The Post-reform Performance of the Manufacturing Sector in India*

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Abstract
Manufacturing played an important part in sustaining India's economic growth in the 1970s and 1980s. The economic reforms of the early 1990s did not lead to sustained growth of the manufacturing sector. After an acceleration in the mid-1990s, growth slowed in the decade's second half. The analysis presented in this paper reveals that manufacturing-sector growth in the post-reform period is "input driven" rather than "efficiency driven," with significant levels of technical inefficiency. The paper advocates policies to improve production efficiency by encouraging investment in research and development, technical training for workers, and technology-aided managerial processes.

1. The setting: Growth and competitiveness of India's manufacturing sector

India's nonagricultural sectors produced 75 percent of the overall output of the country's economy in 1993–2002. Of these nonagricultural sectors, manufacturing accounted for 23 percent of total GDP; the electricity, water supply and gas, mining, and construction subsectors accounted for 9 percent; and the service sector, comprising all other subsectors, accounted for the remaining 43 percent. Thus, manufacturing, when considered a single group of activities, is a major sector in the Indian economy.

The Indian manufacturing sector entered into a slower pace of growth beginning in 1980, but particularly in the

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post-1991 reform period. Considerable controversy exists among researchers about the causes of this slowdown.[1] The sustained growth of this sector is now under threat, primarily because it has been unable to compete effectively in the new environment created by trade liberalization policies. The United Nations Industrial Development Organisation (UNIDO) report of 2002 indicates that India's competitiveness did not improve significantly between 1985 and 1998, whereas the competitiveness of China's industrial sector, as measured by the competitive industrial performance (CIP) index, improved sharply during this time (table 1a). Given the importance of the structure and characteristics of manufactured exports to the calculation of the CIP index, it is worthwhile to examine and compare the manufactured exports of three large labor-abundant economies: India, China, and Indonesia.

Table 1b shows the percentage composition of these three countries' incremental extended manufacturing exports between four pre-reform years (1987–90) and four post-reform years (1993–96) for each of five broad categories of exports: resource-intensive (mainly processed agricultural and mineral products), labor-intensive (light manufactures), scale-intensive (such as chemicals other than drugs), differentiated (mostly machinery and transport equipment), and science-intensive (high-tech products). Traditional labor-intensive and scale-intensive exports together accounted for nearly 80 percent of India's incremental exports. In contrast, differentiated products have increasingly been taking a larger share (54 percent) of the incremental composition of the world's manufactured exports. China and Indonesia have been penetrating this expanding market, but India has not.

Within a short period China has consolidated its position as one of the leading manufacturing locations, so why has India not been able to do so? One of the major determinants of a country's international competitiveness is its productivity relative to that of competing countries and trading partners. Of foremost importance to the improvement of productivity, however, is the ability to operate on the production frontier, that is, the ability of firms to achieve their maximum possible output from a given set of inputs and technology. When a country operates not *on* but *inside* its production frontier, then it is possible to increase output without having to increase

1 Notable earlier controversies center on the work of Ahluwalia (1985, 1991), Goldar (1986), and Balakrishnan and Pushpangadan (1994) on the productivity of the Indian manufacturing sector. Krishna (1987) examines and explains the differences in the results of Ahluwalia (1985) and Goldar (1986). Using data from the pre-reform period, Ahluwalia's 1991 study documents the poor total factor productivity growth in Indian manufacturing up to the end of the 1970s but claims there was a turnaround and a rising trend in total factor productivity during the first half of the 1980s. Balakrishnan and Pushpangadan (1994) provide evidence against Ahluwalia's turnaround hypothesis.

Table 1a. Ranking of countries according to the competitive industrial performance (CIP) index

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

Source: *UNIDO (2002).*

Note: *The composite CIP index is calculated as a simple average of the following four standardized basic indicators: manufacturing value-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 values for these variables are standardized for the sample to range from 0 (worst performers) to 1 (best performers).*

Table 1b. Composition of increment in extended manufacturing exports between 1987–90 and 1993–96

	Increment (%)			
Type of export	**World**	**India**	**China**	**Indonesia**
Resource-intensive	6.2	Negligible	Negligible	22.6
Labor-intensive	11.8	42.4	44.5	43.8
Scale-intensive	15.7	35.3	19.1	—
Differentiated	54.0	Negligible	23.6	15.8
Science-intensive	9.8	Negligible	Negligible	Negligible

Source: *Srinivasan (2001).*

inputs or improve technology. Thus, it is imperative to examine the status of manufacturing productivity in India in the post-reform period.

Basically, output growth results from positive changes to one or both of the following factors: inputs and total factor productivity (TFP). TFP growth arises mainly from technological progress or improvements in technical efficiency. Table 2 indicates that the average growth rate of India's manufacturing output in the 1990s (6.00 percent) was lower than that in the 1980s (6.98 percent). Recent studies by Srinivasan (2001), Tendulkar (2000), and Goldar (2002) suggest that the 1991 trade reforms have contributed to an acceleration in employment growth in organized manufacturing in the post-reform period. This acceleration is mainly attributable to better access to inputs (e.g., from infusions of capital through foreign direct investment [FDI]) and to growth in export-oriented industries, which are more labor-intensive. Thus, the combination of increased employment and decreased growth in manufacturing between 1995–96 and 1999–2000, relative to the 1980s, suggests that manufacturing output growth has been input-driven from the mid-1990s.

Table 2. Structural growth of India's GDP

Period	GDP growth (%)				
	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 the Government of India's* Economic Survey *(various years).*

In other words, manufacturing firms in India appear to be operating inside their production frontier. Using firm-level panel data, Balakrishnan, Pushpangadan, and Babu (2000) concluded that there has not been any significant improvement in productivity growth in Indian manufacturing in the post-reform period, but they did not attempt to explain this result. If the reason for the decline or stagnation in productivity growth is a lack of competitiveness, then policies should address this issue. If the lack of competitiveness is attributable to the "policy environment," then the government should adjust its policies.

The objectives of this paper are to analyze the sources of output growth in the manufacturing sector of India in the post-reform period and to identify the crucial factors that influence manufacturing productivity. Our work attributes the poor growth performance of the Indian manufacturing sector in recent times to poor organization, inappropriate manufacturing strategies, and misguided decision making at the firm level.

Our analysis is based on the corporate database of the Centre for Monitoring Indian Economy (CMIE). The database provides detailed quantification and diagnosis of the growth, profitability, and liquidity of about 7,800 firms in the Indian corporate sector, which is disaggregated over several years by industry, ownership, size, and age. The manufacturing companies included in this database account for about 78 percent of the total value of manufactured output, and the data are available up to FY 2000–2001. Additional data used in our study are from the IMF's *International Financial Statistics Yearbook 2001,* the United Nations' *International Trade Statistics Yearbook,* the Government of India's *Economic Survey,* the Central Statistical Organization's (CSO's) *Annual Survey of Industry* and *National Accounts Statistics,* and CMIE's database PROWESS.[2]

2 PROWESS provides information on about 8,000 companies, covering public, private, cooperative, and joint-sector companies, listed or otherwise. These companies account for more than 70 percent of the economic activity in the organized industrial sector of India. PROWESS is thus the most comprehensive and current database of the Indian corporate

2. The 1991 turning point in Indian economic management

Some researchers argue that the political economy of industrialization in India has been a key determinant of the performance of the manufacturing sector. For example, Joshi and Little (1994, 3) claim that India's postindependence industrialization strategy was not only "micro-economically inefficient, but macro-economically perverse." In India's central-planning era, the Mahalanobis (1955) model of development called for the public sector to be the prime mover of the economy through strong involvement in investment and employment generation. Investments in factories, mining, and power generation expanded greatly in the Second Plan (and thereafter); the mining and power sectors grew relative to the total economy; and within the industrial sector, there was a major shift away from consumer goods toward output of capital goods. Within the broad industrial sector, public activity was growing relative to private activity. By the Third Plan, the proportion of public investments in factories, power generation, and mining exceeded 70 percent. This strategy has been severely criticized for being highly inefficient and for not using India's abundant labor resources (Bhagwati 1993).

