Impact of Reforms on Plant-level Productivity and Technical Efficiency: Evidence from the Indian Manufacturing Sector[*]

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Abstract

It is generally believed that the structural reforms that usher in competition and force companies to become more efficient were introduced later in India following the macroeconomic crisis in 1991. However, whether the post-1991 growth is an outcome of more efficient use of resources or greater use of factor inputs, especially capital, remains an open empirical question. In this paper, we use plant-level data from 1989-90 and 2000-01 to address this question. Our results indicate that while there was an increase in the productivity of factor inputs during the 1990s, most of the growth in value added is explained by growth in the use of factor inputs. We also find that median technical efficiency declined in all but one of the industries between the two years, and change in technical efficiency explains a very small proportion in the change in gross value added.

Keywords: **Productivity, Growth decomposition, Efficiency, Manufacturing**
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1. Introduction

Recent research on the economic reforms in India has made a strong case in favour of the argument that, contrary to popular perceptions, reforms in India were initiated in the 1980s (e.g., Rodrik and Subramanian, 2004). At the same time, however, this strand of the literature has argued that the policies that were implemented in India during the 1980s were pro-incumbent, whereas those that were introduced after the watershed year of 1991 were pro-competition. Since the facilitation of contestability of markets, of which entry is an important ingredient, is considered to be an integral part of structural reforms, this argument has important implications for the relative impact of reforms on productivity and efficiency of the Indian industries during the two decades. *Ceteris paribus*, Indian industries should have witnessed a spurt in productivity growth after 1991, on account of the pro-competition policies of the 1990s should have stimulated it.

There is evidence to suggest that, both trade reforms (Chand and Sen, 2002; Topalova, 2004) and greater competition in the post-1991 period (Krishna and Mitra, 1998; Sivadasan, 2003; Bhaumik, Gangopadhyay and Krishnan, 2006) led to productivity growth in the Indian manufacturing sector. In addition, the empirical evidence suggests that, given inter-regional differences in infrastructure and governance quality, factors like location of production units played an important role in determining 3-digit industry level productivity growth (Aghion and Burgess, 2003). This evidence is consistent with the relationship between competition and productivity growth observed in other emerging markets like China (Li, 1997).

Productivity growth can be brought about by improvement in technology and/or improvement in technical efficiency that captures the extent to which inputs are used efficiently. In the Indian context, there is limited evidence to suggest that the observed productivity growth in the post-1991 period was brought about largely by technological progress, and not by technical efficiency (Kumar, 2006). This is consistent with the evidence reported by Kalirajan and Bhide (2004), who argue that manufacturing growth in India in the later part of the 1990s was "input driven" and not "efficiency driven". Driffield and Kambhampati (2003), on the other hand, have argued that, on account of the reforms, there was improvement in firm-level efficiency in five out of the six manufacturing sectors that were part of their analysis. The Kalirajan and Bhide paper is limited in its analysis because of the coverage of a few sectors that may not be representative of the manufacturing sector as

whole.[1] The Driffield and Kambhampati analysis, on the other hand, does not take into account post-1994 trends which may better manifest the impact of the reforms of the 1990s.[2]

We add to this growing literature by undertaking an explicit and comprehensive comparison of processes in 1989-90 and 2000-01, thereby allowing us to account for the full impact of the market-oriented and, presumably, pro-competition reforms that were introduced in India since 1991. Our analysis suggests that while there was an increase in the returns to factor inputs between the two years, changes in the factor inputs accounted for a much higher proportion of the change in gross value added across industries than changes in the returns to these factors. We also find that change in technical efficiency explains a very small proportion of the growth in the gross value added for all the industries included in our analysis. Indeed, there was a decline in median (and mean) technical efficiency for nearly all the industries between 1989-90 and 2000-01.

The rest of the paper is as follows: In Section 2, we briefly describe the trends in industrial policy in India during 1980s and 1990s. In Section 3, the data are described. The empirical strategy is outlined in Section 4, and the results are reported in Section 5. Section 6 concludes.

2. Industrial Policy in India

Starting from the fifties, the Indian government had taken an approach of directing the process of industrialization to suit the path of development envisaged in the various 5-year Plans. The implementation of the industrial strategies primarily involved the use of two policy instruments. First, the government reserved a number of industrial sectors for state-owned companies alone. Second, though private firms were allowed to operate in other sectors, all industrial units had to take the central government's permission before being set up. Such licenses were given in accordance with the macro-economic plan targets and with a view to balancing out regional disparities in industrialization.

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[1] The sectors covered in the Kalirajan and Bhide (2004) paper are chemicals and chemical products, electrical machinery, and transport components.
[2] Driffield and Kambhampati (2003) used data for the 1987-94 period, and examined changes in firm-level efficiency in the following sectors: food, textiles, chemicals, metals, machine tools, and transport.

Over the years, the government added to these basic instruments of industrial policy other initiatives like import substitution, non-tariff barriers against consumer goods imports, and reservation of some industries for the small scale sector. Many of the policy initiatives that restricted the independent decision making ability of the Indian private sector were taken in the seventies. For example, a 1973 resolution restricted the business houses, defined as those with combined assets of more than INR 200 million, to specific sectors in the economy. This was supplemented in 1977 by a list of over 800 items that were reserved for production in the small scale sector (investment in plant and machinery not exceeding INR 1 million). In addition, all new capacity expansion by existing companies had to be sanctioned by the government and such expansions were usually disallowed if the market share in any product was more than 25 per cent. All of these severely restricted the ability of the private sector to benefit from economies of scale and scope.

The first tentative moves towards economic liberalisation were made by the then Prime Minister Indira Gandhi during the early 1980s, but the pace of liberalisation did not accelerate until the unveiling of the "new" economic policies in 1985, by her son and successor Rajiv Gandhi. The pro-incumbent nature of the policy regime of the 1980s was evident in a number of policy initiatives. The industrial policy resolution of 1980 emphasized the need for improving productivity in existing units and in order to make them globally competitive. The role of scale economies in the private sector, both in terms of new technologies and cost-effective organizational structures, was recognized for the first time since Independence. In keeping with the new vision of industrial development, in 1980, a "business house" was redefined as one whose combined assets exceeded INR 1 billion, i.e., five times the limit of INR 200 million set in 1973. This meant that all firms with assets between INR 200 million and 1 billion could operate in sectors in which they were not allowed entry prior to 1980. Second, business houses were allowed to operate outside their permitted list of sectors if they set up factories in economically backward areas. Third, existing companies could set up new production units, without restriction on size, provided the latter were 100 per cent export oriented. Fourth, access to foreign technology, hitherto severely restricted, was allowed if it resulted in either exports growth or significant improvement in cost structures of the firms. Fifth, the upper limit for capital stock used for defining the small scale sector was increased from INR 1 to 2 million. (The limit for ancillary units was increased to INR 2.5 million from the earlier 1.5 million.)

In addition to such industrial policies, a fiscal policy initiative was introduced in the mid-1980s to encourage firms to undertake long-term investment plans. Duties on project related imports were reduced, along with those on all other capital goods. At the same time, import duties on final goods continued to be high. While all these were favourable to existing companies, *status quo* was maintained with respect to the licensing procedure for most new entrants. In other words, incumbent firms were able to reduce cost of production and, at the same time, extract rent in markets that were protected from import competition. Further, while both incumbent and new firms required licenses, for capacity expansion and production, respectively, the former were at an advantage on account of their continuing relationship with the government bureaucracy. As a consequence, the licensing process (and the playing field, in general) was heavily loaded in favour of incumbents (Bhagwati, 1982, 1988).

