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PRODUCTIVITY MEASUREMENT IN INDIAN MANUFACTURING: A COMPARISON OF ALTERNATIVE METHODS[1]

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Abstract

Very few other issues in Indian economic development has generated so much debate than the measurement of total factor productivity (TFP) growth in Indian manufacturing. This debate has intensified following the major economic reforms in 1991. Using three different techniques – growth accounting (non-parametric), production function accounting for endogeniety (semi-parametric) and stochastic production frontier (parametric) – the paper computes the TFP growth of Indian manufacturing for both formal and informal sectors from 1994-95 to 2005-06. The results indicate that the TFP growth of formal and informal sector has differed greatly during this period and that the estimates are sensitive to the technique used. This suggests that any inference on productivity growth in India since the economic reforms of 1991 is conditional on the method of measurement used, and that there is no unambiguous picture emerging on the direction of change in TFP growth in post-reform India.

Keywords: TFP growth, stochastic frontier, semi parametric, non-parametric

JEL Classification: D24, L60, O30

1. Introduction

Very few other issues in Indian economic development has generated so much debate than the measurement of total factor productivity (TFP) growth in Indian manufacturing (Balakrishnan and Pushpangadan, 1994; Dholakia and Dholakia, 1994; Goldar, 2002). This

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debate has intensified following the major economic reforms in 1991. Estimates of TFPG do not provide a clear picture on what has happened to the rate of productivity growth in manufacturing after the 1991 reforms. Studies by Krishna and Mitra (1998), Unel (2003) and Tata Services Ltd. (2003) find an acceleration in TFPG in the 1990s, whereas studies by Trivedi *et al*. (2000), Srivastava (2000), Balakrishnan *et al*. (2000), Ray (2002), Goldar and Kumari (2003), Goldar (2004), Goldar (2006), Das (2004), Kumar (2004) and RBI (2004) find a deceleration in TFPG in the 1990s. Since the 1991 reforms were specifically targeted to the manufacturing sector due to the realization that the sector offered much greater prospects for capital accumulation, technical change and linkages and hence job creation, it is important to understand what has been the behavior of TFPG in the post-reform period.[5] However, given the different methods used in these studies along with differences in variable construction and data used does not allow for one to infer whether the large differences in estimates (not just in magnitude but also the direction of change) are due to the use of different methods or due to different approaches to variable construction or the use of different data-sets. In addition, most of these studies do not include the informal manufacturing sector in their estimation of TFPG, which is a significant omission, given the importance of this sector in total employment in Indian manufacturing.[6]

This paper contributes to the recent literature on TFPG estimation in India in four important ways. Firstly, it uses three different techniques – growth accounting (GA) (non-parametric), production function with correction for endogeneity – Levinsohn-Petrin (LP) (semi-parametric) and stochastic production frontier analysis (SFA) (parametric), from 1994-95 to 2005-06 to compute TFPG in Indian manufacturing to see how sensitive are the results to different estimation methods. Secondly, it uses firm/plant level-data in the estimation of TFPG, and therefore, estimates TFPG at the most disaggregated level. Thirdly, it pays careful attention to data issues and to methods of variable construction which have been the source of some of the debate on TFPG estimates in India. Finally, it brings together TFPG estimates of both the formal and informal manufacturing sectors, the latter being an important part of the overall manufacturing sector in terms of employment.

The results indicate that the TFP growth of formal and informal sectors has differed greatly over this period and the estimates are sensitive to the technique used. While the GA and SFA methods show a decline in TFPG in the formal sector in 1994-2001, the LP method shows an increase. In 2001-2005, the GA and LP methods show a decline in TFPG, while the SFA method shows an increase for the formal sector. In the case of the informal sector, all three methods show a decline in TFPG in 1994-2001. However, for 2001-2005, the GA and LP methods show a decline in 2001-2005 for the informal sector, while the SFA method shows an

5 It should be noted that the trend in TFPG prior to the 1991 reforms has also been contested. A number of studies (see for example, Brahmananda, 1982; Ahluwalia, 1991; Dholakia and Dholakia, 1994; Majumdar, 1996; Rao, 1996a; Pradhan and Barik, 1998; Trivedi *et al*., 2000 among others) have suggested a decline in the TFPG till 1970s with a turnaround taking place in mid-1980s in line with the more open trade and industrial policies. However, Balakrishnan and Puspangadan (1994) argue that the TFPG growth during the 1980s is the *arte-fact* of using single digit deflation method. The turnaround vanishes if double deflation approach is adopted.

6 About 4/5[th] of the manufacturing workforce in India is in the informal sector (Raj and Sen, 2011).

increase. Thus, there is a lack of convergence of the different methods on TFPG estimates for the formal and informal manufacturing sectors in India.

The organization of the paper is as follows. The next section gives the definition of productivity and how productivity can be measured. The different issues involved in empirical estimation of TFP growth is discussed in section 3. Section 4 gives a brief review of the literature on the TFP studies in India. Section 5 gives the methodology and data used in the estimation. This is followed by results of TFP growth using all the three methods in Section 6. Section 7 concludes.

2. Productivity: Concept and Measurement

It is well acknowledged that economic growth depends both on the use of factors of production such as labour and capital, the efficiency in resource use and technical progress. This efficiency in resource use is often referred to as productivity. Some researchers note that growth in productivity is the only plausible route to increase the standard of living (see for example, Balakrishnan and Pushpangadan, 1998) and is therefore a measure of welfare (Krugman, 1990). The relevance of economic growth is less meaningful if it has not affected productivity growth and hence the standard of living. This increase in productivity or productivity growth can be caused by several factors including investment in human capital, infrastructure, R&D apart from healthy business environment.

Analysis of total factor productivity (TFP) measures the increase in total output which is not accounted for by increases in total inputs. The level of TFP can be measured by dividing total output by total inputs. The TFP index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth rate in total output less the growth rate in total inputs. In other words, TFP growth refers to the amount of growth in real output that is not explained by the growth in inputs. As TFP levels are sensitive to the units of measurement of inputs and outputs, they are rarely estimated; instead TFP growth is preferred. Hence, it is common to use the notation “TFP” to refer to growth rather than levels, and this is the convention adopted in this paper too.

Under this backdrop, this section addresses three key issues: i) how to measure the total factor productivity (TFP) and what are the advantages and disadvantages of different methods?; ii) what are the issues involved in measuring TFP – i.e., selection of output measure, input measure, choice of method etc.?; iii) a brief review of work carried out in measuring TFP in India in the past two decades.

2.1 Productivity and Productivity Growth

Productivity is defined as the ratio of output to input(s). The two most commonly used measures of productivity are single factor productivity (SFP) and multifactor or total factor productivity (TFP). When multiple inputs of heterogeneous nature are used in the production process, aggregation of these inputs requires use of price indices. This implies that productivity can be affected by both changes in relative prices of inputs and input requirements per unit of output.

Single Factor Productivity (SFP) and Total factor Productivity (TFP)

Productivity can be measured with respect to a single input or a combination of inputs. The partial or single factor productivity (or SFP) is defined as the ratio of the volume of output (or value-added) to the quantity of the factor of production for which productivity is to be estimated (e.g., labour productivity or capital productivity).

When the proportion in which the factors of production are combined (e.g., labour and capital) undergoes a change, partial measures of productivity provide a distorted view of the contribution made by these factors in changing the level of production. In a situation where capital-labour ratio follows an increasing trend, productivity of labour is overestimated and that of capital, underestimated. For instance, capital deepening (shifts in technique of production) can lead to a rise in labour productivity and fall in capital productivity over time. In this case, a change in labour productivity is merely a reflection of substituting one factor by another (Majumdar, 2004). Similarly, improvements in labour productivity could also be due to changes in scale economies (Mahadevan, 2004). In short, the partial measure does not provide overall changes in productive capacity since it is affected by changes in the composition of inputs.

Despite the limitation, estimation of productivity of labour is regarded crucial from the welfare point of view. This is because it measures production per unit of labour employed and a country's ability to improve its standard of living over time depends on its ability to raise its output per worker. Chen (1979) using Singapore and Hong Kong as examples has shown that in the long run, it is the growth of labour productivity that is more important than TFP growth.[7] Kendrick (1991) argues that labour productivity measure is useful in showing the savings achieved over time in the use of the input per unit of output. Sargent and Rodriguez (2000) have advocated the use of labour productivity to examine the trends over a period that is less than a decade given the biases in estimating capital stock[8] to obtain TFP growth. Balakrishnan (2004) argues that labour productivity merit attention in its own right and serves a different purpose for which the TFP is not a substitute. He contends that labour productivity is a measure of potential consumption and a steady rise in the productivity of labour is necessary for a sustained increase in the standard of living of a population. Typically, labour productivity moves in the same direction as TFP but grows at a somewhat faster rate reflecting the influence of capital deepening (Mahadevan, 2004).

The concept of total factor productivity (TFP) tries to circumvent the problem encountered in the interpretation of SFP estimates in the event of changing factor intensities. TFP is defined as the ratio of output (or value added) to a weighted sum of the inputs used in the production process. TFP is deemed to be the broadest measure of productivity and efficiency in resource use. It aims at decomposing changes in production due to changes in quantity of inputs used and changes in all the residual factors such as change in technology, capacity utilisation, quality of factors of production, learning by doing, *etc*. An increase in TFP, therefore, implies a decrease in unit cost of production.

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7 As referred in Mahadevan (2003: 366).

8 The biases and other issues involved in measuring capital are given in the next section.

TFP Growth

The concept of TFP growth and what it constitutes has been a subject of debate since the time the term was first introduced in 1940s (Mahadevan, 2003: 365). This has led to several definitions of TFP growth. The term has been used interchangeably with technological change/progress, embodied and/or disembodied technical change. Following are some of the definitions of TFP growth:

TFP Growth = Output Growth – Input Growth
= Technical/Technological Change/Progress
= Embodied (or endogenous) Technical Change
+ Disembodied (or exogenous) Technical Change
= Changes in Technical efficiency + Technological Progress

Of all these definitions, the first one is the most commonly used. As per the definition, TFP growth incorporates all the residual factors after accounting for input growth, and has also been hailed as an 'index of ignorance' (Abramovitz, 1956). Jorgenson and Griliches (1967) argue that if we measure all the inputs carefully, this residual might disappear. The last two definitions are conceptually identical as the change in technical efficiency essentially indicates embodied technical change and technological progress constitutes the disembodied technical change (Mahadevan, 2003: 366). Embodied technical change results from the efficient use of new and better types of capital so as to move towards the frontier. Disembodied technical change, on the other hand, results in the expansion of production boundaries itself due to increase in knowledge.