From the 1970s, the success of the East Asian growth model was increasingly acknowledged in the literature, and the model was being successfully followed in some Southeast Asian countries. This persuaded Indian policymakers to begin recasting India's development strategy. From 1977, and particularly after 1985–86, policy changes were initiated to move the economic policies toward liberalization and deregulation. Some important changes in trade and industrial policies were announced in broad terms in the documents of the Seventh Plan (1985–90). Consequently, the GDP growth rate increased to 5.5 percent from the long-stagnant 3.5 percent. However, in the process of establishing and maintaining heavy industries, the government had accumulated large deficits in internal and external accounts, making the economy highly vulnerable to external shocks.

By 1987, political rivalries had weakened the government and halted further reform. After the general elections of 1989, the Janata Dal government adopted a populist approach and announced agricultural loan waivers, resulting in an additional fiscal burden of Rs 80 billion. Although the procurement prices of wheat and rice were raised twice, they were still less than the open-market prices. Fertilizer prices remained unchanged from 1981, and consequently the burden of the fertilizer subsidy

sector. PROWESS not only exploits the detailed disclosures that are mandatory in the annual accounts of companies in India but also takes information from other reliable sources, such as the stock exchanges and associations of industries. The database is also subjected to rigorous formal validation and quality control by CMIE.

stood at around Rs 4.4 billion (Jalan 1992). Although the Ninth Finance Commission projected the national revenue deficit to be Rs 8.5 billion for 1990–91 and 1991–92, the actual figures were twice as high, with inevitable increases in inflationary pressures (13 percent). These developments worsened the balance of payments deficits (Government of India 1992). These macroeconomic imbalances were then further exacerbated by the Gulf crisis and the disintegration of the former Soviet Union. The Indian government responded vigorously with a program of stabilization and reform in mid-1991. The outcome was not only a significant recovery, but also a new course for the country's economy.

India's manufacturing sector grew faster than the country's overall GDP in the last five decades of the 20th century (table 3). There have been two distinct phases in manufacturing growth since 1993. Manufacturing GDP grew in real terms by 11 percent per year in 1993–97, but by only half this rate in 1997–2003. The decline in the growth rate of manufacturing output is also reflected in the reduction in the share of manufacturing in total GDP (17.25 percent in 1993–97, but 17.10 percent in 1997–2003). It is this decline that has led to concerns about the role of manufacturing as an engine of India's economic growth. The evidence for improvement in manufacturing productivity in India is still mixed: for example, a study by Krishna and Mitra (1996) indicates that the manufacturing sector has enjoyed significant productivity growth in the post-reform period, but Balakrishnan, Pushpangadan, and Babu (2000) claim that there is no evidence of such productivity growth.

3. The manufacturing sector in India

As a result of earlier plan strategies, India's public sector holds an important position in key manufacturing sectors such as steel, automobiles, petroleum, and engineering. The average share of public sector involvement in manufacturing was nearly the same in the 1990s as it was in the previous decade (table 4). A distinction is often made in the Indian manufacturing sector between organized and unorganized sectors. Organized (registered) manufacturing consists of all factories requiring power on the premises that employ 10 or more workers and all factories that do not require power and employ 20 or more workers. Unorganized (unregistered) manufacturing consists of those enterprises with power that employ fewer than 10 workers and those not using power that employ fewer than 20 workers. The output share of the organized sector has continuously increased since 1950–51. Even in the 1990s, the output of the organized sector rose faster than the output of the unorganized sector (table 5). However, in 1997–2001, as reflected in the lower output share, the output of the organized sector increased at a slower rate than that of the unorganized sector. Is the organized sector more constrained than the unorganized sector

Table 3. Share of manufacturing in India's GDP (average for each period in question)

Period	Share of manufacturing in GDP (%) 1981–82 Constant prices	Current prices
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
1993–97	17.25	17.20
1997–2003	17.10	15.75

Source: *Based on data from Central Statistical Organization's* National Accounts Statistics *(various issues).*

Table 4. Public sector participation in manufacturing GDP in India

	Share of public sector in manufacturing GDP (%, average over the period)		Public sector GDP growth (% per year)	
Period	1993–94 prices	Current prices	1993–94 prices	Current prices
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
1997–2000	17.79	14.65	7.87	7.01

Source: *Data are from the Central Statistical Organization's* National Accounts Statistics *(various issues).*

in effecting the changes needed to sustain growth of output? Some analysts claim that labor policies have affected the organized sector more than the unorganized sector. Alternatively, it can be argued that expansion of capacity in the mid-1990s was far greater in the organized sector than in the unorganized sector, and hence the impact of excess capacity was also greater for the organized sector. Another suggestion is that the increased growth of the unorganized sector in recent years was a result of substantial increases in outsourcing by the organized sector (Ramaswamy 1999). In our view, the increase in outsourcing activities was as much a response to the rigid labor policies that restrict a firm's ability to downsize the workforce as to increased demand.

The growth of the private manufacturing sector depends on profitability, which has become an important issue since the mid-1990s. Table 6 shows various measures of profitability for Indian manufacturing corporations. Profitability after tax has declined since FY 1995–96. It should be noted, however, that the declining profit margins are mainly attributable to the downward pressure on manufactured-output prices that was generated by increased competition resulting from economic reforms. Competition compelled some companies to work with thin profit margins. Such a working environment has induced restructuring within the manufacturing

Table 5. Share in India's GDP of registered and unregistered manufacturing firms

	Share in GDP (average over the period, %)			
	1993–94 prices		Current prices	
Period	Registered manufacturing firms	Unregistered manufacturing firms	Registered manufacturing firms	Unregistered manufacturing firms
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
1997–2001	11.19	5.98	10.23	5.64

Source: *Data are from the Central Statistical Organization's* National Accounts Statistics *(various issues).*

Note: *Registered (organized) firms have power on the premises and employ 10 or more workers or do not use power and employ 20 or more workers. Unregistered (unorganized) firms have power on the premises and employ fewer than 10 workers or do not use power and employ fewer than 20 workers.*

Table 6. Profit margins and exports of Indian manufacturing companies

	1995–96	1996–97	1997–98	1998–99	1999–2000	2000–2001
PBDIT/gross sales	13.3	12.5	12.2	11.6	10.9	10.2
PBT/gross sales	6.4	5.5	4.8	3.9	4.7	4.8
PAT/gross sales	4.1	2.3	1.7	0.8	0.8	1.1
Total exports/sales (%)	8.4	8.6	9.0	9.0	8.9	10.1
Export growth (%)	10.9	3.6	7.9	−2.8	15.2	15.7

Source: *CMIE (2002b).*

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

sector. One of the most important means of restructuring is acquisitions and mergers. Table 7 shows that the number of mergers in India's manufacturing corporate sector increased from 197 in 1999–2000 to 297 in 2000–2001. The largest number of mergers and acquisitions occurred in the chemicals industry, followed by the information technology sector. Mergers and acquisitions in the drugs and pharmaceuticals industry showed an increasing trend from 1999 to 2001, but the nature of the mergers changed during this period. In 1999–2000, the majority of the joint-venture buyouts were by Indian partners, whereas in 2000–2001, foreign partners acquired the Indian partners' stakes in the joint ventures. These transactions were facilitated by recent policy measures that made it easier to gain government approval of foreign investment. Has FDI played a major role in boosting capital formation in manufacturing in India?

