The changing role of technological factors in explaining efficiency in Indian firms.

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Abstract

The liberalization process underway in the Indian economy in recent times has thrown up many challenges. This paper investigates the factors explaining industrial efficiency in India and whether there has been a change in these factors since liberalization was ushered in during 1991. Since the economy and in particular the industrial sector has been besieged by recession in recent years it is pertinent to investigate the changing role of the determinants of the efficiency of firms. This paper investigates the efficiency of firms during the period 1991 to 2001, using the concept of frontier production functions. Estimates of inefficiency have been obtained for 23 industry groups using the Capitaline Ole′ database for three years 1991, 1995 and 2001. We find that the variables relating to external competition and technology flow from outside such as royalty payments, exports and import of raw materials have become significant in the year 2001 which was not the case in the year 1991.

Keywords. D24, L11

JEL classification. Efficiency, liberalization

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1. Introduction

The process of liberalization underway in the Indian economy has over the last ten years led to several changes in its different sectors while the industrial sector is thought to have undergone significant changes due to this process (Ahluwalia, 2002). This paper investigates these changes in the industrial sector by examining the factors that explain efficiency. It is thought that with liberalization, variables like technology and those related to international orientation should become more important in explaining efficiency as firms need better technology in order to compete (Pack, 1988).[1] However, one needs to examine whether such a phenomenon has indeed occurred in the case of India. In the next section we look at the literature in this context. In Section 3 we discuss the hypothesis that has been examined in this paper and the methodology followed in testing this hypothesis. In Section 4 we present results emerging from the analysis. The final section sums up the paper.

2. Literature Survey

The best practice level or a frontier is the production function giving the maximum possible output given a set of inputs. However, in order to reach the best practice level, knowledge of this level or the frontier is needed and also the distance from the frontier. In this context it is also important to distinguish between technological progress and changes in technical efficiency. Technological progress occurs through the changes in the best practice production frontier. Total factor productivity change is the sum of the rate of technological progress and changes in technical efficiency. Thus it is important to recognize that changes in technical efficiency affect total factor productivity. In the literature reference is made to allocative and technical efficiency. Allocative efficiency occurs when a firm employs its factors in the correct proportions. On the other hand, technical efficiency arises when a firm makes the best use of its inputs. Technical efficiency is obtained by minimizing the cost incurred at each level of activity. The focus of this paper is technical efficiency. Technical efficiency has also been called X efficiency by Leibenstein (1966) who emphasized that allocative inefficiency was less of a problem compared to technical inefficiency (especially in the context of monopoly). The study of efficiency is important especially in the context of a developing economy. As pointed out by Nishimuzu and Page (1982), developing countries need to explicitly allocate resources to reach the 'best practice level' given a level of technology and thus the knowledge of the best practice level is of paramount importance. In this section we discuss the determinants of efficiency after which we examine the effect of liberalization on efficiency. In this connection we also discuss the Indian case.

2.1 The determinants of efficiency

Caves (1992) has classified the factors explaining inter industry differences in efficiency into five different groups. These categories are namely, (a) competitive conditions, (b) organizational factors, (c) structural heterogeneity, (d) dynamic disturbances, and (e) regulation. Some of these factors can also explain inter firm differences though the last group of factors should affect all firms in the same way. Competitive conditions include factors related to market structure such as concentration, import competition and export intensity. The other factors that are important in explaining efficiency are those related to the organization of an industry such as the scale of plant, diversification by firms (e.g. due to mergers or multiplant operations), extent of subcontracting, prevalence of foreign investment, or the organization of the labor force including the extent of unionization and the use of part time employees. The structural heterogeneity factors are those that cause competing units to exhibit heterogeneous levels of efficiency in the long run and include capital intensity, vintage of capital, product differentiation, fuel intensity, regional dispersion, inter plant dispersion of material labor ratio, diversity of industry product, diversity of plant scale and the proportion of non production workers. The dynamic disturbance factors are intensity of R&D expenditure, technology import payment, technology export receipts, rate of productivity growth, the rate of output growth and the variability of output growth. These factors can cause a shift in the efficient frontier as well as the position of the firms relative to the frontier. Hence, the effect of these factors on efficiency is ambiguous. Finally, among the regulatory policies affecting efficiency are tariff protection and policies that control the entry of firms in an industry.