Measuring TFP Growth[9]

There are two main techniques to measure TFP growth – frontier and non-frontier approaches (Figure 1). These approaches are further divided into parametric and non-parametric techniques. Most studies in the Indian context and elsewhere have used non-frontier techniques with recent emphasis being on parametric estimations.

The crucial distinction between frontier and non-frontier approaches lies in the definition of frontier. In frontier approach aim is to find the bounding function i.e., the best obtainable positions given the inputs or the prices. A 'cost frontier' traces the minimum attainable cost given input prices and output and a 'production frontier' traces the set of maximum obtainable output for a given set of inputs and technology. This is different from the average function which is often estimated by the ordinary least square regression as a line of best fit through the sample data.

Apart from this, the frontier approach identifies the role of technical efficiency in overall firm performance, whereas the non-frontier approach assumes that firms are technically efficient. This difference results in different interpretation for TFP growth for the two approaches. The TFP growth as obtained from frontier approach consist of two components - outward shifts of the production function resulting from technological progress, and technical efficiency related to the movements towards the production frontier. On the other hand, the non-frontier approach considers technological progress as a measure of TFP growth.

[9] This sub-section takes heavily from Mahadevan (2003).

Since in frontier approach, benchmarking is done where a firm's actual performance is compared with its own maximum potential performance, the approach is more suited to describe industry or firm's behaviour (Mahadevan, 2003: 373). Benchmarking has little room in the non-frontier approach. Earlier studies used non-frontier approach to compute estimates of TFP growth at the economy level and later on only with availability of more disaggregated data, the approach has been used for sectoral or industry level analysis. The parametric non-frontier approach is statistical in nature and evaluates firms relative to an average producer.

A feature common to both the frontier and non-frontier approach is that both can be estimated using parametric and non-parametric methods. In parametric method, an explicit functional form is specified for the frontier and the parameters are estimated econometrically using sample data for inputs and output. This implies that the accuracy of the derived estimates is sensitive to the functional form specified.[10] The chief advantage of the non-parametric method like mathematical programming approach or the Data Envelopment Approach (DEA) is that it is parameter free and does not assume any functional form. The major drawback is that no direct statistical tests can be carried out to validate the estimates.

The parametric approach employs econometric technique and in this approach, the deviation of actual output from the maximum output is decomposed into two parts, viz., the statistical noise and inefficiency. The various alternatives within the parametric approach are as follows: (a) econometric frontier approach; (b) thick frontier approach; and, (c) distribution free approach. Each of these approaches involves arbitrary assumptions regarding the distribution of the noise and inefficiency components. The prime difficulty in using the econometric approach lies in separating the noise from the inefficiency. Figure 1 gives a snapshot of different approaches available.

Of late newer techniques have been developed that take care some of the problems of statistical testing etc. These include stochastic DEA, Bayesian approach, testing for statistical properties of DEA estimates using jackknifing and bootstrapping. Incidentally, many of these are being used in operations research rather than their use in computing productivity growth. Even among the commonly used methods available to compute TFP growth, the literature is inconclusive on the best method to estimate TFP growth (Mahadevan, 2003).

Before embarking upon the proposed estimation of TFP growth we discuss issues in measurement of TFP and TFP growth.

3. Issues in Measurement of Total Factor Productivity

The measurement of TFP involves several issues. Some of the concerns have arisen because the data for the estimation of TFP and TFP growth are not available in the required form. For every variable there are different possible ways to adapt the available data and each of these

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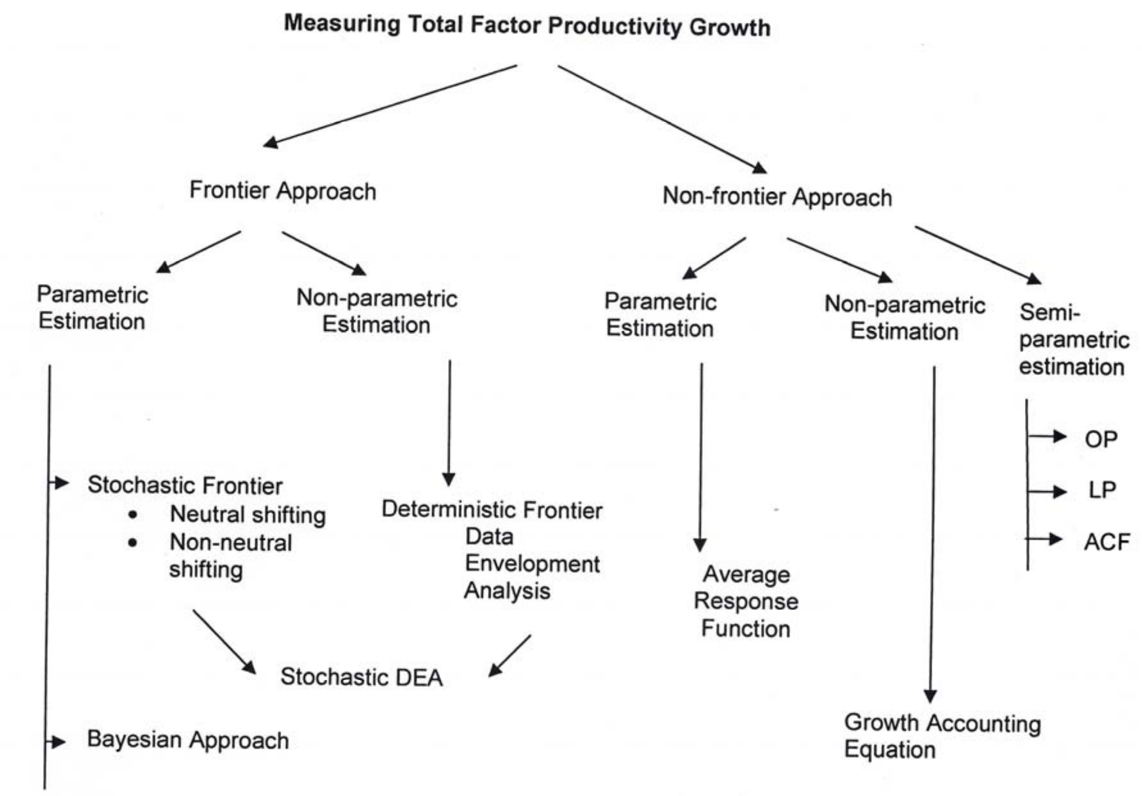
[10] Simultaneity bias is one ignored problem in parametric estimations of the production function. The problem arises because the right-hand side variables containing the inputs are chosen in some optimal way by producers themselves, thus are not exogenous. Adopting Zellner *et al*. (1966) argument that producers maximize expected profit or assume profit maximization *ex ante* or *ex post* reduces the problem. Using instrument variable estimation is one way of correcting the problem econometrically. The difficulty in choosing the right instruments however makes the implementation difficult.

is liable for criticism (Srivastava and Dasgupta, 2000). Measurement error in the original data further complicates the issue. Apart from these, there is a choice between using the traditional growth accounting approach (also known as deterministic approach) and obtaining econometric (or stochastic) estimates. Perhaps that may be the reason that the empirical evidence has given conflicting results sensitive to the choice of method, data used and the manner in which variables have been measured.



Notes: OP – Olley and Pakes approach; LP – Levinsohn and Petrin approach; ACF – Ackerberg, Caves & Frazer model

Source: Adapted from Mahadevan (2003: 372)

Figure 1. Measurement of Total Factor Productivity - Approaches

The *first* issue relates to the measurement of the output to estimate productivity. The issue is choosing between 'output (O)' and 'value-added (VA)'. If VA is chosen, then the related *second* issue is between the use of 'single-deflation' and 'double-deflation' methods for its measurement and separability of the production function. Once decided about the output measure, the *third* issue is about biases in input measurements. The *fourth* issue is choosing between different methods for estimating TFPG.

3.1 Measurement of Output: Gross Output *versus* Value-added

Two types of output measures can be used to calculate TFP and TFP growth: value added and gross output. The separability of the production function is the *de rigueur* for the legitimation of the use of real value added (Balakrishnan and Pushpangadan, 1998). The literature has exhibited strong preference for using value-added as the measure of production. See for example, studies by Goldar (1986), Ahluwalia (1991), Balakrishnan and Pushpangadan (1994, 1998) among others. Norsworthy and Jang (1992) attribute this to the fact that the concept of value-added is useful in national income accounting as it avoids double counting of intermediate inputs. Diewert (2000) argues that value added scores over gross output in inter-industry level studies because the latter includes cost of intermediate inputs which may vary greatly across industries. According to Griliches and Ringsted (1971), use of value added allows comparison between the firms that are using heterogeneous raw materials, and it also takes into account differences and changes in the quality of inputs (Salim and Kalirajan, 1999). The use of gross output that demands the inclusion of raw material as an input variable in the model might diminish the role of capital and labour in productivity growth (Hossain and Karunakara, 2004).

However, the use of value-added provides a distorted view of technology because the effect of changes in prices of purchased raw-material inputs is removed from the costs of production and technology. According to Norsworthy and Jang (1992), it is the aftermath of the energy crisis that has revealed the shortcoming of using real value-added *vis-a-vis* gross real output for productivity estimation.[11]

In contrast, some studies have employed gross output function framework by rejecting the ‘implicitly maintained hypothesis of separability of intermediate inputs like materials and fuel from labour and capital inputs (Rao, 1996a; Pradhan and Barik, 1998; Ray, 2002; Trivedi, 2004; Mukherjee and Ray, 2004). They have argued that a production function relating labor and capital is meaningful only when material inputs are separable from the primary inputs.

Often TFP growth based on value added measure is greater than that of output measure due to the upward bias created by the omission of intermediate goods and services. This bias, however, can be corrected if the ratio of inputs to gross output remained constant (Star, 1974).

3.2 Measurement of Value-added: Single *versus* Double-Deflation Methods

If value-added is used as a measure of output, nominal value-added needs to be converted into real value-added. This conversion can be done with either single deflation (SD) or double deflation (DD) method. In the case of the former, nominal value-added is deflated by the output price index, *i.e.*, both nominal output and nominal material inputs are deflated by the output price index. This is referred to as the SD method.

