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PRODUCTIVITY MEASUREMENT IN INDIAN MANUFACTURING :

A COMPARISON OF ALTERNATIVE METHODS

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ABSTRACT

There is no other issue in explaining economic growth that has generated so much debate than the concept of total factor productivity (TFP) growth. The concept of TFP and its measurement and interpretation have offered a fertile ground for researchers for more than half a century. This paper attempts to provide a review of different issues in the measurement of TFP including the choice of inputs and outputs. The paper then gives a brief review of different techniques used to compute TFP growth. 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 1989-90 to 2005-06. The results indicate that the TFP growth of formal and informal sector has differed greatly during this 16-year period but the estimates are sensitive to the technique used.

Key word : TFP, Technical Efficiency, Indian Manufacturing, Formal and Informal Sectors.

JEL Classification: D24, L60, O30

1. Introduction

There is no other issue in explaining economic growth that has generated so much debate than the concept of total factor productivity (TFP) growth. The concept of TFP and its measurement and interpretation have proved a fertile ground for researchers after the initial work of Abramovitz (1956) and Solow (1957). Three different views exist on what TFP is (Lipsey and Carlaw 2001). The conventional view considers that TFP is the measure of the rate of technical change (see for example, Law, 2000; Krugman, 1996; Young, 1992 among others). The second view (Jorgensen and Griliches, 1967) regards that TFP measures only the free lunches of technical change, which are mainly associated with externalities and scale effects. The third view is highly skeptical whether TFP measures anything useful (Metcalfe, 1987; Griliches, 1995).

The differing views on TFP emerged as the researchers attempted to explain the long-run growth for the United States and other countries. The concept gained prominence after the realization that in the long run the input growth is subject to diminishing returns and will be insufficient to generate high output growth (Mahadevan, 2003). This also resulted in efforts to obtain more accurate estimates of TFP growth for different sectors as well as the economy as a whole.

This paper attempts to provide a review of the different issues in the measurement of TFP including the issue of choice of inputs and outputs. The paper then gives a brief review of different techniques used to compute TFP growth. Using three different techniques – growth accounting (non-parametric), production function with correction for endogeneity (semi-parametric) and stochastic production frontier (parametric) – the paper then computes the TFP growth of Indian manufacturing for both formal and informal sectors from 1989-90 to 2005-06. The results indicate that the TFP growth of formal and informal sectors has differed greatly over this 16-year period but the estimates are sensitive to the technique used.

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 also discussed in section 2. Section 3 gives a brief review of the literature on the TFP studies in India. Section 4 gives the methodology and data used in the estimation. This is followed by results of TFP growth using all the three methods in Section 5. Section 6 concludes.

2. Productivity Measurement – Review of methods and issues in estimation

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.[1] 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[2] 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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[1] As referred in Mahadevan (2003: 366).

[2] The biases and other issues involved in measuring capital is 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[3]

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.

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

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.

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.[4] 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 draw back 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.