In the early 1980s, some sectors were delicensed, and this process was slightly modified in the mid-eighties. However, a more important initiative was that of broad-banding. Originally, a license was given for a specific product. This meant that a producer of two-wheelers, for example, who had a license for scooters, could not produce motorcycle, without seeking a licence. However, with broad-banding, expansion of business into related areas became possible. This, once again, gave a boost to product development as well as economies of scope and scale. However, with the licensing requirement for new entrants still in place, broad-banding gave a clear advantage to the incumbent firms.

An important new law was enacted in the second half of the 1980s: the Sick Industrial Companies (Special Provisions) Act, or SICA, of 1985. Under this Act, a bankruptcy court, named the Board for Industrial and Financial Reconstruction (BIFR), was set up in 1987. Under the SICA, any company that has been registered for more than 7 years and whose net worth has been eroded significantly must apply to BIFR for permission for closure. There are three important aspects to this law. First, small units were kept outside the purview of the law. Second, the application was mandatory and not voluntary as in the US Chapter 11 bankruptcy code. Third, since application to BIFR was mandatory, creditors could not attach and liquidate assets of the defaulting companies. According to the Act, closure of an industrial unit was considered to be a social loss and, hence, this outcome was to be avoided wherever possible. In order to facilitate operation of the sick industrial units, government owned banks and financial institutions provided credit at subsidized interest rates. Further,

and not surprisingly, all capacity and licensing restrictions were suspended if a healthy company merged with a sick one under the supervision of BIFR. Since the managers did not face any cost of bankruptcy, there were strong incentives to overlook impending financial distress (Gangopadhyay and Knopf, 1998), and facilitated the creation of non-performing assets on the balance sheets of the banks (Bhaumik and Mukherjee, 2002). Once again, it skewed the playing field against potential entrants; capital was tied up in loss-making industrial units instead of being delivered to new units of production.

By contrast, the post-1991 reforms laid strong emphases on enabling markets and globalization coupled with lower degrees of direct government involvement in economic activities. The focus was mainly on five areas: foreign investment, entry procedures, technology, monopolies and restrictive trade practices (MRTP Act), and the public sector. Quite significantly, the first policy announcement of the reform process was the abolition of licenses. For the first time in post-Independence India, licensing requirements for all projects were abolished; only those related to defence or potentially environment-damaging industries needed prior permission.[3] As of 1991, an entrepreneur only has to file an information memorandum on new projects and/or for substantial capacity expansions. Further, the MRTP Act was amended such that the need for approval from the central government for establishing a new plant, capacity expansion, merger, takeover and directors' appointments (in the private sector) was abolished.

The 1990s' reforms also encouraged technology adoption and greater participation of foreign companies in the Indian industrial sector. Until 1991, foreign ownership of equity was restricted to less than 40 per cent in all sectors, and FDI was completely disallowed in many of these sectors. In 1991, foreign direct investment up to 51 per cent equity was allowed in some of the sectors, and, over the next fourteen years, there has been a significant relaxation of the rules governing FDI across the board (see Beena et al., 2004). By the end of the 1990s, most manufacturing units in the SEZs[4] were allowed 100 per cent FDI under automatic approval. Further, the "dividend balancing" requirement on 22 consumer goods industry was

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[3] By the end of 1997-98, all but 9 industries had been delicensed.
[4] The following items were excluded: arms and ammunition, explosives and allied items of defence equipment, defence aircraft and warships; atomic substances; narcotics and psychotropic substances and hazardous chemicals; distillation and brewing of alcoholic drinks; and cigarettes/cigars and manufactured tobacco substitutes.

removed.[5] Procedures for the procurement of technology from abroad were also simplified, largely by way of facilitation of ways for payment of patent-related royalties. The high priority industries were given automatic permission for technology transfer.

The 1990s also witnessed the operationalisation of the long-debated policy initiatives on the role of the public sector within the country's industrial structure. Until the end of the eighties, prices of most infrastructure and basic intermediates were controlled by the government on a cost-plus basis, under the aegis of the administered price regime (APR). This created conditions of supply shortages, as administered prices typically failed to clear the market. In the context of these supply shortages, it was easier for incumbent companies with existing supply chains and government contacts to procure the rationed supply of intermediate products. In the nineties, the APR was abandoned, and the list of industries reserved for the public sector was reduced from 17 to 8. In 1993-94, the list of sectors reserved for the public sector was further reduced to 6. State monopolies in insurance, civil aviation, telecommunication and petroleum were abandoned, and the private sector was allowed participation in these sectors. In effect, entry barriers for the Indian industrial sector had been further removed.

It is evident that, as mentioned above, the reforms of the 1990s were much more favourable for entrepreneurship and product market entry by new firms, and hence were more competition-inducing than the reforms of the 1980s. We next examine the likely impact of these pro-competition reforms on technical efficiency in the Indian manufacturing sector.

3. Data

We use plant-level data from the Annual Survey of Industries (ASI). The sample includes production units from the 15 largest Indian states (out of the possible 32 during the period covered by the data presented here).[6] There are many reasons for restricting ourselves to these states. First, these states have existed for the entire period of the data without any change in their geographical area or administrative setup. For example, among the states that have been left out, there are many that have moved from being centrally administered to ones

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[5] Dividend balancing required that a foreign investor plough back its dividends and/or royalty from an Indian operation into the same operation for a stipulated number of years.
[6] These states are as follows: Andhra Pradesh, Bihar (including Jharkhand), Delhi, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh (including Chattisgarh), Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh (including Uttaranchal) and West Bengal.

where they elect their own state-level governments. Second, around 95 percent of the Indian population resides in these states. Third, more than 90 percent of all factories are located in these 15 states. Indeed, in many of the states that are left out of our sample, industrialization is a very recent phenomenon and, therefore, the methodology for collecting data in these states is not the same as in the states we are studying. The data collection methodology for the 15 states included in our sample has remained largely the same throughout our period of analysis.

The ASI defines factories to be all productive units that employ l0 or more labourers and use power, as well as those that do not use power but employ 20 or more labourers.[7] It does not include the service sector. However, certain services and activities like cold storage, water supply and repair services are covered under the survey. The data are widely used in the context of analysis of the Indian industrial sector (see, e.g., Hasan, Mitra and Ramaswamy, 2003; Besley and Burgess, 2004; Lall and Chakravorty, 2005).

INSERT Table 1 about here.

The descriptive statistics for the 14 industries in our sample are reported in Table 1.[8] In order to make the values of gross value added, plant and machinery (our proxy for capital), and total labour cost (our proxy for labour) comparable across the years, we deflate the values of these variables for 2000-01 using appropriate price indices. We deflate the gross value added for each of the 14 industries using the relevant sectoral price indices obtained from the Central Statistical Organisation. The labour cost is deflated using manufacturing wage indices obtained from the International Labour Organization. Finally, the value of plant and machinery (i.e., capital) is deflated using the price indices for machinery and parts. We make the reasonable albeit simplifying assumption that the book value of the non-depreciated capital was built up equally over a 5-year period. In other words, we deflate 20 percent of the

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[7] They also include *bidi* and cigar-manufacturing establishments registered under the Bidi and Cigar Workers Act 1966, i.e., once again, employing l0 or more workers if using power, and 20 or more if not using power. All the units engaged in the generation, transmission and distribution of electricity registered with the Central Electricity Authority are also covered under the ASI, irrespective of their employment size.

