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IS THE MANUFACTURING SECTOR IN INDIA AN ENGINE OF GROWTH ?

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Abstract

Manufacturing has been an engine of growth in India in the seventies and eighties. After the 1991 economic reforms the engine appears to be slowing. This paper attempts to examine the reasons. The analysis reveals that manufacturing output growth in the post-reform period is 'inputs driven' rather than efficiency driven. The paper advocates policies to improve production efficiency through encouraging firms to invest more in R&D, technical training for workers, and technology-aided managerial processes.

The Setting

The composition of the overall output of the Indian economy, in the recent period of 1993-94 to 2001-02, points to the relatively large share of the non-agricultural sectors. The non-agricultural sectors make up 75 per cent of the overall GDP in India. Among the non-agricultural sectors, manufacturing accounts for 23 per cent; electricity, water supply and gas, mining and construction sub-sectors account for 9 per cent, and the service sector, comprising all other sub-sectors, accounts for the remaining 43 per cent. Manufacturing, as a single group of activities, thus is a major sector in the Indian economy. In this study, we focus on the manufacturing sector within the non-agricultural sector.

The large size of the population and the base for industrialization that was set up in the 1950s and 1960s enabled growth of manufacturing in India in the subsequent two decades. However, the performance of the manufacturing sector in recent times, particularly in the post 1991-reform period has been controversial and has attracted the attention of several researchers[1]. The sustained growth of this sector has now been threatened primarily by the lack of 'competitiveness' of the sector in a period where trade liberalization

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policies have been implemented. In fact, the UNIDO report of 2002 provides evidence for the stagnation of India's competitiveness, while showing that China has sharply improved its global ranking in the industrial sector's competitiveness (Table 1). While China has consolidated its position as one of the leading manufacturing locations within a short period, why is India not able to do so? One of the major determinants of international competitiveness of a country is its productivity in comparison with that of its competing countries and trading partners. However, what is of foremost importance for a country to improve its productivity is to operate on the production frontier by achieving the maximum possible output from its chosen set of inputs and technology. Thus, it becomes imperative to examine the status of manufacturing productivity in India in the post-reform period.

The average growth rate of output of manufacturing in the 1990s has been lower than in the 1980s (Table 2). Nevertheless, recent studies by Tendulkar (2003) and Goldar (2002) have argued that the 1991 trade reforms seem to have contributed to acceleration in employment growth in organized manufacturing in the post-reform period, mainly due to better access to inputs including capital through foreign direct investment and to the growth in export-oriented industries, which are more labour-intensive. Thus, combining the larger employment with a lower growth in manufacturing between 1995-96 and 1999-2000 than in the eighties, one may conjecture that the manufacturing output growth has been input-driven from the mid-90s. A recent National Manufacturing Survey (NMS) conducted by Chandra and Sastry (2002) at the Indian Institute of Management in Ahmedabad shows that material cost comprises about 65 per cent of the total production cost, direct labour accounts for about 9 per cent and other costs including overheads account for the remaining 26 per cent between 1997 and 2001. The survey clearly indicates that efforts to improve the competitiveness of the manufacturing sector need to be targeted on reduction in material costs as well as overheads.

Table 1: Ranking of Countries by the Competitive Industrial Performance (CIP) index

Country	CIP Index		Ranking	
	1985	1998	1985	1998
Switzerland	0.808	1	0.751	2
Japan	0.725	2	0.696	4
Germany	0.635	3	0.632	5
Sweden	0.633	4	0.562	7
United States	0.599	5	0.564	6
Singapore	0.587	6	0.883	1
Ireland	0.379	15	0.739	3
China	0.021	61	0.126	37
India	0.034	50	0.054	50
Total number of countries	80		87	

Source : UNIDO (2002).

Note: The values for each of the following four variables are standardized for the sample to range from 0 (worst performers) to 1 (best performers): manufacturing valued added, manufactured exports per capita, share of medium- and high-tech activities in manufacturing value added, and share of medium- and high-tech products in manufactured exports. The composite index is calculated as simple average of the above four standardized basic indicators.

Table 2: Structural Growth of Gross Domestic Product (GDP) in India

Years	GDP Growth (per cent)				
	Agriculture	Industry	Services	Manufacturing	Total
1980s	4.37	7.33	6.35	6.98	5.80
1990s	3.13	5.89	7.34	6.00	5.77
2001-2002	5.69	3.35	6.18	3.34	5.43
1993-94 to 1999-2000	3.28	7.04	8.25	7.64	6.53
1995-96 to 1999-2000	2.77	6.30	8.80	6.61	6.51
1997-98 to 2001-2002	2.11	4.10	7.70	3.70	5.35

Source: Based on Economic Survey, various years.

In other words, manufacturing firms in India appear to be operating inside their production frontier. Balakrishnan *et al* (2000), using firm-level panel data, have concluded that there has not been any significant improvement in productivity growth in Indian manufacturing in the post-reform period. However, they do not attempt to explain the reasons for lack of productivity growth in Indian manufacturing. If the explanation for the decline or stagnation in productivity growth is the 'lack of competitiveness', then policies should address this issue. If the lack of competitiveness is due to 'policy environment', there is clearly a need to re-align policies. For an economy that needs to grow at a rapid pace of over 7 per cent per year in overall real GDP terms to achieve its basic developmental goals, the role of manufacturing sector in the economy cannot be ignored.

In this context, the objectives of this paper are to analyze the sources of output growth in manufacturing in the post-reform periods, and to identify the crucial factors influencing manufacturing productivity. We will also examine the characteristics of foreign direct investment in Indian manufacturing to determine the prospects for technical progress in manufacturing in India. Drawing on the poor growth performance of the Indian manufacturing sector in recent times, we would like to test the following hypotheses:

1. Indian manufacturing is still primarily geared to domestic consumption. Therefore, its growth is limited by domestic demand. For increasing production to meet export demand, there has to be substantial productivity improvement.

2. Indian manufacturing is not expanding because it is not changing either in terms of its composition of output, technology or technical efficiency improvement. These changes improve competitiveness in global markets. Changes are not taking place because of poor organization, manufacturing strategies and decision making at the firm level.

The rest of the paper is organized as follows. A brief description of the performance of the manufacturing sector in India in the 90s is given in the following section. Identification of the crucial factors that impinge on manufacturing productivity growth is attempted in the next section. A final section brings out the policy implications of this study.

The Post-Reform Status of the Manufacturing Sector in India

The analysis in this study is based on the corporate database of the Centre for Monitoring of Indian Economy (CMIE). CMIE documents a large database of about 7,800 companies with detailed quantification and diagnosis of the growth, profitability and liquidity of the Indian corporate sector, which is disaggregated by industry, ownership, size and age, over several years (Economic Intelligence Service 2002a). The manufacturing companies included in this database account for about 78 per cent of the total value of manufactured output and the data are available up to FY 2000-01. Additional information is obtained from International Financial Statistics Yearbook, International Trade Statistics Yearbook, Economic Survey, Annual Survey of Industry, CMIE (2001), and National Accounts Statistics.

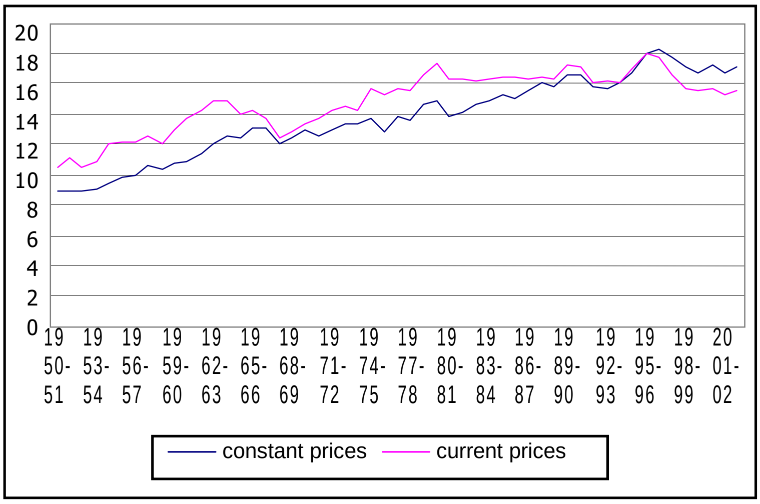
The manufacturing sector grew faster than the overall GDP growth in all the five decades since 1950-51. After a slow growth in the 1970s, the growth of manufacturing GDP accelerated in the 1980s and the pace was nearly the same in the 1990s (Table 3). In the 1990s, however, there were two distinct phases in manufacturing growth. Between 1994-95 and 1996-97, manufacturing GDP grew in real terms by 11 per cent per year. However, in the more recent five-year period 1997-98 to 2002-03, growth was less than half this rate. The decline in the growth rate of manufacturing output is also reflected in the lower share of manufacturing in total GDP. Since 1997-98, there has been a decline in the share of manufacturing in total GDP, both in 1981-82 constant prices and in current prices (Figure 1). It is this decline that has led to concerns on the role of manufacturing as an engine of economic growth in the country. The pattern shown in Figure 1 also reflects the sharp decline in the share in terms of current prices as compared to constant price shares indicating slower rise in the prices of manufactured products than of other goods and services. While a study by Krishna and Mitra (1998) indicates that the manufacturing sector has been enjoying a significant growth in productivity in the post-reform period, other studies such as Balakrishnan et al (2000) show no evidence of productivity growth in Indian manufacturing in the post-reform period. Thus, the existing literature reveals that the evidence on the improvement in manufacturing productivity in India is still mixed and without a consensus. This necessitates more empirical studies examining the improvement in manufacturing productivity in recent times that is attempted in this study.