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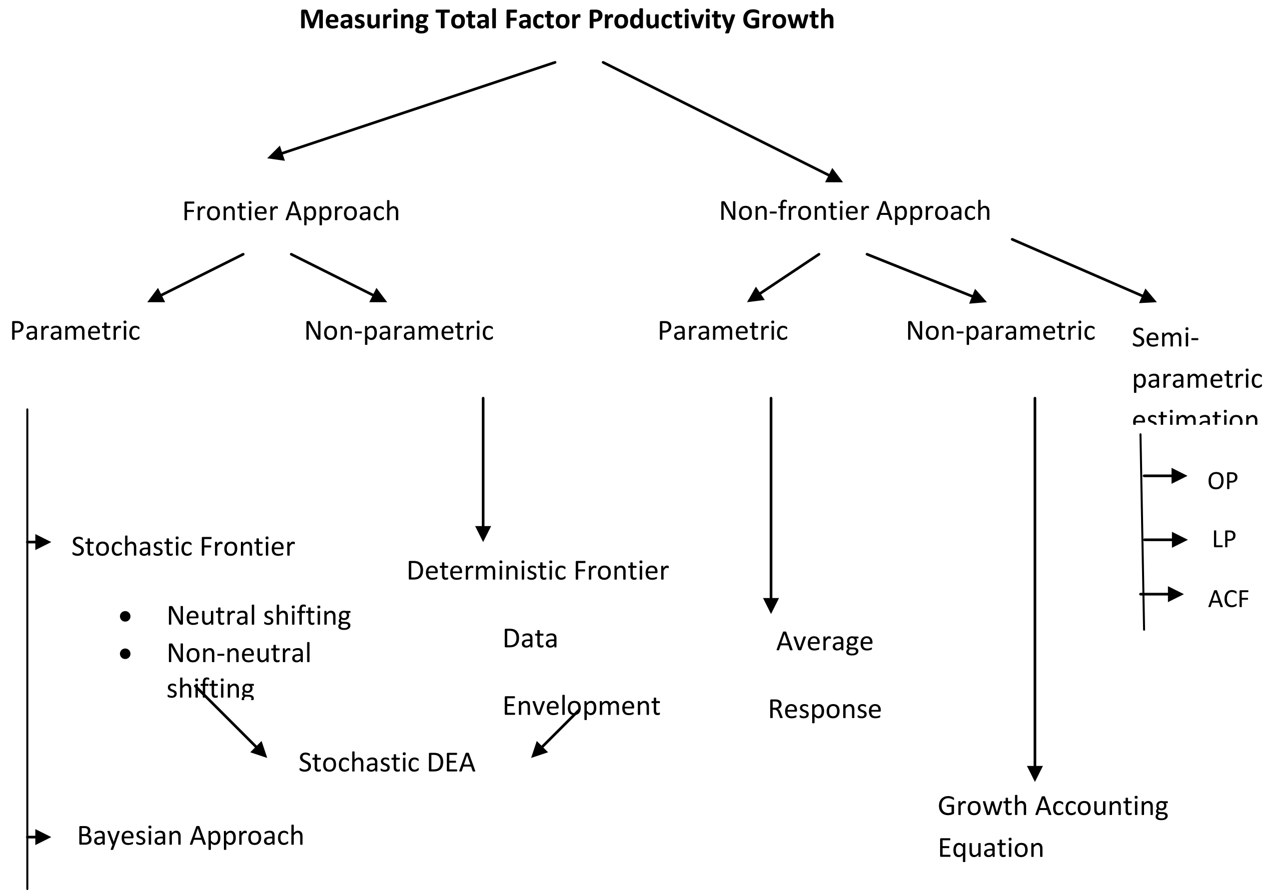
[4] Simultaneity bias is one ignored problem in parametric estimations of the production function. The problem arises because the right-hand side variables containing the inputs are chosen in some optimal way by producers themselves, thus are not exogenous. Adopting Zellner *et al.* (1966) argument that 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.

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).



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

Figure 1: Measurement of Total Factor Productivity - Approaches

Source: Adapted from Mahadevan (2003: 372)

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

2.2 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 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.

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 frontier and non-frontier approaches to estimate TFPG. Once decided to use frontier or non-frontier approach, the *fifth* choice is between using the parametric approaches – the 'Production Function Approach' or the stochastic frontier approach and the non-parametric approaches comprising 'Growth Accounting Approach' or the data-envelopment techniques. Within growth accounting approach, the *sixth* and the last issue is of assumptions that are necessary for implementing the approach.

2.2.1 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.[5]

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).

2.2.2 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 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.[6] 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

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[5] 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.

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

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.

2.2.3 Measurement of Inputs[7]

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).

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[7] This sub-section builds on 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.