[8] There was a change in the industry classification codes used for the Annual Survey of Industries between 1989-90 and 2000-01. We, therefore, matched the national industry codes (NIC) for these two years to ensure that the plants in each of our industry categories belong to the same industry in both the years.

book value of capital at the end of period *t* using the price index for period *t*, 20 percent of the book value using the price index for period *t*-1, etc. Our computations took into account the change in the base year for price indices from 1981-82 to 1993-94.

The descriptive statistics indicate that there was a growth in both gross value added and value of the factor inputs, namely, capital and labour, between 1989-90 and 2000-01. The relative magnitudes of the changes indicate that, for most industries, the growth rates in the labour cost were very similar to the growth of the value added. However, the growth rate of capital was much higher for all industries except paper, paper products and printing. This is consistent with the view that there was significant capacity expansion in the Indian manufacturing sector in the immediate aftermath of the 1991 reforms (Uchikawa, 2001, 2002). These growth rates of value added and the factor inputs for all the industries included in our analysis are reported in Figure 1.

INSERT Figure 1 about here.

Given that the growth rate of capital exceeds the growth rate of labour cost, it is reasonable to hypothesise that labour productivity in 2000-01 would be higher than that in 1989-90. However, to the extent that capital embodies new technology, addition to the capital stock might have increased productivity of capital as well. The descriptive statistics also indicate that, as argued by Kalirajan and Bhide (2004), we can expect changes in factor inputs to explain a significant proportion of the changes in gross value added between 1989-90 and 2000-01. In other words, changes in factor inputs and their productivity may explain much of the growth in value added between the two years, as opposed to a change in technical efficiency. We shall revisit this issue later in the paper.

4. Stochastic Frontier and Measurement of Technical Efficiency

The neo-classical production theory implicitly assumes that all production activities are on the frontier of a feasible production set (subject to random errors). The frontier itself is defined as of the maximum possible output that is technically attainable for the given inputs (output-oriented measure), or as the observed output level that can be produced using lesser inputs (input-oriented measure). The production efficiency literature, however, relaxes the assumption, and considers the possibility that producers may operate below the frontier due to technical inefficiency. Technical efficiency can be *output-oriented* if actual output

produced is less than the frontier output for a given amount of input (subject to random errors). Alternatively, it can be *input oriented* if the amount of inputs actually used is more than the minimum required to produce a given level of output. Graphically, the inefficient production plans are located below the production frontier.

INSERT Figure 2 about here.

In Figure 2, $f(x)$ is the production frontier, and point A is an inefficient production point. There are two ways to see why it is inefficient. The first way is to see that at the current level of input x more output can be produced, given the technology. The distance AB shows the amount of output that is lost due to the technical inefficiency, and it forms the basis from which the output-oriented (OO) technical inefficiency can be measured. The other way to see why point A is inefficient is to recognize that the same level of output can be produced using less inputs, which means that the production point can move to the frontier by reducing inputs. The distance AC measures the amount by which the input can be reduced without reducing output. Since this move is associated with reducing inputs, the horizontal distance AC forms the basis to measure the input-oriented (IO) technical inefficiency.

Mathematically, a production plan with IO technical inefficiency is written as

$$y = f(x\exp(-\eta)), \quad \eta \geq 0 \tag{1}$$

where η measures IO technical inefficiency (TI), and $\exp(-\eta)$ measures IO technical efficiency (TE). For small η, $\exp(-\eta)$ can be approximated by $1 - \eta$. Thus, we get the following familiar relationship, TE = 1 - TI, which is clear from the above figure since OB/OA=1-AB/OA.

A mathematical formulation of OO technical inefficiency is

$$y = f(x)\exp(-u), \quad u \geq 0 \tag{2}$$

where u measures OO technical inefficiency. Again for small u we can approximate $\exp(-u)$ by $1-u$, which gives us the familiar result, TE = $\exp(-u) = 1 - u = 1$ - TI.

Since inefficiency can be viewed either in the input or output direction, we get the following relationship between the two measures, viz., $f(x)\exp(-u) = f(x.\exp(-\eta))$. If the production function is homogeneous of degree k (which is nothing but returns to scale) then these two

inefficiency measures follow the relationship, $\eta.k = u$. That is, OO inefficiency is a constant multiple (returns to scale) of IO inefficiency. In the special case when returns to scale is unity, both inefficiency measures are the same. If returns to scale is neither constant nor unity, the relationship is more complicated (although exact and is given by $f(x)\exp(-u) = f(x.\exp(-\eta))$) and it depends on the input quantities.

For econometric estimation, a parametric function form on $f(.)$ is assumed and a multiplicative noise component is appended in the production relations in (1) and (2). This is more realistic in the sense that there are uncertainties and possible omitted variables that can affect output, given the technology and input quantities. In estimating efficiency the impact of these uncertainties are to be accounted for. Since inefficiency is not observed, the production function specified in either (1) or (2) cannot be estimated using OLS. At least the use of OLS in a cross-sectional set-up will not give estimates of inefficiency for each observation. For estimating inefficiency and production function parameters the maximum likelihood (ML) method is used. The ML method is based on distributional assumptions on the random and inefficiency terms. That is, for estimation point of view, especially in a cross-sectional set-up one has to assume inefficiency to be a random variable. For the producer it may be known but not to the analyst/econometrician. Once the model parameters are estimated (in)efficiency for each observation can be obtained.

The standard distributional assumptions are: (i) the noise term (v) is independently normally distributed with zero mean and constant variance, i.e., $v \sim N(0, \sigma_v^2)$ (ii) the inefficiency term is independently distributed as half-normal (zero mean, constant variance normal truncated at zero from below – to make it non-negative), i.e., $u \sim N(0, \sigma_u^2), u \geq 0$, (iii) the inefficiency and noise components are assumed to be independent of each other and are also independent of the inputs[9]. Assuming that the production function is Cobb-Douglas (CD) the output-oriented (OO) technical inefficiency model can be written as

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[9] Various other distributions for inefficiency such as exponential, gamma, truncated normal have been used in the literature. The estimates of inefficiency are in most cases quite robust to distributional assumptions. Models are developed to allow correlation between the noise and inefficiency components. Such correlations may not be very intuitive. Independence of inefficiency and inputs can be relaxed in a panel model as well as in models that introduce behavioral assumptions (such as cost minimization and profit maximization) explicitly. See Kumbhakar and Lovell (2000) for a survey of these models.