Table 3 : Share (%) of Manufacturing in GDP

Period	1981-82 Constant prices	Current prices
Averages for the period		
1950s	9.67	11.67
1960s	12.29	13.83
1970s	13.56	15.30
1980s	15.17	16.43
1990s	16.86	16.62
1993-1997	17.25	17.20
1997-2003	17.10	15.75

Source: RBI (2003)

Figure 1: Share (per cent) of Manufacturing in GDP



Source: RBI (2003)

It is important to note that the current deceleration in output growth of manufacturing follows a faster growth of 11 per cent for 3 consecutive years in the mid 1990s. Removal of a number of restrictions on new investments by the private sector led to a sharp rise in investment spending during this period. The slowdown is also a reflection of creation of excess capacities in several sectors of the industry, capacities that were primarily aimed at serving the domestic demand (IMF, 2001a, p.10). In other words, there was no immediate possibility of diverting excess production to export markets. Further, there was also a global economic slowdown during the period following the Asian financial crisis and the meltdown of stock markets around the world. Monetary policies were tightened leading to slowdown in industrial growth but the subsequent easing of policies has not revived growth, leading to the nature of the current phase of slower growth of manufacturing activity. If the global economic slowdown is the major reason for the slower growth of manufacturing in India, how do firms in China continue to raise market shares internationally?

In order to answer the above question, it is necessary to examine the broad contours of changes in manufacturing output over time; we consider the composition of output in terms of public and private sector and organized and unorganized sectors.

Public sector holds an important position in Indian manufacturing with its presence in key sectors such as steel, automobiles, petroleum sector and engineering industries. The average share of public sector in manufacturing is nearly the same in the 1990s as in the previous decade (Table 4) reflecting the slowdown in the public sector as well as the private sector. There are, however,

Table 4 : Public Sector Participation in Manufacturing in India

	Share of Public Sector in Mfg. GDP per cent		Public Sector GDP Growth (per cent per year)	
	1993-94 prices	Current prices	1993-94 prices	Current prices
Averages				
1960s	12.53	5.62	14.67	26.68
1970s	14.52	10.75	5.86	18.32
1980s	17.03	16.60	8.07	19.25
1990s	17.94	16.95	5.69	9.98
1993-97	17.67	16.43	9.96	12.29
1997-00	17.79	14.65	7.87	7.01

Source : RBI (2003)

negative growth rates for the public sector output of manufacturing in the 1990s, indicating significant pressures within the sector. While there are pressures of privatization on the public sector enterprises, the competitive pressures from the private sector and from imports may also be affecting the operations of the public sector. The point here is that the public sector may reduce in importance in the coming years in the manufacturing sector and substitution of public sector enterprises by the private sector will be needed to maintain the output of the sector as a whole. Alternatively, the withdrawal of the public sector from manufacturing may also be one of the reasons for the slowdown in manufacturing output in the 1990s.

Another distinction that is often made in the Indian manufacturing sector is between organized and unorganized sectors. The share of the organized sector (comprising manufacturing units utilizing electric power and with 10 or more workers on the premises) has continuously increased over the years since 1950-51. Even in the 1990s, the organized sector's output rose faster than the output of the unorganized sector (Table 5). However, in the second half or post-1997-98 period of the 1990s, as reflected in the lower output shares, the output of the organized sector increased at a slower rate than that of the unorganized sector. In other words, the causes of the slower rate of growth of manufacturing affected the organized sector more sharply than the unorganized sector. Is the organized sector more constrained in effecting efficiency changes needed to sustain the growth of output than the unorganized sector? One area where such a constraint has been debated is the labour policies that affect organized sector more than the unorganized sector. Alternatively, it can be argued that expansion of capacities was far greater in the organized sector in the mid-1990s as compared with that in the unorganized sector and hence the impact of excess capacity was also greater for the organized sector. Also, increase in the growth of the unorganized sector in recent times is due to substantial increase in outsourcing by the organized sector (Ramaswamy 1999). Further, the likely reduction in the size of the public sector in manufacturing in future requires the growth of the private organized sector to sustain the growth of the manufacturing sector as a whole.

Table 5 : Indian Manufacturing: Registered and Unregistered Firms

Year	Shares (%) in GDP			
	1993-94 prices		Current Prices	
	Regd. Mfg.	Uregd. Mfg.	Regd. Mfg.	Uregd. Mfg.
Average Shares				
1950s	4.81	4.88	5.81	5.93
1960s	6.98	5.33	7.86	6.03
1970s	7.98	5.57	8.92	6.44
1980s	9.34	5.84	10.22	6.20
1990s	10.98	5.88	10.78	5.82
1993-97	11.41	5.85	11.37	5.87
1997-01	11.19	5.98	10.23	5.64

Source: *Economic and Political Weekly* (2002)

However, the growth of the private manufacturing sector depends on profitability, which is an important issue since the mid nineties. Table 6 shows various measures of profitability for Indian manufacturing corporates. Profitability after tax (PAT) has declined over the years from FY 1995-96. However, it should be noted that the declining profit margins are mainly due to the downward pressure on manufactured output prices emanating from competition created by economic reforms. Thus, competition compelled some companies to work with a thin profit margin. Such a working environment has induced restructuring within the manufacturing sector. One of the important means of restructuring is acquisitions and mergers. Table 7 indicates that the number of mergers in the manufacturing corporate sector increased from 197 in 1999-2000 to 297 in 2000-01. The maximum number of mergers and acquisitions occurred in the chemicals industry followed by the IT industry. Mergers and acquisitions in the drugs and pharmaceuticals industry showed an increase in 2000-01 from that in 1999-2000 but with a difference. In 1999-2000, the majority of the joint venture buy-outs were by Indian partners, while in 2000-01, foreign partners acquired the Indian partners' stakes in joint ventures, which was facilitated by the recent introduction of a set of policy measures for easy entry of foreign investment. Has foreign direct investment (FDI) played a major role in boosting capital formation in manufacturing in India?

Using data from the National Accounts Statistics, one may see that FDI inflows constitute only about 5 per cent of capital formation in the registered manufacturing in India during the post-reform period of 1992-2000.

Table 6: Profit Margins and Exports of the Manufacturing Companies

	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01
PBDIT/Gross sales	13.3	12.5	12.2	11.6	10.9	10.2
PBT/Gross sales	6.38	5.46	4.77	3.85	4.68	4.76
PAT/Gross sales	4.1	2.3	1.7	0.8	0.8	1.1
Total exports/sales	8.39%	8.62%	9.04%	8.95%	8.85%	10.07%
Export growth (%)	10.9	3.6	7.9	-2.8	15.2	15.7

Source: Economic Intelligence Service (2002a).

Notes: PBDIT = profit before depreciation, interest and tax.
PBT = profit before tax; PAT = profit after tax.

Table 7: Acquisitions and Mergers in the Corporate Sector (All Companies)

	1999-2000	2000-2001
Acquisition		
1. Number	1291	1184
2. Value in crores (Rs.)	51,765	33,788
Mergers		
1. Number	197	297
Open offers		
1. Number	89	76
2. Value in crores (Rs.)	752	2,625

Source: Economic Intelligence Service (2002a)

Generally, for most years in the 1990s, the ratios of actual FDI to approvals have been about 20 per cent. Between the years 1992 and 2000, the share of manufacturing industries in FDI approvals was about 42 per cent. Approvals were given mainly in priority industries such as food and agro-processing, chemicals and chemical products, metallurgical industries, electrical machinery and transport equipment. These five industries attracted about 30 per cent of FDI approvals (Table 8). To put it differently, only a small percentage of FDI flows in the 1990s went into export-oriented industries and the bulk went into import-competing or non-traded industries such as power and fuel. It is worth noting here that India's experience has been different from several other developing countries where FDI has generally been central to the production of export-oriented industries. In India, FDI inflows have been more towards domestic market-oriented industries. Such a characteristic of FDI is partly due to government policies that favour FDI in priority industries and partly due to the fact that India has a large domestic market that attracts market-oriented FDI rather than efficiency- and overseas market-oriented FDI (Goldar 2002).