2.2.4 Non-Frontier Approach: Production Function *versus* Growth Accounting Approaches

The two main approaches in non-frontier method for the estimation of growth in TFP are the Production Function Approach (PFA) – the parametric approach and the Growth Accounting Approach (GAA) – the non-parametric approach (Figure 1). Both the parametric and non-parametric approaches use the production function as a starting point. However, GAA is an estimator of technical change that does not have a stochastic term. Therefore, the model is not estimated statistically. As a result, the usual test statistics used in econometric work cannot be applied to GAA. On the other hand, growth accounting approach makes it easy to calculate the change in total factor productivity from year to year, while the econometric estimation (PFA) provides an average rate for a given period. In this subsection, we discuss each of these approaches.

The relation between productivity and productivity growth would be represented as follows:

$$O = A(t) * f(X) \quad (1)$$

$$V = A(t) * f(X') \quad (2)$$

where, O is the single homogenous output, V is real value added, A(t) is index of technological change or of TFP; f(X) is the functional form specifying the relationship between the output (O) and the input vector (X) which includes labour, capital and raw-materials; f(X') is the functional form specifying the relationship between the output (V) and the input vector (X') which includes only factor inputs, *viz.*, labour and capital.

2.2.4.1 Production Function Approach

PFA involves specification of the functional forms for A(t) and for f(X) or f(X'). The functional form which is most often used for A(t) is given as:

$$A(t) = A_0 e^{\lambda t} \quad (3)$$

Above equation implies that technological progress occurs at a constant rate λ. The modelling of technological progress as in above equation has received sharp criticism. To quote Norsworthy and Jang (1992), "Production economics has only begun to recognize the importance of technology. Until recently, technological changes and its productivity effects have been ignored or, perhaps worse, proxied by faceless time trends".

Apart from the specification of technological change, one needs to specify the functional forms f(X) or f(X') in the PFA. Three major forms of production functions as employed in the empirical literature on productivity measurement are: (i) Cobb-Douglas (CD) production function; (ii) Constant Elasticity of Substitution (CES) production function; and, (iii) Transcendental Logarithmic (TL) production function. The most frequently used form of production function in empirical studies, *viz.*, CD production function, is given in equation (4). In this equation, V, L, K and t denote real value added, labour, capital and time, respectively. λ, α's and β's are constants and denote the rate of technical progress, partial elasticity of output with respect to labour and partial elasticity of output with respect to capital, respectively. Empirical estimates of this equation not only provide a measure of growth of TFP or the rate of technological change (λ) but also allow one to extract information on the returns to scale. If ($\alpha+\beta$ -1) is not significantly different from zero, the condition of constant returns to scale holds true. If this magnitude is greater (lesser) than zero, it depicts the condition of increasing (decreasing) returns to scale. Regarding CD function, Rodrik (1997) has cautioned that during situations when the sum of output elasticity of inputs is less than one, capital deepening would lead to a decline in share of capital over time and a corresponding increase in TFP growth.

A functional form more flexible than both CD and the CES functions was developed by Chirstensen, Jorgenson and Lau (1971, 1973). This functional form, known as the transcendental logarithmic or the translog production function (henceforth, TL), is given in equation (5).

$$\log (V/L)_i = a + (\alpha+\beta-1)\log L_i + \beta\log(K_i/L_i) + \lambda t + \mu_i \qquad (4)$$

$$\log V_i = \alpha_0 + \alpha_L(\log L_i) + \alpha_K(\log K_i) + \alpha_t t + 1/2\beta_{LL}(\log L_i)^2 + 1/2\beta_{KK}(\log K_i)^2 + \beta_{LK}(\log L_i)(\log K_i) + \beta_{Lt}(\log L_i)t + \beta_{Kt}(\log K_i)t + 1/2\beta_{tt}t + e_i \qquad (5)$$

TL function imposes fewer *a priori* assumptions regarding technology used in the production process. In TL function, technology does not have to be of the Hicks-neutral type; it does not have to proceed at a constant rate; the elasticity of substitution need not be either unity (as in the case of CD function) or constant (as in the CES function). Due to the problem of the very few degrees of freedom, the translog production function is not often used for empirical estimation of TFPG in a time series framework.