2.2 The effect of liberalization on efficiency

The amount of efficiency dispersion in an industry has been studied by estimating the frontier production technology which defines the maximum amount of output y^* available from a given vector of inputs, x, such that $y^* = f(x)$. For observed combinations of output and inputs at the i^{th} firm (y_i, x_i), the ratio $y_i / f(x_i)$ is interpreted either as an efficiency index itself (in the deterministic approach) or as an efficiency index contaminated by measurement errors beyond the control of the plant managers (in the stochastic approach). These are the two approaches to the estimation of efficiency and are known as the deterministic frontier and the stochastic frontier. Cross plant average efficiency levels are the most commonly reported summary measures of industry's performance. Cross firm variance in efficiency levels are high in developing countries as shown by Pack (1988), Blomstrom and Kokko (1998), etc. Tybout (2000) reports that the mean technical efficiency levels are around 60 to 70 per cent of the best practice frontier in developing countries.

Theoretical models of industry evolution have shown that regulatory conditions have impeded efficiency improvements. Hopenhayn (1992) has shown that high entry costs not only reduce the amount of entry but it also encourages incumbents with lower efficiency to remain in the market. This increases the efficiency dispersion in the market. In Jovanovic's (1982) model, market interventions like artificial entry barriers, severance laws or policies that prop up dying firms are detrimental to the industry. Policies that inhibit expansion or contraction have similar consequences. Hopenhayn and Rogerson (1993) have simulated the effects of severance laws to show this effect. The empirical validation of this phenomenon has been to show the extent of dispersion with respect to the efficiency frontier.

The efficiency costs of trade protection and industrial regulation have been documented in the studies of Little, Scitovsky and Scott (1970), Balassa (1971), Bhagwati (1978) and Krueger (1978). There are four basic arguments in favor of market oriented policy reform: (see Rodrik 1995) (1) economic liberalization reduces static efficiencies arising from resource misallocation and waste; (2) economic liberalization enhances learning, technological change and economic growth; (3) outward oriented economies are better able to cope with adverse external shock, and (4) market based economic systems are less prone to wasteful rent seeking activities. The benefits on account of the first have been shown in the form of the Harberger triangles and are quantitatively minor compared to the other three benefits.[2] [3] Other arguments also exist for example, trade and industrial policy reform leads to improved capacity utilization in the face of bottlenecks and macroeconomic policy failures.

Havrylyshyn (1990) surveys the literature that gives evidence on the link between trade policy and efficiency gains in developing countries. Most of the studies measure technical efficiency gains and correlate these gains with the degree of protection, and find that there is evidence of a positive effect of trade policy liberalization on efficiency, for example, Nishimuzu and Page (1982) for Yugoslavia and Page (1984) for India; though Moran (1987) in a study of thirty two countries finds no such evidence. Tybout, de Melo and Corbo (1991) analyse changes in the industrial sector performance accompanying the Chilean trade liberalization of the 1970s. They find very little evidence in overall productivity improvements. They construct industry-specific indices of the changes in returns to scale, average efficiency level and dispersion in efficiency levels between 1967 and 1979. Tybout (2000) reviews the literature on trade liberalization and efficiency and concludes that the improvement in efficiency is probably due to intra plant improvement and unrelated to internal or external scale economies.

The dynamic effects of liberalization are thought to enhance learning, technological change and economic growth. The relationship between protection and poor technological performance has been shown in the literature by firm level case studies, cross industry studies of technical efficiency and productivity change and cross country studies of economic growth.[4] The firm level case studies of technological change like Katz (1987), Lall (1987) and Pack (1987) do not lead to any generalizations regarding the extent to which trade regimes affect the pace of learning.