India's structure of manufactured exports reveals the existing nature of relationship between FDI and the manufacturing sector. The manufacturing exports are dominated in low-technology products and concentrated in slow growing market segments (Lall 1998) (Table 9). India lacks a base in several high technology products that are experiencing a high growth in world trade, which might explain its relatively poor performance.

Table 8: Industry-wise Approvals of FDI, 1992-1999

Industry type	FDI approvals (Rs. Billion) (1992-1999)	Shares (per cent)
Manufacturing Food and agro-based	114.2	5.5
Textiles	31.1	1.5
Paper	29.9	1.4
Chemical and chemical products	136.4	6.5
Plastic and rubber goods	11.8	0.6
Non-metallic mineral products	39.8	1.9
Metallurgical industries	125.5	6.0
Electrical machinery	133.3	6.4
Non-electrical machinery	48.2	2.3
Transportation	174.1	8.3
Miscellaneous	31.8	1.5
Total manufacturing	876.1	41.9
Power and fuel	634.5	30.3
Service sector	581.7	27.8
Total inflows	2092.4	100.0

Source : Goldar (2002).

It is worth noting that neither the 1991 trade and industrial reforms nor the post-reform FDI inflows have had any effect on the export structure. Table 9 shows that the composition of India's manufactured exports during the pre- and post-reform periods has not changed significantly. The Herfindahl index (HI), which is defined as the sum of the squares of the share of each commodity in India's total manufacturing exports, can be used as a measure to verify this proposition. The lower limit of HI is the reciprocal of the square of the number of manufacturing products exported and the upper limit is 1. When the calculated value is nearer the lower limit, it means that manufactured exports are significantly diversified. When the calculated value is nearer the upper limit, the manufactured exports are concentrated in a few commodities. For the 2-digit levels of classification with 43 manufactured commodities, the lower limit for the HI may be worked out as 0.00043. The calculated HI for the years 1987-89 and 1997-99 were 0.086 and 0.081 respectively. Thus, there is no evidence of India's manufactured exports becoming more diversified over time.

A study by Tendulkar (1999) for the period 1987-1996 shows that the growth rates for labour-intensive manufactured products were relatively higher than the growth rates for skill-intensive products in India, while the reverse is true in the case of China.

Table 9 : Structure of India's Manufactured Exports during the Pre- and Post-reform Periods

Manufactured exports	Shares (per cent) in pre-reform 1987-89	Shares (per cent) in post-reform 1997-99
Leather manufactures	7.5	4.6
Chemicals and allied products	6.0	8.8
Plastic and linoleum products	0.5	1.5
Rubber, glass, paints, enamels and products	1.5	1.9
Engineering goods	11.1	14.0
Readymade garments	11.2	12.3
Textile yarn, fabrics, made-up etc.,	8.1	11.6
Jute manufactures	1.2	0.4
Gems and jewellery	19.3	17.9
Carpets	2.0	1.3
Sports goods	0.3	0.2
Other manufactures	2.3	2.9
Total manufactured goods	71.0	77.4

Source : Reserve Bank of India (2003).

India's share in world exports of skill-intensive and differentiated products, which are technologically more sophisticated, is substantially lower than that of China in 1998 (Table 10). The irony is that though both the labour-surplus economies of China and India enjoy comparative advantage in labour-intensive manufactured products, China has been diversifying into the production of differentiated and skill-intensive products. The question is: while China can climb up the technology ladder, what prevents India from climbing up? In this context, the conclusion reached by Sachs and Warner (1995, p.53) is worth noting: "… open economies tend to adjust more rapidly from being primary-intensive to manufacture-intensive exporters. The difference in the speed of adjustment is statistically significant. While many countries adopted the model of import protection as export promotion (of manufactures), it was the open economies that did best in promoting the export of manufactures". Thus, the above analysis clearly supports the first hypothesis that Indian manufacturing is still primarily geared to domestic consumption. Therefore, its growth is limited by domestic demand. For increasing production to meet export demand, there has to be substantial productivity improvement. Have the post-reform FDI inflows contributed to manufacturing growth through technological progress and spillover effects, though they might not have played a significant role in increasing India's trade orientation? An attempt is made to answer the above question using mainly the PROWESS data for chemical and chemical products (National Industrial Classification (NIC) 31), electrical machinery (NIC 35), and transport equipment (NIC 37) only. These industries do have good amounts of FDI, and reform measures seem to be relatively more useful to them.

Table 10 : Percentage Share in World Exports of Manufactured Products for China and India, 1998

Country	Resource intensive	Scale intensive	Differentiated products	Labour intensive	Science based	Miscellaneous products
China	3.27	17.25	5.12	2.56	3.71	3.95
India	0.50	1.52	0.15	2.20	0.53	0.55

Source : Author's calculations based on IMF (2001b) and UN (1998). Classifications are based on UN-ESCAP (1991).

Identification of the Crucial Factors Influencing Manufacturing Productivity

In accounting for output growth, the conventional Solow (1956) "residual" approach fails to recognise and estimate effectively the key role of technical change within the components of total factor productivity (TFP) growth. At any point in time, total factor productivity is the combined result of technical progress and technical efficiency; or the efficiency with which factors are used, given the technology. As the measure of technical efficiency is highly correlated with the level of human capital development, the latter assumes particular significance in the reform process. From the perspective of long-run policy, it is crucial to distinguish the increment in productivity that occurs from technical progress from that which results from improved technical efficiency in the application of already established technologies. How does one bring the above distinctions into the primal production function modelling?

If the production process were simply the engineering relationship between a set of inputs x_{it} and observed output y_t, then a well-defined production function would describe the process accurately and any variation in inputs would result in a corresponding change in output. However, in reality, observed output is often the result of a series of producers' decisions, which influence the method of application of inputs, and so the variables associated with the relevant production environment also play an important part in an enterprise's decisions and consequently on the output. For this reason alone, some enterprises may be producing not on but inside the frontiers with consequent gap between 'best practice' techniques and 'realized' methods of production. This gap may arise from the negative effects of non-price and/or organizational factors such as lack of human capital endowment, and insufficient infrastructure, which are the results of the present production environment emerging from the existing institutions. For example, lack of incentives, both the Centre's and states' soft budget constraints, inefficient transmission of information about production processes to producers, and ineffectiveness of government control over enterprises could all cause deviation of realized production methods from the 'best practice' techniques. It is very difficult to model the influence of each of the above non-price and organizational factors on output. Nevertheless, the combined influence of all factors can be introduced into the production function in several ways.

One method concerns representing such non-price and organizational variables in the model in an additive fashion, and the effects of changes in these variables on outputs are analyzed within the framework of the model. This is unrealistic, as Maddala (1977, p.403) pointed out, ".....if economic agents are indeed maximizing, they would be taking these non-price and organizational variables into account in their decisions and thus the variables would be entering the model not in an additive fashion but as determinants of the parameters of the model". Therefore, a varying parameter model or a varying coefficient model (VCM) is appropriate in evaluating the effects of economic reforms and behavioural differences on outputs across manufacturing firms. Can such variations in parameters be restricted only to intercept terms?

There is no reason to believe that reforms and behavioural differences would have influenced each manufacturing firm's production behaviour equally, so different levels of output may be obtained by different firms, *albeit* using the same set of inputs. In other words, manufacturing firms' maximum output varies regardless of input levels because the response from each input varies from firm to firm. Hence, the conventional varying intercept and fixed slope production frontier popularized by Aigner *et al* (1977) may not be appropriate for measuring a firm's performance, and particularly for measuring firm-specific productive efficiency, as has been pointed out by Kalirajan, *et al* (1996). Rather, while modelling the firms' behaviour, the slope coefficients should be allowed to vary in the production function to take into account the different input responses to output. Lucas provides further justification for using the full varying coefficients frontier production function model. In his critique of econometric policy evaluation, he argued, "the standard stable parameter view of econometric theory and quantitative policy evaluation appears not to match several important characteristics of econometric practice. For example, fixed coefficient econometric models may not be consistent with the dynamic theory of optimizing behavior (of firms); that is, changes in economic or policy variables will result in a new environment that may, in turn, lead to new optimal decisions and new economic structures" (Lucas 1981:109-110).

How does the estimation of the varying coefficients frontier production function differ from the estimation of a conventional production function? Production function is traditionally estimated as an average output response to a given level of inputs and technology, though theoretically it is defined as the maximum possible or potential output. The assumption in the conventional estimation of a production function of a firm is that the 'average' response is indeed the 'maximum' possible with the given technology, and that the difference between the estimated and realized outputs is due to factors beyond the firm's control. On the other hand, in the estimation of the varying coefficients frontier production function, it is argued that the difference between the estimated and realized outputs is due to both factors within the firm's control and factors beyond the firm's control.