Semi-parametric approach[8]

The estimation of the coefficients of labour and capital using production function approach implicitly assumes that the input choices are determined exogenously. 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 overlooked by the researcher 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.

Researchers in the past have used techniques like fixed effect estimation to correct this bias. The fixed effects estimation however eliminates only unobservable *fixed* firm characteristics that may affect simultaneously input choices and TFP; there may still be unobserved *time varying* firm characteristics affecting input choices and TFP.

Simultaneity arises because productivity is observed by the profit maximizing firms (but not by the econometrician) early enough to influence their input levels (Marschak and Andrews, 1944). This means that

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[8] This section is heavily borrowed from Van Biesebroeck (2007).

the firms will increase (decrease) their use of inputs in case of positive (negative) productivity shocks. Thus estimating the production functions using ordinary least squares would result in biased parameter estimates because it does not account for the unobserved productivity shocks.

Olley and Pakes (1996) (henceforth OP) method overcomes the simultaneity problem by using the firm's investment decision to proxy unobserved productivity shocks. The estimation rests on two assumptions. First, productivity – a state variable in the firm's dynamic problem – is assumed to follow a Markov process and is unaffected by the firm's control variables. Second, investment – one of the control variables of the firm – becomes part of the capital stock with a one period lag. In the OP method, labour is treated as a non-dynamic input and capital is assumed to be a dynamic input. A firm's choice of labour has no impact on the future profits of the firm. The OP estimation involved two steps. The coefficients of the variable inputs and the joint effect of all state variables on output are estimated in the first step. In a two input framework, the former is just labour and the latter are capital and productivity. Investment is assumed to be a monotonically increasing function of productivity and inverting the investment equation non-parametrically provides an observable expression for productivity. This expression is used to substitute the unobserved productivity term of the production function, hence allowing identification of the variable input elasticities.

The coefficients of the observable state variables (capital if there are only two inputs) are identified in the second step by exploiting the orthogonality of the quasi-fixed capital stock and the current change in productivity. A nonparametric term is included in the production function to absorb the impact of productivity, to the extent it was known to the firm when it chose investment in the last period. The second term included in equation (7) below captures the unobserved productivity shock and uses the results of the first stage (i.e., equation 6).

The estimating equations for the two steps are

$$y_{ist} = \beta . l_{ist} + \gamma . k_{ist} + h_{is}(i_{ist}, k_{ist}) + e_{ist} \tag{6}$$

$$V_{ist} = \gamma . k_{ist} + g(\emptyset_{t-1} - \gamma . k_{t-1}) + \mu_{ist} + e_{ist} \tag{7}$$

The functions *h* and *g* are approximated non-parametrically by a fourth order polynomial or a kernel density. Once both the equations are estimated, we have estimates for all the parameters of interest. The labour coefficient is obtained in the first stage and capital coefficient in the second stage. These estimates are termed as OP estimates. A major advantage of this approach is the flexible characterization of productivity, only assuming that it evolves according to a Markov process. However, the method also has few drawbacks. OP method demands a strictly monotonous relationship between the proxy, which is investment, and output.

This means that observations with zero investment have to be dropped from the dataset in order for the correction to be valid. Given that not every firm will have strictly positive investment every year, this may lead to a considerable drop in the number of observations in the dataset, an obvious efficiency loss. This is all the more important for firms in the unorganised sector, where for years together firms hardly invest in capital. Levinsohn and Petrin (2003) developed an estimation technique that is very much similar to the one developed by OP but use intermediate inputs (*m*) as a proxy rather than investment.[9] Typically, many datasets will contain significantly less zero-observations in materials than in investment. This is what has been used in the present study. In LP, the first stage involves estimating the following equation:

$$y_{ist} = \beta_0 + \beta_l l_{ist} + \emptyset_t(m_{ist}, k_{ist}) + \varepsilon_{ist} \tag{8}$$