The other alternative is to deflate the nominal output by output price index and the nominal material inputs by the input price index, *i.e.*, the DD method. If both the output and input prices change in the same proportion, then the ratio of input-output prices remains constant and in such a situation, the estimates of TFP growth obtained by both SD and DD methods will

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[11] Rao (1996a, 1996b) has labelled the estimate of productivity based on gross output and real value-added as 'Total Productivity' (TP) and 'Total Factor Productivity' (TFP), respectively.

coincide. During the periods when the input price index increases at a faster rate than the output price index, the estimate of real value-added obtained by using SD method will be lower than that obtained by using DD method and *vice versa*.

Bruno (1984) has highlighted the role of increasing relative price of raw materials to output in explaining the productivity slowdown in USA and has argued that its effect on the estimation of productivity is analogous to that of Hicks-neutral technological regress.[12] Goldar (1986) states that the use of SD method based on product prices for estimation of real value-added may not be appropriate but due to the difficulty of compiling a materials price index required for DD method, most of the studies including his has used SD method. Ahluwalia (1991) has also expressed the problems associated with the use of the SD approach in the context of measurement of productivity for petroleum and coal industries with the caveat that in the absence of official estimate of value-added in these sectors by the DD method, productivity estimates for these industries need to be interpreted with caution. The study by Balakrishnan and Pushpangadan (1994) for Indian manufacturing sector was the first of its kind to use the DD method and to highlight the importance of changing relative prices in estimation of growth of TFP. They pointed out that deflating value added by a single deflator (as had been done by Ahluwalia, 1991 and Goldar, 1986) would be valid if the price of material inputs did not change relative to the price of the output, which in ordinary circumstances would not be valid. Their study at the aggregate level for the manufacturing sector then refutes the claim made by Ahluwalia (1991) that there was a positive turnaround in TFPG in the Indian manufacturing sector in the 1980-81. It attributed this result to overestimation of productivity by the use of SD method in the event of declining relative prices in the early 1980s.

Measurement of Output – other issues

Apart from the issue of choosing value added or output and going for single or double deflation method, there are other concerns pertaining to the output. These include how to account for newer outputs and the problem of product mix. In reality, very few firms produce single homogenous product. Firms not only produce differentiated products, but also produce variety of products and often change their product mix over time. As a result of these changes in output, the input mix also changes (Mahadevan, 2003: 370). Any index of real output also has to account for quality. Market prices in the base period are often taken to reflect relative values that capture quality differences, but when quality changes are not associated with increases in production costs (and hence market prices) productivity is underestimated. The problem of considering quality changes is more pronounced in service output. For instance, how to account for improved communication system, faster transport and increased array of financial services? Since these are difficult to capture, any estimate of TFP using either VA or output would yield biased results.

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[12] A technical change is considered to be Hicks neutral if the change does not affect the labour and capital in the products production function.

3.3 Measurement of Inputs[13]

Labour

The customary way of measuring labour input is either to use the number of hours worked or the number of workers employed. A large number of studies have used the former as it accounts more accurately for part- and full-time employees in terms of actual hours worked. Still the measure suffers from a limitation if a mix of skilled and unskilled workers is employed. This is because the contribution of skilled workers to production is much higher than that of unskilled workers. Thus, appropriate labour measure would require incorporating the quality of the labour inputs accounting for the sex, education, employment status of the worker etc. (Mahadevan, 2003).

Capital

With respect to capital a number of issues exist. Irrespective of whether frontier or non-frontier approach is used in TFP growth estimation, the flow of output is linked to the flow of inputs' services. Since the data on the flow of capital services is not available, it is assumed that capital flows are proportional to net capital stock after depreciation. Moreover the depreciation rate is assumed specific to asset type instead of specific to industries, and also it does not change over time. Since the asset mix in a given industry might change significantly over time, a technology intensive asset mix would result in capital under-representation and *vice versa*.

The capital also needs to be adjusted for utilization since the use of capital is subject to cyclical factors. For instance in recession capacity utilization is low. If excess capacity is understated, then the residual TFP growth would be understated. In a way, utilization rates are seen as a means of converting capital stock to flows. It is claimed that in the long run, cyclical fluctuations in the flow of services average out and one can take the ratio of capital services flow to the capital stock to be constant, which allows the use of the perpetual inventory equation to measure capital services (Mahadevan, 2003).

In practice, the measurement of capital input is the most complex of all input measurements. There is no universally accepted method for its measurement and, as a result, several methods have been employed to estimate capital stock. In many studies, the capital unit is treated as a stock measured by the book value of fixed assets. Some studies have employed the perpetual inventory method to construct capital stock series from annual investment data. In this case it is assumed that the flow of capital services is proportional to the stock of capital. However, it is essential to point out that each of these measures has drawbacks. The book value method has three limitations. First, the use of 'lumpy' capital data underestimates or overestimates the amount of capital expenditure. Second, the book value may not truly represent the physical stock of machinery and equipment used in the production. Third, it does not address the question of capacity utilization. Perpetual inventory method also does not address the question of capacity utilization. The flow measure is criticized on the ground that the depreciation charges in the financial accounts may be unrelated to the actual wear and tear of hardware.

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[13] This sub-section builds on Mahadevan (2003).

3.4 Issues related to Method Selection

While discussing the pros and cons of the parametric and non-parametric methods, Lovell (1993) has concluded "…in my judgment neither approach strictly dominates the other, although not everyone agrees with this opinion, there still remains some true believers out there". From the above statement it is quite clear that no technique is perfect in TFP calculation. However, whether to use frontier or non-frontier approach depends on the question a researcher is addressing. For instance, if the objective of the study is to assess the contribution made by each input to output growth or to estimate how much output, on average, has been obtained from a set of inputs, then non-frontier approach would be a better choice. On the other hand, to address the questions on maximum productive or best practice output levels, given the inputs and technology, the frontier approach would be the best method. Besides, to examine the sources of TFP growth, the frontier approach is more useful as it decomposes TFPG into various components. However, if the researcher wants to know if the output growth is due to TFP growth or input growth, then the non-frontier approach would serve the purpose.

If the preferred approach is the frontier approach, then the next question is whether to use SFA, which represent absolute frontier (maximality over all possible sample points) or DEA representing best practice frontier constructed from the given sample. The decision depends on many considerations/ factors. Table 1 gives a comparison of different methods based on seven key parameters.

If multiple inputs and outputs are involved in the production process, then DEA is the appropriate method. The DEA method can accommodate multiple inputs and multiple outputs simultaneously. One of the principal disadvantages of DEA is that it can be extremely sensitive to variable selection and data errors. For example the data collected from agricultural sector suffers from two errors - measurement error due to poor quality of data and weather playing a significant role. In this context, the parametric stochastic production frontier is highly recommended. However, DEA appears to be more appropriate when knowledge about underlying technologies is weak. Stated differently, if the employed functional form is close to the given underlying technology, SFA outperforms DEA. In any case, before deciding on the best approach, one should also collect additional information about the type of activity under study. For instance, information about scale and substitution possibilities is best handled with parametric approach.[14]

4. Empirical Work in India – A Review

Depending on the coverage, studies on productivity can be classified into three major types, *viz*., macro, meso and micro level studies (Wagner and Ark, 1996). Macro level studies deal with the entire economy, whereas, meso level studies pertain to a sector or an industry. Micro level studies are conducted at the firm level. Table 2 lists some of the important macro, meso and micro level studies carried out in the post-1980 period for India.

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[14] For a more extended discussion on methods see Kathuria *et al*. (2011).

Table 1. Comparison between Different Methods of Productivity Measurement

Problem	***Semi-Parametric***	***Non-parametric***		***Parametric***	
		GAA	***DEA***	***Regression***	***SFA***
Multiple inputs and outputs	Complex, rarely taken up	Simple	Simple	Complex, rarely taken up	Complex, rarely taken up
Specification of functional form	Required may be incorrect	Required	Not required	Required may be incorrect	Required may be incorrect
Outliers	Not as sensitive	Sensitive	Inaccurate efficiency assessment	Not as sensitive	Not as sensitive
Sample Size	Moderate sample size is required	Small sample size adequate	Small sample size can be adequate	Moderate sample size is required	Large sample size is needed
Prevalence of high collinearity among inputs	Possible misleading interpretation of relationships	Possible misleading interpretation of relationships	Better discrimination	Possible misleading interpretation of relationships	Possible misleading interpretation of relationships
Noise, such as measurement error	Not specifically modeled, but assumptions required	Sensitive	Highly sensitive	Affected but impact is less as compared to DEA	Specifically modeled - strong distributional assumptions required
Statistical Testing	Straightforward statistical testing	Not possible	Sensitive analysis is possible but complex	Straightforward statistical testing	Straightforward statistical testing

Source: Raj (2006) and own compilations

As is evident from Table 2, considerable research attention has been devoted to analyzing the various aspects of the formal manufacturing sector to the relative neglect of informal manufacturing. Recently only there have been some attempts to examine the productivity performance of the informal segment of manufacturing sector (Unni *et al*., 2001; Marjit and Kar, 2009; Kathuria *et al*., 2010; Raj, 2011; Raj and Babu, 2011). Studies by Marjit and Kar (2009), Raj, 2011 and Raj and Babu, 2011 that employed frontier approach to estimate TFPG report gain in TFPG in the informal sector in the 1990s and early 2000s. On the other hand, studies that employ non-frontier approach (Unni *et al*., 2001; Kathuria *et al*., 2010) find a deceleration in productivity following reforms.