A general formulation of the Cobb Douglas varying coefficients stochastic production frontier in terms of panel data is as follows:

$$y_{it} = \sum_{j} \beta_{ijt} x_{ijt} + \in_{it} \qquad (1)$$

$$i = 1,2,.....n$$

$$t = 1,2,.....T$$

where y_{it} is the logarithm of output of the i^{th} state in the t^{th} period, x_{ijt} is the logarithm of the j^{th} input used by the i^{th} state in the t^{th} period when $j \neq 1$; (an intercept is included in this model by considering $j = 1$; β_{i1t} is the intercept of the i^{th} state in the t^{th} period; and β_{ijt}, when $j \neq 1$, is the slope coefficient concerning the j^{th} input used by i^{th} the State in the t^{th} period, and ϵ is the disturbance term.

It can be seen from equation (1) that the output response coefficients with respect to different inputs vary across manufacturing firms. It is rational to argue that the non-price and organizational factors, which vary across firms, would influence outputs indirectly through the method of application of inputs. When firms follow the best method of application of inputs required by the selected technology to effectively utilize the chosen inputs, they obtain the maximum possible outputs for the given set of inputs because the production response coefficients are the maximum indicating that the firms are technically efficient. As firms cannot produce more than a theoretically possible level of output, the above model is consistent with the production theory. If due to adverse effects of some non-price and organizational factors (e.g. poor management decision making) manufacturing firms are not able to follow the best method of application of inputs, the output response coefficients with respect to inputs are at levels lower than the maximum that the firms would have obtained, had they followed the best method of application of inputs. In this situation, firms are called technically inefficient. Further, any other firm-specific intrinsic characteristics that are not explicitly included such as capacity utilization may produce a combined contribution over and above the individual contributions. This 'lump sum' contribution, if any, can be measured by the varying intercept term.

The specification of the above model implies that manufacturing firms could be technically efficient completely, if and only if, the chosen inputs are effectively utilized by following the best method of application. This means that non-price and institutional/ organisational factors, which influence the method of application of inputs, do not exert any adverse effects on production. This can be interpreted as the reform policies being able to eliminate the adverse effects that constrain the firms from fully realizing their productive efficiency. On the other hand, if reform measures are not fully effective, firms would not be able to follow the best method of application of inputs and so there would be a significant gap between the firms' realized outputs and their maximum possible outputs. One advantage of this methodology is that it is possible to identify which input application is more influenced by differences in firm characteristics over time.

Equation (1) implies that production response coefficients are specific to each individual manufacturing firm and to each time period for the same firm. Unfortunately, model (1) cannot be estimated as the number of parameters to be estimated exceeds the number of observations. This necessitates imposing certain restrictions on the structure of (1). Drawing on Swamy (1971), one method to reduce the number of parameters in (1) is to follow the analysis of variance (ANOVA) approach. This means imposing the following restrictions on (1):

$$\beta_{ijt} = \overline{\beta}_j + u_{ij} + v_{jt} \quad ; \qquad j = 1,2,....,m$$

$$\sum_{i}^{n} u_{ij} = 0 \qquad \text{and} \qquad \sum_{t}^{T} v_{jt} = 0$$

where u_{ij} and v_{jt} respectively denote cross-sectional and temporal variation of the production coefficients b_{ijt}.

The above specification is a more general case of the specification discussed by Cornwell *et al* (1990), and so is not parsimonious. Alternatively, model (1) can be transformed into the random coefficients framework with the assumption that u_{ij} and v_{jt} are random variables. The random coefficients specification facilitates economising on the number of parameters to be estimated, but still allows the coefficients to vary across individual decision making units, and over time. Drawing on the estimation procedures suggested by Griffiths (1972), the individual response coefficients can be estimated.

Following the above discussion about the method of application of inputs, the highest magnitude of each response coefficient, and the intercept term from the production coefficients of equation (1), constitutes the production coefficient of the frontier function, providing the maximum possible output. To elaborate, let $b^{*}_{0\text{¢}}$ $b^{*}_{1\text{¢}}$ $b^{*}_{2\text{¢}}$ $b^{*}_{3\text{¢}}$ ……… b^{*}_{K} be the estimates of the parameters of the frontier production function yielding the maximum possible output for any given levels of inputs. The frontier coefficients b^{*}s are chosen to reflect the condition that they represent the production response by following the 'best practice' method of application of inputs. These are obtained from among the individual response coefficients, which vary across observations (states). Let b^{*}s be the estimates of the coefficients of the frontier production function, that is,

$$\beta^{*}_{jt} = \max_{i}\{\beta_{ijt}\} \quad i = 1,2,....,n; \quad j = 1,2,....,m \quad \text{and} \quad t = 1,2,....,T$$

where b^{*}_{jt} is the frontier coefficient of the j^{th} input in the t^{th} period, and b_{ijt} is the coefficient of the j^{th} input of the i^{th} manufacturing firm in the t^{th} period.

Now the maximum possible frontier output for individual firms can be calculated as

$$y_{it} = \sum_{j} \beta_{ijt} x_{ijt} + \in_{it}$$

$$i = 1,2,..... n$$
$$t = 1,2,..... T$$

Technical efficiency of the manufacturing firm can be calculated as:

$$(TE)_{it} = \exp(y_{it}) / \exp(y^{*}_{it}) \qquad (2)$$

where y_{it} is the logarithm of the observed output of the i^{th} firm in the t^{th} time period and y^*_{it} is the logarithm of the estimated frontier output of the i^{th} firm in the t^{th} period.

A major advantage of the above methodology is that the analysis can also be carried out even with cross-sectional data. Unlike in the conventional frontier approach, this method facilitates identifying which firms are following the best practice technique of applying which inputs. It can easily be related to actual observations, which is evidently useful for policy analysis.

Following Kalirajan and Shand (1997), Figure 2 illustrates the decomposition of total output growth into input growth, technical progress and technical efficiency improvement. In periods 1 and 2, the firm faces production frontiers in logarithms F_1 and F_2 respectively. If a given firm has been technically efficient, output would be y_l* in period 1 and y_2* in period 2. On the other hand, if the firm is technically inefficient and does not operate on its frontier due to some firm-specific non-price and organizational factors, then the firm's realised output is y_l in period 1 and y_2 in period 2. Technical inefficiency (TE) is measured by the vertical distance between the frontier output and the realized output of a given firm, that is, TE1 in period 1 and TE2 in period 2 respectively. Hence, the change in technical efficiency over time is the difference between TE1 and TE2. Now, suppose, there is technical progress, due to the improved quality of human and physical capital, so a firm's potential frontier shifts to F_2 in period 2. If the given firm keeps up with the technical progress, more output is produced from the same level of input. So, the firm's output will be y_1** from x_1 input shown in the figure. Technical progress in this paper is measured by the distance between the two frontiers (y_l**- y_l*) evaluated at x_1. Denoting the contribution of input growth to output growth (between periods 1 and 2) as Δy_x, the total output growth, (y_2 – y_l), can be decomposed into three components: input growth, technological progress and technical efficiency change.

Referring to figure 1, the decomposition can be shown as follows:

$$
\begin{aligned}
D &= y_2 - y_l \\
&= A+B+C \\
&= [y_l^* - y_l] + [y_l^{**} - y_l^*] + [y_2 - y_l^{**}] \\
&= [y_l^* - y_l] + [y_l^{**} - y_l^*] + [y_2^* - y_1^{**}] - [y_2^* - y_2] \qquad (3) \\
&= \{[y_l^* - y_l] - [y_2^* - y_2]\} + [y_l^{**} - y_l^*] + [y_2^* - y_l^{**}] \\
&= [\{TE1 - TE2\} + TC] + \Delta y_x \\
&= \text{TFP growth} + \text{inputs growth},
\end{aligned}
$$

where

$y_2 - y_l$ = output growth,

$TE1 - TE2$ = technical efficiency change,

TC = technical change, and

Δy_x = output growth due to input growth.

This decomposition of total factor productivity growth into technical efficiency improvement (catching-up) and technological advance is, therefore, useful in distinguishing innovation or adoption of new technology by 'best practice' firms from the diffusion of new advanced technology which leads to improved technical efficiency amongst firms 'catching-up'. Co-existence of a high rate of technological progress and a low rate of change in technical efficiency may reflect failures in achieving technological mastery or effective diffusion of best technical practices. It may also reflect high levels of technological dynamism in an industry with rapid obsolescence rates for technology. Such results have been reported for other countries including China (Kalirajan *et al*).