Nelson (1981) has emphasized the importance of technological change on a firm's productivity growth. To understand how technology affects efficiency one has to examine how it diffuses through the economy. The impact of technological changes on productivity and efficiency depends on whether these changes are incremental or paradigmatic.[5] Incremental changes constitute movement along the trajectories while paradigmatic changes involve changes in the frontier itself. Paradigmatic changes lead to increased efficiency for the firms adopting it, but this may raise the distance between the frontier and the average firms. This may result in a decline in average efficiency of the industry. Thus, the effect of technology on efficiency is ambiguous (see Caves 1992). Technology usage also has complementarity with skill. Other studies have looked at the effect of multinational firms on domestic technological effort. Such effects are known as productivity spillovers and take place when the entry or presence of MNE affiliates leads to productivity and efficiency benefits to domestic firms. Foreign owned firms have been found to be more productive than their domestic competitors (e.g. Haddad and Harrison 1993) and the effect of MNEs on labor productivity has been shown (e.g. Caves 1974; Globerman 1979; Blomstrom, 1986; etc.). The effect of MNEs on domestic technological effort depends on how the technology diffuses to the local firms. Swan (1973), Tilton (1971) and Lake (1979) have provided evidence of the role of MNEs in diffusion of technologies to host countries. The impact of MNEs on the technologies used by local firms has been studied by Katz (1969). He shows that technical progress did not take place only in the MNEs' own industries but also in other sectors because of the standards imposed by them with respect to quality, delivery dates, etc. in their supplies of raw materials and parts.

There are some other factors that contribute to efficiency and these are factors related to international exposure. Chen and Tang (1987) and Aw and Hwang (1994) find that firms that sell primarily in the export market tend to have higher technical efficiency than those that sell primarily in the domestic market. However, the interpretation of these studies are also open to question as the causality could be running from efficiency to export orientation and not the other way around.[6] Aw and Batra (1993) treat export and technological effort as endogenous and estimate a bivariate probit model and show that export orientation has no causal effect on technical efficiency in firms that report R&D spending while it has a positive effect on those that do not. Foreign ownership has also found to be an important contributory factor.

Coming to the literature on the impact of liberalization on efficiency in the Indian context, Srivastava (2001) has estimated the technical efficiency of Indian manufacturing firms for the period 1980-81 to 1996- 97. He finds that mean technical efficiency has gone down in the nineties (the period of liberalization) compared to the eighties.

3. Empirical Exercise

The hypothesis examined in this paper is whether there have been changes in the factors affecting the efficiency of Indian manufacturing firms in the pre and post liberalization era. We have data on the firms for the period 1991 to 2001 from Capitaline Ole′ database maintained by Capital Markets (I) Pvt. Ltd. Since we have data on firms for the period 1991 to 2001, we have done a cross sectional study for the years 1991, 1995 and 2001 to compare the factors explaining the efficiency of the firms in these three years.[7] In this section we first examine the concept of efficiency used in this paper. In the second part we discuss issues related to the measurement of variables needed to estimate efficiency. We also discuss the variables that have been used to capture the changes in the determinants of efficiency.

3.1 The dependent variable

The estimation of technical efficiency dates back to Farrell (1957). He established that technical inefficiency could occur through the use of bundles of inputs that were larger than the minimum required to obtain the output. Subsequently, the estimation of efficiency has been made by using the stochastic production frontier. According to this approach the production function is given by,

$$y_i = f(x_i) + v_i - u_i, \quad u_i \geq 0, \tag{1}$$

where y is output, x is input and v is a symmetric error term while u is an asymmetric error term that is caused by technical inefficiency. The frontier production function is given by $f(x\ ) + v$ and is the maximum output possible from a given amount of input. Random disturbances, measurement errors and minor omitted variables are represented by v while u represents the distribution of technical efficiency beneath the frontier. The measures of efficiency are based on the moments of the residual i.e. v and u.[8] These measures of efficiency capture the efficiency of the entire industry and not of the individual firm as noted in Caves (1992) and Caves and Barton (1990). The efficiency of a firm has been estimated in the literature using a panel of firms over a period of time. This follows from the work of Aigner et al. (1977) and Meeusen and van den Broeck