Table 2. Productivity Studies in India – A brief Review

Study (Year)	Measure of Output	Deflation Method	Estimation Approach	Functional Form of PF	Index Used in GA Approach	Period	Sector
Brahmananda (1982)	NDP	SD	GAA	-	KI	1950-1981	Formal and Informal
Goldar (1986)	VSD	SD	GAA & PFA	CD & SMAC	TLI, KI, & SI	1951-1979	Formal
Ahluwalia (1991)	VSD	SD	GAA & PFA	CD, TL& CES	TLI	1959-1986	Formal
Mohanty (1992)	NDP	SD	PFA	CD	-	1970-1989	
Balakrishnan and Pushpangadan (1994)	VDD	DD	GAA	-	TLI	1970-1989	Formal
ICICI Limited (1994)	VSD	SD	GAA	-	TLI, KI, & SI	1970-1992	Formal
Dholakia and Dholakia (1994)	VSD & VDD	SD & DD	GAA	-	TLI	1970-1989	Formal
Rao (1996a)	O	-	GAA	-	TLI	1973-1993	Formal
Rao (1996b)	O	-	GAA	-	TLI	1973-1993	Formal
Krishna and Mitra (1998)	O	-	PFA	-	-	1986-1993	Formal
Pradhan and Barik (1998)	O	-	GAA	-	TLI	1963-1992	Formal
Balakrishnan *et al.* (2000)	O	-	PFA	-	-	1988-1998	Formal
Trivedi *et al*. (2000)	O	-	GAA	-	TLI	1973-1998	Formal
Ray (2002)	O	-	DEA	-	MI	1991-2001	Formal
Unel (2003)		SD				1979-1998	Formal
TSL (2003)	O	-	GAA	-	TLI	1981-2000	Formal
Das (2004)	O	-	GAA	-	SI	1980-2000	Formal
Goldar and Kumari (2003)	O	-	GAA	-	TLI	1981-1998	Formal
Kumar (2004)	O	-	DEA	-	MI	1982-2001	Formal
Trivedi (2004)	O	-	GAA & PFA	CD	TLI	1980-2001	Formal
Unni *et al.* (2001)	VSD	SD	GAA	-	SI	1978-1995	Formal and Informal
Goldar (2006)	O, VSD & VDD	SD & DD	GAA	-	SI	1981-1998	Formal
Marjit and Kar (2009)	-	-	DEA	-	MI	1989-2001	Formal and Informal
Kathuria *et al*. (2010)	VSD	SD	PFA - LP	-	-	1994-2006	Formal and Informal
Raj (2011)	VSD	SD	DEA	-	MI	1978-2001	Informal
Raj and Babu (2011)	VSD	SD	DEA	-	MI	1984-2006	Informal

Notes: (a) VSD and VDD - single deflated and double deflated value added respectively; NDP is net domestic product; CD - Cobb-Douglas Production Function; O - gross output and; (b) KI – Kendrick Index, SI – Solow Index, TLI – Translog Index and MI – Malmquist Index; (c) GAA – growth accounting approach, PFA- production function approach, PFA-LP - Levinsohn and Petrin methodology (d) CD – Cobb-Douglas, TL – translog, CES – constant elasticity of substitution and SMAC – Solow-Minhas-Arrow-Chenery function.

Source: Own compilations

In brief, the table indicates that it is only in the last few years that the productivity studies in India have considered the use of gross output over the real value-added as a measure of production and a large number of studies have used GAA. Of late, application of frontier approach is found to be common among researchers for estimating TFPG in the Indian manufacturing sector.

5. Methodology and Data

5.1 Methodology Used

In this paper, TFPG is estimated using parametric, semi-parametric and non-parametric methods. The stochastic production frontier (SPF) is employed in the parametric approach, Levinsohn-Petirn method (LP) in the semi-parametric approach and the growth accounting methodology (GA) in the non-parametric approach.

The Stochastic Production Frontier

We used stochastic frontier analysis (SFA) to estimate firm efficiency of both formal and informal manufacturing sectors. The technical efficiency levels are obtained by employing the stochastic frontier production model proposed by Battese and Coelli (1995). We estimated the Cobb-Douglas production frontier with two inputs labour (L) and capital (K) in equation (1).

$$\ln Q_i = \beta_0 + \beta_1 \ln K_i + \beta_2 \ln L_i + v_i - u_i \qquad \text{... (1)}$$

where ln Q is the log of gross value added; ln K is the log of the value of total capital equipment; ln L is the log of the total number of workers; and β's are the parameters to be estimated.

Understanding and acknowledging that firms are technically inefficient might not be a valuable exercise in isolation, unless an additional effort to identifying the sources of the inefficiencies is made. Thus as a useful second step, we also investigated the factors that determine technical inefficiency in these firms. This is done by estimating equation (2) where we modeled the mean of u_i as a function of a host of firm-specific characteristics.

$$U_i = \delta' z_i + \omega_i \qquad \text{... (2)}$$

where z_i is a vector of explanatory variables related to technical inefficiency for the ith firm; δs are the inefficiency parameters to be estimated; and w is the error term. We identified four such firm-specific characteristics - size, organization type, location, region and nature of the firm (formal/informal) - that could possibly impact the level of inefficiencies of firms in the manufacturing sector.

Growth Accounting Method

The growth accounting (GA) method is widely used in India for estimating TFPG of the manufacturing sector (refer Table 2). This approach measures TFPG as the difference between the rate of growth of output and the weighted rates of growth of factor inputs. In this paper, the Divisia-Tornquist (D-T) approximation has been used for the calculation of TFPG. The TFPG under the D-T approximation is given by the following equation:

$$TFPG = \left(\ln Q_t - \ln Q_{t-1}\right) - \sum_{i=1}^{n} 1/2\left(s_{i.t} - s_{i.t-1}\right)\left(\ln X_{i.t} - \ln X_{i.t-1}\right) \qquad \text{... (3)}$$

where TFPG represents Total Factor Productivity Growth, Q denotes output, X_i factors of production and s_i shares of factors of production. In the growth accounting framework, information about the share of each factors of production (s_i) in the value added is required. We consider the share of emoluments in total value added as the share of labour. Assuming constant returns to scale, the share of capital is one minus the share of labour.

Levinsohn and Petrin Method

We also employed a Cobb-Douglas (CD) production function to estimate TFPG for the formal and informal manufacturing sectors. The estimation is carried out by employing the Levinsohn-Petrin method to address the potential simultaneity bias in production function estimations. We estimated equation (4) separately for each of the 15 major Indian states.

$$\ln Y_{ijt} = A_{it} + \beta_L \ln L_{ijt} + \beta_K \ln K_{ijt} \qquad \text{... (4)}$$

The subscript 'i' indexes the state, 'j' indexes the industry and 't' indexes the time period. The variables Y, L and K represent the real value added, labour and capital input respectively. 'A' is TFP which represents the efficiency of the firm in transforming inputs into output.

The estimation of the coefficients of labour and capital using the ordinary least squares (OLS) method implicitly assumes that the input choices are determined exogenously. However, the firm's input choices can be endogenous too. For instance, the number of workers hired by a firm and the quantity of materials purchased may depend on unobserved productivity shocks. These are commonly overlooked by researchers but they certainly represent the part of TFP known to the firm. Since input choices and productivity are correlated, OLS estimation of production functions will yield biased parameter estimates. This endogeneity bias can be partly corrected using fixed effects estimation for the production function, which eliminates unobservable fixed firm characteristics that may affect simultaneously input choices and TFP. However, there may still be unobserved time-varying firm characteristics simultaneously affecting input choices and TFP. We corrected for the potential simultaneity bias generated by firm time-varying unobservables by employing a methodology developed by Levinsohn and Petrin (2003). The main idea behind this methodology is that an observable firm characteristic can be used to proxy for the unobserved firm productivity and estimate unbiased production function coefficients.

The Levinsohn and Petrin (LP) method overcomes the simultaneity problem by using intermediate inputs (*m*) to proxy unobserved productivity shocks.[15] In LP, the first stage involves estimating the following equation:

$$y_{it} = \beta_o + \beta_l l_{it} + \Phi_t(m_{it}, k_{it}) + \varepsilon_{it} \qquad \text{... (5)}$$

where $\Phi_t(m_{it}, k_{it}) = \beta_k k_{it} + \int_t^{-1}(m_{it}, k_{it})$ is a non-parametric function. The estimates of β_l and Φ_t are obtained in the first stage.

The second stage of the LP estimation obtains the estimate of β_l. Here, LP assumes that productivity (ω) follows a first-order Markov process, and is given by

$$\omega_{it} = E\left[\omega_{it} \middle| \omega_{it-1}\right] + \in_{it} \qquad \text{... (6)}$$

15 Levinsohn and Petrin use electricity as a proxy in their study. We, however, could not use electricity as that would have compelled us to drop from our analysis a large number of units in the unorganised sector that work without power, which we did not want to do.

This assumption states that capital does not respond immediately to ϵ_{it}, which is the innovation in productivity over the last period's expectation (that is, the shock in productivity). It leads directly to the following moment condition:

$$E\left[\epsilon_{it} \middle| k_{it}\right] = 0 \qquad \text{... (7)}$$

The equation (7) states that the unexpected part of the innovation in productivity in the current period is independent of this period's capital stock, which was determined by the previous period's investment. Using this moment condition, β_k can be estimated from the following expression:

$$\epsilon_{it}\left(\beta_k\right) = \omega_{it} - E\left[\omega_{it} \middle| \omega_{it-1}\right] = \left(\hat{\Phi}_{it} - \beta_k k_{it}\right) - \hat{\varphi}\left(\beta_k\right) \qquad \text{... (8)}$$

This moment condition identifies the capital coefficient, β_k. The salience of this strategy lies in the assumption that the current period's capital stock is determined before the shock in the current period's productivity.

5.2 Data and Variable Construction

A key feature of the present paper is the use of unit level data for both formal and informal manufacturing sector. The data for the informal manufacturing sector for the fifteen major states are obtained from the National Sample Survey Organization (NSSO) surveys on the informal manufacturing sector for 1994-95, 2000-01 and 2005-06.[16] The states included are Andhra Pradesh (AP), Assam, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh (MP), Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu (TN), Uttar Pradesh (UP), and West Bengal (WB).

In order to compare with the trends in the formal sector, data for the same three years were obtained from the Annual Survey of Industries (ASI). We have aggregated the unit level data to arrive at the four-digit industry level data for each state. The data cleaning as necessitated by the requirements of the selected methods and the research questions in mind involved the following steps: a) the study has considered only those industries for which three years of data were available; b) while aggregating the data up to four digit level, we have omitted units reporting zero or negative capital stock, zero output and zero employment; and c) as in 2000, Bihar, MP and UP were bifurcated and three new states Uttarakhand, Chattisgarh and Jharkhand

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16 The NSSO conducts surveys on the unorganized manufacturing sector at five-year intervals. Though the NSSO initiated this survey in 1978-79, a complete firm level dataset covering all the categories of unorganized firms – Own account manufacturing enterprises (OAMEs), employing only family labour, Non-directory manufacturing enterprises (NDMEs), employing upto six workers with at least one hired worker and directory manufacturing enterprises (DMEs), employing more than six workers with at least one hired worker - was available only from 1994-95. For the SFA estimation we also considered the 1989-90 dataset. The major drawback of the 1989-90 dataset supplied by the NSSO is the non-availability of information on DMEs. This might not affect the results considerably as the number of DMEs are less in number (in 2005-06, DMEs constitute less than 4 per cent of total enterprises). But this certainly will not affect our comparison with the results obtained using other methods as the comparison is done for the period, 1994-95-2005-06.

were carved out, we merged these three states with their parent states so as to have consistent data for all the three time periods.

