhelmingly show that foreign firms are allocatively efficient compared to the domestic firms. The pattern of mean input use indicates that there is no reason to believe that foreign firms are overusing capital. This could be an implication of several factors. Generally foreign firms in developing countries choose to operate with optimal use of inputs and less distortion than counterparts. The results could be also due to the over capital investment during the pre-liberalisation as mentioned earlier. Besides the results also could be a reflection of prevailing labour market conditions in India as discussed earlier.

4.4. Comparison of Stochastic Frontier and DEA Results

Although we have used two different techniques, it is instructive to compare the stochastic frontier and DEA efficiency scores in each industry. This comparison will reveal the robustness of the DEA results (Table 8).

[Insert Table 8]

Firstly, we found that the DEA efficiency scores have a higher magnitude than SF efficiency scores. Similar finding has been found in other papers too (Kumbhakar, et, al. (1997)). Secondly, the foreign firms are technically more efficient and statistically significant in both the techniques in Industrial Machinery, Machine Tools, Drugs and Pharmaceuticals, Cosmetics and Toiletries and Fertiliser and Pesticides. Thirdly, in both the techniques, foreign firms are more cost efficient than their local counterparts in at least two industries: Machine Tools and Paints and Dyes.

We also compare the two techniques, by finding the Spearman's Rank correlation between technical efficiency scores in SF and DEA and correlation between cost efficiency scores in SF and DEA. Suppose we have n comparisons of paired data (x,y) and d is the difference in the rank of x and y for a particular pair, then we calculate sum(d^2) for all n pairs. Spearman's Rank Correlation coefficient (R) can be written as

$$R = 1 - \left[\frac{6\sum d^2}{n^3 - n} \right]$$

If the coefficient is equal to1 it means there is perfect rank correlation between the variables. For perfect negative correlation coefficient it should be equal to -1. In Table 8, correlation coefficient value for cost efficiency is small but positive and significant in *eight out of eleven* industries (Machine Tools, General Purpose Machinery, Automobiles, Chemicals, Paints and Dyes, Electrical Appliances, Cosmetics and Toiletries and Fertiliser and Pesticides).The rank correlation coefficient for stochastic technical efficiencies is positive and significant in *all the industries* indicating a positive correlation.

4.4 Temporal Pattern of efficiency

We can also empirically investigate whether there is any convergence in efficiency for the two groups of firms using DEA. The argument for convergence is that in the long run through learning, competition and technology spillover, Indian firms may be becoming more productive due to the presence of foreign firms. Generally the temporal pattern of technical and cost efficiency shows that Indian owned firms are showing a tendency for convergence with foreign firms. We found that generally cost efficiency gap is very small in most of the industries (Chemicals, Drugs and Pharmaceuticals, Fertiliser and Pesticides, Paints and Dyes, Industrial Machinery, Electrical Appliances and General Purpose Machinery). This implies that there is a scope for technology spillover in these industries. With regard to allocative efficiency, generally foreign firms have been dominating over the years. Allocative efficiency seems to have played major role in increasing the total economic efficiency gap between foreign and domestic firms especially in Automobile Ancillaries and Automobiles, Machine Tools. There is no consistent pattern for convergence in allocative efficiency but there is a tendency for convergence in technical and cost efficiency (Graph 1).

5. Conclusion

The paper has examined the technical, cost and allocative efficiency patterns for foreign and domestic firms within each manufacturing industries of India using two different techniques- Stochastic Frontier and DEA. However, the primary focus is the allocative efficiency in the foreign and domestic firms. The average allocative efficiency scores could explain whether foreign firm's use of input ratio is more deviating from the optimal or cost minimising input ratio and thus shed light on the appropriateness of technology used by foreign and domestic firms. Besides, the temporal pattern of cost as well as technical efficiency gap over time has been also examined to explain whether there is convergence between foreign and domestic firms and hence any scope for spillover.

The stochastic frontier estimations show that generally foreign firms are technically efficient with significant mean difference compared to the domestic firms. Even in DEA, this was found to be generally true except few exceptions. However, the average cost efficiency scores in Stochastic Frontier show a mixed result. In this technique there is a week indication for foreign firms to be allocatively inefficient in Drugs and Pharmaceuticals compared to the domestic firms since the former is on average technically efficient but cost inefficient. However, the DEA results show that foreign firms are generally allocatively more efficient than domestic firms. Thus the results do not show that there is more distortion in the input use of foreign firms than domestic firms. We also found that foreign firms are using more labour than capital in their production while Indian-owned firms despite being a labour-intensive country are using more capital. Hence we conclude that in Indian case the foreign firms are not using an inappropriate technology. Possibly this could be due to the heavy capital investment by the Indian industries during the pre-liberalisation period. Besides the temporal patterns of efficiency show that there is a general trend for convergence and hence there could be scope for technology spillover in these industries.