Data from the *National Accounts Statistics* (CSO) indicate that FDI inflows constituted only about 5 percent of capital formation in India's registered manufacturing firms during the post-reform period of 1992–2000. Generally, for most years in the

Table 7. Acquisitions and mergers in India's corporate sector (all companies)

	1999–2000	2000–2001
Acquisitions		
Number	1,291	1,184
Value in crore (Rs)	51,765	33,788
Mergers		
Number	197	297
Open offers		
Number	89	76
Value in crore (Rs)	752	2,625

Source: *CMIE (2002a).*

Note: *Rs = Indian rupees.*

1990s, the ratios of actual FDI to approvals have been about 20 percent. Between 1992 and 2000, approvals were given mainly in the priority industries, such as food and agro-processing, chemicals and chemical products, metallurgical industries, electrical machinery, and transport equipment. These five industries together attracted about 33 percent of FDI approvals (table 8). To put it differently, only a small percentage of FDI flows in the 1990s went into export-oriented industries; the bulk went into import-competing or nontraded industries such as power and fuel. India's experience has hence been different from that of several other developing countries, for which FDI has generally been central to the production of export-oriented industries. This is partly because of government policies that favor FDI in certain industries and partly because India has a large domestic market that attracts market-oriented FDI rather than efficiency-oriented and overseas-market-oriented FDI (Goldar 2002).

The structure of India's manufactured exports reveals the nature of the relationship between FDI and the manufacturing sector. Manufactured exports are mainly low-technology products concentrated in slow-growing market segments (Lall 1998) (table 9). India lacks a base in several high-technology products that are experiencing high growth in world trade, which might explain the country's relatively poor export performance. Neither the 1991 trade and industrial reforms nor the post-reform FDI inflows have had any effect on India's export structure: table 9 shows that the composition of India's manufactured exports has not changed significantly between the pre- and post-reform periods. The Herfindahl index (HI), which is defined as the sum of the squares of the share of each commodity in total manufactured exports, can be used as a measure to verify this proposition. The lower limit of the HI is the reciprocal of the square of the number of manufacturing products exported, and the upper limit of the HI is 1. When the calculated value for HI is near the lower limit, it means that manufactured exports are significantly diversified. When the calculated value is near the upper limit, this means that manufactured exports are concentrated in a few commodities. For the two-digit levels of classifica-

Table 8. India's approvals of FDI by industry, 1992–99

Industry type	FDI approvals (Rs billion)	Share of total FDI (%)
Manufacturing		
Food and agriculture-based products	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
Nonmetallic mineral products	39.8	1.9
Metallurgical industries	125.5	6.0
Electrical machinery	133.3	6.4
Nonelectrical 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	2,092.4	100.0

Source: *Goldar (2002).*

Table 9. Structure of India's manufactured exports during the pre- and post-reform periods

Manufactured exports	Share of total manufactured exports (%) in pre-reform period (1987–1989)	Share of total manufactured exports (%) in post-reform period (1997–1999)
Leather and 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-ups, etc.	8.1	11.6
Jute manufactures	1.2	0.4
Gems and jewelry	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 (2000).*

tion of 43 manufactured commodities, the lower limit for the HI is 0.00043. The calculated HIs for the years 1987–89 and 1997–99 are 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) shows that the growth rates for labor-intensive manufactured products in India during 1987–96 were relatively higher than the growth rates for skill-intensive products, but the reverse is true in the case of China. India's share in world exports of scale-intensive and differentiated products, which are technologically more sophisticated, was substantially lower than that of China in 1998 (table 10). The irony is that although China and India enjoy a comparative advantage in labor-intensive manufactured products (both economies have a labor

Table 10. Percentage share in world exports of China and India's manufactured products, 1998

Country	Resource-intensive products	Scale-intensive products	Differentiated products	Labor-intensive products	Science-based products	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

Sources: *Authors' calculations are based on IMF (2001) and UN (1998). Classifications are based on UNESCAP (1991).*

surplus), China has been diversifying into the production of differentiated and skill-intensive products. The question is what prevents India from climbing up the technology ladder as well. The conclusion reached by Sachs and Warner (1995, 53) is that "open economies tend to adjust more rapidly from being primary-intensive to manufactures-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." This analysis clearly supports the hypothesis that Indian manufacturing is still primarily geared toward domestic consumption. Therefore, its growth is limited by domestic demand.

4. Crucial factors influencing manufacturing productivity

In accounting for output growth, the conventional "residual" approach of Solow (1956) fails to recognize and estimate effectively the key role of technical change within the components of TFP growth. At any point in time, TFP is the combined result of technical progress and technical efficiency, or the efficiency with which factors are used, given the technology. From the perspective of long-run policy, it is crucial to distinguish the increment in productivity that occurs as a consequence of technical progress from the increment that results from improved technical efficiency in the application of already-established technologies. How does one account for the above distinctions in primal production function modeling?

If the production process were simply the engineering relationship between a set of inputs 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. In reality, however, observed output is often the result of a series of producers' decisions that influence the method of application of inputs. Thus the variables associated with the relevant production environment will also play an important part in an enterprise's decisions and consequently on its output. For this reason alone, some enterprises may be producing not *on* but *inside* their production frontiers, with a gap between "best-practice" techniques and "realized" methods of production. This gap may arise owing to the negative effects of nonprice or organizational factors (such as lack of adequate human capital) or to the impacts of insufficient infrastructure, which are the result of the existing production environment emerging from the existing institutions. For example, lack of incentives, soft budget constraints of the central and state governments, inefficient transmission of information about production processes to producers, and ineffective government control over enterprises could all cause deviations from best-practice production techniques. It is very difficult to model the influence of these nonprice and organizational factors on output. Nevertheless, their combined influence can be introduced into the production function in several ways.

One method represents such nonprice 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. As Maddala (1977, 403) notes, however, this approach is unrealistic: "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-parameters model or a varying-coefficient model is appropriate in evaluating the effects of economic reforms and behavioral differences on outputs across manufacturing firms.

How does the estimation of a frontier production function with varying coefficients differ from the estimation of a conventional production function? A production function is traditionally estimated as an average output response to a given level of inputs and technology, and it is theoretically defined as the maximum possible output or potential output. The assumption in the conventional estimation of a firm's production function 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 the result of factors beyond the firm's control. In the estimation of a frontier production function with varying coefficients, however, the difference between the estimated and realized outputs is considered to be attributable to factors both within and 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:

$$y_{it} = \sum_j \beta_{ijt} x_{ijt} + \epsilon_{it},\ i = 1, 2, \ldots, n,\ t = 1, 2, \ldots, T, \tag{1}$$

where y_{it} is the logarithm of output of the ith state in the tth period; x_{ijt} is the logarithm of the jth input used by the ith state in the tth period when $j \neq 1$ (an intercept is included in this model by considering $j = 1$); β_{i1t} is the intercept of the ith state in the *t*th period, and β_{ijt}, when $j \neq 1$, is the slope coefficient concerning the *j*th input used by the *i*th 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 nonprice and organizational factors, which vary across firms, influence outputs indirectly through the method of application of inputs. When firms follow the best method of application of inputs (i.e., the method required by the selected technology to utilize the chosen inputs effectively), they obtain the maximum possible outputs for the given set of inputs, because the production response coefficients will be the maximum, indicating that the firms are technically efficient. As firms cannot produce more than the theoretically possible level of output, the above model is consistent with the production theory. If, because of the adverse effects of some nonprice or 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 will be 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. Furthermore, 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 are fully technically efficient if and only if the chosen inputs are effectively utilized by following the best method of application. This means that nonprice, institutional, or organizational 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 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 makes it possible to identify which applications of inputs are 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 equation (1) is to follow the analysis of variance (ANOVA) approach. This means imposing the following restrictions on equation (1):