It needs to be stated upfront that improvement in sampling approach and conceptual modifications introduced to accommodate the need for improved data collection may, to an extent, affect the comparability of NSSO data over time (Kathuria *et al*., 2010). There are also differences across rounds in terms of coverage of the survey. In the 56th round (2000-01), to minimize errors in data furnished, the reference period for collecting the data on GVA has been changed to '30 days preceding the date of survey' while in the earlier rounds it was collected with reference to a period of '365 days preceding the date of survey'. Similarly, in 2005-06 round, NSSO followed dual sampling procedure to give larger weight to DMEs (Directory Manufacturing Enterprises – enterprises employing more than 6 workers but not registered under the Factories Act). This conceptual difference between the rounds may not cause serious distortions as far as the entire informal manufacturing sector is concerned but may affect the comparison between different types of enterprises.[17]

Variables

The variables used in this exercise are output, labour, capital, and intermediate inputs. To make the values of output, capital and intermediate inputs comparable over time and across industries and states, suitable deflators have been used. The definition of the variables and the deflators used are as given below. The discussion also highlights various issues involved while selecting these variables.

Output

Gross value added (GVA) is used as the measure of output in this study. The advantages and disadvantages of using GVA at constant prices to represent output has already discussed earlier (refer subsection 3.1).

Since our study is covering the period following the post-1990s reforms when the economy was being more integrated to the world economy, the industries must be experiencing large relative price changes, significant changes in factor shares, and large changes in the value of inputs relative to output. In this context of transition, the use of the DD procedure would be more ideal than the SD procedure. However, DD method demands deflating output and intermediate inputs separately using appropriate deflators. The method requires quantification of all items of output and input, availability of item-wise data on quantity and value and matching of items between the base year and the year for which these estimates are required. The method also necessitates estimations at very detailed level of items and is difficult to adopt, particularly for multi-product industry groups and in cases where inputs account for a significant part of output (CSO, 2007: 127). We could not use DD method for three reasons: a) ASI data consists of large number of multi-product firms; b) value added as a proportion of output is low in the formal sector which leads to GVA becoming negative for several industries with DD method for cases where the input price deflator is higher than the output price deflator (CSO, 2007: 127); and c) the non-availability of industry specific input deflators. Accordingly we used SD method.

[17] Given that DMEs are more productive than other types of enterprises in the unorganized manufacturing sector, more weight to DMEs in fact should result in estimation of the true productivity profile of unorganized sector rather than biasing it.

It should be noted that for a few firms, real value added was negative. We converted these values to one so as to take log transformation required for production function estimation.[18]

Capital

The measurement of capital input has been a controversial topic in the theoretical as well as the empirical literature. As mentioned in subsection 3.3, there is no universally accepted method for its measurement.

Despite its limitations, most studies in the Indian manufacturing sector have used the PIAM to arrive at the time series of capital stock. In the present study, we have used data for different time points and the data does not provide information on the accumulated depreciation of capital. Hence, we could not employ PIAM. Instead we have used the total fixed assets as given in the ASI and NSSO reports to represent capital input in the formal and informal sector respectively. The capital input includes land, buildings and other construction, plant and machinery, transport equipment, tools and other fixed assets that have a normal economic life of more than one year from the date of acquisition. The total fixed assets were deflated by WPI for machine and machinery tools in both the sectors. The WPI for machine and machinery tools are not available at the industry level forcing us to use the values at the all India level to deflate gross fixed assets. The values are expressed in 1993-94 prices.

Labour

Total number of persons engaged is used as the measure of labour input. Since working proprietors / owners and supervisory/managerial staff have a significant influence on the productivity of a firm, the number of persons engaged was preferred to the total number of workers.

6. Results

This section discusses the main results obtained using three methods – growth accounting, LP and SFA.

6.1 Results – Growth Accounting

TFPG estimates for the formal and informal sector obtained using growth accounting (GA) method are presented in Table 3. The estimates are reported for two sub-periods, 1994-2001 and 2001-2006. On an average, they suggest a continuous fall in productivity for both the formal and informal sectors. While the decline has slowed down in the formal sector during 2001-2006, a faster decline is observed for the informal sector. A turnaround in productivity is witnessed for Punjab, Haryana, Uttar Pradesh (UP), Bihar, West Bengal (WB), Madhya Pradesh (MP) and Maharashtra in the formal sector and for WB in the informal sector. On the other hand, TFP grew in the formal sector in Rajasthan and the informal sector in Bihar and Kerala in the first period but declined in the second period. Maharashtra is the only state where the informal sector reported positive TFP growth in both the periods. The sector witnessed a faster growth of TFP in

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18 As indicated in the limitations of using the DD method, the number of industries with negative value added rose considerably when we employed DD method for ASI sector in the present study.

the second period in the state. Karnataka is the state for which TFP decline in the second period is more than that in the first in both the sectors. For Gujarat, AP, TN and Orissa TFP decline though reduced, but persisted irrespective of the sector.

Table 3. State-wise TFPG in the Formal and Informal Sector – GA method

State	*Formal Sector*		*Informal Sector*	
	1994-2000	*2000-2005*	*1994-2000*	*2000-2005*
Punjab	-8.19	7.58	-19.16	-0.64
Haryana	-13.56	7.07	-34.58	-10.45
Rajasthan	0.36	-8.65	-0.95	-5.03
UP	-16.81	2.21	-11.15	-4.24
Bihar	-34.67	1.46	3.60	-14.72
Assam	3.30	-8.92	-3.50	-11.53
WB	-4.24	0.50	-26.83	13.51
Orissa	-5.41	-3.65	-26.35	-49.82
MP	-2.88	7.66	36.07	-10.42
Gujarat	-9.96	-33.52	-22.59	-4.92
Maharashtra	-7.51	0.50	1.40	12.40
AP	-10.77	-8.27	-4.23	-2.06
Karnataka	-6.79	-11.80	-19.50	-24.65
Kerala	-4.10	-4.08	10.35	-6.22
TN	-2.85	-0.21	-1.36	-24.63
Mean	**-8.30**	**-3.33**	**-7.13**	**-9.66**

Notes: Estimated from the data without outliers and outliers are defined having values beyond Mean +/- 2*Standard Deviation; Light shaded are the states for which there is turnaround in TFPG from negative to positive, whereas dark shaded are those states for which TFPG is positive in both the periods.

6.2 Results – LP

The estimated CD production function using LP method shows that, barring a few states, the elasticity of output with respect to labour and capital is significantly different from zero in the informal manufacturing sector (Table 4). In 12 out of 15 states, the elasticity of capital is relatively higher than that of labour, implying that the former played a more significant role in the production process. Only in Bihar and MP, the contribution of capital is found to be insignificant. This possibly points to the fact that the firms in the informal sector are moving towards a more capital-intensive production process. Perhaps this may be the reason why we find increasing returns to scale in all the 15 states in informal sector.

On the contrary, labour is a major contributor to output in the formal manufacturing sector. We find the labour input contributing significantly to output in 12 major states in our analysis. Interestingly, its contribution is considerably higher in industrialized states like Gujarat and Tamil Nadu. In many states contributions from capital is found to be insignificant. Indeed the relatively lesser contribution of labour in the informal sector is perturbing as the segment is the larger employment provider by a wide margin vis-à-vis the formal sector.

TFP growth estimates

The TFP reported a marginal increase in the formal manufacturing sector over the period 1994-2005 (Table 5). A comparison of TFPG during 1994-2001 and 2001-2005 reveals that TFP growth declined in the latter period. The average TFP registered a much faster growth in 1994-2001, at an annual average rate of growth of over 8 per cent. But this was reversed in the period 2001-2005, when the TFP declined by 1.6 per cent per annum. We also find that the aggregate growth masks the inter-regional differences in productivity growth. As is evident from Table 5, TFPG improved in the second period in Punjab, Haryana, Bihar, Orissa and Kerala, slowed down in UP and Assam and declined in all other states. The biggest decline in TFP in the second period is observed in TN, at an annual rate of 20 per cent which probably pulled down the overall TFPG of the formal sector. Ironically, Tamil Nadu is the state where the TFP grew the fastest in the period 1994-2001. If we exclude TN, the overall TFPG in the first period drops to 7.4 per cent and in the second period to -0.07 from -1.59 per cent. For the entire period, the TFPG rises from 1.44 to 2.52.

Table 4. LP estimates (at the four-digit level)

States	*Formal Sector*		*Informal Sector*	
	Labour	*Capital*	*Labour*	*Capital*
Punjab	0.840* (0.474)	0.317 (0.39)	0.749* (0.202)	0.621* (0.16)
Haryana	0.583 (0.377)	0.567* (0.26)	0.686* (0.157)	0.709* (0.187)
Rajasthan	0.840* (0.445)	-0.0887 (0.337)	0.432* (0.061)	0.907* (0.091)
Uttar Pradesh	1.181* (0.324)	-0.107 (0.431)	0.415* (0.196)	0.709* (0.119)
Bihar	0.374* (0.151)	0.432* (0.158)	0.844* (0.269)	0.192 (0.316)
Assam	0.999* (0.458)	0.320 (0.243)	0.311* (0.090)	0.998* (0.183)
West Bengal	1.248* (0.422)	-0.202 (0.308)	0.293* (0.043)	0.785* (0.061)
Orissa	0.314 (0.500)	0.393 (0.435)	0.333* (0.050)	0.902* (0.083)
Madhya Pradesh	1.659* (0.338)	-0.258 (0.350)	0.634* (0.332)	0.326 (0.418)
Gujarat	2.637* (0.608)	-1.113 (0.693)	0.519* (0.132)	0.870* (0.146)
Maharashtra	1.237* (0.310)	-0.091 (0.341)	0.289* (0.051)	0.878* (0.137)
Andhra Pradesh	1.351* (0.464)	-0.0207 (0.357)	0.443* (0.067)	0.904* (0.169)
Karnataka	1.790* (0.431)	-0.620 (0.384)	0.423* (0.117)	0.910* (0.147)
Kerala	1.492* (0.331)	-0.246 (0.303)	0.331* (0.068)	1.083* (0.093)
Tamil Nadu	2.455* (0.583)	-0.90* (0.517)	0.467* (0.054)	0.669* (0.1)

Notes: * - indicates the coefficient is statistically significant at minimum 10% level. Figure in parenthesis are the standard errors.