(1977). The calculation of efficiency in the case of a panel of firms for particular years has been discussed in Cornwell, Schmidt and Sickles (1990).

We have estimated the inefficiency of firms for a cross section using the concept of Corrected Ordinary Least Squares. We have not estimated inefficiency for a panel of firms for the following reasons. The problem of using a panel consists in obtaining data on physical output that is of unchanging quality. If such data could be obtained this would provide the best measure of inefficiency. However, if such data is not available, the data has to be deflated. In this case deflators have to be devised at the firm level and the deflation should capture quality improvement. Any quality improvement in output that is not reflected in the deflator will result in a downward bias in the estimate. The second problem has to do with prices. In an imperfect competition setting prices may differ across micro units and assuming constant prices implies that establishments with prices higher than average prices will be assigned higher efficiency. In order to rectify this problem, knowledge of the demand for differentiated products is necessary. One way out of this problem could be to estimate inefficiency across a cross section of firms and thus avoid the problem of deflation. The measure of inefficiency used in this paper can be illustrated with the help of the simple diagram that follows.

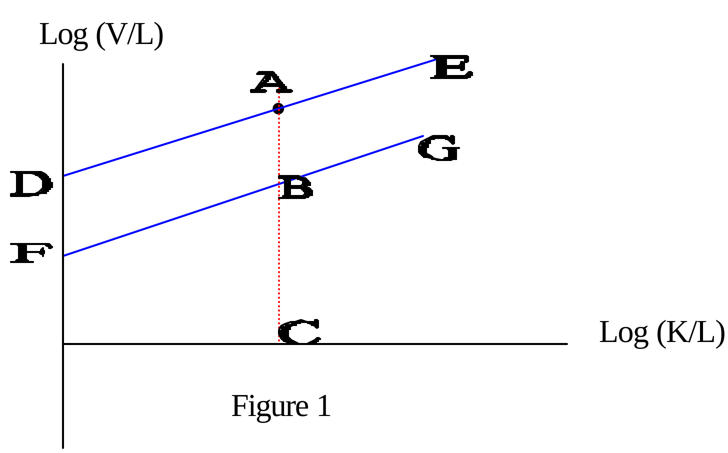

Figure 1

In Fig. 1 the production function for an industry is shown by FG and the frontier firm is given by the point A. Point B represents any other point. The intercept of the regression is corrected so that the production function now passes through the frontier firm and is shown by the line DE. The measure of efficiency that we have used is the ratio of the distance AB to AC[9] (AB is the distance from the frontier for the firm given by point B while AC is the height of the industry frontier). This is a measure of inefficiency since it measures the relative distance of a firm from the frontier and is similar to a measure of efficiency[10] for a cross section of firms discussed earlier.[11]

The estimation of efficiency was done by identifying the frontier firm for each industry group. After finding the highest intercept, the intercept of the regression line was corrected by the distance of this from the frontier firm such that the regression line now passed through the frontier firm. The frontier firm is the one with the highest intercept in that industry group. The intercept of each firm was obtained by substituting the value of the slope of the regression line in the coordinates of each firm. We then obtained the distance of each firm from the frontier. This distance was normalized by the height of each industry frontier to obtain a measure of efficiency. The inefficiency measure obtained for each firm was normalized so that it was comparable across industries.