$$\beta_{ijt} = \bar{\beta}_j + u_{ij} + v_{jt},\ j = 1, 2, \ldots, m,\ \sum_i^n u_{ij} = 0,\ \sum_t^T v_{jt} = 0,$$

where u_{ij} and v_{jt} denote cross-sectional and temporal variation, respectively, of the production coefficients β_{ijt}. The above specification is a more general case of the specification discussed by Cornwell, Schmidt, and Sickles (1990) and so is not parsimonious. Alternatively, model (1) can be transformed into a random-coefficients framework with the assumption that u_{ij} and v_{jt} are random variables. The random-coefficients specification facilitates economizing 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 coefficients of the frontier function, providing the maximum possible output. To elaborate, let $\beta^*_0, \beta^*_1, \beta^*_2, \beta^*_3, \ldots, \beta^*_K$ be the estimates of the parameters of the frontier production function yielding the maximum possible output for any given level of inputs. The frontier coefficients (β^*s) are chosen to reflect the condition that they represent the production response by following the best-practice method of application of inputs. These coefficients are obtained from among the individual response coefficients, which vary across observations (states). Let the β^*s be the estimates of the coefficients of the frontier production function, that is,

$$\beta^*_{jt} = \max_i \{\beta_{ijt}\},\ i = 1, 2, \ldots, n,\ j = 1, 2, \ldots, m,\ t = 1, 2, \ldots, T,$$

where β^*_{jt} is the frontier coefficient of the jth input in the tth period, and β_{ijt} is the coefficient of the jth input of the ith manufacturing firm in the tth period.

In special cases of the production process in which constant returns to scale are imposed on the individual response coefficients (β_{ijt}), the estimation of β^*_{jt} is complicated and intractable. Even when the condition of constant returns to scale is imposed on the mean response coefficients ($\bar{\beta}_j$), then as a result of the relationship $\beta^*_j = \max_i(\bar{\beta}_j + v_{ij})$, the possibility that $\Sigma\beta^*_j > 1$ cannot be ruled out. In either case, the problem that remains is that the best-practice production outcome might not be feasible if all production processes had to have constant returns to scale by some strict technical rule. However, in the present study, the production frontier model can be viewed as a disequilibrium model of endogenous technological progress in which long-run growth is driven primarily by the accumulation of best-practice knowledge by firms. Therefore, drawing on the endogenous-growth models popularized by Romer (1986), it is rational to argue that production as a function of the stock of knowledge of best-practice techniques and other inputs will exhibit increasing returns to scale. Why is this so? Following Arrow (1962), it may be argued that increasing returns arise because a new (best-practice) technique is discovered as investment and production takes place. Therefore, $\Sigma\beta_j^* > 1$ does not pose any problem (theoretically) for the measurement of efficiency. Furthermore, the underlying assumption in our model is that all firms within an industry use more or less similar technology and have equal access to the best-practice techniques of the given technology. Because the above model facilitates measurement of the technical efficiency of firms, given their resources and technology, using a primal production frontier, cost minimization is not the concern here.

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

$$y_{it} = \sum_j \beta_{ijt} x_{ijt} + \epsilon_{it}, \; i = 1, 2, \ldots, n, \;\; t = 1, 2, \ldots, T.$$

Technical efficiency of the ith manufacturing firm can be calculated as

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

where y_{it} is the logarithm of the observed output of the ith firm in the tth time period, and y^*_{it} is the logarithm of the estimated frontier output of the ith firm in the tth time period. A major advantage of the above methodology is that the analysis can be carried out even with cross-sectional data. Unlike in the conventional frontier approach, this method facilitates identification of which firms are following the best-practice technique of applying which inputs. It can easily be related to actual observations, which is obviously useful for policy analysis.

Following Kalirajan and Shand (1997), figure 1 illustrates the decomposition of total output growth into input growth, technical progress, and technical-efficiency improvement. In periods 1 and 2, a firm faces production frontiers denoted by F_1 and F_2, respectively. If a given firm has been technically efficient, output would be y^*_1 in period 1 and y^*_2 in period 2. On the other hand, if the firm has been technically inefficient and does not operate on its frontier because of firm-specific nonprice and organizational factors, then the firm's realized output is y_1 in period 1 and y_2 in period 2. Technical inefficiency is measured by the vertical distance between the frontier output and the realized output of a given firm, that is, TE_1 in period 1 and TE_2 in period 2, respectively. Hence, the change in technical efficiency (TE) over time is the difference between TE_2 and TE_1. Now, suppose there is technical progress from improved quality of human and physical capital, so that a firm's potential frontier shifts to F_2 in period 2. If the given firm continues the technical progress, more output is produced from the same level of input. So, as shown in figure 1, the firm's output will be increased to y_1^{**} for input x_1. We measure technical progress as the distance between the two frontiers ($y_1^{**} - y_1^{*}$), 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 ($y_2 - y_1$) can be decomposed into three components: input growth, technological progress, and technical-efficiency change.

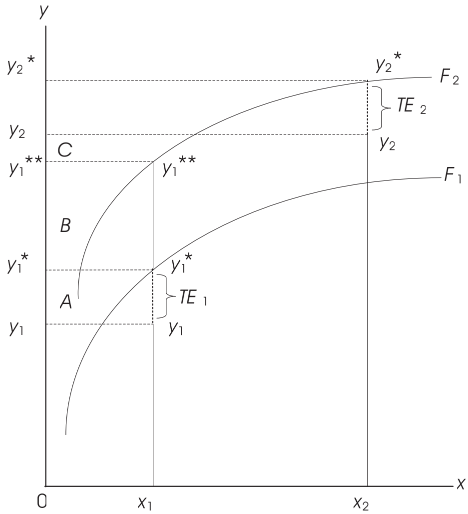
Referring to figure 1, the decomposition can be shown as

$$\begin{aligned} D &= y_2 - y_1 \\ &= A + B + C \\ &= [y_1^{*} - y_1] + [y_1^{**} - y_1^{*}] + [y_2 - y_1^{**}] \\ &= [y_1^{*} - y_1] + [y_1^{**} - y_1^{*}] + [y_2^{*} - y_1^{**}] - [y_2^{*} - y_2] \qquad (3) \\ &= \{[y_1^{*} - y_1] - [y_2^{*} - y_2]\} + [y_1^{**} - y_1^{*}] + [y_2^{*} - y_1^{**}] \\ &= [\{TE_1 - TE_2\} + TC] + \Delta y_x \\ &= \text{TFP growth} + \text{input growth}, \end{aligned}$$

where $y_2 - y_1$ = output growth; $TE_1 - TE_2$ = technical-efficiency change; TC = technical change; and Δy_x = output growth attributable to input growth.

This decomposition of total factor productivity growth into technical-efficiency improvement ("catching up") and technological advance is therefore useful in distinguishing between innovation or adoption of new technology by best-practice firms and the diffusion of new advanced technology that leads to improved technical efficiency among firms that are catching up. The coexistence 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.

Figure 1. Decomposition of total output growth



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, Obwona, and Zhao 1996).