Table 5. Total Factor Productivity Growth in the Formal Sector - LP Method

State	*1994-2000*			*2000-2005*			*1994-2005*		
	Obs.	*Mean*	*SD*	*Obs.*	*Mean*	*SD*	*Obs.*	*Mean*	*SD*
Punjab	83	0.81	22.01	83	5.13	25.86	81	3.14	16.59
Haryana	82	-2.12	21.80	81	3.09	30.03	82	-1.00	17.73
Rajasthan	81	4.59	29.89	82	-4.26	37.32	82	-2.82	27.56
Uttar Pradesh	93	6.72	18.81	94	2.79	39.08	93	0.99	27.95
Bihar	73	-1.37	23.59	72	8.06	32.68	72	0.39	19.76
Assam	36	5.41	33.88	37	4.96	18.65	37	10.62	24.87
West Bengal	85	8.25	17.36	88	-0.91	37.03	83	7.17	11.86
Orissa	61	-0.14	15.47	62	0.45	31.55	63	-1.61	22.15
Madhya Pradesh	86	10.93	32.37	86	-3.03	37.99	87	1.31	28.67
Gujarat	86	22.67	49.13	85	-1.62	47.94	86	4.68	36.83
Maharashtra	92	7.04	11.30	95	-5.71	35.12	87	5.31	7.89
Andhra Pradesh	88	9.61	14.37	92	-4.16	35.05	85	5.69	9.96
Karnataka	90	18.30	30.46	90	-7.59	43.05	82	8.20	18.47
Kerala	83	7.08	18.40	76	8.27	23.85	83	-3.62	28.90
Tamil Nadu	90	26.90	24.21	94	-19.73	52.91	92	-11.50	40.54
Mean		**8.86**			**-1.59**			**1.44**	

Note: Estimated from the data without outliers.[19]

We noticed a completely different picture with regard to TFP growth in the informal manufacturing sector (Table 6). TFP reported a steady decline over the period 1994-2005. The decline that started during 1994-2000 continued unabated in the period 2000-2005 with a decline of 16 per cent in this period. Majority of the states registered TFP decline in both the periods. Only two states - Bihar and MP – registered TFP growth during 1994-2001 while UP is the only state where TFP grew in the period 2001-2005.

We also estimate whether TFP growth is different across various sectors for the two time periods. We find that TFP growth rates differ significantly across two-digit industries in the formal sector (Table 7, major column 1). Most of the industries gained considerably in TFP during the period 1994-2005. However, an examination of TFPG for the two sub-periods presents a different story. TFP reported positive growth performance only in nine out of 22 industries and that too the growth accelerated in the second period for only two industries – food products and minerals. The decline was dramatic in industries producing radio and television, office machinery and motor vehicles. In minerals industry, TFP grew the fastest, at a rate of nearly 13 per cent per annum, in the period 2001-2005. It can be seen from the table that petroleum industry has experienced very wide fluctuation in the two sub-periods. Exclusion of petroleum leads to drop in average TFPG for first sub-period by 2 per cent and increase in average TFPG by 1 per cent.

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19 On checking standard deviation of TFP growth, it was found that for some states, few industries were influencing TFPG. The present table gives TFP growth estimates after omitting the industries falling beyond mean+/-2*StdDev. The TFPG estimates from the data with outliers are available on request.

Table 6. Total Factor Productivity Growth in the Informal Sector – LP Method

State	*1994-2001*			*2001-2005*			*1994-2005*		
	Obs.	*Mean*	*SD*	*Obs.*	*Mean*	*SD*	*Obs.*	*Mean*	*SD*
Punjab	66	-7.69	10.39	65	-3.72	24.57	65	-6.25	12.02
Haryana	57	-8.91	10.55	56	-11.04	21.26	57	-10.63	10.69
Rajasthan	61	-7.60	10.23	62	-11.48	20.51	61	-9.96	10.10
Uttar Pradesh	96	-2.80	21.58	96	4.44	20.83	96	0.60	9.51
Bihar	79	0.74	24.26	79	-13.75	31.26	79	-8.48	22.20
Assam	41	-3.89	10.92	42	-32.52	12.27	42	-18.33	7.73
West Bengal	80	-4.54	8.49	80	-10.75	21.38	82	-8.48	10.55
Orissa	49	-6.67	10.40	49	-34.18	9.74	47	-20.29	4.59
Madhya Pradesh	66	7.99	32.95	64	-4.06	23.38	65	4.92	14.92
Gujarat	69	-2.51	12.06	66	-19.38	16.90	66	-10.70	8.83
Maharashtra	86	-2.45	10.22	88	-4.74	22.70	87	-4.03	12.06
Andhra Pradesh	66	-3.08	9.88	66	-26.98	16.26	67	-14.73	9.08
Karnataka	61	-3.64	10.79	60	-26.52	15.20	60	-15.26	9.52
Kerala	60	-13.70	12.39	61	-22.21	14.30	62	-17.94	8.89
Tamil Nadu	77	-1.42	6.96	78	-23.14	19.21	77	-12.59	9.63
Mean		**-4.01**			**-16.00**			**-10.14**	

Note: Estimated from the data without outliers.

Table 7. Industry-wise TFPG estimates (LP) for formal and informal sectors

Industry	*Formal Sector*			*Informal Sector*		
	1994-2001	*2001-2005*	*1994-2005*	*1994-2001*	*2001-2005*	*1994-2005*
Food	4.07	4.81	3.31	-4.86	-0.03	-12.40
Tobacco	14.87	6.08	5.41	-2.51	-0.37	-7.04
Textiles	12.86	3.17	3.20	-1.34	-1.74	-8.12
Apparel	6.77	-8.44	1.21	-11.79	-	-18.45
Leather	9.30	-9.72	3.97	-4.35	-3.45	-13.07
Wood	8.57	-4.40	-4.68	-6.21	-1.28	-15.63
Paper	8.82	7.68	9.26	-4.64	-2.83	-5.64
Publishing	8.20	-8.62	2.62	-7.81	-0.49	-9.82
Petroleum	152.30	-22.53	-11.25	-0.97	2.62	-5.08
Chemicals	10.68	-10.61	-6.73	-5.36	0.07	-3.83
Rubber	12.82	-2.71	1.43	-2.41	-0.25	-4.18
Minerals	12.49	12.70	11.28	4.49	-0.55	-10.45
Basic metal	7.22	8.62	8.69	1.67	-1.46	-5.34
Metal products	6.09	4.34	6.81	-3.84	-1.20	-6.84
Machinery	6.44	1.25	0.81	-1.23	-0.12	-7.33
Office machinery	3.81	-15.44	-20.63	-8.29	-	-6.24
Electrical machinery	10.25	-9.03	-5.17	-6.90	0.63	-10.56
Radio & Television	8.54	-19.19	-19.81	-0.40	-3.26	-0.81
Medical, precision inst.	10.32	1.32	3.04	-0.58	-7.44	-6.50
Motor vehicles	8.47	-10.80	-21.92	2.87	-	13.76
Transport equipment	13.96	-1.38	3.44	3.40	-0.42	-10.92
Furniture	8.68	-9.03	4.85	-1.79	-0.48	-12.45
Average	11.34	-1.07	1.11	-3.0	-0.6	-9.4

Notes: Estimates are without outliers; For three industries in the informal sector, removal of outliers removes all the firms in the second time period.

On the contrary we observed a consistent decline in TFP in majority of the industries in the informal sector (Table 7, major column 2). Barring petroleum goods, chemicals and electrical machinery, which has recorded positive gains in TFP in the second period, all industries registered negative TFP growth in the second sub-period. For ten industries, the decline in TFPG in the second sub-period was not as steep as was in the first sub-period. Minerals, basic metals and transport goods witnessed their TFP levels plummeting in the second period, from a positive growth in the first sub-period. The industry producing textiles, medical and precision equipments, and radio & television reported drastic decline in TFP as compared to the first sub-period.

6.3 Results – SFA

This sub-section discusses the parameter estimates and levels of technical efficiency obtained by estimating the stochastic frontier production function.[20] The elasticities of output with respect to each input are estimated at their mean values for four time periods (1990, 1995, 2001 and 2006) and are reported in Table 8. The results show that the production in the manufacturing sector in most of the Indian states is largely driven by labour than capital signifying the labour intensive nature of production process in place in the sector. It is even interesting to note that the highly significant role of labour in the production process remained the same during the 16 year period of our analysis. For four states – MP, Gujarat, TN and Kerala, the contribution of capital has gone up in the last 16 years. On the other hand, for three states – UP, Orissa and Punjab, the contribution of labour has gone up. Interestingly, Punjab is the only state for which capital contribution has gone down but labour contribution in the production function has gone up. For remaining states, however there is no discernible pattern.

Next we examine the levels of and changes in technical/productive efficiency of manufacturing firms in selected states. An attempt is also made to understand the factors that may explain inter-regional variation in efficiency levels of manufacturing firms. We looked at both absolute and relative technical efficiency levels. Absolute technical efficiency captures the extent to which firms in the manufacturing sector are producing the maximum possible output, for a given bundle of inputs, in a given industry. Improvements in the absolute technical efficiency of the average firm imply a higher level of output being produced on average, for a given level of inputs in that industry (Kumbhakar and Lovell 2000). Relative technical efficiency, on the other hand, captures the extent to which the efficiency levels of other firms are close to the most efficient firm in a given industry, and improvements in relative technical efficiency imply a more equal distribution of efficiency in the industry. We present the absolute efficiency scores for the formal and informal sector firms in Table 9 and the relative efficiency scores in Table 10.

[20] For SFA, we limit our analysis of informal firms to only those which hire outside labour, as in SFA we intend to find the variation in technical efficiency in the informal sector. Inclusion of OAMEs may influence the results as they are often in business simply because running a small enterprise allows them to bring in additional income with little additional effort and they are unlikely to expand or invest in their businesses (Banerjee and Duflo, 2008).