The production technology is represented by a Cobb-Douglas varying coefficients function[2]. It is a rare phenomenon that the response in the dependent variable to a unit change in the independent variable is the same for all t = 1,2,...T. Equal doses of labour and capital in a particular production process may yield different levels of output over different years in view of technical progress and technical efficiency improvement that might take place during the course of the sample period due to the varying influence of economic reforms. Drawing on Swamy and Mehta (1977), the motivations for time and cross-sectionally varying coefficient models are: (i) to allow for different coefficients for each individual unit to account for spatial or inter-individual heterogeneity, and (ii) to modify continually the values of coefficients over time so as to allow the relationship to adopt itself to local conditions such as industry-specific reforms. Therefore, using time-specific dummies, D, to account for inter-year differences, we can express in logarithmic form the temporal firm-specific manufacturing production function as[3].

$$\ln Y_{it} = \beta_{1it} + \sum_{j=2}^{4} \gamma_{ji} D_{jit} + \sum_{k=2}^{4} \beta_{kit} \ln X_{kit} \qquad (4)$$

i = 1, . . . ,14 and t = 1(1997), . . . ,4 (2000)

where the parameters b_{kit}'s and g_{ji}'s are input-specific and firm-specific response coefficients;

D_{jit} = 1 if j = t and zero otherwise; and

Y = real value of manufactured output at the 1981-82 constant prices for the concerned firm in the concerned industry using industry specific wholesale price index deflators.

X_2 = real gross capital stock measured in 1981-82 constant prices[4].

X_3 = labour hours used in production at year end[5].

X_4 = real value of material inputs used in production measured in 1981-82 prices[6].

For a given t, employing the specifications and estimation procedures described above, the mean and individual response production coefficients were obtained[7]. For brevity, only the mean response coefficients with standard errors and the range of the individual response coefficients are given in Table 11. The range of the coefficients clearly shows that the input-specific response coefficients do vary across firms. The entire core input coefficients and the year dummy coefficients are also significant at the 5 per cent level. The elasticity coefficient estimates for fixed capital and labour are lower than that of the material inputs. Combining these three estimates, it may be argued that the selected manufacturing industries have been operating more or less at constant returns to scale. From the yearwise estimates, frontier outputs for each period t were calculated using the frontier production coefficients given in Table 11. For the sample firms, these frontier estimates show the maximum possible contribution of core inputs to output when the inputs are applied in accordance with the best practice techniques of the given technology. Finally, sources of output growth in the later post-reform periods (1997-2000) were calculated as shown in equation (3) to test our second hypothesis concerning the productivity debate of the manufacturing sector in the post-reform period.

Table 11: Mean and the Range of Response Coefficients Estimates of Frontier Production Functions for Manufacturing Industries

Variables	Minimum estimate			Maximum estimate			Mean estimate		
	Chem.	Elec.	Trans.	Chem.	Elec.	Trans.	Chem.	Elec.	Trans.
Constant	10.687	9.675	10.563	13.565	11.346	15.676	11.362 (7.890)	10.563 (8.885)	13.865 (6.901)
Capital	0.234	0.227	0.238	0.258	0.239	0.262	0.250 (2.568)	0.232 (2.871)	0.258 (3.067)
Labour	0.104	0.115	0.108	0.118	0.136	0.125	0.110 (2.774)	0.129 (3.256)	0.118 (4.015)
Materials	0.597	0.611	0.602	0.643	0.650	0.635	0.636	0.640	0.621

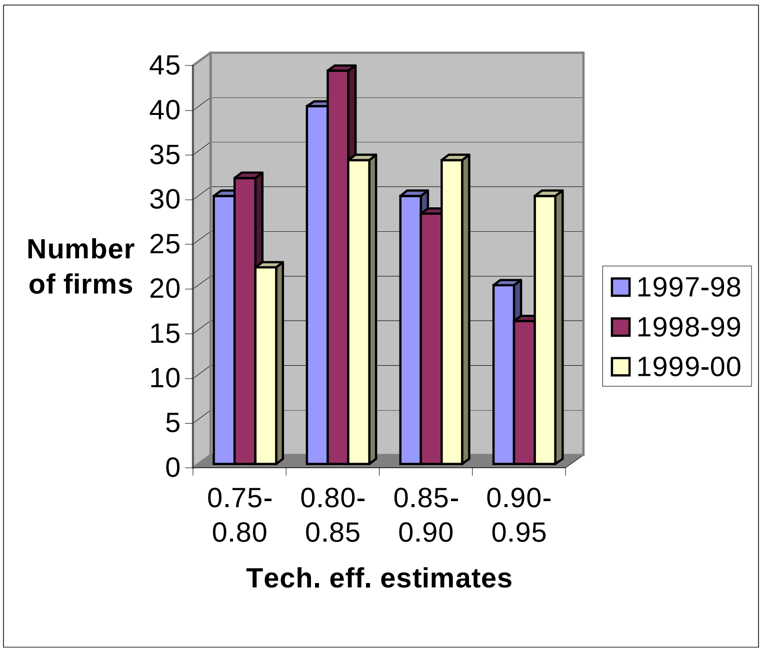
Source: Author's estimation

Note: Figures in brackets are t-values. All the coefficients are significant at least at the 5 per cent level.

The concept of the frontier output provides the basis for a decomposition of output growth during a period into contributions due to (1) inputs growth, (2) changes in efficiency and (3) technical progress. The contribution of technical progress is the shift in the production frontier or potential output between any two years; and the contribution of inputs growth is the movement along a production function. The contribution of efficiency is the difference in output for the same level of inputs between the actual production function and the frontier production function in any one time period, and therefore, the contribution of changes in efficiency is the difference between the contributions of efficiency during any two periods in question.

The results in Table 12 imply that output growth in the selected three industries is mainly inputs driven in the later post-reform period. Though inputs growth, technical efficiency change, and technical progress contributed positively to output growth, the contribution of inputs growth was the most. This result corroborates the findings of Chandra and Sastry (2002) through a recent national survey of manufacturing that both material cost and labour cost constitute about 75 per cent of total production cost. The contribution of changes in technical efficiency to output growth, however, indicates that technical efficiencies in chemical products industry and in electrical machinery industries have shown the evidence of improvement during 1999-2000. However, technical efficiency in the transport equipments industry appears to be deteriorating over time. Generally, efficiency is seen to improve when the input growth is relatively lower and to deteriorate when it is higher.

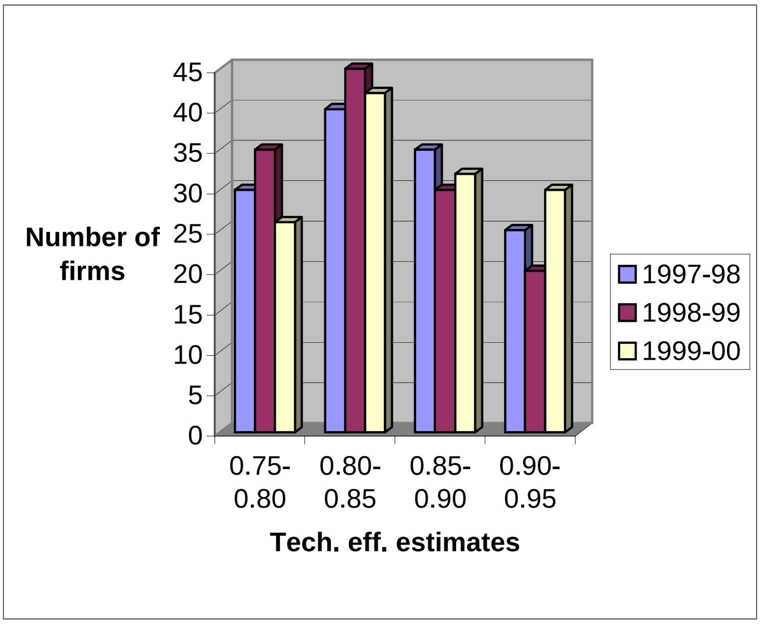
Figure 2 : Technical Efficiency Estimates of the Chemical Products Industry



Source : Author's estimates.

While efficiency changes have contributed to the decline of output growth rate, the lower level of efficiency itself has meant lower level of output as compared to the potential output. The technical efficiency estimates shown in Figures 2 to 4 point to the potential gains from improved efficiency in the manufacturing sector. In this sense, attempts to improve the level of technical efficiency are an important source of output growth. In other words, mean technical efficiency measures during 1997-2000 for the manufacturing industries of chemical products, electrical machinery and transport equipments worked out to be around 0.85, 0.86 and 0.80 respectively, which implies that about 15 per cent, 14 per cent and 20 per cent of output supply can be increased in the respective industry without having to increase any inputs, but by following the best practice technique of the method of application of the technology at the firm level.