The production technology is represented by a Cobb-Douglas varying-coefficients function.[3] 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 $t = 1, 2, \ldots, T$. Equal doses of labor and capital in a particular production process may yield different levels of output over different years, depending on technical progress and technical-efficiency improvement that might take place during the course of the sample period as a result of the varying influences of economic reforms. Drawing on Swamy and Mehta (1977), the motivations for time-varying and cross-sectionally varying coefficient models are (1) to allow for different coefficients for each individual unit to account for spatial or interindividual heterogeneity and (2) to modify continually the values of coefficients over time to allow the relationship to adapt itself to local conditions, such as industry-specific reforms. Therefore, using time-specific dummies (D) to account for interyear differences, we can express in logarithmic form the temporal firm-specific manufacturing production function as[4]

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

4 All variables are taken as simple 3-year average values over 1997–2000.

$$\ln Y_{it} = \beta_{1it} + \sum_{j=2}^{4} \gamma_{ji} D_{jit} + \sum_{k=2}^{4} \beta_{kit} \ln X_{kit},\ i = 1, \ldots, 14,\ t = 1\,(1997), \ldots, 4\,(2000), \quad (4)$$

where

parameters β_{kit} and γ_{ji} are input-specific and firm-specific response coefficients;

D_{jit} = 1 if $j = t$, 0 otherwise;

Y = real value of manufactured output at 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;[5]

X_3 = labor hours used in production at year end;[6]

X_4 = real value of material inputs used in production measured in 1981–82 constant prices.[7]

For given values of t, employing the specifications and estimation procedures described above, the mean and individual response production coefficients were obtained.[8] For brevity, we present only the means of the estimated response coefficients with standard errors and the ranges of the individual response

5 There is no universally accepted methodology for constructing a capital stock series. In the case of India, 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 real capital stock in the benchmark year and I_t the real gross investment in fixed capital in the tth year. Let r be the annual rate of discarding of assets. Then the real gross fixed capital stock for the tth year is $K_t = K_0 + \Sigma\, I(t)$, where $I(t) = I_t - rK_{t-1}$. As the balance sheet figures for capital are at historic cost, such book value of capital has to be converted into asset value at replacement cost before the PIM can be followed. Following Balakrishna, Pushpangadan, and Babu (2000), but with a 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 Balakrishna, Pushpangadan, and Babu (2000), it is not repeated here.

6 The PROWESS database provides data on total wages paid to all employees. In order to work out the labor man-days, the wage rate per man-day is constructed from the *Annual Survey of Industries* (CSO), with corresponding industrial classification. Because of lack of data, labor days could not be divided into skilled and unskilled labor hours.

7 To work out the real value of material inputs, a material inputs price index with base 1981–82 was constructed by taking weights from the I-O Transaction Matrix 1989–90 (CSO 1997) to combine the wholesale prices of the relevant inputs.

8 A computer package (TERAN) developed to estimate the unconstrained variance-covariance matrix of the random coefficients, the generalized-least-squares mean estimator, and individual response coefficients (Griffiths 1972) was used to estimate the empirical model.

coefficients for the frontier production functions (table 11). The range of the coefficients clearly shows that the input-specific response coefficients vary across firms. All of the core input coefficients and the year dummy coefficients are also significant at the 5 percent level. The elasticity coefficient estimates for fixed capital and labor are lower than those for the material inputs. Combining these three estimates, we conclude that the selected manufacturing industries (chemical, electrical, and transport) have been operating more or less at constant returns to scale. From the year-wise estimates, frontier outputs for each period *t* were calculated using the frontier production coefficients given in table 11. 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 a given technology. Finally, sources of output growth in the later post-reform period (1997–2000) were calculated as shown in equation (3) to examine the pattern of change in the manufacturing sector's productivity in the post-reform period.

A decomposition of output growth during a given period into contributions attributable to (1) input growth, (2) changes in efficiency, and (3) technical progress is based on the concept of the frontier output. The contribution of technical progress is the shift in the production frontier or potential output between any 2 years, and the contribution of input growth is the movement along a production function. The contribution of efficiency is the difference in output for the same level of input 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 three selected industries is mainly input-driven in the later post-reform period. Input growth, technical-efficiency change, and technical progress all contributed positively to output growth, but the contribution of input growth was largest. This result corroborates the finding of a recent national survey of manufacturing that claims that material cost and labor cost constitute about 75 percent of total production cost (Chandra and Sastry 2002). The contribution of technical-efficiency change to output growth, however, indicates that technical efficiencies in the chemical products and electrical machinery industries have improved during 1999–2000. In contrast, technical efficiency in the transport industry appears to have been deteriorating since 1997. Generally, for the periods in question, technical efficiency improves when input growth is lower, and when input growth is higher, technical efficiency deteriorates. Although the efficiency changes have contributed to the decline in the output growth rate, the lower level of efficiency itself has meant lower levels of output, compared with potential output. The technical-efficiency estimates shown in figures 2–4 point to po-

Table 11. Mean and range of estimates of response coefficients of production functions for manufacturing industries in India

Variable	Minimum estimate			Maximum estimate			Mean estimate		
	Chemical products	Electrical machinery	Transport	Chemical products	Electrical machinery	Transport	Chemical products	Electrical machinery	Transport
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)
Labor	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: *Authors' estimations based on firm-level data for 1997–2000.*

Note: *Figures in parentheses are t-values. All the coefficients are significant at no less than the 5 percent level.*

Table 12. Sources of growth in selected manufacturing industries in India, 1997–2000

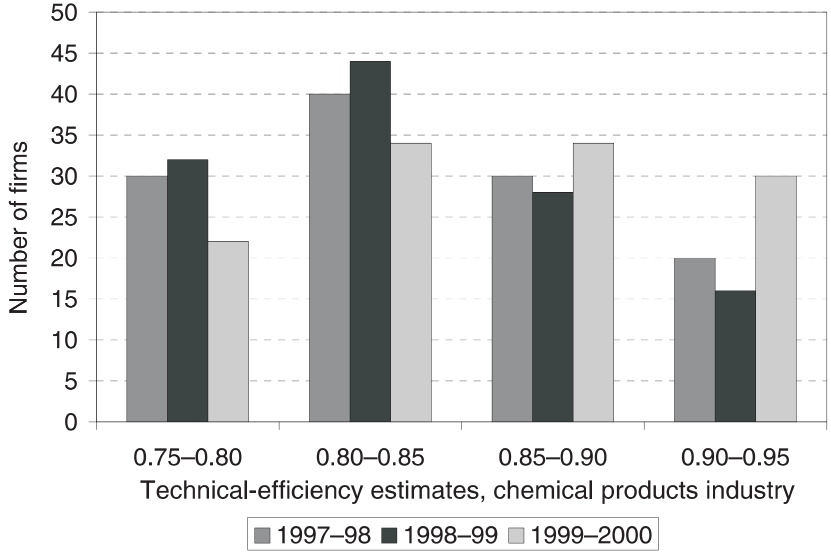
Industry and period	Contribution to output growth (%) by		
	Input growth	Technical-efficiency change	Technical progress
Chemical products			
1997–98	77.35	9.25	13.40
1998–99	82.10	8.45	9.45
1999–2000	76.14	11.35	12.51
Electrical machinery			
1997–98	70.75	11.25	18.00
1998–99	75.30	10.35	14.35
1999–2000	68.15	16.75	15.10
Transport			
1997–98	76.35	9.65	14.00
1998–99	83.45	8.25	8.30
1999–2000	85.28	7.65	7.07

Source: *Authors' calculations.*

tential gains that would result from improved efficiency in the manufacturing sector. Improvements in the level of technical efficiency would be an important source of output growth. To put it differently, the mean technical-efficiency measures during 1997–2000 for the manufacturing industries of chemical products, electrical machinery, and transport equipment were around 0.85, 0.86, and 0.80, respectively. These figures imply that output supply can be increased by about 15 percent, 14 percent, and 20 percent in these respective industries, without having to increase any inputs, by following the best-practice technique of application for a given technology at the firm level.