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Figure 1

Concepts of Technical, Allocative and Cost Efficiency

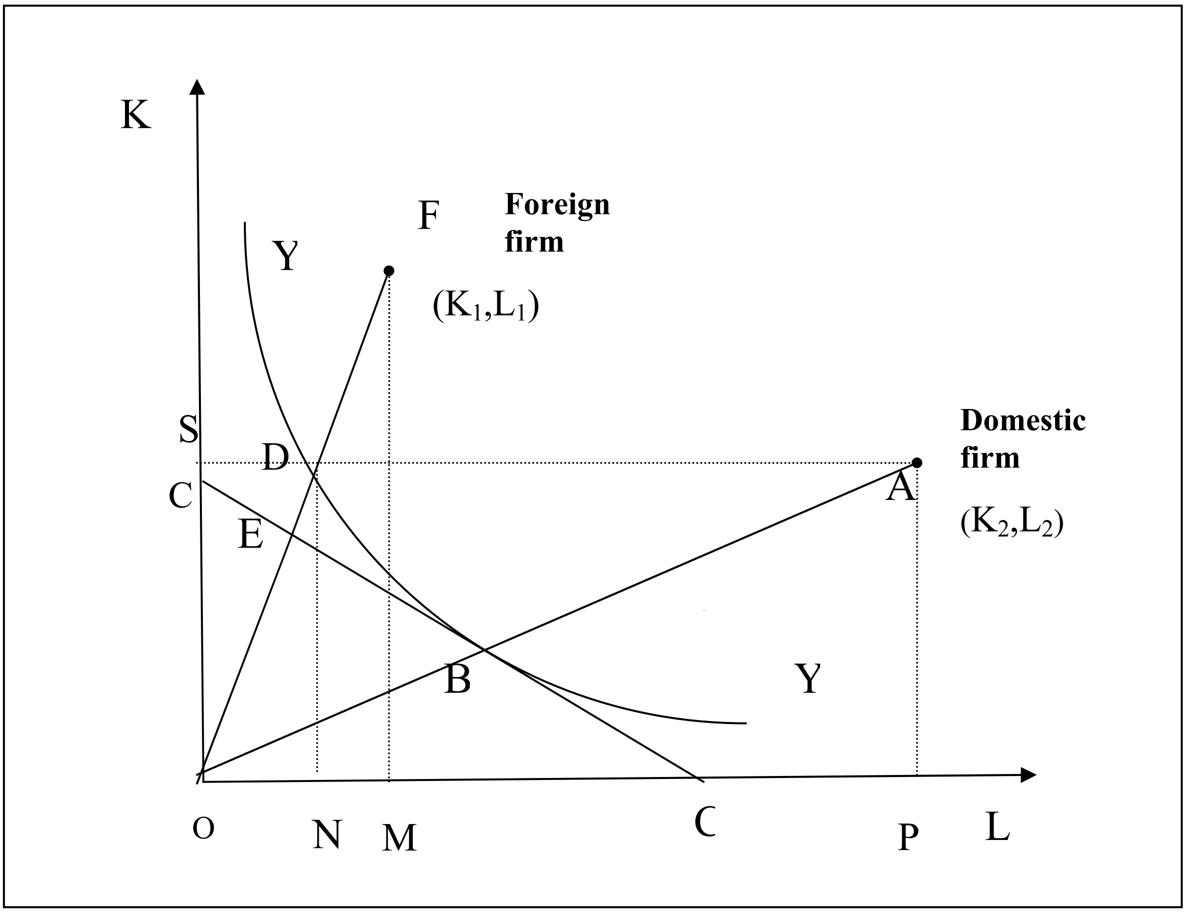


Table 1

Market Share of Foreign Firms in the Manufacturing Sectors of India

No.	*Industry Name*	*Number of obs*	*Number of firms*	*Number of foreign firms*	*Foreign share in total sales (%) (1990-99)*	*Foreign share in total sales in (1990) (%)*	*Foreign share in total sales (1999) (%)*
1.	Industrial Machinery	468	59	13	33.43	40.85	36.23
2.	Machine Tools	282	34	7	44.68	45.10	48.73
3.	General Purpose Machinery	358	42	13	42.39	41.56	45.92
4.	Automobiles	198	20	4	31.69	25.68	32.74
5.	Automobiles Ancillaries	912	112	7	21.28	19.53	23.09
6.	Chemicals	1005	131	6	13.77	18.35	15.00
7.	Drugs and Pharmaceuticals	1291	181	21	30.00	43.94	25.42
8.	Paints and Dyes	370	51	7	27.11	32.67	26.87
9.	Electrical Appliances	349	42	6	15.61	15.45	19.81
10.	Cosmetics and Toiletries	162	21	5	58.43	65.44	51.00
11.	Fertilisers and Pesticides	613	75	7	6.89	4.34	9.43
	Total	6008	768	96			

Table 2

Average Capital Intensity, Labour productivity and Capital Productivity

(1).	*Industry* (2)	*Foreign firms K/L* (3)	*Domestic firms K/L* (4)	*Labour productivity* (5)		*Capital productivity* (6)	
				Foreign	*Domestic*	*Foreign*	*Domestic*
1	Industrial Machinery	69.18	95.08	224.72	166.49	5.04	3.34
2	Machine Tools	82.97	107.51	133.49	145.16	2.94	1.87
3	General Purpose Machinery	101.94	96.12	164.00	163.48	2.49	2.35
4	Automobiles	262.68	137.09	586.38	368.97	3.61	3.43
5	Automobiles Ancillaries	569.64	788.69	1163.47	1398.29	2.46	2.47
6	Chemicals	200.05	345.07	223.96	421.61	1.56	2.01
7	Drugs and Pharmaceuticals	41.05	71.79	250.08	457.79	7.30	4.41
8	Paints and Dyes	73.46	324.32	232.16	439.62	3.90	3.34
9	Electrical Appliances	115.50	238.42	234.70	534.49	3.08	4.16
10	Cosmetics and Toiletries	42.51	90.81	311.80	502.36	8.23	10.65
11	Fertilisers and Pesticides	233.49	575.05	966.00	647.13	8.14	2.17

Table 4

Testing restrictions on Stochastic Frontier Production Function (SPF) And Stochastic Frontier Cost Function (SCF)

Industry	No technical inefficiency γ=0 # (dof=2)	No time effect on the inefficiency error, η =0 (dof=1)	No cost inefficiency γ=0 # (dof=2)	No time effect on the inefficiency error, η =0 (dof=1)
	SPF		SCF	
Industrial Machinery	153.10***	1.62	186.69***	0.29
Machine Tools	149.75***	41.6**	180.19***	27.82***
General Purpose Machinery	37.61***	0.05	92.06***	4.65**
Automobile	49.06***	25.94**	57.98***	13.51***
Automobile Ancillaries	665.75***	4.32**	683.39***	17.07***
Chemicals	288.69***	23.44**	242.44***	5.53**
Drugs and Pharmaceuticals	300.45***	8.68**	589.66***	0.29
Paints and Dyes	121.24***	25.74***	140.96***	62.04***
Electrical Appliances	37.70***	5.01**	65.98***	6.65**
Cosmetics and Toiletries	50.03***	8.60**	51.63***	2.76**
Fertilisers and Pesticides	285.55***	43.7***	453.70***	0.38

Note: dof is degree of freedom.***Significant at 1% significance level. ** Significant at 5% significance level.