Table 8. SFA estimates, 1990

States	*1990*		*1995*		*2001*		*2006*	
	Capital	*Labour*	*Capital*	*Labour*	*Capital*	*Labour*	*Capital*	*Labour*
Punjab	0.339*	0.921*	0.253*	1.015*	0.248*	1.021*	0.205*	1.648*
	(0.008)	(0.011)	(0.010)	(0.013)	(0.009)	(0.012)	(0.016)	(0.021)
Haryana	0.203*	1.193*	0.331*	0.918*	0.397*	0.903*	0.335*	1.434*
	(0.044)	(0.068)	(0.012)	(0.018)	(0.013)	(0.019)	(0.024)	(0.033)
Rajasthan	0.198*	1.002*	0.317*	0.937*	0.303*	0.995*	0.487*	1.454*
	(0.028)	(0.032)	(0.012)	(0.019)	(0.010)	(0.016)	(0.020)	(0.030)
Uttar Pradesh	0.063*	0.077	0.450*	0.852*	0.416*	0.866*	0.595*	1.275*
	(0.017)	(0.053)	(0.007)	(0.010)	(0.006)	(0.010)	(0.013)	(0.020)
Bihar	0.433*	0.950*	0.355*	0.921*	0.344*	0.878*	0.456*	1.557*
	(0.010)	(0.017)	(0.012)	(0.016)	(0.011)	(0.017)	(0.017)	(0.027)
Assam	0.326*	1.038*	0.278*	0.914*	0.357*	0.729*	0.486*	1.205*
	(0.016)	(0.023)	(0.016)	(0.025)	(0.016)	(0.024)	(0.023)	(0.036)
West Bengal	0.315*	1.246*	0.311*	0.992*	0.314*	0.949*	0.427*	1.479*
	(0.019)	(0.043)	(0.008)	(0.013)	(0.008)	(0.013)	(0.016)	(0.027)
Orissa	-0.007	0.142	0.374*	0.852*	0.350*	0.935*	0.510*	1.352*
	(0.042)	(0.141)	(0.017)	(0.029)	(0.017)	(0.030)	(0.027)	(0.047)
Madhya Pradesh	0.224*	1.147*	0.380*	0.935*	0.383*	0.937*	0.481*	1.379*
	(0.034)	(0.107)	(0.014)	(0.022)	(0.011)	(0.019)	(0.022)	(0.036)
Gujarat	0.244*	1.191*	0.338*	0.982*	0.365*	0.853*	0.391*	1.016*
	(0.021)	(0.044)	(0.007)	(0.011)	(0.008)	(0.012)	(0.012)	(0.022)
Maharashtra	0.141*	0.591*	0.316*	1.071*	0.348*	0.951*	0.347*	1.230*
	(0.015)	(0.063)	(0.006)	(0.009)	(0.007)	(0.011)	(0.012)	(0.023)
Andhra Pradesh	0.342*	1.069*	0.392*	0.923*	0.385*	0.871*	0.421*	1.339*
	(0.010)	(0.017)	(0.007)	(0.011)	(0.008)	(0.012)	(0.014)	(0.022)
Karnataka	0.303*	1.190*	0.487*	0.909*	0.457*	0.833*	0.544*	1.130*
	(0.017)	(0.027)	(0.011)	(0.017)	(0.010)	(0.015)	(0.018)	(0.025)
Kerala	0.343*	1.105*	0.344*	0.981*	0.373*	0.882*	0.442*	1.388*
	(0.008)	(0.015)	(0.10)	(0.015)	(0.009)	(0.015)	(0.016)	(0.022)
Tamil Nadu	0.255*	1.334*	0.355*	0.947*	0.375*	0.905*	0.407*	1.386*
	(0.013)	(0.020)	(0.006)	(0.008)	(0.005)	(0.008)	(0.009)	(0.014)

Table 9. Region-wise absolute efficiency scores, 1990-2006 – SFA Method

State name	*State code*	*NSSO*				*ASI*				*ASI/NSSO*			
		1990	*1995*	*2001*	*2006*	*1990*	*1995*	*2001*	*2006*	*1990*	*1995*	*2001*	*2006*
Punjab	3	0.617	0.580	0.663	0.940	0.625	0.626	0.705	0.942	1.013	1.079	1.064	1.002
Haryana	6	0.522	0.521	0.605	0.940	0.554	0.585	0.655	0.942	1.060	1.122	1.082	1.002
Rajasthan	8	0.513	0.941	0.690	0.880	0.559	0.942	0.718	0.886	1.089	1.001	1.041	1.007
Uttar Pradesh	9	0.964	0.606	0.599	0.965	0.967	0.637	0.635	0.965	1.003	1.052	1.061	1.001
Bihar	10	0.536	0.967	0.723	0.986	0.593	0.967	0.733	0.986	1.106	1.000	1.014	1.000
Assam	18	0.987	0.577	0.986	0.984	0.987	0.607	0.986	0.985	1.000	1.051	1.000	1.000
West Bengal	19	0.521	0.637	0.612	0.983	0.622	0.657	0.642	0.983	1.194	1.030	1.049	1.000
Orissa	21	0.955	0.521	0.574	0.940	-	0.576	0.606	0.942	-	1.106	1.054	1.002
Madhya Pradesh	23	0.941	0.506	0.559	0.940	0.944	0.575	0.614	0.942	1.003	1.137	1.098	1.002
Gujarat	24	0.941	0.631	0.646	0.073	0.942	0.661	0.668	0.416	1.001	1.047	1.034	5.685
Maharashtra	27	0.941	0.532	0.592	0.135	0.944	0.577	0.639	0.400	1.003	1.085	1.079	2.960
Andhra Pradesh	28	0.985	0.590	0.543	0.642	0.986	0.627	0.601	0.701	1.000	1.064	1.105	1.091
Karnataka	29	0.494	0.456	0.544	0.940	0.559	0.532	0.595	0.942	1.132	1.165	1.095	1.002
Kerala	32	0.388	0.962	0.550	0.976	0.518	0.962	0.558	0.977	1.334	1.000	1.016	1.000
Tamil Nadu	33	0.610	0.681	0.696	0.977	0.641	0.695	0.715	0.977	1.051	1.020	1.027	1.000
Mean	All	0.728	0.647	0.639	0.820	0.746	0.682	0.671	0.866	1.071	1.064	1.055	1.450

***Distribution is assumed to be half-normal**

Table 10. Region-wise relative efficiency scores, 1990-2006 – SFA Method

State name	*State code*	*NSSO*				*ASI*				*ASI/NSSO*			
		1990	*1995*	*2001*	*2006*	*1990*	*1995*	*2001*	*2006*	*1990*	*1995*	*2001*	*2006*
Punjab	3	68.9	63.3	71.5	99.3	69.8	68.3	76.1	99.5	1.0	1.1	1.1	1.0
Haryana	6	63.0	59.6	68.3	99.4	66.8	66.8	73.9	99.6	1.1	1.1	1.1	1.0
Rajasthan	8	65.1	98.8	75.1	97.8	70.9	98.9	78.2	98.5	1.1	1.0	1.0	1.0
Uttar Pradesh	9	99.7	67.3	65.5	99.8	100.0	70.8	69.5	99.8	1.0	1.1	1.1	1.0
Bihar	10	63.1	99.6	80.6	100.0	69.8	99.6	81.7	100.0	1.1	1.0	1.0	1.0
Assam	18	99.9	66.3	99.9	99.9	99.9	69.8	99.9	99.9	1.0	1.1	1.0	1.0
West Bengal	19	62.9	69.9	67.0	99.9	75.1	72.1	70.3	100.0	1.2	1.0	1.0	1.0
Orissa	21	99.5	59.2	65.3	99.4	-	65.4	68.9	99.5	-	1.1	1.1	1.0
Madhya Pradesh	23	99.2	58.5	62.8	99.4	99.5	66.5	69.0	99.6	1.0	1.1	1.1	1.0
Gujarat	24	99.4	69.3	71.5	8.0	99.5	72.5	73.9	45.4	1.0	1.0	1.0	5.7
Maharashtra	27	99.5	58.4	65.4	15.3	99.8	63.3	70.5	45.4	1.0	1.1	1.1	3.0
Andhra Pradesh	28	99.9	65.7	61.3	78.1	99.9	69.9	67.7	85.2	1.0	1.1	1.1	1.1
Karnataka	29	57.8	52.7	59.7	99.4	65.4	61.4	65.4	99.6	1.1	1.2	1.1	1.0
Kerala	32	44.0	99.5	60.8	99.9	58.7	99.5	61.8	99.9	1.3	1.0	1.0	1.0
Tamil Nadu	33	74.5	76.8	75.3	99.9	78.2	78.4	77.4	99.9	1.1	1.0	1.0	1.0
Mean	All	79.8	71.0	70.0	86.4	82.4	74.9	73.6	91.5	1.1	1.1	1.1	1.5

*Distribution is assumed to be half-normal

Our results show that average efficiency for the formal and informal sectors presents a similar trend. The 1990s witnessed a decline in average efficiency, but this was reversed in the period 2001-2006. We also observed that formal firms, on average, more efficient than the informal firms in all the states. Our SFA results also point to the narrowing of efficiency gap between formal and informal firms in the recent period in majority of the states. We do not find significant variation in efficiency level across regions. Barring two industrialized states, Gujarat and Maharashtra, in all other states the mean technical efficiency level of formal and informal firms is over 90 per cent. We find a significant drop in efficiency for firms in the formal and informal sectors in Gujarat and Maharashtra. Results reveal that informal firms in these two states can increase their production, on an average, between 87 percent and 93 percent and formal firms between 58 and 62 per cent. In other words, there exists a large scope for expanding output in these states by improving the firms' technical efficiency levels using the existing resources and technology. We observed a steady increase in absolute efficiency during 1990-2006 only for Punjab and Haryana in the formal sector and for Tamil Nadu in the formal and informal sectors. Our findings on relative efficiency suggest a gradual decline in the 1990s and an increase thereafter. A surge in relative efficiency is noted for majority of the states over the period 2001-2006 suggesting that firms in both the formal and informal sectors have moved closer to the frontier in this period.