3.2 Estimation of inefficiency

The first step in the process of estimating efficiency is the estimation of the production function. For this data on output, inputs such as capital and labor are needed. Output has been measured both by value added and gross output in the efficiency literature as discussed by Caves (1992). The estimates based on value added have yielded better results than those based on gross production. We have measured output by value added.[12] In the literature, labor has been measured by compensation received, total number of employees or by equivalent production worker hours. Nadiri and Kim (1996) have used total compensation for the labor input for estimating productivity. Caves (1992) has used compensation to measure labor. We have measured labor by employee cost.[13] Capital in the efficiency literature has been measured by the sum of assets and inventories or by average tangible assets per plant.[14] We have measured capital by adding depreciation, 15 per cent of fixed assets[15] and inventories.[16]

The question of selecting the appropriate production function arises in the context of efficiency and has been discussed in Caves (1992). Both the Translog and Cobb Douglas production function have been used in the estimation of efficiency. Estimates of efficiency based on the Translog production function have yielded better results. The form of the production function[17] that we have used is the following:

$$\log \left(\frac{V}{L}\right) = c + \log \left(\frac{K}{L}\right). \qquad (2)$$

For each year after cleaning the data[18] we have estimated the production function for each industry group. After cleaning the data the year 1991 had 1082 firms, the year 1995 had 2589 firms and the year 2001 had 1669 firms.

3.3 Factors affecting efficiency

In the literature we have discussed the factors affecting efficiency. Caves has discussed the factors in the context of inter industry differences and hence some of the variables may not be relevant for an analysis based on a cross section of firms. In the following table we present the variables that have been used in this paper to explain the efficiency of firms.

Table 1: Factors affecting efficiency

	Variables	Expected sign	Explanation	Data available
1	Outward orientation Imports (raw material)	Minus	The greater the imports the lower the inefficiency.	Imports of raw materials to sales turnover
2	Outward orientation Imports (capital)	Minus	The greater the imports the lower the inefficiency.	Imports of capital goods to sales turnover
3	Outward orientation Exports	Minus	The greater the exports the lower the inefficiency.	Exports (FOB) to sales turnover
4	Vintage of capital	Plus	The older the vintage of capital used the more the inefficiency.	Ratio of depreciation allowance to the value of plant and machinery
5	Product differentiation	Plus	The greater the product differentiation the greater the inefficiency.	Advertising expenditure to sales turnover
6	R&D expenditure intensity	Plus /minus	Effect ambiguous.	Total expenditure on R&D to sales turnover
7	Technology import payment	Minus	The more the payment the lower the efficiency	Royalty and technical fees paid in foreign exchange to sales turnover.
8	Fuel intensity	Plus	The greater the fuel intensity the greater the inefficiency.	Power and fuel cost to sales turnover.

The impact of technology investment affects the product quality and hence the efficiency of the firm. Investment in technology could be made domestically or sourced from abroad. The investment in technology that is of domestic origin leads to change in the capital vintage and is accounted for by investment in plant and machinery. R&D performed domestically also leads to changes in product quality and hence efficiency. The other source of investment in technology is by sourcing it from abroad and import of capital goods that add to the capital stock of the country as well payments of technical fees for technology procured from abroad capture this source.

The outward orientation variables contribute to competitiveness and are expected to decrease inefficiency.[19] The vintage of capital is expected to contribute to inefficiency and is thus expected to have a positive sign. The coefficient of advertising intensity or the product differentiation variable is reported positive in the literature (see Caves and Barton, 1990; Caves, 1992) as this variable is responsible for generating inefficiency. The effect of R&D intensity on efficiency is reported to be ambiguous in the literature since R&D that operates to expand the frontier can cause overall inefficiency for the industry but R&D could lead to more efficient production thus improving efficiency for the firm. Imported technology helps to attain a higher growth and so higher technology import payment should be associated with higher efficiency. The greater use of fuel might indicate inefficiency. Collecting these variables in a equation gives the estimated model