Table 5

Mean Cost efficiency and Technical Efficiency using Stochastic Frontiers *(mean 1990-91 to 1999-2000)*

Industries	*Cost efficiency scores*			*Technical Efficiency scores*		
	Foreign firms Mean (se)	*Domestic firms Mean (se)*	*Mean-difference (se)*	*Foreign firms Mean (se)*	*Domestic firms Mean (se)*	*Mean-difference (se)*
Industrial Machinery	0.730 (0.128)	0.731 (0.007)	-0.001 (0.128)	0.784 (0.009)	0.746 (0.006)	0.038** (0.011)
Machine Tools	0.832 (0.014)	0.799 (0.010)	0.033* (0.017)	0.900 (0.013)	0.774 (0.008)	0.126** (0.016)
General Purpose Machinery	0.557 (0.013)	0.631 (0.011)	-0.074** (0.017)	0.877 (0.003)	0.883 (0.004)	-0.006** (0.005)
Automobiles	0.882 (0.010)	0.896 (0.008)	-0.014 (0.013)	0.903 (0.013)	0.934 (0.006)	-0.031** (0.009)
Automobiles Ancillaries	0.647 (0.008)	0.716 (0.003)	-0.069** (0.008)	0.789 (0.011)	0.810 (0.003)	-0.021 (0.056)
Chemicals	0.521 (0.009)	0.684 (0.005)	-0.163** (0.010)	0.605 (0.009)	0.710 (0.004)	-0.105** (0.010)
Drugs and Pharmaceuticals	0.582 (0.012)	0.643 (0.005)	-0.061** (0.013)	0.846 (0.007)	0.791 (0.003)	0.060** (0.008)
Paints and Dyes	0.909 (0.009)	0.882 (0.006)	0.027** (0.011)	0.858 (0.010)	0.814 (0.006)	0.044** (0.012)
Electrical Appliances	0.904 (0.013)	0.895 (0.006)	0.009 (0.014)	0.902 (0.012)	0.889 (0.004)	0.013** (0.013)
Cosmetics and Toiletries	0.568 (0.021)	0.549 (0.009)	0.019 (0.023)	0.879 (0.017)	0.664 (0.010)	0.215** (0.020)
Fertilisers and Pesticides	0.649 (0.024)	0.626 (0.009)	0.023 (0.026)	0.876 (0.009)	0.823 (0.005)	0.053** (0.010)

Note: ** indicates mean difference is statistically significant at 5 percent critical value in a two tailed t test. * indicates mean difference is statistically significant at 10 percent critical value in a two tailed t test.

Table 6. **Mean Cost efficiency, Technical Efficiency and Allocative efficiency- Using DEA**

(*Mean 1990-91 to 1999-2000*)

No.	*Industry Name*	*Cost Efficiency Scores*			*Technical Efficiency Scores*			*Allocative Efficiency Scores*		
		Foreign Firms Mean (se)	*Domestic firms Mean (se)*	*Mean diff (semean difference)*	*Foreign Firms Mean (se)*	*Domestic firms Mean (se)*	*Mean diff (semean difference)*	*Foreign firms Mean (se)*	*Domestic firms Mean (se)*	*Mean diff (semean difference)*
1.	Industrial Machinery	0.817 (0.014)	0.718 (0.008)	0.010** (0.016)	0.896 (0.012)	0.844 (0.008)	0.052** (0.014)	0.909 (0.009)	0.853 (0.006)	0.056** (0.011)
2.	Machine Tools	0.836 (0.016)	0.761 (0.010)	0.075** (0.019)	0.968 (0.008)	0.879 (0.009)	0.089** (0.012)	0.865 (0.016)	0.866 (0.007)	-0.001 (0.017)
3.	General Purpose Machinery	0.751 (0.012)	0.754 (0.008)	-0.003 (0.014)	0.869 (0.010)	0.868 (0.008)	0.001 (0.013)	0.864 (0.008)	0.870 (0.006)	-0.006 (0.01)
4.	Automobiles	0.855 (0.023)	0.898 (0.008)	-0.043 (0.024)	0.952 (0.010)	0.964 (0.005)	-0.03 (0.008)	0.897 (0.021)	0.930 (0.006)	-0.033 (0.021)
5.	Automobiles Ancillaries	0.673 (0.028)	0.541 (0.008)	0.132* (0.029)	0.885 (0.014)	0.869 (0.004)	0.016 (0.014)	0.755 (0.025)	0.616 (0.007)	0.139** (0.026)
6.	Chemicals	0.679 (0.025)	0.620 (0.008)	0.059** (0.026)	0.836 (0.017)	0.835 (0.004)	0.001 (0.003)	0.804 (0.026)	0.743 (0.009)	0.061** (0.027)
7.	Drugs and Pharmaceuticals	0.612 (0.017)	0.535 (0.006)	0.077** (0.018)	0.840 (0.012)	0.751 (0.005)	0.089** (0.013)	0.735 (0.018)	0.714 (0.007)	0.021 (0.019)
8.	Paints and Dyes	0.590 (0.031)	0.494 (0.016)	0.096** (0.035)	0.925 (0.009)	0.934 (0.005)	-0.009 (0.010)	0.629 (0.031)	0.518 (0.016)	0.111** (0.035)
9.	Electrical Appliances	0.806 (0.020)	0.828 (0.006)	-0.022 (0.021)	0.905 (0.017)	0.952 (0.005)	-0.047** (0.018)	0.890* (0.013)	0.869 (0.006)	0.021* (0.014)
10.	Cosmetics and Toiletries	0.925 (0.017)	0.739 (0.018)	0.186** (0.025)	0.957 (0.012)	0.911 (0.012)	0.046** (0.017)	0.964 (0.009)	0.814 (0.017)	0.150** (0.019)
11.	Fertilisers and Pesticides	0.776 (0.014)	0.744 (0.007)	0.032** (0.016)	0.958 (0.010)	0.860 (0.006)	0.098** (0.012)	0.811 (0.014)	0.863 (0.005)	-0.052** (0.015)

Note: ** indicates the mean difference is statistically significant at 5 percent critical value in a two tailed t- test. *indicates the mean difference is statistically significant at 10 percent critical value in a two tailed t-test.