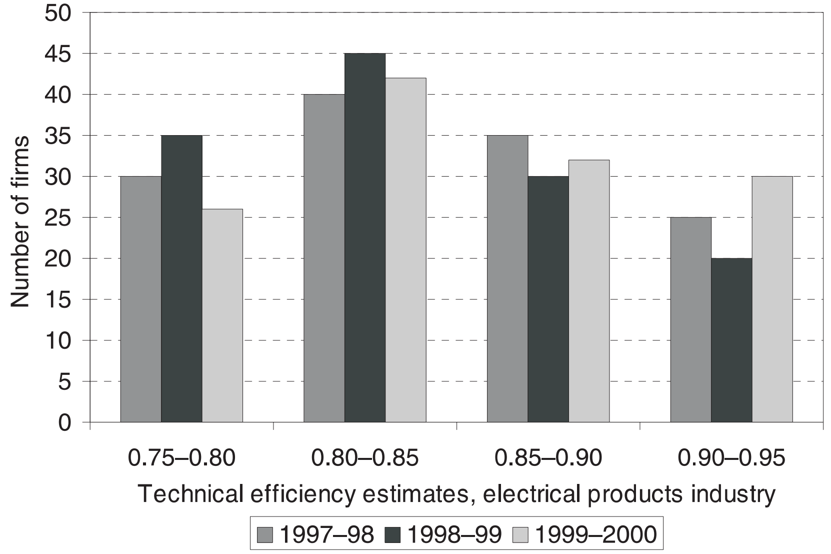
Significant gains in productivity could be achieved, particularly in firms with lower technical efficiencies, by raising the operation of the firm to be on its frontier. Obvi-

Figure 2. Chemical products industry: Technical-efficiency estimates



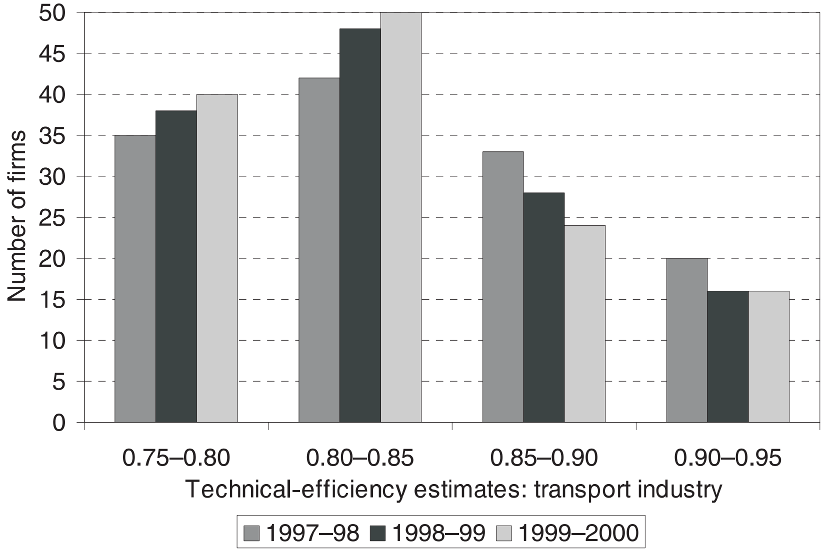
Source: *Authors' estimates.*

Figure 3. Electrical products industry: Technical-efficiency estimates



Source: *Authors' estimates.*

Figure 4. Transport industry: Technical-efficiency estimates



Source: *Authors' estimates.*

ously, not all firms can be put on their frontiers; however, if the factors associated with high technical inefficiencies can be determined, then improvements can be achieved through facilitating the effective functioning of those factors. Particularly relevant in this context are factors that would improve the competitiveness of manufacturing firms. Appropriate policy measures can be tailored and implemented to influence those factors to reduce the gaps between the most-efficient and least-efficient firms.

The 1991 economic reform in India opened up the country's economy to more foreign trade and investment. Though economists continue to argue about the nature of the relationship between productivity improvement and trade liberalization, the elements of stimulus to manufacturing growth resulting from economic reforms as a whole cannot be overlooked. For example, capital market reforms that encourage foreign-capital entry, when combined with tariff reductions, improved access to imported capital equipment and raw materials, and technical and financial collaboration with foreign companies, would certainly boost manufacturing production and exports. The impact of such policy-influenced factors on competitiveness is examined by regressing the average firm-specific technical-efficiency measures over the period 1997–2000 separately for each of the three manufacturing sectors for the sampled National Industrial Classification (NIC) 31, NIC 35, and NIC 37 industries on export intensity, raw-material import intensity, technology import intensity, research and development (R&D) intensity, foreign collaboration, and advertising intensity in the following model specification:[9]

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

where

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

x_2 = raw-material import intensity, which gauges the 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 the firm's expenditure on imported technology to its total value of sales;

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

x_5 = advertising intensity, which is measured as the advertising-to-sales ratio for each firm and serves as a measure of product differentiation (Greer 1971) and also as an index of risk (Ornstein, Weston, and Intriligator 1973);

D_1 = foreign collaboration, which is defined as a dummy variable taking a value of one if there is a foreign partner and zero otherwise, as determined using IMF rules, which treat a firm as a foreign direct investment enterprise if 10 percent of its stock is held abroad by a single investor.

The ordinary-least-squares estimates of equation (5) for the three industries are given in table 13. Several coefficient estimates are statistically significant at the 5 percent level or better, with theoretically acceptable signs and adjusted R^2 values that are reasonably high. The important result from this analysis is that the largest coefficients for the selected industries are those of R&D, thus highlighting the importance of R&D, including training of workers, to improving firms' competitiveness. When firms increase their export intensity, they tend to improve their technical efficiencies, and the magnitude of the coefficient of intensity is greater in the trans-

9 Because technical-efficiency measures vary from zero to one, they are transformed into $\ln[1/(1-TE)]$ to obtain ordinary-least-squares estimates that are best linear unbiased estimates.

Table 13. Determinants of firm-specific technical efficiencies in India (1997–2000)

Variables	Unit of measurement	Ordinary-least-squares regression estimates for industries: Chemical products	Electrical machinery	Transport
Export intensity	Ratio of value of exports to total value of sales	0.1160*ns* (1.1815)	0.1260 (3.1206)	0.1835 (2.2511)
Imported-raw-material intensity	Ratio of value of imported raw materials to total value of raw materials	0.1255 (2.3254)	0.1065*ns* (1.1676)	0.1892 (3.0354)
Imported-technology 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: *Authors' estimates.*

Notes: *Firm-specific technical efficiency = ln[1/(1−TE)]. Figures in parentheses are t-ratios.* ns = *not significant at the 5 percent level.*

port industries than in the electrical-machinery industries (table 13). However, the coefficient for export intensity is not significant for the chemicals industry. The use of imported raw materials appears to increase technical efficiency in the transport industry more than it does in the chemical products industry. These results indicate that the transport industry will gain more technical efficiency and will improve its competitiveness through further trade liberalization. The coefficient of intensity on imported raw materials is not significant for the electrical-machinery industry.

The regression raises a few interesting questions. Is the electrical-machinery industry working with outdated technology? Has this industry been acquiring foreign technology effectively? Is the industry able to adapt the acquired foreign technology? The coefficient of imported-technology intensity may provide some answers. This coefficient is significant for the transport industry, which confirms our earlier conclusions about the link between efficiency improvement in this industry and trade liberalization. It is also significant for the chemical products industry, although its magnitude is smaller than that for the transport industry. The imported-technology intensity coefficient is statistically significant for the electrical-machinery industry, but very small. It may be conjectured that firms in the electrical-machinery industry may be slow in applying and adapting new technology because they lack appropriate means of training workers to use the new technology, a hypothesis that warrants further analysis. Kundu and Lalitha (1998) show that use of nonstandard tools and methods of production have locked a large number of Indian manufacturing firms into low-level quality equilibria. Their study also reveals that the extent of mechanization in these firms is still very low, although most firms understand that mechanization guarantees improvements in product quality and process times. In contrast, a number of Chinese manufacturing firms have implemented large-volume production systems such as flow manufacturing systems and utilize efficient assembly lines and globally acceptable equipment and tools of production (Nolan 2001).