Efficiency = *f* (exports, imports of raw materials, import of capital goods, capital vintage, product differentiation, fuel intensity, payments for technology imports, R&D)

4. Results

We have obtained the estimates of inefficiency for the firms for three years 1991, 1995 and 2001. In order to investigate the effect of factors in explaining inefficiency we have used the estimates of inefficiency in a multiple regression equation in the second step. The objective is to investigate which of the explanatory variables can explain inefficiency for each year under study and highlight the changes in factors explaining inefficiency. The results of the multiple regression exercise are presented in Table 2.[20]

Table 2: The multiple regression

Independent variables [a]	1991	1995	2001
CONSTANT	0.319985 (6.54)	0.384643 (11.19)	0.527975 (9.00)
CAPVINT	-0.066075 (-1.46)	0.008400* (2.86)	-0.001416 (-1.45)
RD	0.122355 (0.21)	-0.027969* (-5.90)	0.015777 (0.10)
PRODIFF	0.756964 (1.80)	0.964811 (3.83)	-0.243345 (-1.32)
FUELINT	0.439374* (4.04)	0.072323* (9.19)	0.023286* (4.19)
IMPR	0.004310 (0.70)	-4.36E-05 (-0.00)	-0.042319* (-2.07)
IMPC	-0.007295 (-0.48)	0.001196 (4.82)	-0.245166 (-1.62)
EX	-0.037498 (-0.98)	-0.008686 (-0.44)	-0.057052* (-2.19)
ROYAL	-3.301984 (-1.80)	-0.529393 (-1.51)	-3.102004* (-2.03)
DAUTO	0.133315 (2.24)	0.028984 (0.59)	-0.213882 (-3.06)
DCEMENT	-0.145707 (-2.42)	-0.074729 (-1.73)	-0.284465 (-4.38)
DCHEMICALS	-0.027016 (-0.51)	-0.005734 (-0.15)	0.135216 (2.25)
DELECTRONICS	0.168224 (3.16)	0.138785 (3.69)	0.177592 (2.94)
DFOOD	0.191851 (3.42)	0.254388 (6.65)	0.128160 (1.97)
DFERTILIZERS	0.009888 (0.17)	0.038595 (0.95)	-0.195883 (-3.08)
DSTEEL	0.053128 (1.01)	0.115610 (3.20)	-0.100065 (-1.52)
DPAPER	-0.159373 (-2.57)	-0.045974 (-1.18)	-0.156439 (-2.31)
DPHARMA	0.075795 (1.41)	0.237687 (6.70)	-0.029527 (-0.46)
DPLASTICS	-0.019796 (-0.32)	-0.035952 (-0.92)	-0.116926 (-1.57)
DGLASS	-0.061593 (-0.97)	-0.020386 (-0.43)	-0.066335 (-0.98)
DTEXTILES	0.096056 (1.90)	0.222333 (6.28)	0.108527 (1.79)
DPAINTS	-0.07839 (-1.32)	0.040954 (1.04)	-0.039458 (-0.57)
DPETROCHEM	-0.133791 (-2.05)	-0.104078 (-2.10)	-0.288484 (-4.05)
DPERSONALCARE	0.121960 (1.82)	0.049752 (0.95)	-0.122206 (-1.36)
DENGINEERING	0.049895 (0.95)	0.268297 (7.16)	0.159063 (2.35)
DSUGAR	-0.029467 (-0.48)	-0.036120 (-0.87)	-0.329061 (-5.32)
DCABLE	-0.064450 (-0.97)	-0.096379 (-2.39)	-0.183968 (-2.65)
DMETAL PARTS	0.017261 (0.29)	0.197097 (5.16)	0.003403 (0.05)
DALUMINIUM	-0.091571(-1.36)	-0.182286 (-4.37)	-0.142087 (-1.89)
DELECTRICAL EQUIP	0.104015 (1.83)	0.055725 (1.34)	0.082795 (1.04)
DAUTOANCILLIARIES	0.146592 (2.74)	0.039819 (1.02)	-0.047631 (-0.76)
$\bar{R}^2$	0.16	0.30	0.24
Number of firms	1028	2589	1669

* indicates significance at 5% level.