$$\ln y = \beta_0 + \sum_{j=1}^{J} \beta_j \ln x_j + v - u \qquad (3)$$

Based on the above distributional assumptions the likelihood function of $\varepsilon = v - u$ can be written as (see Kumbhakar and Lovell, 2000)

$$L = \frac{2}{\sigma} \phi \left[\frac{\varepsilon}{\sigma} \right] \Phi \left[-\frac{\lambda \varepsilon}{\sigma} \right] \qquad (4)$$

where $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $\lambda = \sigma_u / \sigma_v$ and $\varepsilon = \ln y - \ln f(x) = \ln y - (\beta_0 + \sum_{j=1}^{J} \beta_j \ln x_j)$. Finally, $\phi(.)$ and $\Phi(\cdot)$ are the probability density and distribution function, respectively, of a standard normal variable. The logarithm of the above likelihood function (after adding it over all the observations) can be maximized to obtain ML estimates of all the parameters in the model. Once the parameters are estimated, one can obtain observation-specific technical inefficiency from the conditional mean of u given ε, viz.,

$$\mathrm{E}(u|\varepsilon) = \mu_* + \sigma_* \left[\frac{\phi(-\mu_* / \sigma_*)}{1 - \Phi(-\mu_* / \sigma_*)} \right] \qquad (5)$$

where $\mu_* = -\varepsilon \sigma_u^2 / \sigma^2$ and $\sigma^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$. If the interest is to obtain observation-specific estimates of technical efficiency, the following formula can be used

$$\mathrm{TE} = E[\exp(-u \,|\, \varepsilon)] = \left[\frac{1 - \Phi(\sigma_* - \mu_* / \sigma_*)}{1 - \Phi(-\mu_* / \sigma_*)} \right] \exp \left\{ -\mu_* + \frac{1}{2} \sigma_*^2 \right\} \qquad (6)$$

The above formulation shows how to estimate the model and obtain observation-specific estimates of technical (in)efficiency using the OO formulation. The IO formulation is more complex (see Kumbhakar and Tsionas, 2006 for details). Instead of directly estimating the IO model, one can estimate the OO model and obtain input-oriented inefficiency measure for each observation from the relationship $f(x)\exp(-u) = f(x.\exp(-\eta))$ which for the translog production function can be expressed as

$$u = \eta \, RTS(x) + .5 \eta^2 \sum_{k=1}^{J} \sum_{j=1}^{J} \beta_{jk} \qquad (7)$$

where $RTS(x) = \sum_{j=1}^{J} \left[\beta_j + \sum_{k=1}^{J} \beta_{jk} \ln x_j \right]$. One can solve for η from (7) once the parameters estimates including u are known. This way one can avoid the complicated econometric model of Kumbhakar and Tsionas (2006) at the expense of solving one quadratic equation for each observation.

5. Econometric Models and Results

In the empirical model we use two inputs, viz., labour and capital, each measured in terms of Indian rupees, i.e., we use labour cost instead of the total number of labourers. This measure of labour, allows us to control for heterogeneity in labour quality across plants.[10] Our model specification also includes a vector of other attributes such as plant age and ownership types, some of which may affect both output and efficiency.

Specifically, we take into consideration the possibility that technical efficiency and productivity of labour and capital may vary across firms/plants of different ownership. It is stylized in the literature that ownership has significant impact on firm-level productivity, and that, on average, privately owned firms are more productive than state-owned firms (see, e.g., Hill and Snell, 1989; Ehrlich et al., 1994). It has also been argued that joint ventures between the state and public entrepreneurs may not be as efficient as firms that are entirely privately owned (Jin and Qian, 1998). In the Indian context, Majumdar (1998) has demonstrated that this hierarchical order, namely, that private firms are more efficient than firms with mixed ownership which, in turn, are more efficient than state-owned firms, holds true in India as well. As evident from Table 1, our sample for each sector is overwhelmingly dominated by privately owned plants, such that state-owned and joint sector plants each account for a very small fraction of the sample. Hence, we include in the specification a solitary control for ownership that takes the value unity when the plant is privately owned.

Finally, in the Indian context, there is reason to believe that firm performance might be influenced by the location of the plant, given the significant diversity of infrastructure quality, human capital, etc., across the Indian states (Bhaumik, Gangopadhyay and Krishnan, 2006). Hence, we use control for location using dummy variables for the states; Delhi is the omitted category.

For each of the fourteen industries, we estimate the following augmented Cobb-Douglas specification for simplicity[11]:

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[10] For a discussion about the potential biases associated with the use of labour hours as a measure for labour in the context of estimation of production functions, see Feldstein (1967).

[11] Similar qualitative results were obtained from the translog form, especially the capital and labour elasticities at the mean. However, we found some implausible elasticities at many other points. Although this is not unusual for a translog function, we decided not to use it simply because these implausible results occurred at too many points.

$$\ln y = \beta_0 + \beta_1 \ln k + \beta_2 \ln l + \beta_3 AGE + \beta_4 PVT + \sum_{j=i}^{n} \rho_j DS_j + v - u \qquad (8)$$

when y is output, l is labour, k is capital, AGE is plant age,[12] PVT is the dummy variable that controls for ownership, DS_j is dummy for state/location j, and v and u have properties that were discussed earlier in the paper.

INSERT Table 2 about here.

The parameter estimates are reported in Table 2. The results suggest the following:

- Marginal productivity of capital in the formal manufacturing sector in India is much lower than the marginal productivity of labour.[13] This indicates that the plants or production units are over-capitalised, which is not surprising in view of Indian labour laws that generally make it difficult for a company to lay off labourers during periods of low profitability (see Besley and Burgess, 2004).

- There was an increase in the returns to both factor inputs between 1989-90 and 2000-01. However, the percentage change in the returns to capital is much more significant than the corresponding change in the returns to labour, even though, as indicated earlier, the rate of growth of capital stock during the 1990s was much than the growth in labour cost. This is perhaps a reflection of both a significant upgrade in the quality of technology that is embodied in the capital, and an improvement in the skill of the labour force that use the capital stock during the production process.

- There was an increase in the returns to scale (RTS), such that the RTS in 2000-01 were much closer to 1 than those in 1989-90. In other words, in 2000-01, an average manufacturing sector plant in the Indian manufacturing sector was operating much closer to the minimum point of its long run average cost curve than in 1989-90. This

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[12] We experimented with several functional forms involving plant age, and it was evident that the logarithm of plant age best fit the data.

[13] It is easily seen from Table 1 that the average values of plant-level capital and labour cost are roughly equal for all the industries. Hence, the difference in marginal productivity of these two factor inputs depends primarily on the difference between the estimated coefficients of (log) capital and (log) labour.

is consistent with the Rodrik and Subramanian (2004) argument that the policy environment in India was much more pro-competition in the 1990s than in the 1980s.

- There was a noticeable decline in the median (and mean) level of technical efficiency for each industry between 1989-90 and 2000-01. For each industry, z-statistics (t-statistics), not reported in this paper, rejected the null hypothesis of equality of median (mean) values of technical efficiency across the two years, in favour of the alternative hypothesis that the median (mean) in 1989-90 is higher than that in 2000-01. This is also evident from the distributions of plant-level technical efficiency for a sample of industries that are reported in Figure 3.

INSERT Figure 3 about here.

Overall, the coefficient estimates and the estimates of technical efficiency indicate that changes in returns to factor inputs can partially account for the changes in gross value added between the two years, but that changes in technical efficiency would not be able to explain the growth in gross value added to a significant extent. In order to better understand the relative impact of changes in factor inputs, returns to these inputs and technical efficiency on growth of average gross value added of the 14 industries, we undertake a decomposition analysis.