Figure 3: Technical Efficiency Estimates of the Electrical Industry



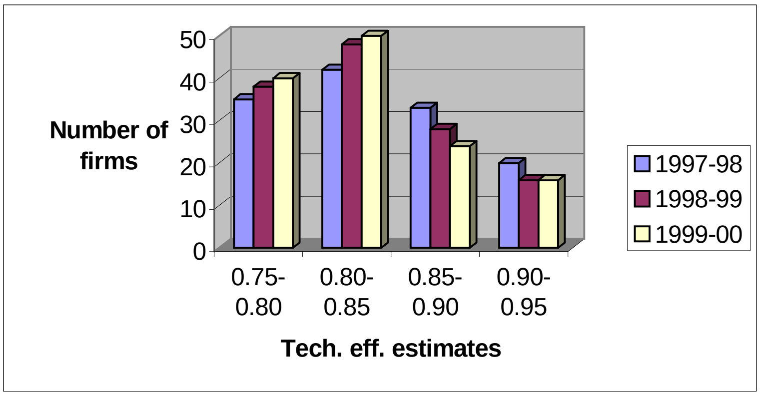
Source : Author's estimates.

Table 12 : Sources of Growth in Selected Manufacturing Industries, 1997-2000

Years/Industry	Contribution to output growth by		
	Inputs growth (%)	Technical efficiency change (%)	Technical progress (%)
Chemical products			
1997-98	77.35	9.25	13.40
1998-99	82.10	8.45	9.45
1999-00	76.14	11.35	12.51
Electrical Machinery			
1997-98	70.75	11.25	18.00
1998-99	75.30	10.35	14.35
1999-00	68.15	16.75	15.10
Transport			
1997-98	76.35	9.65	14.00
1998-99	83.45	8.25	8.30
1999-00	85.28	7.65	7.07

Source: Author's calculations.

Figure 4: Technical Efficiency Estimates of the Transport Industry



Source: Author's estimates.

By raising the operation of a firm to be at its frontier, particularly those with lower technical efficiencies, significant gains in productivity could be achieved. Obviously, not all firms can be put on their frontiers, however, if the factors associated with high technical inefficiencies can be determined, improvements in technical efficiencies could be achieved through facilitating the effective functioning of the factors. Particularly relevant in this context are factors that could improve the competitiveness of manufacturing firms. Appropriate policy measures can then be tailored and implemented to influence the factors to effectively reduce the gaps between the most efficient and least efficient firms. It is widely known now that the 1991 economic reform opened up the economy for greater foreign trade and investment in the post-reform period. Though economists continue to argue over the elusive nature of the relationship between productivity improvement and trade liberalization, the elements of stimulus to manufacturing growth that emanate from economic reforms as a whole cannot be overlooked. For example, the capital market reforms with regard to foreign capital entry when combined with trade reforms with reduction in tariffs, improved access to imported capital equipment and raw materials, and facilitation to technical and financial collaboration with foreign companies would certainly boost manufacturing production and export promotion. The impact of such policy-influenced factors on improving competitiveness is examined by regressing the average firm-specific technical efficiency measures over the period 1997-2000 separately for the sampled NIC 31, NIC 35, and NIC 37 industries on export intensity, raw material import intensity, technology import intensity, R&D intensity, foreign collaboration, and advertising intensity in the following model specification[8]:

$$\ln(1/1-TE) = \alpha_0 + \sum_{j=1}^{5} \alpha_j x_j + \alpha_6 D_1 + u \qquad (5)$$

where,

x_1 = export intensity, which indicates the company's exposure to foreign output markets, and is measured as the ratio of firm's export to its sales value.

x_2 = raw material import intensity, which gauges firm's degree of exposure to foreign input markets, and is measured as the ratio of the value of imported raw materials to the total value of raw materials used

x_3 = technology import intensity, which represents the degree of use of advanced technology in production, and is measured as a ratio of firm's expenditure on imported technology to its total value of sales.

x_4 = R&D intensity, which refers to firm's effort to absorb and adapt new technology through research and training, and is measured as a ratio of firm's expenditure on R&D to its value of sales.

x_5 = advertising intensity and is measured as advertising to sales ratio for each firm. This serves as a measure of product differentiation (Greer 1971) and also an index of risk (Ornstein *et al* 1973).

D_1 = foreign collaboration, which is defined as a dummy variable taking value 1 if there is a foreign partner or 0 otherwise. The presence of a foreign partner is decided using IMF rules, which treats a firm as a foreign direct investment enterprise if 10 per cent of its stock is held abroad by a single investor.

The OLS estimates of equation (5) for the sampled industries are given separately in Table 13. Several coefficient estimates are significant statistically at least at the 5 per cent level with theoretically acceptable signs and a reasonably high adjusted R^2 values. The important result from this analysis is that the coefficients of R&D for the selected industries are the largest, which highlights the importance of R&D including training of workers to improving firms' competitiveness. When firms increase their export orientation, they tend to improve their technical efficiencies and the magnitude seems to be higher in transport equipment industry. However, the coefficient is not significant for the chemicals industry. The use of raw materials imports appears to increase technical efficiencies more in the transport equipment industry. These results indicate that the transport equipment industry will gain more technical efficiency and will improve its competitiveness through further trade liberalization. The coefficient of raw materials imports is not significant for the electrical industry. There are a few interesting questions. Is the electrical industry working with outdated technology? Has the industry been acquiring foreign technology effectively? Is the industry able to adopt the acquired foreign technology? The coefficient of technology intensity may provide some answers.

Table 13 : Determinants of Firm-Specific Technical Efficiencies [ln(1/1-TE)], 1997-2000

Variables	Unit of measurement	OLS estimates for industries		
		Chemical	Electrical	Transport
Export intensity	Ratio of export value to total value of sales	0.1160[ns] (1.1815)	0.1260 (3.1206)	0.1835 (2.2511)
Raw materials import intensity	Ratio of raw materials import value to total value of raw materials	0.1255 (2.3254)	0.1065[ns] (1.1676)	0.1892 (3.0354)
Technology import intensity	Ratio of expenditure on imported technology to total value of sales	0.1264 (3.0015)	0.0675 (2.4502)	0.1520 (2.8856)
R & D intensity	Ratio of expenditure on R&D to total sales value	0.1268 (2.8756)	0.2020 (3.4522)	0.2115 (3.8712)
Advertising intensity	Ratio of advertising expenses to total sales value	0.0564[ns] (1.1089)	0.1005 (2.2245)	0.1855 (3.6421)
Foreign collaboration	Dummy: 1 = presence 0 = absence	0.0022 (2.2015)	0.0035 (2.0085)	0.0052 (3.5429)
Constant		-0.3210 (-4.6782)	-0.2285 (-6.7720)	-0.4205 (-8.4523)
Adjusted R^2		0.5104	0.5080	0.5318

Source : Author's estimation.

Notes : Figures in parentheses are t-ratios. "ns" refers to 'not significant at the 5 per cent level'.

The technology intensity coefficient is significant for the transport equipments industry, which confirms our earlier conclusions about the link between its efficiency improvement and trade liberalization. The coefficient of technology intensity is significant for the chemicals industry, though the magnitude is smaller than that for the transport equipments industry. The technology intensity coefficient is significant for the electrical industry, though the magnitude is very small. It may be conjectured that firms may be slow in applying and adapting the new technology due to lack of appropriate training for workers, which warrant further analysis. A study by Kundu and Lalitha (1998) has shown that use of non-standard tools and methods of production have locked a large number of manufacturing firms in low-level quality equilibrium in India. The study also reveals that the extent of mechanization has been still very low, though the firms understand that mechanization guarantees quality improvement and short-process times.

On the other hand, a number of Chinese manufacturing firms have implemented large volume production systems like flow manufacturing systems, efficient assembly lines, and globally acceptable equipments and tools of production (Nolan 2001). As expenditure on R&D increases, technical efficiency appears to be increasing substantially across all industries. However, the impact of R&D is relatively more for the transport equipments industry than for the other two industries. Chandra and Sastry (2002) through their two national surveys have shown that the priority for invention and R&D in Indian manufacturing firms has been declining from 1997. The implication has been that India's manufacturing products lack sophistication in terms of attracting and sustaining customers both domestically and in exports. Also as Lall (1998) has argued, Indian manufacturing firms export relatively more low-technology products due to lack of sufficient R&D and technical training programmes for production workers. Though many Indian firms provide managerial training to their managers, only a few provide computer-based decision support systems for helping their managers make effective decisions (Chandra and Sastry 2002).

On the other hand, in the case of Chinese manufacturing enterprises, each large firm has its own technology research centers, which have facilitated firms to move gradually from manual to automated manufacturing process with appropriate technical training for their workers (Nolan 2000). As seen earlier, India's share in world exports in differentiated products is very small compared to that of China, and hence one would expect a positive relationship between advertising intensity and technical efficiency in the selected industries. The coefficient appears to increase technical efficiency more in the transport equipments industry than in the electrical industry. Though the coefficient is positive, it is not significant for the chemical products industry. This may be expected, as advertising may not help to increase market power in chemical products that are greatly diversified. Further, though India's share in scale intensive exports of which chemical products constitute one group is equal to that of China, the major proportion comes from gems and precious stones. The presence of a foreign partner in production tends to increase technical efficiency in all the selected industries, which is expected owing to the spillover of knowledge, technology and market from the foreign collaboration. The impact is relatively more for the transport equipments industry.