Table 7. **Input Use ratios (in DEA)** *(Geometric mean 1990-91 to 1999-2000)*

No.	*Industry Name*	*Capital*			*Labour*			*Material*		
		Foreign Mean(se)	*Domestic Mean(se)*	*Mean diff (se)*	*Foreign Firms Mean(se)*	*Domestic firms Mean(se)*	*Mean diff (se)*	*Foreign firms Mean(se)*	*Domestic firms Mean(se)*	*Meandiff (se)*
1.	Industrial Machinery	0.620 (0.045)	0.711 (0.029)	-0.91* (0.053)	0.927 (0.059)	1.167 (0.040)	-0.24** (0.071)	1.156 (0.021)	1.164 (0.016)	-0.008 (0.026)
2.	Machine Tools	0.828 (0.117)	0.751 (0.033)	0.077 (0.121)	0.918 (0.092)	0.831 (0.030)	0.087 (0.097)	1.121 (0.051)	1.248 (0.021)	-0.127** (0.055)
3.	General Purpose Machinery	0.897 (0.051)	0.984 (0.042)	-0.087 (0.066)	1.008 (0.037)	1.011 (0.034)	0.007 (0.050)	1.146 (0.023)	1.300 (0.018)	-0.154** (0.029)
4.	Automobiles	0.626 (0.053)	0.704 (0.036)	-0.078 (0.064)	0.564 (0.052)	0.835 (0.037)	-0.271** (0.064)	1.187 (0.053)	1.08 (0.036)	0.107* (0.064)
5.	Automobiles Ancillaries	1.716 (0.102)	2.287 (0.039)	-0.571** (0.109)	0.988 (0.062)	0.910 (0.068)	0.078 (0.092)	0.850 (0.017)	0.742 (0.007)	0.108** (0.040)
6.	Chemicals	1.05 (0.10)	1.137 (0.04)	-0.087** (0.108)	0.849 (0.072)	0.985 (0.016)	-0.136** (0.073)	0.976 (0.032)	0.985 (0.013)	-0.009** (0.034)
7.	Drugs and Pharmaceuticals	0.881 (0.048)	0.983 (0.024)	-0.102** (0.054)	2.060 (0.166)	1.944 (0.067)	0.116 (0.179)	0.924 (0.026)	0.970 (0.014)	-0.046 (0.029)
8.	Paints and Dyes	1.833 (0.112)	2.319 (0.097)	-0.486** (0.148)	1.119 (0.101)	0.727 (0.036)	0.392** (0.107)	0.899 (0.033)	0.940 (0.017)	-0.041 (0.037)
9.	Electrical Appliances	1.000 (0.080)	0.916 (0.051)	0.084 (0.095)	1.010 (0.066)	0.680 (0.029)	0.33** (0.072)	1.068 (0.016)	1.181 (0.014)	-0.113** (0.021)
10.	Cosmetics and Toiletries	0.836 (0.054)	0.696 (0.068)	0.14 (0.087)	0.868 (0.046)	0.662 (0.060)	0.206** (0.076)	1.047 (0.013)	1.215 (0.029)	-0.168** (0.032)
11.	Fertilisers and Pesticides	0.210 (0.032)	0.566 (0.021)	-0.356** (0.038)	1.153 (0.164)	1.157 (0.040)	-0.004 (0.169)	1.528 (0.048)	1.265 (0.012)	0.263** (0.049)

Note: ** indicates the mean-difference is statistically significant at 5 percent critical value in a two tailed t-test while * indicates the mean-difference is statistically significant at 10 percent critical value in a two tailed t-test.

Table 8.

Spearman's Rank Correlation Coefficient Test

No.	*Industry Name*	*Rank correlation for Cost efficiency*	*Rank Correlation for Technical efficiency*
1.	Industrial Machinery	0.011	0.260**
2.	Machine Tools	0.606**	0.625**
3.	General Purpose Machinery	0.217**	0.360**
4.	Automobiles	0.48**	0.290**
5.	Automobiles Ancillaries	0.032	0.543**
6.	Chemicals	0.13**	0.280**
7.	Drugs and Pharmaceuticals	0.034	0.350**
8.	Paints and Dyes	0.420**	0.401**
9.	Electrical Appliances	0.408**	0.261**
10.	Cosmetics and Toiletries	0.230**	0.217**
11.	Fertilisers and Pesticides	0.106**	0.37**

Note: ** R is statistically significant at 5 percent critical value in a two-tailed test.

Table 3a.

Technology Parameters in the Stochastic Production Frontier

No	Industry	α_0 (constant)	α_l (l)	α_m (m)	α_k (k)	α_t (t)	*Parameters* γ	η	σ^2	*Returns to Scale*	*LLF#*	Obs
1	Industrial Machinery	4.87 (59.07)	0.06** (2.88)	0.85** (57.14)	0.01 (0.77)	0.012** (2.59)	0.87** (24.71)	0.025 (1.45)	0.11** (4.04)	0.92** (-18.31)	234.72	468
2	Machine Tools	4.72 (45.54)	0.19** (7.41)	0.70** (37.57)	0.09** (3.78)	0.04** (6.21)	0.93** (44.43)	-0.16** (-7.31)	0.30** (3.59)	0.98** (-13.94)	101.50	282
3	General Purpose Machinery	4.80 (48.33)	0.17** (6.55)	0.78** (39.72)	0.07** (3.55)	-0.002 (-0.54)	0.53** (4.42)	0.007 (0.23)	0.04** (4.23)	1.02** (-14.36)	177.43	358
4	Automobile	4.52 (43.13)	-0.005 (-0.27)	0.91** (63.63)	0.10** (4.56)	0.03** (6.39)	0.87** (17.51)	-0.27** (-6.96)	0.09** (2.48)	1.005** (-17.18)	139.84	198
5	Automobile Ancillaries	4.89 (64.98)	0.11** (11.37)	0.73** (75.00)	0.11** (9.03)	0.002 (0.67)	0.88** (45.97)	0.023* (2.15)	0.07** (6.73)	0.95 (-1.51)	699.68	912
6	Chemicals	5.85 (65.70)	0.14** (10.44)	0.88** (75.68)	0.03** (3.03)	-0.08** (16.27)	0.84** (30.32)	0.07** (5.92)	0.10** (6.22)	1.05** (-27.52)	473.96	1006
7	Drugs and Pharmaceutica l	5.18 (93.59)	0.13** (11.82)	0.87** (74.03)	0.004 (0.40)	0.03** (6.73)	0.77** (21.91)	-0.05** (-2.89)	0.14** (6.87)	1.004** (-29.30)	222.38	1291
8	Paints and Dyes	5.07 (73.10)	0.14** (11.11)	0.80** (58.60)	0.009 (0.66)	0.02** (5.50)	0.93** (46.16)	-0.15** (-5.06)	0.18** (3.57)	0.95 (-1.28)	234.41	370
9	Electrical Appliances	4.55 (59.26)	0.05** (2.70)	0.84** (46.69)	0.08** (5.20)	0.06** (12.25)	0.65** (6.89)	-0.08** (-2.15)	0.08** (4.03)	0.97** (-17.90)	91.63	350
10	Cosmetics and Toiletries	5.04 (38.86)	0.06** (2.43)	0.78** (35.78)	0.06* (1.93)	-0.01 (-1.19)	0.94** (36.55)	-0.07** (-2.97)	0.29** (2.65)	0.90 (-1.26)	63.22	162
11	Fertilisers and Pesticides	4.76 (72.77)	0.09** (6.43)	0.91** (66.54)	0.03** (3.57)	-0.003 (-0.85)	0.85** (28.80)	-0.09** (-6.18)	0.16** (5.46)	1.03** (-25.27)	225.77	613

Notes: # Log likelihood function. In the parenthesis I have given the t-statistics. *Parameters:* $\sigma^2=(\sigma^2_u+\sigma^2_v)$; $\gamma=\sigma_u/(\sigma_u+\sigma_v)$. *A*** indicates statistically significant at 1% critical value, * indicates statistically significant at 5% critical value.