[a] the dependent variable is efficiency. The values in parentheses are the t values where the standard errors have been corrected for heteroscadasticity.

As can be seen from the results, fuel intensity and product differentiation are significant in explaining efficiency[21] for all the years.[22] As only these variables were significant in 1991 while no other variables was, it seems that the only way to increase efficiency in that period was by reducing cost.

Table 3: Summary Of The Results

	Variables	1991	1995	2001
1.	Capital vintage		Significant	
2.	R&D		Significant	
3.	Product differentiation	Significant (at 10% level)	Significant	
4.	Fuel intensity	Significant	Significant	Significant
5.	Exports			Significant
6.	Royalty payments	Significant (at 10% level)		Significant
7.	Raw materials import			Significant
8.	Import of capital goods		Significant (wrong sign)	

The variables that are significant in the year 1995 are vintage of capital, R&D and import of capital goods. These variables can be said to be variables that are related to factors affecting the liberalization of the internal economy or are internal factors. The factors that are significant in the year 2001 are the external factors like exports,[23] royalty and import of raw materials. These factors are ones related to the external controls of the economy. Thus one must note that factors relating to technology and international orientation have become significant in the year 2001 while they were not so in 1991.

The impact of investment in technology through domestic factors seem to be important in the year 1995 as both the R&D variable and the vintage of capital variable are significant. However, there are changes in factors explaining efficiency in 2001 as these variables are not significant and instead royalty payments which capture the investment in technology sourced from abroad are so. Thus, there seems to be a change in the relative importance of the domestic factors of investment as opposed to the external factors of technology investment.

However, it is important to ask why the factors that are significant in 1995 are not so in 2001? One explanation that could be given is that there has been a change in the nature of technology over the period. Thus the import of capital goods was important at the beginning of the period since the embodied technology (Teece 1977) of the goods is easier to assimilate. The significance of the import of raw materials and royalty in the later year points to the fact that disembodied technology is now being absorbed in the economy and which is more difficult to absorb than embodied technology. This is in line with the dynamic arguments provided in favor of the liberalization discussed in the literature survey. As has been discussed earlier technology usage has complementarity with skill. The capacity to absorb and assimilate technology from foreign sources also depends on the proportion of skilled labour. India has an advantage in this respect compared to other developing countries and hence extending the conclusions reached in this study to other developing countries may not be justifiable. However, a deeper examination of the issues is needed to arrive at definite conclusions.[24]

5. Conclusion

In this paper we have examined the issue of efficiency of Indian firms in the context of the liberalization process initiated in India. Since the economy and in particular the industrial sector has been besieged by recession in recent years it is pertinent to investigate the changing role of the determinants of the inefficiency of firms. We have examined whether the factors explaining inefficiency of manufacturing firms have changed over this period 1991 to 2001. Using the concept of frontier production function this paper estimates inefficiency in 1991, 1995 and 2001. The inefficiency of firms has been estimated for 23 industry groups using the Capitaline Ole′ database. It then investigates the factors explaining industrial efficiency in India and whether there has been a change in these factors over the aforementioned period. We find that the variables relating to external competition and technology flow from outside such as royalty payments, exports and import of raw materials have become significant in the year 2001 which was not the case in the year 1991. The conclusions emerging from the study suggest that the factors relating to technology and international orientation have become significant in explaining inefficiency in the year 2001 compared to the year 1991.

This paper has used firm level data to analyse how the exposure to foreign technologies has helped to improve the efficiency of firms. Given the relative importance of foreign technology, the next step would be to study technology diffusion in India taking into account all the channels of such transfers. This would be the direction of future research into this area.