The methodology used for the decomposition is analogous to that of Oaxaca (1973). Suppose that the estimated production functions for 1989-90 (year 1) and 2000-01 (year 2) are as follows:

$$y_1 = \hat{\alpha}_1 + \hat{\beta}'_1 X_1 + v_1 - u_1 \tag{9}$$

$$y_2 = \hat{\alpha}_2 + \hat{\beta}'_2 X_2 + v_2 - u_2 \tag{10}$$

when y is the (log) value added, X is a vector of variables including (log) labour cost and (log) capital, v is the *iid* error term, and u is the inefficiency term with a half-normal distribution. As a matter of fact v-u in (9) and (10) are the ML residuals. It is easy to show that the difference between the average (log) value added between the two time periods is given by

$$\bar{y}_2 - \bar{y}_1 = (\hat{\alpha}_2 - \hat{\alpha}_1) + \hat{\beta}'_2 (\bar{X}_2 - \bar{X}_1) + (\hat{\beta}'_2 - \hat{\beta}'_1)\bar{X}_1 + (\bar{v}_2 - \bar{v}_1) - (\bar{u}_2 - \bar{u}_1) \tag{11}$$

It is, of course, obvious that the change in (log) value added, factor inputs etc. can be estimated for each individual plant in the sample. However, for an individual plant, the *iid* error term *v* need not equal zero; the *mean* of the distribution of the *iid* term across plants equals zero, by assumption. Hence, it is stylised to undertake this decomposition exercise using mean values for *y* and *X*.

Since the *iid* error term *v* has zero mean, the mean values of v_1 and v_2 will be zero (or close to zero) and so is the $(\bar{v}_2 - \bar{v}_1)$ term, which will be either zero or small enough to ignore. Equation (11) can then be reduced to

$$\bar{y}_2 - \bar{y}_1 = \hat{\beta}_2^{'}(\bar{X}_2 - \bar{X}_1) + [(\hat{\alpha}_2 - \hat{\alpha}_1) + (\hat{\beta}_2^{'} - \hat{\beta}_1^{'})\bar{X}_1] - (\bar{u}_2 - \bar{u}_1) \qquad (11a)$$

The first term on the right hand side of equation (11a) is the contribution of change in inputs to growth of value added between two time periods. The second term is the contribution of technology differences between the two time periods on output growth. It captures the impact of changes in both factor productivity and returns to plant characteristics, as well as the impact of neutral technical change on the value added.[14] Finally, the last term captures the contribution of the difference in technical efficiency to output growth. We label them *input effect*, *technology effect* and *efficiency effect*, respectively.

INSERT Table 3 about here.

The decomposition results for each industry are reported in Table 3. In column 1 we report the difference in the mean (log) value added between the two time periods for each industry. It varies from 1.79 to 2.89 (log points) across industries. The contributions of input effect, technology effect and efficiency effect to the growth in value added are reported in columns 2, 4 and 6, respectively, while the corresponding percentage contributions are reported in

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[14] One can further decompose technology effects into two components, namely, the growth in value added that can be attributed to changes in input productivity and returns to plant characteristics (*j*), $(\hat{\beta}_{2j} - \hat{\beta}_{1j})x_j$, and to the difference in the intercept term $(\hat{\alpha}_2 - \hat{\alpha}_1)$. It is tempting to argue that the constant or intercept term in a log production function represents x-efficiency (see Jovanovic and Gilbert, 1993). When viewed from this perspective, the difference in the estimated constant terms of the regression models captures the effect of change in the average managerial quality and x-efficiency between the two time periods on output growth. However, it is also likely to capture differences in neutral technical change. Given the ten-year gap in the data, which is necessary to facilitate a discussion about the impact of reforms in India, it is difficult for us to intuitively distinguish between technical change and x-efficiency. Hence, we are not interpreting the differences in the intercept terms as the effect of changes in x-efficiency on output growth.

columns 3, 5 and 7. For example, for the rubber and plastic products industry, the change in mean (log) value added between 1989-90 and 2000-01 was 2.47. Of this, 2.37 log points (i.e., 96 percent of 2.47) is explained by changes in factor inputs and plant characteristics, 0.14 log points (i.e., 5.62 percent of 2.47) is explained by changes in factor productivity, returns to plant characteristics, and neutral technical change. Finally, (-) 0.4 log points (i.e., 1.62 percent of 2.47) is explained by changes in technical efficiency.

It is easily seen that *input effect* is the largest component of the average change in (log) value added at the plant level, i.e., growth in factor inputs contributes the most to the overall output growth, with some support from changes in plant characteristics. This is true for every industry, and is the highest for the wood and wood products, chemicals and basic metals and alloys industries. The *technology effect*, by contrast, is quite small, explaining, on average, 5-6 percent of the change in (log) gross value added between the two years. This effect is the largest for the non-electrical machinery industry, accounting for 10.84 percent of the growth in value added. The contribution of technical efficiency change (*efficiency effect*) to the overall output growth is even smaller and negative for all industries (barring wood and wood products, and leather and leather products). This is consistent with the median values of technical efficiency reported in Table 2, and the kernel densities of technical efficiency (for select industries) reported in Figure 3.

The implications for the results are discussed in the concluding section.

6. Concluding Remarks

India has experienced significant policy changes since 1984-85, and these policy changes, in turn, have resulted in significant structural changes in the economy. The nature of these reforms and their likely impact on the economy are well documented in the literature. In particular, it has been argued that, in contrast to the reforms introduced during 1984-91, the reforms introduced after 1991 were pro-competition. There is some evidence to indicate that, as expected, these pro-competition reforms have resulted in increase in plant/industry level total factor productivity. However, there is as yet no consensus about the extent to which changes in productivity or technical efficiency have contributed to industrial growth in India. In this paper, we examined this issue in some detail, using plant-level data for 14 industries, for 1989-90 and 2000-01.

We find that growth in value added for all the industries during the period 1990-2001 were primarily input-driven. Changes in factor inputs (and average plant characteristics) account for 92 to 124 percent of changes in plant level (log) value added. To this extent, our results are consistent with those of Kalirajan and Bhide (2004). The impact of technological change on output growth is found to be positive for most of the industries. However, the technology effect is found to be much smaller compared to the input effects. Finally, there was a mild decline in average (and median) technical efficiency levels across industries, and the absolute value of this (negative) change in efficiency accounted for a small proportion in the observed change in (log) gross value added.

The overwhelming importance of the input effect in explaining industrial growth in India is perhaps consistent with evidence about the growth experience of its Asian neighbours. Growth accounting figures indicate that, between 1980 and 1995, 80-127 percent of the growth of the East Asian countries (except Japan and Hong Kong) could be explained by changes in capital stock and labour force. By contrast, growth of factor inputs explained 35-60 percent of the growth in France, Germany, the United Kingdom, and the United States (Lau and Park, 2003). Resource mobilisation, as opposed to technological progress and more efficient use of inputs may, therefore, be inevitable during the early stages of rapid growth, as a developing economy approaches its output (or production) possibility frontier. Yet the danger of input driven growth lies with the inevitability of diminishing returns on factor inputs. Further, even in labour-surplus economies, it is not feasible to forever mobilise labourers to add to industrial value added without taking into consideration the skill requirements for an industrial labour force.