The foregoing analysis reveals that Indian manufacturing firms lack sharp focus on productivity and factors influencing improvement in productivity. The interesting questions are: Whether such unsharpened focus on productivity is due to firms' weakness in strategic decision making? Which core inputs are being wasted due to ineffective methods of applications emanating from the unsharpened focus on productivity? Answers to these questions are necessary from the policy perspective.

The firm-specific technical efficiency measures discussed above are not capable of identifying which of the inputs are applied more efficiently and which are not. Here, it is worth noting the remark made by Kopp (1981, p.491), "In a sense, these measures treat the contribution of each factor to productive efficiency equally and thereby mask any differences in efficiency that might be attributed to particular factor inputs. For example, the parsimonious use of fuel and excessive use of capital can yield the same technical efficiency as the reverse pattern of factor use". The extension of the concept of technical efficiency to input-specific levels is then necessary, particularly if there is *a priori* knowledge about some inputs being used more efficiently than others. For example, the pattern shown in Figure 1 reflects the sharper decline in the share in terms of current prices as compared to constant price shares. In the context of the debate on deindustrialization (Rowthorn and Ramaswamy 1997), this decline in the share in real terms relative to the fall in current prices share may reflect an improvement in the productivity of the manufacturing sector in India, which requires a careful empirical examination. Also, combining the larger employment with a lower growth in manufacturing between 1995-96 and 1999-2000 than in the eighties, one may conjecture that labour may not only be inefficiently used but also underutilized relative to capital and material inputs within certain firms in selected industries in the later post-reform period. The need to test the above propositions cannot be overlooked, which requires the extension of the firm-specific technical efficiency analysis into firm- and input-specific technical efficiency analysis[9].

Following the earlier discussion in equation (4), technical efficiency in the use of input 2, for example, can be defined as,

$$IEFF_{2jt} = (b_{2jt} / b_{2t}^{*}), \text{ where } b_{2t}^{*} = \max (b_{2jt}) \text{ over } j = 1 \text{ to } n \qquad (6)$$

Where $IEFF_2$ is the technical efficiency of j th producer with respect to input 2 at the t^{th} period; and b_{2t}^{*} is the coefficient of the most efficient producer with respect to the use of input 2 at the t^{th} period. We term efficiencies with respect to the use of specific inputs as 'embodied or input specific' efficiencies and the efficiency implied by variations in the intercept ($MEFF_j = b_{0jt} / b_{0t}^{*}$) is termed as 'disembodied efficiency'. Embodied (or input specific) efficiency refers to efficiency arising from following the best practice production technique of applying specific inputs. Disembodied efficiency refers to efficiency that is independent of any inputs appearing in the production function. For example, in crop production where fertilizer and irrigation are two inputs, 'embodied' efficiency is specific to the use of these two inputs, whereas 'disembodied' efficiency is a more general concept that may reflect capacity utilization, organizational or such efficiencies of combining these core inputs. The terminology is similar to the one used in the case of technical progress in economics literature.

Firm- and input-specific technical efficiency measures for the selected industries for the sample period have been calculated as in equation (6) and the summary statistics are presented in Tables 14 to 16. Generally, the results in these tables do not show any clear pattern concerning the question of which inputs are efficiently used by which industry and in which time period. However, one conclusion is clear; that is, labour, capital and materials inputs have not all been used fully and effectively across the selected industries. This situation is alarming because, as seen earlier, output growth has been input driven in the period of analysis and here it is seen that they are being used ineffectively. How does one promote the effective use of these core inputs? The reform measures so far implemented have influenced the growth of the manufacturing sector through the liberalization of capital market, foreign exchange market, dismantling of government controls on capacity creation and export promotion. However, the firm level analysis here shows that manufacturing output on average could be increased by about 15 per cent without having to increase inputs, in spite of the favorable production environment created by the above reform measures. The analysis also identifies that the 15 per cent increase should come by improving the method of application of capital, labour and materials inputs. No doubt, it is logical to argue that capital and materials inputs might have been more influenced by the reform measures so far undertaken, as there are no reforms directly influencing labour-related issues. Then it is rational to expect that at least capital and materials inputs be used effectively relative to labour input. The analysis in this study does not confirm this expectation. Therefore, the policy implication is that any measures aimed to reduce technical inefficiency should be directed mainly at firms' managers and decision makers.

Table 14 : Estimates of Firm- and Input-Specific (Labour) Technical Efficiency Measures

Description	Minimum	Maximum	Mean	Variance
Chemical production				
1997-98	0.9172	1.000	0.9415	0.0018
1998-99	0.9305	1.000	0.9526	0.0035
1999-2000	0.9335	1.000	0.9572	0.0027
Electrical				
1997-98	0.9272	1.000	0.9632	0.0036
1998-99	0.9364	1.000	0.9716	0.0042
1999-2000	0.9382	1.000	0.9765	0.0055
Transport				
1997-98	0.8856	1.000	0.9120	0.0046
1998-99	0.8976	1.000	0.9215	0.0052
1999-2000	0.8995	1.000	0.9265	0.0037

Source : Author's calculations.

The inference from the results of this study is that until proper managerial and strategic decisions are undertaken at the firm level, the benefits of the existing reforms cannot be realized fully.

Table 15 : Estimates of Firm- and Input-Specific (Capital) Technical Efficiency Measures

Description	Minimum	Maximum	Mean	Variance
Chemical production				
1997-98	0.9572	1.000	0.9732	0.0026
1998-99	0.9664	1.000	0.9816	0.0032
1999-2000	0.9782	1.000	0.9865	0.0035
Electrical				
1997-98	0.9228	1.000	0.9405	0.0025
1998-99	0.9324	1.000	0.9565	0.0037
1999-2000	0.9386	1.000	0.9578	0.0038
Transport				
1997-98	0.9115	1.000	0.9430	0.0020
1998-99	0.9108	1.000	0.9646	0.0024
1999-2000	0.9175	1.000	0.9665	0.0027

Source : Author's calculations.

Table 16 : Estimates of Firm- and Input-Specific (Materials) Technical Efficiency Measures

Description	Minimum	Maximum	Mean	Variance
Chemical production				
1997-98	0.9505	1.000	0.9735	0.0054
1998-99	0.9644	1.000	0.9800	0.0064
1999-2000	0.9656	1.000	0.9845	0.0077
Electrical				
1997-98	0.9135	1.000	0.9255	0.0022
1998-99	0.9275	1.000	0.9405	0.0038
1999-2000	0.9365	1.000	0.9485	0.0054
Transport				
1997-98	0.8930	1.000	0.9250	0.0056
1998-99	0.9105	1.000	0.9365	0.0072
1999-2000	0.9206	1.000	0.9425	0.0138

Source : Author's calculations.

Conclusions

Manufacturing has been an engine of growth in India in the seventies and eighties. After the 1991 economic reform, it appears that the speed of the engine has slowed down. While the manufacturing sector in China has achieved international recognition in terms of attracting foreign direct investment within a short period after the implementation of economic reforms, the experience of the Indian manufacturing appears to be different. The central focus of this paper is to examine why it is so. The analysis reveals that unlike in the Chinese case manufacturing output growth in the post-reform period has been inputs driven rather than efficiency driven. The analysis indicates that on average about 15 per cent output growth can be achieved by improving firms' efficiency without having to increase any inputs. The responsibility for improving efficiency in the production process appears to be with the strategic decision making at the firm level. The national survey of manufacturing industries indicates that though firms do understand the importance of R&D to improving competitiveness, they seem to overlook this aspect. Policy measures should aim at encouraging firms to invest more in R&D, providing technical training programmes for workers, and facilitating managers with more computer aided design and decision making processes. Identifying what exact policy measures should be implemented is beyond the scope of this paper. Though labour union militancy has been on the decline, it may be necessary to implement labour reforms, particularly with respect to hiring and firing to facilitate firms to upgrade production skills of manufacturing workers to improve competitiveness. Also, greater opening up of the economy through further trade reforms in terms of bringing the tariff structure in line with the Asian tigers would provide more fuel to the engine of growth.

Notes

[1] Some of the notable earlier controversies with respect to the productivity of the Indian manufacturing sector concern the works of Ahluwalia (1985), Goldar (1986), Ahluwalia (1991) and Balakrishnan and Pushpangadan (1994). Krishna (1987) has examined and provided reasons for the difference in the results between Ahluwalia (1985) and Goldar (1986). Using data from the pre-reform period, the latter study by Ahluwalia (1991) documented that though there was poor performance of the total factor productivity growth in Indian manufacturing up to the end of the seventies, there was a turnaround with a rising trend in the first half of the eighties. However, a study by Balakrishnan and Pushpangadan (1994) has negated Ahluwalia's turnaround hypothesis.