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Endnotes

[1] Balassa (1988) has argued that outward orientation provides the carrot and stick of competition that gives inducement to technological change.

[2] The estimate of welfare costs of relative price distortions under usual neoclassical assumptions do not produce numbers in excess of a couple of percentage points of GNP (Srinivasan and Whalley 1986).

[3] We discuss the second argument in greater detail as it is relevant in this paper. For discussion on the other arguments see Rodrik (1995).

[4] The empirical evidence on trade and growth based on the cross country studies have shown that increased trade has improved growth. These studies suffer from many problems according to Rodrik (1995) including endogenity of the trade regime variable, causality between the relationships specified, failure to specify the mechanism which leads to growth and measurement problems in the sense that trade regime variables are confused with macroeconomic variables.

[5] See Dosi (1988).

[6] Bernard and Jensen (1999) have shown that more efficient firms are likely to export but exporting does not lead to change in efficiency.

[7] We do not have sufficient data for years preceding 1991 to study the pre liberalization period.

[8] Four measures of technical efficiency have been used in the literature for cross section studies, see Caves (1992) and Caves and Barton (1990). One of the measures is based on the ratio of the intercept shift of the production frontier to the average position of the production frontier and is given by $\frac{\sqrt{(2/\pi)}\sigma_u}{\bar{y} + \sqrt{(2/\pi)}\sigma_u}$ and measures inefficiency.

[9] The measure of efficiency that we use helps us capture the efficiency of each firm in the industry unlike the measures of efficiency for cross section studies reviewed in the literature which provides a measure of efficiency for an industry.

[10] As discussed before that measure is given by the ratio of the intercept shift of the frontier to the average position of the frontier.

[11] A similar measure of inefficiency has been used in the literature in the context of linear programming models of the frontier. See Caves and Barton (1990) pp. 167. Caves (1992) has also discussed such a measure, see pp. 38.

[12] Value added has been defined as gross profit plus depreciation plus excise duty plus interest plus employee cost.

[13] We do not have data on employment and so some proxy has to be used. One alternative is to obtain a value of labour using the wages and wage bill for that industry group from ASI. However, the assumption underlying this method is that the wages are the same in the entire industry which may not be true. Hence we have used employee cost of the firm.

[14] This is given by (tangible fixed assets + (acquisition of tangible fixed assets – removal of tangible fixed assets – depreciation of tangible fixed assets)) /2 + (initial total inventory + final total inventory)/ 2.

[15] This definition of capital is common and has been used extensively, e.g. Basant and Fikkert (1996).

[18] In order to use the above form of the production function, which assumes constant returns to scale (CRS), we have first checked for CRS. This has been done by estimating the production function in the full form i.e.

$$\log V = c + \log K + \log L$$

We have computed the F statistic for each industry. Since the F statistic was in the permissible range for most industries in the three years the ratio form of the production function or equation (2).

[17] We have used this form of the production function as this helps in readily calculating the efficiency of each firm in a particular industry group. We discuss this in detail shortly.

[18] We have cleaned the data by omitting firms not belonging to manufacturing and then those with value added, salaries, employee cost or capital equal to or less than zero.

[19] The causality in the case of exports is not straightforward. While firms that are more efficient export, exporting does not increase efficiency (see Bernard and Jensen 1999).

[20] The variables are: (1) royal – royalty and technical fees, (2) rd - total R&D, (3) capvint – capital vintage, (4) fobexp – exports, (5) impr – import of raw materials, (6) prodiff – product differentiation, (7) fuelint – fuel intensity, (8) impc – import of capital goods.

[21] Royalty was significant in 1991 at the 10% level.

[22] Product differentiation and fuel intensity are highly correlated in 2001. Dropping one variable makes the other variable significant.

[23] The export results must be treated with caution as we have noted in the literature survey that there is a problem of causality in this case.

[24] We have also tried some interaction terms in the three regressions but the results are not significant and did not indicate any particular trend.