Sources of Technical Efficiency

We also examined the factors that determine efficiency levels in formal and informal manufacturing sectors. The firm-specific characteristics included in the efficiency model are size, organization type (pvt. Ltd. /public Ltd. /public sector) , location (rural / urban), region and nature of the firm (formal/informal). We used both absolute and relative technical efficiency as our dependent variables in the model. Tables 11 and 12 present the main results. Cols. (1) to (3) of the two tables examine whether the gains in efficiency is related to the firm being located in the rural or urban sector. In Col. (1), we introduced only year dummies. We then introduce state dummies in Col. (2) and industry dummies in Col. (3). Our results clearly show that firms in urban areas are more efficient than those in rural areas. We bring in ownership type and location together in Col. (4) along with year, industry and state dummies. We find that public limited companies are more efficient than privately held and public sector firms. We next examine whether firm efficiency varies across size of the firm. We measured firm size in two ways: (a) Size as a categorical variable (nsize as zero to 6 is constructed as follows – 0 – 0-5, 1 – 6-10, 2 – 11-20, 3 – 21-50, 4 – 51-100, 5 – 101-500, 6 – 500+) and (b) Size measured as log of number of workers. Results are presented in Col. (5), Col. (6), Co. (7) and Col. (8). Both the variables suggest 'small is efficient' as we find that gains in efficiency is relatively higher in firms with less number of workers than large firms. But when we introduce a dummy capturing the status of the firm i.e, a formal firm or an informal firm, we find formal firms technically more efficient than informal firms. Taken together with our finding on firm size, this implies that there is an inverted U shaped relationship between efficiency and firm size, with mid-sized firms (smaller firms in the formal sector) the most efficient compared to small (mostly informal firms) and large-sized firms.

Table 11. Correlates of Absolute Technical Efficiency – SFA Method

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Location	0.00159	0.0183*	0.0154*	0.0148*	0.0136*	0.0139*	0.0136*	0.0140*	0.0135*	0.013*
	(0.00104)	(0.000950)	(0.00112)	(0.00112)	(0.00112)	(0.00112)	(0.00112)	(0.00112)	(0.00117)	(0.001)
Nsize					-0.00857*	-0.00945*	-0.00132			
					(0.000340)	(0.000381)	(0.00101)			
nsize*nsize							-0.00176*			
							(0.000205)			
orgtypdum1				-0.0166*		0.00540*	0.00639*	-0.000753	0.00117	-0.007*
				(0.00189)		(0.00198)	(0.00197)	(0.00193)	(0.00206)	(0.002)
orgtypdum2				-0.0119*		0.0104*	0.0122*	0.00682*	0.00665*	-0.0001
				(0.00187)		(0.00198)	(0.00200)	(0.00201)	(0.00214)	(0.002)
orgtypdum3				-0.0265*		-0.000801	0.00219	0.000471	-0.0109*	-0.018*
				(0.00469)		(0.00469)	(0.00467)	(0.00467)	(0.00496)	(0.005)
Emp								-0.000201*	-0.000193*	-0.0002*
								(1.16e-05)	(1.20e-05)	(0.000)
emp*emp								9.14e-08*	8.24e-08*	1.04e-07*
								(1.40e-08)	(1.41e-08)	(1.55e-08)
regiondum1									-0.0268*	-0.027*
									(0.00123)	(0.001)
regiondum2									-0.176*	-0.176*
									(0.00192)	(0.002)
regiondum3									-0.0501*	-0.052*
									(0.00129)	(0.001)
ASI										0.020*
										(0.001)
Constant	0.700*	0.688*	0.677*	0.680*	0.696*	0.698*	0.696*	0.689*	0.744*	0.737*
	(0.00133)	(0.00147)	(0.00185)	(0.00188)	(0.00206)	(0.00207)	(0.00208)	(0.00195)	(0.00207)	(0.002)
Industry effects?	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Year Effects?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
State Effects?	N	Y	Y	Y	Y	Y	Y	Y	N	N
Observa-tions	181824	181824	151120	150217	151120	150217	150217	150217	150217	150217
R-squared	0.109	0.244	0.256	0.257	0.260	0.260	0.260	0.260	0.194	0.195

Note: (a) Robust standard errors in parentheses; (b) * indicates level of significance at 10 per cent; (c) dummy for location (0-rural and 1 -urban), dummy for organization type (Orgtyp – 0-HUF+partnership+proprietorship, 1 – Pvt Ltd, 2 – Public Ltd, 3 - Govt), dummy for formal firm or informal firm (ASI) and dummy for region which is equal to 0 for WB, Orissa and Assam, 1 for Punjab, Haryana and Rajasthan and UP, 2 for MP, Maharashtra and Gujarat and 3for TN, AP, Karnataka and Kerala. Size is represented in two ways (a) Size as a categorical variable (nsize – 0 – 0-5, 1 – 6-10, 2 – 11-20, 3 – 21-50, 4 – 51-100, 5 – 101-500, 6 – 500+) and (b) Size measured as No. of workers and square of No. of workers.

Table 12. Correlates of Relative Technical Efficiency

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Location	0.450*	2.155*	1.816*	1.769*	1.637*	1.681*	1.638*	1.684*	1.711*	1.636*
	(0.104)	(0.0945)	(0.111)	(0.112)	(0.111)	(0.111)	(0.111)	(0.111)	(0.116)	(0.116)
nsize					-0.859*	-0.993*	0.231*			
					(0.0340)	(0.0376)	(0.101)			
nsize*nsize							-0.265*			
							(0.0206)			
orgtypdum1				-1.257*		1.054*	1.204*	0.548*	0.736*	-0.448*
				(0.190)		(0.198)	(0.197)	(0.194)	(0.207)	(0.211)
orgtypdum2				-0.961*		1.381*	1.659*	1.172*	1.168*	0.127
				(0.189)		(0.198)	(0.199)	(0.202)	(0.215)	(0.214)
orgtypdum3				-2.923*		-0.226	0.225	0.150	-1.153*	-2.132*
				(0.472)		(0.471)	(0.468)	(0.467)	(0.496)	(0.496)
emp								-0.0228*	-0.0227*	-0.028*
								(0.00118)	(0.00123)	(0.001)
emp*emp								1.02e-05*	9.82e-06*	0.000*
								(1.44e-06)	(1.48e-06)	(1.69e-06)
regiondum1									-2.072*	-2.121*
									(0.117)	(0.117)
regiondum2									-17.54*	-17.519*
									(0.192)	(0.192)
regiondum3									-3.896*	-4.106*
									(0.121)	(0.121)
ASI										2.844*
										(0.146)
Constant	77.17*	75.78*	74.39*	74.71*	76.38*	76.58*	76.34*	75.75*	80.85*	79.929*
	(0.126)	(0.148)	(0.185)	(0.188)	(0.206)	(0.207)	(0.208)	(0.196)	(0.197)	(0.206)
Industry effects?	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Year Effects?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
State Effects?	N	Y	Y	Y	Y	Y	Y	Y	N	N
Observations	181824	181824	151120	150217	151120	150217	150217	150217	150217	150217
R-squared	0.093	0.235	0.247	0.248	0.251	0.251	0.252	0.252	0.185	0.186

Note: (a) Robust standard errors in parentheses; (b) * indicates level of significance at 10 per cent; (c) dummy for location (0-rural and 1 -urban), dummy for organization type (Orgtyp – 0-HUF+partnership+proprietorship, 1 – Pvt Ltd, 2 – Public Ltd, 3 - Govt), dummy for formal firm or informal firm (ASI) and dummy for region which is equal to 0 for WB, Orissa and Assam, 1 for Punjab, Haryana and Rajasthan and UP, 2 for MP, Maharashtra and Gujarat and 3for TN, AP, Karnataka and Kerala. Size is represented in two ways (a) Size as a categorical variable (nsize – 0 – 0-5, 1 – 6-10, 2 – 11-20, 3 – 21-50, 4 – 51-100, 5 – 101-500, 6 – 500+) **a**nd (b) Size measured as No. of workers and square of No. of workers.

6.4 Productivity and Efficiency in the Indian Manufacturing: A Synthesis of Results

This study finds that estimates of TFPG in India are sensitive to the methods used in the computations (Table 13). GA and LP methods both show a decline in TFPG in informal sector. These methods give different results for the formal sector – while GA show a continuous TFPG decline, LP shows a decline only in the second period. Comparing efficiency at the firm level by location, ownership type and firm size, the paper finds higher efficiency among urban firms and public limited companies as compared to rural, privately held and public sector firms. The paper also finds that there is an inverted U shaped relationship between efficiency and firm size, with mid-sized firms the most efficient compared to small and large-sized firms.

Table 13. Trends in Productivity and Efficiency: Synthesis of Results

*Method**	*Formal Sector*		*Informal Sector*	
	1994-2001	*2001-2005*	*1994-2001*	*2001-2005*
GA	Decline	Decline	Decline	Decline
LP	Increase	Decline	Decline	Decline
SFA	Decline	Increase	Decline	Increase

Note: * GA and LP report TFPG and SFA reports technical efficiency.

7. Conclusion

Very few other issues in Indian economic development has generated so much debate than the measurement of total factor productivity (TFP) growth in Indian manufacturing. This paper contributes to the recent literature on TFPG estimation in India in four important ways. Firstly, it uses three different techniques – growth accounting (GA) (non-parametric), production function with correction for endogeneity – Levinsohn-Petrin (LP) (semi-parametric) and stochastic production frontier analysis (SFA) (parametric), from 1994-95 to 2005-06 to compute TFPG in Indian manufacturing to see how sensitive are the results to different estimation methods. Secondly, it uses firm/plant level-data in the estimation of TFPG, and therefore, estimates TFPG at the most disaggregated level. Thirdly, it pays careful attention to data issues and to methods of variable construction which have been the source of some of the debate on TFPG estimates in India. Finally, it brings together TFPG estimates of both the formal and informal manufacturing sectors, the latter being an important part of the overall manufacturing sector in terms of employment.

The results indicate that the TFP growth of the formal and informal sectors has differed greatly during the study period and that the estimates are sensitive to the technique used. While the GA and SFA methods show a decline in TFP growth in the formal sector in 1994-2001, the LP method shows an increase. In 2001-2005, the GA and LP methods show a decline in TFP growth, while the SFA method shows an increase for the formal sector. In the case of the informal sector, all three methods show a decline in TFP growth in 1994-2001. However, for 2001-2005, the GA and LP methods show a decline in 2001-2005 for the informal sector, while the SFA method shows an increase. The lack of convergence of the different methods on TFP growth estimates for the formal and informal manufacturing sectors in India suggest that any inference on productivity growth in India since the economic reforms of 1991 is conditional on the method of measurement used, and that there is no unambiguous picture emerging on the direction of change in TFP growth in post-reform India.

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