As expenditure on R&D increases, technical efficiency appears to increase substantially across all industries (table 13). However, the impact of R&D is relatively more significant for the transport industry than for the other two industries treated in the table. Chandra and Sastry (2002), through two national surveys, show that within Indian manufacturing firms, the priority given to invention and R&D has been declining since 1997 as compared to the early 1990s. The implication has been that India's manufacturing products have lacked sophistication in terms of attracting and satisfying domestic and foreign customers. Lall (1998) argues that Indian manufacturing firms export relatively more low-technology products relative to high-technology products because they lack sufficient R&D and technical training programs for production workers. Though many Indian firms provide managerial training, only a few have computer-based decision support systems for helping their managers make effective decisions (Chandra and Sastry 2002). Each large Chinese manufacturing enterprise, in contrast, has its own technology research center that helps it to move gradually from manual to automated manufacturing processes and provides appropriate technical training for workers (Nolan 2001).

As mentioned above, India's share in world exports in differentiated products is very small compared with that of China. One would expect a positive relationship between advertising intensity and technical efficiency in the selected industries. The advertising intensity coefficients in table 13 appear to indicate that advertising increases technical efficiency more in the transport industry than in the electrical-machinery industry. For the chemical products industry, the advertising intensity coefficient is positive, but it is not significant. This result may be expected, because advertising may not help increase market power in chemical products that are greatly diversified. Furthermore, India's share in scale-intensive exports (of which chemical products constitute one group) is equal to that of China, but gems and precious stones constitute a major proportion of such exports.

Collaboration with a foreign partner in production tends to increase technical efficiency in all the selected industries, according to the table, which is expected as a result of the spillover of knowledge, technology, and market from the foreign collaboration. The impact is relatively greater, as the table shows, for the transport industry than for the other two industries depicted.

The foregoing analysis reveals that Indian manufacturing firms are failing to focus on productivity and the factors that influence improvements in productivity. Is this lack of focus on productivity a result of firms' weakness in strategic decision making? Which core inputs are being wasted because of ineffective methods of application 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 inputs are applied more efficiently and which less so. As Kopp (1981, 491) has noted, technical-efficiency measures in a sense "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 instance, the sharper decline in current price share than in constant price share may reflect an improvement in the productivity of India's manufacturing sector. Also, between 1995–96 and 1999–2000, India's total employment was higher but its manufacturing growth was lower than in the 1980s. This might suggest that labor may not only be inefficiently utilized but also underutilized, relative to capital and material inputs, within certain firms in the selected industries in the later post-reform period. Extension of the firm-specific technical efficiency analysis into a firm- and input-specific technical-efficiency analysis will allow these propositions to be tested.[10]

Following the earlier discussion concerning equation (4), technical efficiency in the use of a given input (say, input 2) can be defined as

$$IEFF_{2jt} = (\beta_{2jt} / \beta^*_{2t}), \tag{6}$$

Where $IEFF_{2jt}$ is the technical efficiency of the jth producer with respect to input 2 at the tth period and $\beta^*_{2t} = \max(\beta_{2jt})$, $j = 1$ to n, is the coefficient of the most efficient producer with respect to the use of input 2 at the tth period. We term efficiencies

10 Our method differs from the method suggested by Kumbhakar (1988) in two ways. 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, Kumbhakar makes the implicit assumption that the frontier function is neutrally shifted from the average and realized production functions.

with respect to the use of specific inputs as "embodied" or "input-specific" efficiencies, and the efficiency implied by variations in the intercept ($MEFF_j = \beta_{0jt} / \beta^*_{0t}$) is termed "disembodied efficiency." Embodied 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, embodied efficiency is specific to the use of fertilizer and irrigation (two key inputs), whereas disembodied efficiency is a more general concept that may reflect capacity utilization, organization, or efficiencies of combining these inputs. The terminology is similar to that used in the case of technical progress in economics literature.

Firm- and input-specific technical-efficiency measures for the three previously discussed industries for the sample period have been calculated using equation (6). The statistics are presented in tables 14–16. Generally, the results in these tables do not show any clear pattern that suggests an answer to the question of which inputs are efficiently used by which industry and in which time period. However, one conclusion is clear: across the selected industries, labor, capital, and materials inputs have not been used fully effectively. This situation is alarming because (as noted above) output growth has been input-driven in the period of analysis, but here the analysis reveals that inputs are being used ineffectively. How does one promote the effective use of core inputs? The reform measures implemented to date have influenced the growth of the manufacturing sector through the liberalization of capital markets and foreign-exchange markets, the elimination of government controls on capacity creation, and the promotion of exports. However, our firm-level analysis shows that manufacturing output on average could be increased by about 15 percent without having to increase inputs, even with the favorable production environment created by these reforms. The analysis also identifies that the 15 percent increase should come through improving the method of application of capital, labor, and materials inputs. It would no doubt be logical to argue that capital and materials inputs might have been more influenced by the reform measures so far undertaken than labor inputs have been, because none of the reforms directly addressed labor-related issues. If this were the case, it would be rational to expect that at least capital and materials inputs have been used effectively, compared with labor inputs since the reforms, but our analysis does not confirm this expectation. The policy implication is that any measures aimed at reducing technical inefficiency should be directed mainly at firms' managers and decision makers. Until proper managerial and strategic decisions are undertaken at the firm level, the benefits of the existing reforms cannot be fully realized.

Table 14. Estimates of firm- and input-specific (labor) technical-efficiency measures

	Minimum	Maximum	Mean	Variance
Chemical products				
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 machinery				
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: *Authors' calculations.*

Table 15. Estimates of firm- and input-specific (capital) technical-efficiency measures

	Minimum	Maximum	Mean	Variance
Chemical products				
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 machinery				
1997–98	0.9228	1.000	0.9405	0.0025
1998–99	0.9324	1.000	0.9565	0.0037
1999–2000	0.9382	1.000	0.9765	0.0055
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: *Authors' calculations.*

Table 16. Estimates of firm- and input-specific (materials) technical-efficiency measures

	Minimum	Maximum	Mean	Variance
Chemical products				
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 machinery				
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	0.9365	1.000	0.9425	0.0138

Source: *Authors' calculations.*

5. Conclusions

Manufacturing was an engine of growth in India in the 1970s and 1980s. Since the 1991 economic reform, it appears that the speed of the engine has slowed down. Whereas China has consolidated its position as one of the leading manufacturing countries within a short period after the implementation of economic reforms, the experience of Indian manufacturing has been different. Our analysis reveals that unlike the Chinese case, India's manufacturing output growth in the post-reform period has been input-driven rather than efficiency- or technology-driven. On average, an increase in output of about 15 percent can be achieved by improving firms' efficiency through following best-practice techniques, without having to increase any inputs or improve the existing technology. Improving efficiency in the production process requires improvement in strategic decision making at the firm level. The national survey of manufacturing industries reported by Chandra and Sastry (2002) indicates that although Indian firms understand the importance of R&D in improving efficiency and competitiveness, they seem unable to make the necessary changes. Policy measures should encourage firms to invest more in R&D, implement technical training programs for workers, and provide managers with more computer-aided design and decision-making tools.