Additionally, average firm-level technical efficiency in all industries is quite low for both years in our sample. The obvious implication is that there is scope to improve output without increasing inputs. For example, if the mean technical efficiency for an industry is 60 percent, plant level output in this sector can be increase by 40 percent, on average, simply by eliminating inefficiency. The challenge for policymakers, therefore, lies in addressing the question as to what causes this inefficiency and why the extent of inefficiency has increased despite the introduction of market-oriented reforms. If factor prices reflect the true economic cost of inputs, high average level of inefficiency may be a consequence of an anachronistic bankruptcy regime that imposes high exit costs even on firms (or parts thereof) that are unprofitable and have low efficiency levels. Alternatively, it could be a consequence of

ownership structures that do encourage meritocratic choice of managers and, at the same time, protect even inefficient firms from all forms of market discipline. We have already discussed the problems with the Indian bankruptcy regime earlier in this paper. There is also evidence to suggest that management succession in Indian firms, a large proportion of which are group affiliated and family-owned (Piramal, 1996), is based on blood connection as opposed to merit (Sharma and Rao, 2000), and that incidence of persistent bad-performance is fairly common among group-affiliated Indian firms (Chacar and Vissa, 2005). Aside from the obvious need to enact laws that makes it easy for inefficient firms to declare bankruptcy, therefore, the way forward perhaps lies in developing institutions that facilitate corporate takeovers which, in turn, breed market discipline and, hence, efficiency.

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Table 1: Descriptive statistics

Industry	Year	Log gross value added	Log capital	Log labour cost	Log plant age	Percentage of plants in private sector
Agricultural products	1989-90	13.34	13.15	12.34	2.42	95.43
	2000-01	*16.07*	*16.59*	*14.96*	*2.67*	*81.72*
Textiles (without apparel)	1989-90	13.47	13.46	12.70	2.26	92.78
	2000-01	*16.15*	*17.22*	*15.33*	*2.64*	*87.51*
Textile products	1989-90	13.43	12.84	12.51	2.17	98.67
	2000-01	*15.73*	*15.45*	*14.87*	*2.01*	*99.03*
Wood & wood products	1989-90	12.50	12.01	11.70	2.38	96.24
	2000-01	*15.07*	*15.93*	*14.62*	*2.38*	*100.00*
Paper, paper products & printing	1989-90	13.31	13.49	12.38	2.44	96.90
	2000-01	*14.92*	*15.17*	*14.09*	*2.30*	*96.43*
Leather & leather products	1989-90	13.83	13.58	12.93	1.99	97.44
	2000-01	*15.71*	*16.13*	*14.51*	*2.61*	*96.89*
Chemicals & chemical products	1989-90	13.63	13.22	12.63	2.26	97.21
	2000-01	*16.02*	*16.56*	*15.02*	*2.61*	*93.73*
Rubber & rubber products	1989-90	13.28	13.61	12.25	2.06	97.56
	2000-01	*15.66*	*16.33*	*14.31*	*2.33*	*94.76*
Non-metallic products	1989-90	12.89	12.65	12.21	2.24	97.41
	2000-01	*15.58*	*16.40*	*14.63*	*2.52*	*94.93*
Basic metals & alloys	1989-90	13.61	13.57	12.64	2.69	98.39
	2000-01	*15.86*	*16.71*	*14.78*	*2.49*	*95.95*
Metals & metal products	1989-90	13.00	12.84	12.12	2.38	97.90
	2000-01	*15.33*	*15.59*	*14.49*	*2.38*	*94.94*
Non-electrical machinery	1989-90	13.34	13.15	12.46	2.49	97.86
	2000-01	*15.57*	*15.63*	*14.75*	*2.73*	*96.38*
Electrical machinery & equipment	1989-90	13.51	13.27	12.63	2.13	96.62
	2000-01	*15.69*	*15.82*	*14.80*	*2.64*	*94.73*
Transport equipment	1989-90	13.49	13.34	12.59	2.35	98.47
	2000-01	*16.32*	*16.79*	*15.36*	*2.51*	*96.11*

Figure 1: Changes in value added, capital and labour
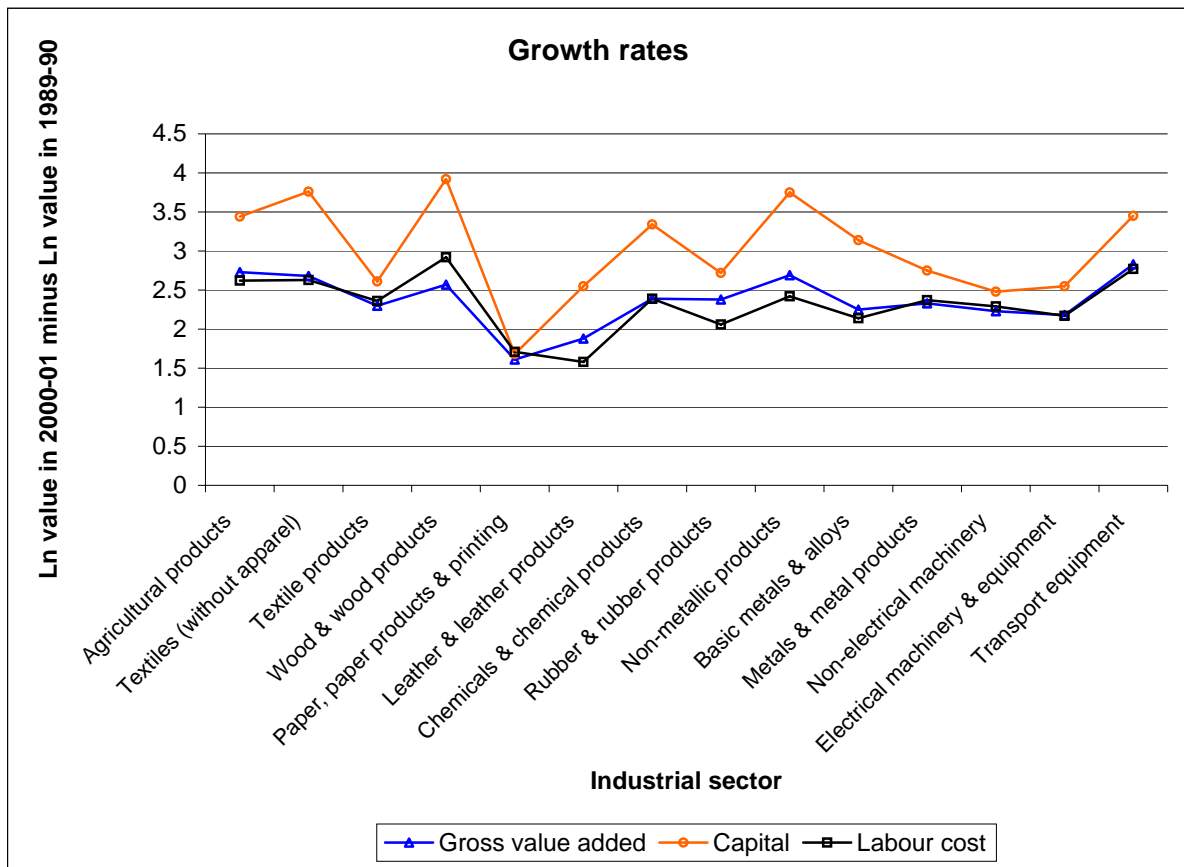
Figure 2: Technical efficiency
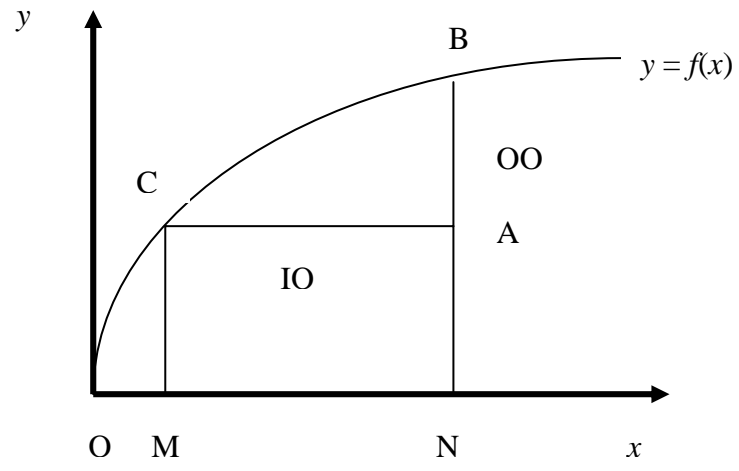
Table 2: Coefficient estimates of production function