[2] A preliminary test on functional forms ruled out the possibility of using a translog form.

[3] All variables are taken as simple three-year average values over 1997-2000.

[4] There is no universally accepted methodology to construct a capital stock series. In the Indian context, most of the recent studies on TFP growth have used the perpetual inventory method (PIM), which was first introduced in empirical analysis by Goldsmith (1951). In this method the capital stock of a given year is traced to the stream of past investments at constant prices. PIM requires an estimate of the capital stock for a benchmark year and estimates of investment in the subsequent periods. Let K_0 denote the benchmark year real capital stock and I_t the real gross investment in fixed capital in the t^{th} year. Let r be the annual rate of discarding of assets. Then the real gross fixed capital stock for the t^{th} year is obtained as follows:

$K_t = K_0 + S\ I(t)$ where, $I(t) = I_t - rK_{t-1}$. As the balance sheet figures for capital are at historic cost, it has to be converted into asset value at replacement cost before the PIM can be followed. Following Balakrishnan *et al* (2000), but with the modification of taking 1999-2000 as the base year, the value of capital at replacement cost for the base year is arrived at by revaluing the base year capital. As the approach is well documented in Balakrishnan *et al* (2000), it is not repeated here.

[5] PROWESS database provides total wages paid to all employees. In order to work out the labour hours, the wage rate per hour is

constructed from the Annual Survey of Industries with corresponding industrial classification.

[6] To work out the real value of materials inputs, a materials inputs price index with base 1981-82 was constructed by taking weights from the I-O Transaction Matrix 1989-90 to combine the wholesale prices of the relevant inputs.

[7] A computer package TERAN developed to estimate the unconstrained variance-covariance matrix of the random coefficients, the GLS mean estimator and individual response coefficients (Griffiths 1972) was used to estimate the empirical model.

[8] As technical efficiency measures vary from 0 to 1, they are transformed into ln(1/1-TE) to obtain OLS estimates that are BLUE.

[9] Our method differs from the method suggested by Kumbhakar (1988) on two accounts. First, Kumbhakar's procedure requires explicit specification of a one-sided inefficiency related random term and assigning a distribution to it to facilitate estimation by the maximum likelihood method. Second, he makes the implicit assumption that the frontier function is neutrally shifted from the average and realized production functions.

References

Aigner, D.J., C.A.K. Lovell and P. Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, Vol.6, pp.21-37.

Ahluwalia, I.J. (1985), *Industrial Growth in India – Stagnation since Mid-Sixties*, Delhi: Oxford University Press.

Ahluwalia, I.J. (1991), *Productivity Growth in Indian Manufacturing*, Delhi: Oxford University Press.

Balakrishnan, P. and K. Pushpangadan (1994), "TFPG in Manufacturing Industry: A Fresh Look", *Economic and Political Weekly*, 30 July, pp.2028-2032.

Balakrishnan, P., K. Pushpangadan and M. Suresh Babu, (2000), "Trade Liberalization and Productivity Growth in Manufacturing: Evidence from Firm-Level Panel Data", *Economic and Political Weekly*, 7 October, pp.3679-3682.

Chandra, P. and T. Sastry (2002), "Competitiveness of Indian Manufacturing: Findings of the 2001 National Manufacturing Survey", Indian Institute of Management, Ahmedabad, June, (mimeo).

Centre for Monitoring Indian Economy (CMIE) (2001), *Foreign Trade and Balance of Payments*, Mumbai: CMIE.

Central Statistical Organization (CSO) (various years), *Annual Survey of Industries*, Ministry of Planning and Programme Implementation, New Delhi, Government of India.

Cornwell, C., P. Schmidt and R.C. Sickles (1990), "Production Frontiers with Cross-sectional and Time Series Variation in Efficiency Levels", *Journal of Econometrics*, Vol.46, pp.185-200.

Economic Intelligence Service (2002). *Corporate Sector*. Mumbai: Centre for Monitoring Indian Economy.

——— (2002a). Prowess: Indian Corporate Database. Mumbai: Centre for Monitoring Indian Economy.

Economic and Political Weekly (2002). National Accounts Statistics of India 1950–51 to 2000–2001. Mumbai: EPW Research Foundation.

Goldar, B. (1986), *Productivity Growth in Indian Industry*, Delhi: Allied Publishers.

Goldar, B. (2002), *Trade Liberalization and Manufacturing Employment: The Case of India*, Employment Paper 2002/34, Geneva: ILO.

Goldsmith, R.W. (1951), "A Perpetual Inventory of National Wealth", *Studies in Income and Wealth*, Vol.14, NBER.

Greer, D.F. (1971) "Advertising and Market Concentration", *Southern Economic Journal*, Vol. 38, pp. 19-32.

Griffiths, W.E. (1972) 'Estimation of Actual Response Coefficients in the Hildreth-Houck Random Coefficient Model'. *Journal of the American Statistical Association*, 67, 633-635.

International Monetary Fund (2001a), *India: Recent Economic Developments and Selected Issues*, IMF Country Report No. 01/181, Washington, D.C.: International Monetary Fund.

International Monetary Fund (2001b), *International Financial Statistics Yearbook 2001*, Washington, D.C.: International Monetary Fund.

Kalirajan, K. P., M.B. Obwona and S. Zhao (1996), "A Decomposition of Total Factor Productivity Growth: The Case of Chinese Agriculture Growth Before and After Reforms", *American Journal of Agricultural Economics*, Vol. 78, pp.331-338.

Kalirajan, K.P. and R.T. Shand (1997), "Sources of Growth in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol.52, pp.693-706.

Kopp, R.J. (1981), "The Measurement of Productive Efficiency: A Reconsideration", *Quarterly Journal of Economics*, Vol. 97, pp. 477-503.

Kumbhakar, S.C. (1988), "Estimation of Input-Specific Technical and Allocative Inefficiency in Stochastic Frontier Models", *Oxford Economic Papers*, Vol.40, pp.535-549.

Kundu, A. and N. Lalitha (1998), "Informal Manufacturing Sector in Urban India: Sectoral Trends and Interdependencies", *The Indian Journal of Labour Economics*, Vol. 41, pp. 201-215.

Lall, S. (1998), "Technological Capabilities in Emerging Asia", *Oxford Development Studies*, Vol. 26, No.2, pp.213-244.

Lucas, R.E. (1981), *Studies in Business Cycle Theory*, Cambridge, MA: MIT Press.

Maddala, G.S. (1977), *Econometrics*, New York: McGraw-Hill.

Nolan, P. (2001), *China and the Global Economy*, London: Palgrave Macmillan.

Ornstein, S.I., Weston, J.F. and M.D. Intriligator (1973) "Determinants of Market Structure", *Southern Economic Journal*, Vol. 39, pp. 612-625.

Ramaswamy, K.V. (1999), "The Search for Flexibility in Indian Manufacturing: New Evidence on Outsourcing Activities", *Economic and Political Weekly*, 6 February, pp.363-368.

Reserve Bank of India (RBI) (2003), *Handbook of Statistics on Indian Economy*, Mumbai: RBI.

Rowthorn, R. and R. Ramaswamy (1997), "Deindustrialization: Causes and Implications", *IMF Working Paper No. WP/97/42*, April, Washington, D.C.: International Monetary Fund.

Sachs, J.D. and A. Warner (1995), "Economic Reform and the Process of Globalization", *Brookings Papers on Economic Activity*, *1*, pp.1-95, http://links.jstor.org/sici?sici=0007-2303%281995%291995%3A1%3C1%3AERATPO%3E2.0.CO%3B2-G (Accessed on 18 March 2003).

Solow, R. (1956), " A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, Vol. 70, No. 1 (February), pp. 65-94.

Swamy, P.A.V.B. (1971), *Statistical Inference in Random Coefficient Regression Models*, Berlin: Springer-Verlag.

Swamy, P.A.V.B. and J.S. Mehta (1977), "Estimation of Linear Models with Time and Cross-sectionally Varying Coefficients", *Journal of the American Statistical Association*, Vol. 72, pp.890-898.

Tendulkar, S D. (1999), "Exports in India's Growth Process", Working Paper Number 46, New Delhi: Indian Council for Research on International Economic Relations, January, Obtained through the Internet site, http://www.icrier.res.in/public/46.html (Accessed on 19 March 2003).

UN-ESCAP (1991), *Industrial Restructuring in Asia and the Pacific*, Bangkok: ESCAP.

United Nations (1998), *International Trade Statistics Yearbook*, Volume II, Trade by Commodity, Statistics Division, New York: United Nations.

United Nations Industrial Development Organisation (UNIDO) (2002). Industrial Development Report 2002/2003, Competing through Innovation and Earning, Vienna.