Identifying the exact policy measures that should be implemented is beyond the scope of this paper; however, some broad suggestions can be made. Militant actions and demands by labor unions have been on the decline in India, which may mean that management of human resources can be more flexible; nevertheless, it may be necessary to implement labor reforms, particularly with respect to hiring and firing, to help firms improve the production skills of manufacturing workers and thereby improve competitiveness. Also, further opening up of the economy through more trade reforms, such as bringing the tariff structure in line with that of the Asian Tigers, would add more fuel to the engine of growth. India's excise duties and sales taxes on food products are currently very high relative to those of several comparable countries.

We do not deny that the reforms undertaken so far have improved the openness of the Indian economy and have facilitated India's integration with the global economy to some extent. Our study indicates that significant potential growth still remains unrealized in the manufacturing sector, mainly because of a failure to invest in R&D and upgrade old technology. Experiences from East Asian and Southeast Asian economies show that aggressive canvasing by public and private enterprises to generate technical collaboration and FDI from big overseas enterprises, using facilities provided by the central and state governments (such as special economic zones), appears to be an effective way to boost manufacturing exports. As the liberalized rules for FDI in manufacturing have already been in place, the onus for attracting FDI mainly lies with domestic entrepreneurs.

References

Ahluwalia, Isher J. 1985. *Industrial Growth in India—Stagnation since the Mid-sixties.* Delhi: Oxford University Press.

———. 1991. *Productivity Growth in Indian Manufacturing.* Delhi: Oxford University Press.

Arrow, Kenneth J. 1962. The Economic Implications of Learning by Doing. *Review of Economic Studies* 29 (3):155–73.

Balakrishnan, Pulapre, and K. Pushpangadan. 1994. TFPG in Manufacturing Industry: A Fresh Look. *Economic and Political Weekly,* 30 July, pp. 2028–32.

Balakrishnan, Pulapre, 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. 3679–82.

Bhagwati, Jagdish. 1993. *India in Transition: Freeing the Economy.* Oxford: Clarendon.

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

———. Various issues. *National Accounts Statistics.* New Delhi: Ministry of Planning and Programme Implementation, Government of India.

———. 1997. *Input-Output Transactions Table 1989–90.* New Delhi: Ministry of Planning and Programme Implementation, Government of India.

Centre for Monitoring Indian Economy (CMIE). 2002a. The Corporate Sector. Mumbai: Economic Intelligence Service, Centre for Monitoring Indian Economy.

———. 2002b. Industry, Financial Aggregates and Ratios. Mumbai: Economic Intelligence Unit, Centre for Monitoring Indian Economy.

Chandra, Pankaj, and Trilochan Sastry. 2002. Competitiveness of Indian Manufacturing: Findings of the 2001 National Manufacturing Survey. Ahmedabad: Indian Institute of Management.

Cornwell, Christopher M., Peter Schmidt, and Robin C. Sickles. 1990. Production Frontiers with Cross-Sectional and Time Series Variation in Efficiency Levels. *Journal of Econometrics* 46 (1/2):185–200.

Goldar, Bishwanath. 1986. *Productivity Growth in Indian Industry.* Delhi: Allied.

———. 2002. Trade Liberalization and Manufacturing Employment: The Case of India. Employment Paper no. 2002/34. Geneva: International Labour Organization.

Goldsmith, Raymond W. 1951. A Perpetual Inventory of National Wealth. In *Studies in Income and Wealth,* Vol. 14, pp. 76–112. New York: National Bureau of Economic Research.

Government of India. Various years. Economic Survey. New Delhi: Ministry of Finance.

Greer, Douglas F. 1971. Advertising and Market Concentration. *Southern Economic Journal* 38 (1):19–32.

Griffiths, William E. 1972. Estimation of Actual Response Coefficients in the Hildreth-Houck Random Coefficient Model. *Journal of the American Statistical Association* 67 (339):633–35.

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

Jalan, Bimal, ed. 1992. *The Indian Economy: Problems and Prospects.* New Delhi: Viking.

Joshi, Vijay, and I. M. D. Little. 1994. *India: Macroeconomics and Political Economy, 1964–91.* New Delhi: Oxford University Press.

Kalirajan, Kaliappa 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* 78 (2):331–38.

Kalirajan, Kaliappa P., and Ric T. Shand. 1997. Sources of Growth in Indian Agriculture. *Indian Journal of Agricultural Economics* 52 (4):693–706.

Kopp, Raymond J. 1981. The Measurement of Productive Efficiency: A Reconsideration. *Quarterly Journal of Economics* 96 (3):477–503.

Krishna, K. L. 1987. Industrial Growth and Productivity in India. In *The Development Process of the Indian Economy,* edited by P. R. Brahmananda and V. R. Panchamukhi, pp. 348–87. Mumbai: Himalaya.

Krishna, Pravin, and Devashis Mitra. 1996. Trade Liberalization, Market Discipline and Productivity Growth: New Evidence from India. Working Paper 96–8. Providence, R.I.: Department of Economics, Brown University.

Kumbhakar, S. C. 1988. Estimation of Input-Specific Technical and Allocative Inefficiency in Stochastic Frontier Models. *Oxford Economic Papers* 40 (3):535–49.

Kundu, Amitabh, and N. Lalitha. 1998. Informal Manufacturing Sector in Urban India: Sectoral Trends and Interdependencies. *Indian Journal of Labour Economics* 41 (3):201–15.

Lall, Sanjaya. 1998. Technological Capabilities in Emerging Asia. *Oxford Development Studies* 26 (2):213–44.

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

Mahalanobis, P. C. 1955. The Approach of Operational Research to Planning in India. *Sankhya: The Indian Journal of Statistics* 16 (Parts 1 and 2):3–130.

Nolan, Peter. 2001. *China and the Global Economy.* London: Palgrave Macmillan.

Ornstein, Stanley I., J. Fred Weston, and Michael D. Intriligator. 1973. Determinants of Market Structure. *Southern Economic Journal* 39 (4):612–25.

Ramaswamy, K. V. 1999. The Search for Flexibility in Indian Manufacturing: New Evidence on Outsourcing Activities. *Economic and Political Weekly,* 6 February, pp. 363–68.

Reserve Bank of India. 2000. *Handbook of Statistics on Indian Economy.* Mumbai: Reserve Bank of India.

Romer, Paul M. 1986. Increasing Returns and Long-Run Growth. *Journal of Political Economy* 94 (5):1002–37.

Sachs, Jeffrey D., and Andrew M. Warner. 1995. Economic Reform and the Process of Globalization. *Brookings Papers on Economic Activity* 1:1–95.

Solow, Robert M. 1956. A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics* 70 (1):65–94.

Srinivasan, T. N. 2001. Integrating India With the World Economy: Progress, Problems and Prospects. Revised version of a paper presented at the conference India Economic Prospects: Advancing Policy Reforms, Center for Economic Development and Policy Reforms (CREDPR), 1–2 June, Stanford University, Stanford. Available at http://www.econ.yale.edu/~srinivas/IntegratingIndia.pdf (accessed 10 June 2003).

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* 72 (360):890–98.

Tendulkar, Suresh. 1999. Exports in India's Growth Process. Working Paper no. 46, January. New Delhi: Indian Council for Research on International Economic Relations. Available at http://www.icrier.res.in/public/46.html (accessed 19 March 2003).

———. 2000. Indian Export and Economic Growth Performance in Asian Perspective. Working Paper no. 54. New Delhi: Indian Council for Research on International Economic Relations.

United Nations, Statistics Division. Various years. *International Trade Statistics Yearbook.* Volume II, *Trade by Commodity.* New York: United Nations.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 1991. *Industrial Restructuring in Asia and the Pacific.* Bangkok: United Nations Economic and Social Commission for Asia and the Pacific.

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