Table 3b.

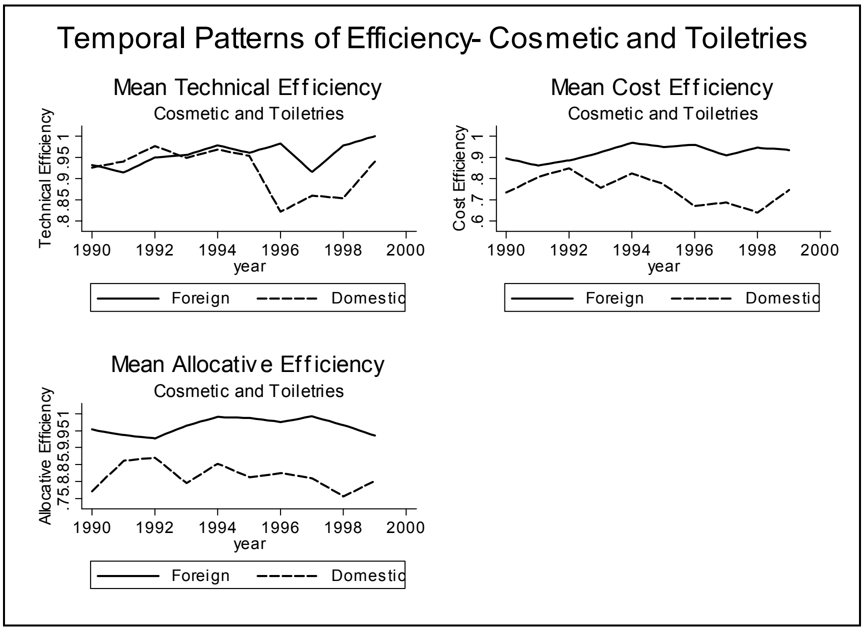
Technology Parameters in the Stochastic cost Frontier

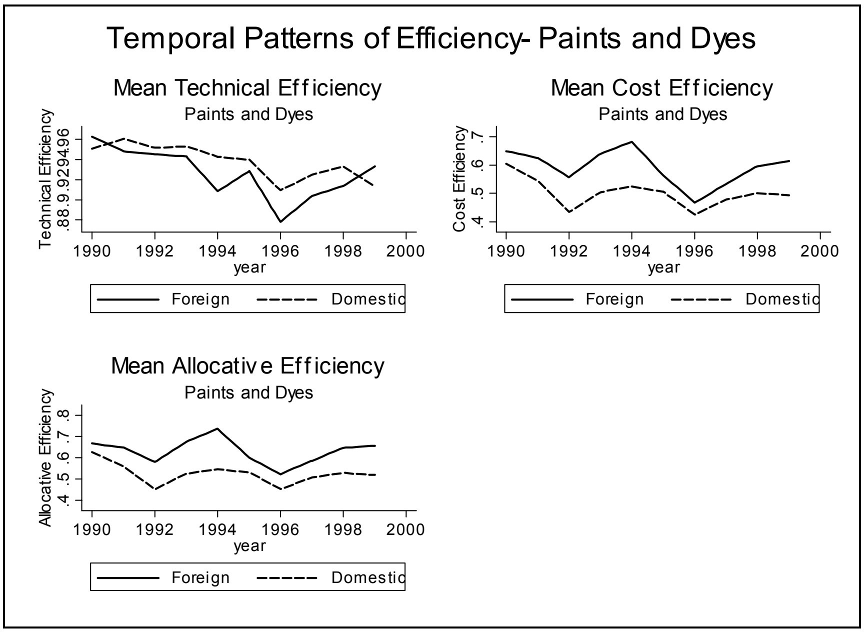
No.	*Industry*	β_0 *(constant)*	B_l *(Lp)*	B_m *(Mp)*	B_y *(y)*	B_t *(t)*	*Parameters* γ	η	σ^2	*Returns to Scale*	*LLF#*	*Obs*
1	Industrial	-3.96	0.05	0.87**	0.87**	0.51	0.85**	0.008	0.11**	1.15**	186.69	468
	Machinery	(-10.6)	(0.28)	(5.22)	(66.87)	(0.63)	(22.75)	(0.55)	(4.04)	(11.49)		
2	Machine Tools	-3.71	0.10	0.78*	0.93**	-0.03**	0.94**	-0.20	0.39**	1.07**	78.25	282
		(-5.19)	(0.34)	(2.60)	(61.84)	(-3.29)	(49.65)	(-7.85)	(3.62)	(5.01)		
3	General Purpose	-4.29	-1.00**	1.68**	0.77**	0.07**	0.96**	0.019**	0.29**	1.29**	201.98	358
	Machinery	(-6.53)	(-3.49)	(5.56)	(41.75)	(4.66)	(69.58)	(2.22)	(3.26)	(16.59)		
4	Automobile	-0.36	0.024	0.82**	0.95**	0.02	0.073	0.23**	0.027**	1.02 **	68.98	198
		(-4.82)	(0.67)	(2.35)	(95.54)	(1.26)	(1.00)	(4.14)	(8.28)	(5.31)		
5	Automobile	-3.74	0.21**	0.60**	0.92**	0.02**	0.94**	0.03**	0.12**	1.09**	699.22	912
	Ancillaries	(-39.3)	(9.57)	(25.15)	(106.93)	(5.89)	(114.23)	(4.12)	(8.36)	(10.11)		
6	Chemicals	-4.25	-0.04	0.92**	0.81**	0.07**	0.90**	0.02**	0.18**	1.23**	401.53	1006
		(-21.60)	(-0.60)	(14.23)	(68.47)	(12.06)	(49.92)	(1.77)	(5.70)	(19.54)		
7	Drugs and	-2.62	0.64**	0.22	0.81**	0.013**	0.90**	0.004	0.29**	1.23**	157.56	1291
	Pharmaceuticals	(-11.0)	(3.62)	(1.41)	(7.80)	(2.30)	(56.07)	(0.55)	(7.20)	(4.69)		
8	Paints and Dyes	-3.98	0.003	0.89**	0.96**	-0.02**	0.93**	-0.29**	0.22**	1.04 **	189.94	370
		(-10.2)	(0.03)	(7.39)	(132.39)	(-4.79)	(47.09)	(-8.79)	(4.06)	(5.95)		
9	Electrical	-4.00	-0.48**	1.25**	0.99**	-0.03**	0.87**	-0.30**	0.17**	1.01**	141.61	350
	Appliances	(-15.1)	(-9.25)	(22.08)	(117.30)	(-5.36)	(22.33)	(-4.22)	(3.41)	(-118.03)		
10	Cosmetics and	-3.52	-0.09	0.76**	0.93**	0.06**	0.93**	0.04**	0.28**	1.07**	49.38	162
	Toiletries	(-5.80)	(-0.39)	(3.35)	(39.03)	(3.10)	(29.06)	(2.04)	(2.44)	(3.14)		
11	Fertilisers and	-4.26	-0.75**	1.61**	0.79**	0.05**	0.95**	-0.003	0.41**	1.26**	171.83	613
	Pesticides	(-9.71)	(-3.18)	(6.46)	(62.71)	(5.37)	(81.89)	(-0.59)	(4.93)	(97.37)		