Industry	Year	Constant $[\beta_0]$	Capital $[\beta_1]$	Labour $[\beta_2]$	Plant age $[\beta_3]$	Private $[\beta_4]$	Wald χ^2 (Prob $> \chi^2$)	Nobs	Returns to Scale	Technical Efficiency
Agricultural products	1989-90	2.13 *** (0.15)	0.16 *** (0.01)	0.76 *** (0.01)	0.04 *** (0.01)	0.42 *** (0.05)	10834.44 (0.00)	4635	0.92	0.55
	2000-01	1.83 *** (0.27)	0.23 *** (0.02)	0.77 *** (0.02)	- 0.14 *** (0.03)	0.51 *** (0.07)	4675.89 (0.00)	1547	1.00	0.52
Textiles (without apparel)	1989-90	2.34 *** (0.17)	0.21 *** (0.01)	0.68 *** (0.01)	- 0.03 ** (0.01)	0.51 *** (0.05)	8109.54 (0.00)	2618	0.89	0.59
	2000-01	1.87 *** (0.25)	0.27 *** (0.01)	0.68 *** (0.02)	- 0.22 *** (0.03)	0.75 *** (0.07)	6188.50 (0.00)	1377	0.95	0.54
Textile products	1989-90	2.09 *** (0.34)	0.17 *** (0.02)	0.75 *** (0.02)	0.03 (0.02)	0.17 (0.17)	2320.99 (0.00)	979	0.92	0.62
	2000-01	1.04 (0.79)	0.11 *** (0.03)	0.87 *** (0.04)	- 0.01 (0.05)	0.13 (0.43)	815.98 (0.00)	307	0.98	0.58
Wood & wood products	1989-90	1.71 *** (0.29)	0.17 *** (0.02)	0.76 *** (0.03)	- 0.002 (0.03)	0.44 *** (0.11)	2827.20 (0.00)	797	0.93	0.60
	2000-01	1.42 * (0.73)	0.27 *** (0.06)	0.71 *** (0.07)	- 0.11 (0.07)	--	850.21 (0.00)	171	0.98	0.65
Paper, paper products & printing	1989-90	2.14 *** (0.20)	0.20 *** (0.01)	0.74 *** (0.02)	- 0.10 *** (0.02)	0.18 ** (0.09)	5285.22 (0.00)	1503	0.94	0.61
	2000-01	0.83 (0.85)	0.14 *** (0.03)	0.89 *** (0.05)	- 0.16 *** (0.06)	0.41 (0.31)	920.07 (0.00)	280	1.03	0.52
Leather & leather products	1989-90	2.43 *** (0.65)	0.23 *** (0.03)	0.67 *** (0.05)	- 0.07 * (0.04)	0.12 (0.25)	674.32 (0.00)	351	0.90	0.53
	2000-01	0.87 * (0.48)	0.13 *** (0.01)	0.95 *** (0.03)	- 0.22 *** (0.04)	0.13 (0.26)	2486.92 (0.00)	482	1.08	0.61

Chemicals & chemical products	1989-90	3.25 *** (0.25)	0.13 *** (0.01)	0.73 *** (0.02)	- 0.03 (0.02)	0.13 (0.10)	3378.49 (0.00)	1857	0.86	0.56
	2000-01	*0.59 * (0.33)*	*0.25 *** (0.02)*	*0.80 *** (0.02)*	*- 0.12 *** (0.04)*	*0.29 ** (0.12)*	*5521.74 (0.00)*	*1192*	*1.05*	*0.51*
Rubber & plastic products	1989-90	2.04 *** (0.27)	0.24 *** (0.01)	0.72 *** (0.02)	- 0.03 (0.02)	0.02 (0.14)	3922.75 (0.00)	1586	0.96	0.55
	2000-01	*0.85 * (0.50)*	*0.36 *** (0.03)*	*0.71 *** (0.04)*	*- 0.15 *** (0.06)*	*0.05 (0.18)*	*4541.50 (0.00)*	*534*	*1.07*	*0.53*
Non-metallic products	1989-90	2.19 *** (0.17)	0.13 *** (0.01)	0.77 *** (0.01)	- 0.01 (0.01)	0.18 ** (0.07)	7322.74 (0.00)	2221	0.90	0.60
	2000-01	*0.99 *** (0.35)*	*0.33 *** (0.02)*	*0.70 *** (0.02)*	*- 0.15 *** (0.03)*	*0.18 (0.19)*	*5024.96 (0.00)*	*586*	*1.03*	*0.56*
Basic metals & alloys	1989-90	3.24 *** (0.24)	0.18 *** (0.01)	0.69 *** (0.02)	- 0.04 ** (0.02)	- 0.11 (0.12)	4825.73 (0.00)	1854	0.87	0.56
	2000-01	*0.79 * (0.42)*	*0.36 *** (0.03)*	*0.66 *** (0.04)*	*- 0.16 *** (0.05)*	*0.60 *** (0.16)*	*3625.48 (0.00)*	*615*	*1.02*	*0.51*
Metals & metal products	1989-90	1.99 *** (0.20)	0.17 *** (0.01)	0.77 *** (0.02)	- 0.03 * (0.02)	0.09 (0.07)	5182.09 (0.00)	1993	0.94	0.64
	2000-01	*1.17 ** (0.52)*	*0.16 *** (0.03)*	*0.88 *** (0.04)*	*- 0.21 *** (0.05)*	*0.13 (0.23)*	*1716.46 (0.00)*	*434*	*1.04*	*0.54*
Non-electrical machinery	1989-90	2.15 *** (0.17)	0.19 *** (0.01)	0.73 *** (0.01)	- 0.05 *** (0.01)	0.07 (0.08)	7947.23 (0.00)	2289	0.92	0.66
	2000-01	*1.84 *** (0.36)*	*0.16 *** (0.02)*	*0.84 *** (0.03)*	*- 0.19 *** (0.03)*	*0.18 (0.16)*	*4827.25 (0.00)*	*884*	*1.00*	*0.56*
Electrical machinery &	1989-90	2.19 *** (0.26)	0.19 *** (0.02)	0.73 *** (0.02)	0.001 (0.02)	0.30 *** (0.10)	3144.49 (0.00)	1617	0.92	0.53

equipment	*2000-01*	*1.47 **** *(0.42)*	*0.25 **** *(0.03)*	*0.77 **** *(0.04)*	*- 0.15 **** *(0.05)*	*- 0.02* *(0.18)*	*3197.16* *(0.00)*	*493*	*1.02*	*0.51*
Transport equipment	1989-90	2.24 *** (0.25)	0.16 *** (0.01)	0.74 *** (0.02)	- 0.07 *** (0.02)	0.35 *** (0.10)	4293.70 (0.00)	1176	0.90	0.68
	2000-01	*0.82 *** *(0.35)*	*0.24 **** *(0.03)*	*0.78 **** *(0.03)*	*- 0.16 **** *(0.03)*	*0.32 ** *(0.17)*	*4901.29* *(0.00)*	*591*	*1.02*	*0.60*

Notes: The values within parentheses reported after the coefficient estimates (β) are robust standard errors.

***, ** and * indicate significance at 1%, 5% and 10% levels, respectively.

In 2000-01, 100% of the plants in the sample for the wood and wood products were privately owned, and hence the regression model for that industry did not have a control for ownership.
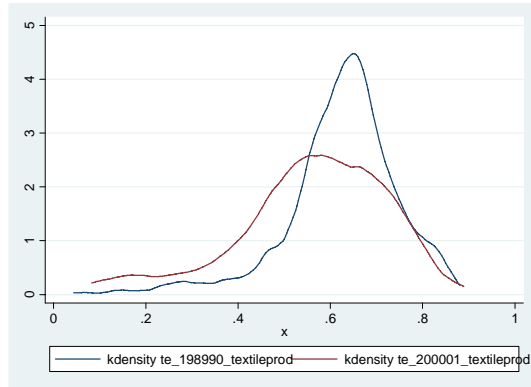
The return to scale for each industry is the sum of the coefficients for log capital and log labour cost.

The technical efficiency measure reported for each industry is the median technical efficiency for that industry.
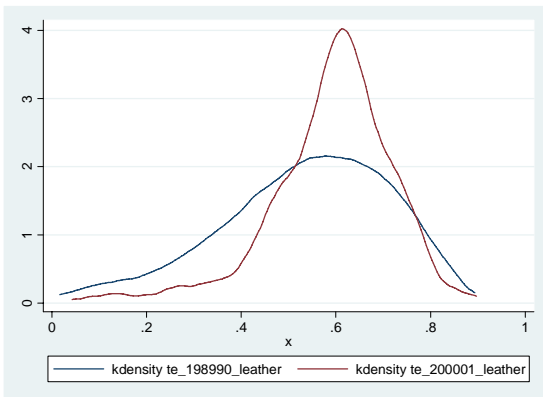
Figure 3: Technical efficiency distributions in select industries
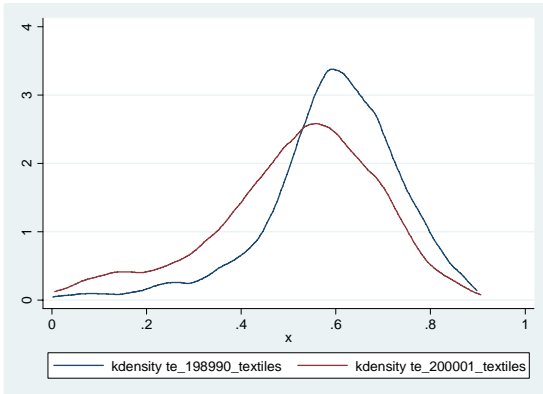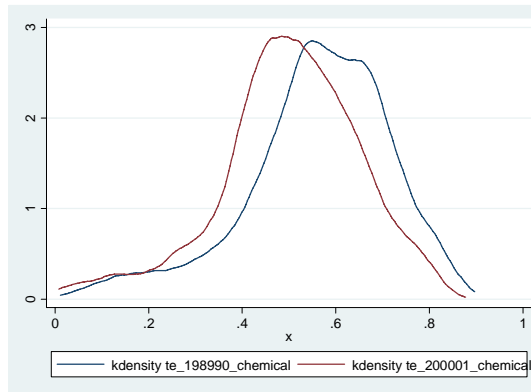

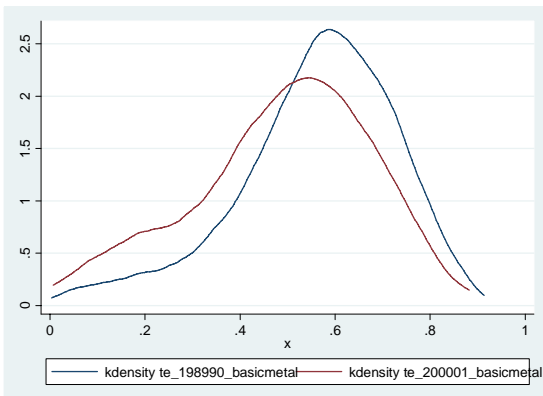Textiles (without apparel)
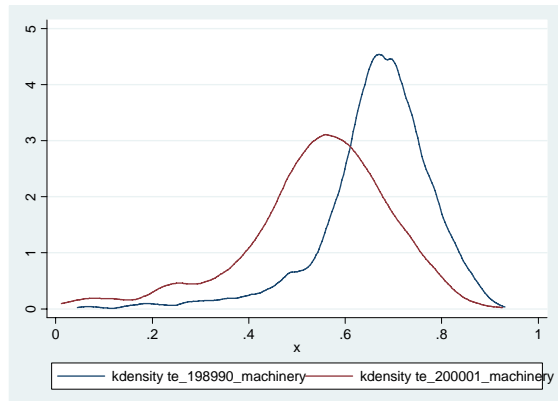

Textile products

Leather & leather products

Chemicals

Basic metals & alloys

Non-electrical machinery

Table 3: Decomposing growth in gross value added

Industry	Total	Input effect Effect	Input effect % of Total	Technology effect Effect	Technology effect % of Total	Efficiency effect Effect	Efficiency effect % of Total
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Agricultural products	2.82	2.67	94.37	0.20	7.04	-0.04	-1.42
Textiles (without apparel)	2.82	2.68	95.28	0.20	7.20	-0.07	-2.48
Textile products (incl. apparel)	2.40	2.44	101.60	0.02	0.89	-0.06	-2.50
Wood & wood products	2.53	3.13	123.75	-0.63	-24.93	0.03	1.18
Paper, paper products and printing	1.80	1.86	103.39	0.04	2.17	-0.10	-5.56
Leather & leather products	1.79	1.66	93.04	0.06	3.60	0.06	3.36
Chemicals	2.50	2.69	107.81	-0.14	-5.41	-0.06	-2.40
Rubber & plastic products	2.47	2.37	96.00	0.14	5.62	-0.04	-1.62
Non-metallic products	2.79	2.88	103.37	-0.03	-1.22	-0.06	-2.15
Basic metals & alloys	2.39	2.49	104.02	-0.03	-1.10	-0.07	-2.93
Metals & metal products	2.52	2.49	98.86	0.16	6.31	-0.13	-5.16
Non-electrical machinery	2.39	2.25	94.19	0.26	10.84	-0.12	-5.02
Electrical machinery & equipment	2.23	2.26	101.22	0.00	0.12	-0.03	-1.34
Transport equipment	2.89	2.67	92.20	0.33	11.25	-0.10	-3.45

Note: The numbers are percentage difference between the predicted (log) values of value added for 2000-01 and 1989-90.