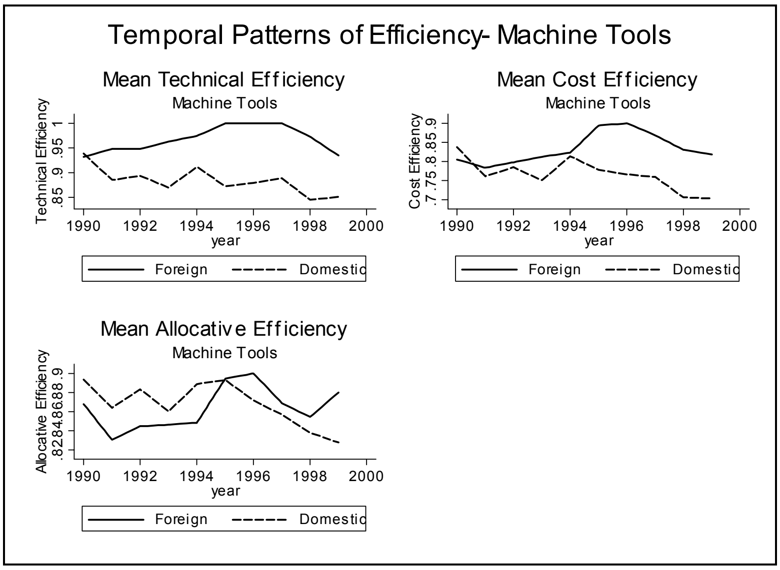
Notes: # Loglikelihood function. In the parenthesis I have given the t-statistics. *Parameters:* $\sigma^2=(\sigma^2_u+\sigma^2_v)$; $\gamma=\sigma_u/(\sigma_u+\sigma_v)$. *A* ** indicates statistically significant at 1% critical value, *A* * indicates statistically significant at 5% critical value.

Graph 1

Temporal Pattern of Efficiency and Ownership – Using DEA







Temporal Patterns of Efficiency- Machine Tools
Mean Technical Efficiency
Machine Tools
Technical Efficiency
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1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Cost Efficiency
Machine Tools
Cost Efficiency
.7 .75 .8 .85 .9
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
Machine Tools
Allocative Efficiency
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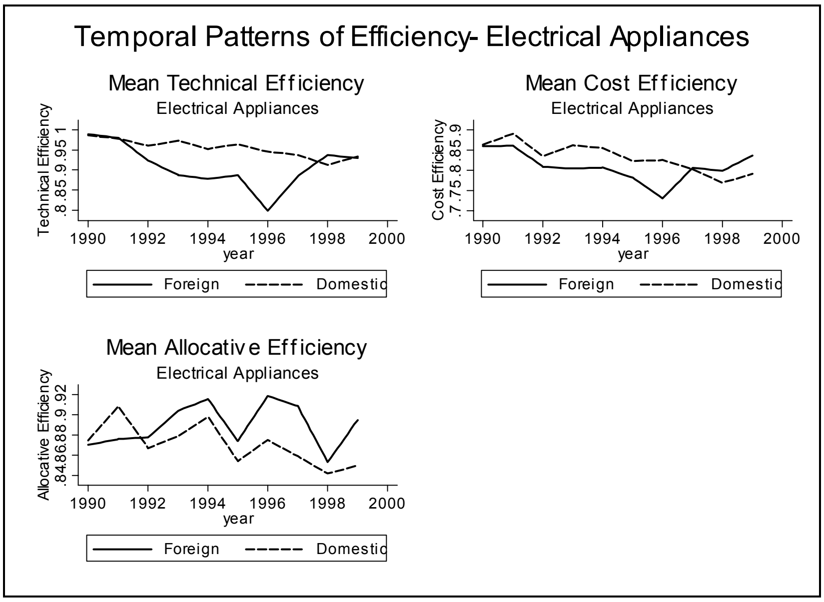
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic



Temporal Patterns of Efficiency- Electrical Appliances
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Electrical Appliances
Technical Efficiency
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year
Foreign
Domestic
Mean Cost Efficiency
Electrical Appliances
Cost Efficiency
.7 .75 .8 .85 .9
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
Electrical Appliances
Allocative Efficiency
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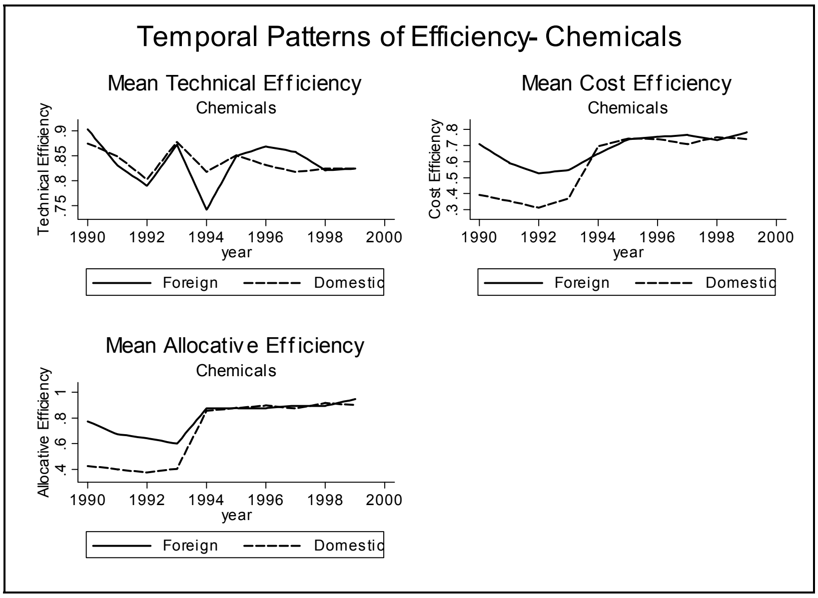
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic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Technical Efficiency
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Foreign
Domestic
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Chemicals
Cost Efficiency
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year
Foreign
Domestic
Mean Allocative Efficiency
Chemicals
Allocative Efficiency
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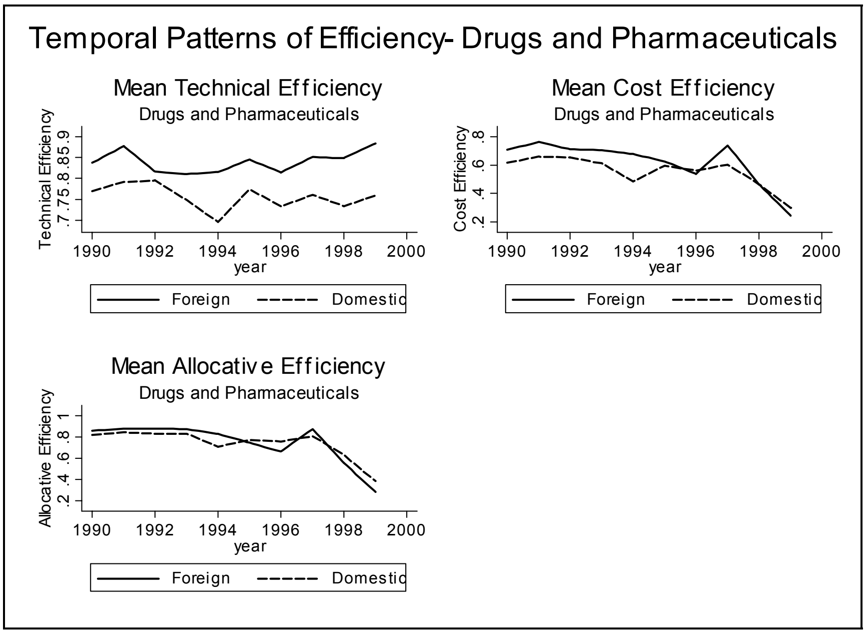
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic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1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Cost Efficiency
Drugs and Pharmaceuticals
Cost Efficiency
.2 .4 .6 .8
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
Drugs and Pharmaceuticals
Allocative Efficiency
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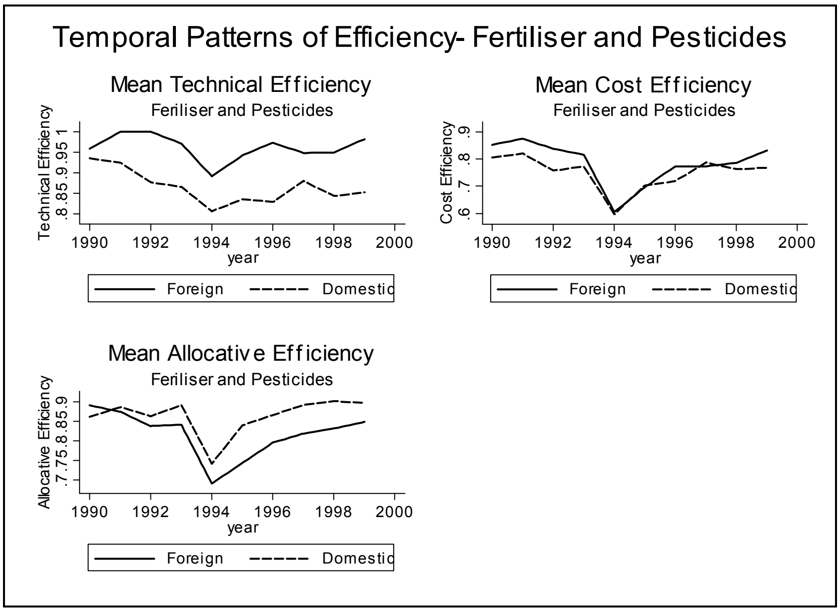
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic


Temporal Patterns of Efficiency- Fertiliser and Pesticides
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Feriliser and Pesticides
Technical Efficiency
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1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Cost Efficiency
Feriliser and Pesticides
Cost Efficiency
.6 .7 .8 .9
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
Feriliser and Pesticides
Allocative Efficiency
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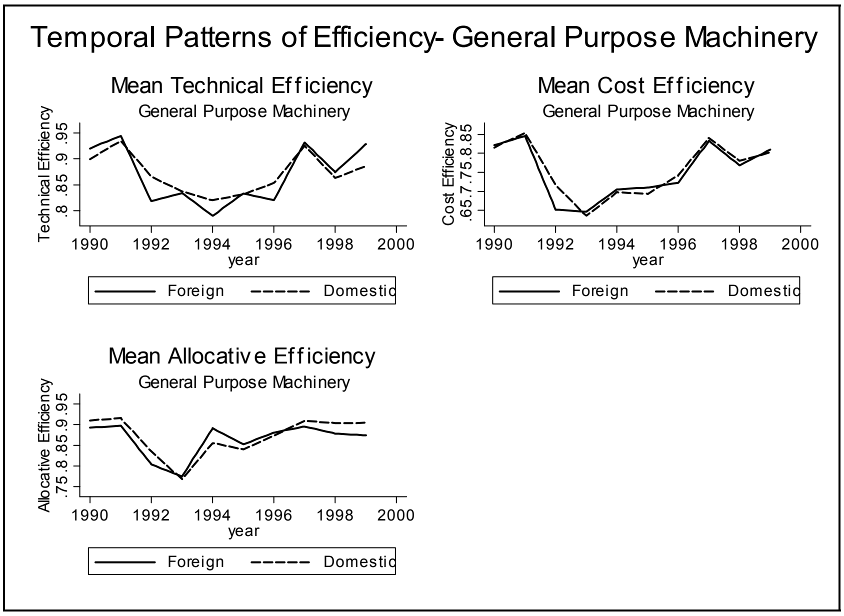
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic


Temporal Patterns of Efficiency- General Purpose Machinery
Mean Technical Efficiency
General Purpose Machinery
Technical Efficiency
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1990 1992 1994 1996 1998 2000
year
Foreign
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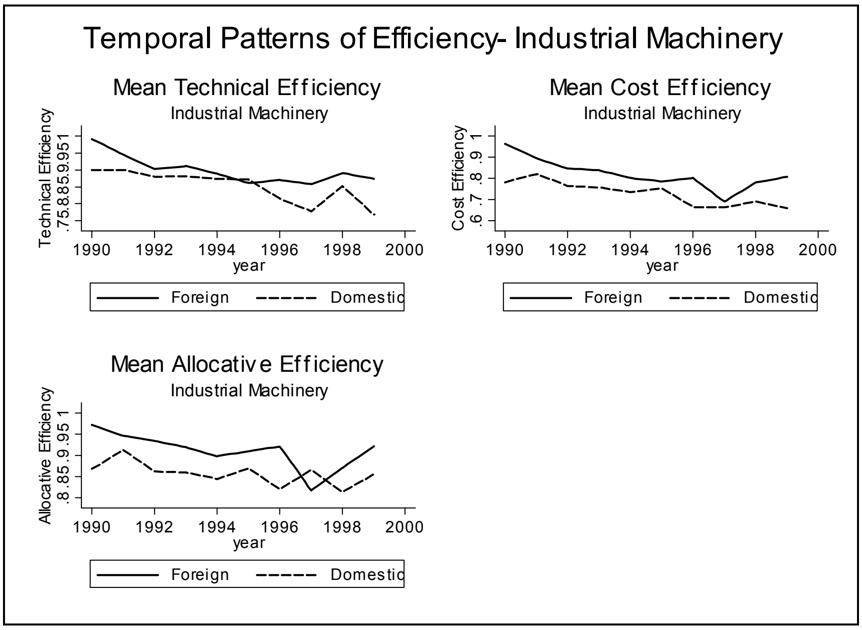
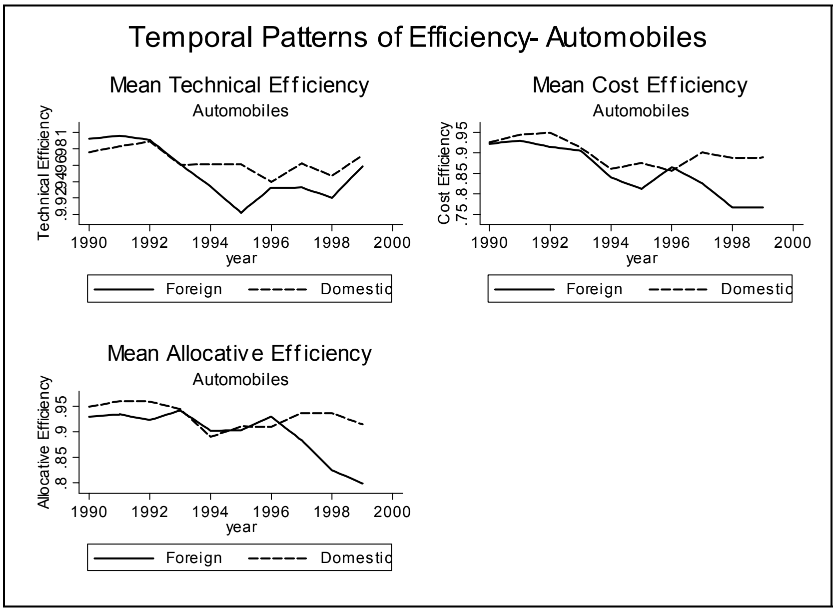
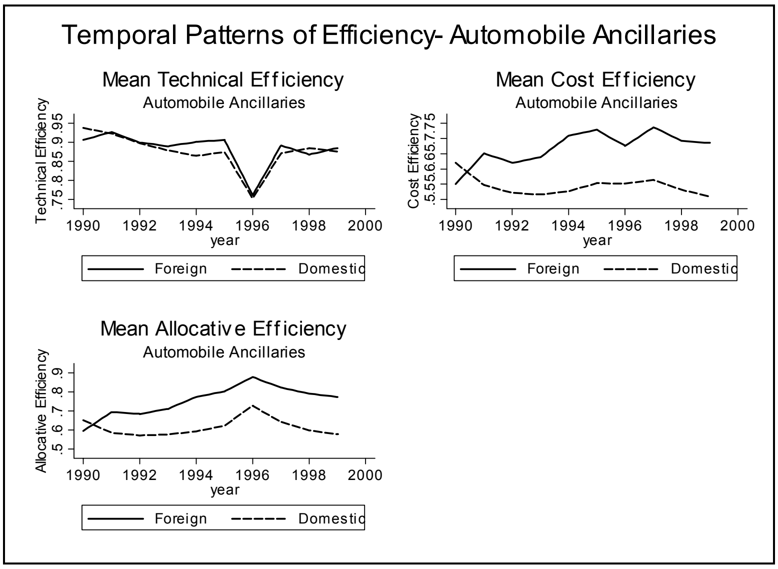
Mean Cost Efficiency
General Purpose Machinery
Cost Efficiency
.65 .7 .75 .8 .85
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
General Purpose Machinery
Allocative Efficiency
.75 .8 .85 .9 .95
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic


Temporal Patterns of Efficiency- Industrial Machinery
Mean Technical Efficiency
Industrial Machinery
Technical Efficiency
.75.8.85.9.951
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Cost Efficiency
Industrial Machinery
Cost Efficiency
.6 .7 .8 .9 1
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
Industrial Machinery
Allocative Efficiency
.8.85.9.95 1
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic


Temporal Patterns of Efficiency- Automobiles
Mean Technical Efficiency
Automobiles
Technical Efficiency
.9929496981
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Cost Efficiency
Automobiles
Cost Efficiency
.75.8.85.9.95
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic
Mean Allocative Efficiency
Automobiles
Allocative Efficiency
.8 .85 .9 .95
1990 1992 1994 1996 1998 2000
year
Foreign
Domestic


Temporal Patterns of Efficiency- Automobile Ancillaries
Mean Technical Efficiency
Automobile Ancillaries
Technical Efficiency
.75 .8 .85 .9 .95
1990 1992 1994 1996 1998 2000
year
Foreign Domestic
Mean Cost Efficiency
Automobile Ancillaries
Cost Efficiency
.5 .55 .6 .65 .7 .75
1990 1992 1994 1996 1998 2000
year
Foreign Domestic
Mean Allocative Efficiency
Automobile Ancillaries
Allocative Efficiency
.5 .6 .7 .8 .9
1990 1992 1994 1996 1998 2000
year
Foreign Domestic