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

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

$$\omega_{ist} = E[\omega_{ist}|\omega_{ist-1}] + \epsilon_{ist} \tag{9}$$

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

$$E[\epsilon_{ist}|k_{ist}] = 0 \tag{10}$$

The equation (10) 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:

$$\epsilon_{ist}(\beta_k) = \omega_{ist} - E[\omega_{ist}|\omega_{ist-1}] = (\hat{\emptyset}_{ist} - \beta_k k_{ist}) - \hat{\varphi}(\beta_k) \tag{11}$$

---

[9] LP use electricity as a proxy in their study. In case, if the purpose is to find productivity of informal sector firms, this would eliminate large number of firms, especially in developing countries context, as majority of firms in the informal sector work without power.

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

However, Ackerberg, Caves and Frazer (2005) illustrate that the implicit assumptions required to identify the variable input coefficients in both LP and OP are relatively restrictive. They later generalized the approach, estimating the elasticities on both the variable and quasi-fixed inputs in the second step.

2.2.4.2 Growth Accounting Approach

The crux of the growth accounting approach (GAA) is the separation of change in production on account of change in the quantity of factors of production from residual influences, *viz.*, technological progress, learning by doing, managerial efficiency, *etc*. TFP growth proxies these residual influences. The origins of GAA can be traced back to Tinbergen (1942) and Solow (1957).

The three main indices - used in the GAA - are: (i) Kendrick arithmetic Index (KI) (Kendrik, 1961); (ii) Solow geometric Index (SI) (Solow, 1957); and, (iii) Theil-Tornquist or Translog-Divisia Index (TLI). The TLI is considered to be superior to both KI and SI. Following are the details of these indices.

i) Kendrick Index

Kendrick index measures TFP using a distribution equation derived from a homogenous production function and the Euler condition. The index is interpreted as the ratio of actual output to the output, which would have resulted from increased inputs alone, i.e., in absence of technological change. Kendrick index for TFP (A_t) for the time period 't' will be:

$$A_t = O_t / (w_o L_t + r_o K_t) \qquad (12)$$

where 'w_0'and 'r_0' denote the factor rewards to labour and capital respectively in the base year 'o'. Generally, income shares are used as weights to compute the ratio of output to a weighted combination of inputs. It is to be noted that use of these weights entails a number of assumptions, such as: factor rewards are equal to their marginal productivity. In other words, the applicability of marginal productivity theory of distribution is assumed. *Second*, technological change is of Hicks-neutral type. In the case of Hicks-neutral technical change the marginal rates of technical substitution remain unchanged and the technical progress increases the output attainable from a given bundle of inputs. The *third* assumption is that of constant returns to scale. In brief, the assumption of constant returns to scale combined with the applicability of marginal productivity theory yields the product exhaustion or the Euler's theorem, which means that entire output is exhausted by payment to labour and capital. Thus, in the base year A_0 will be equal to unity by definition.

One of the major limitations of the Kendrick Index is that it is based on a linear production function (and hence, infinite elasticity of substitution between the factors of production) and does not allow for the diminishing marginal productivity of factors of production.

ii) Solow Index

Solow (1957) used a linear homogenous Cobb-Douglas production function in order to obtain the TFPG. It is to be noted that all the assumptions of the linearly homogenous CD function, *viz*., disembodied Hicks-neutral technical progress and unitary elasticity of substitution are built into Solow (1957) residuals. The measure is computed as follows:

$$\frac{dA}{A} = \frac{dQ}{Q} - \left[\alpha \frac{dL}{L} + \beta \frac{dK}{K} \right]; \qquad \alpha + \beta = 1 \tag{13}$$

where α and β are the shares of labour and capital, and dQ, dL, and dK are the time derivatives of Q, L and K. This measure is equivalent to Kendrick's index for small changes in the quantities of inputs and outputs. The Solow concept of TFPG is unambiguous for infinitesimally small and continuous shifts in technology across time. Empirical estimates of productivity change are based on a discrete set of price and quantity data. A solution to this problem lies in using a flexible form of production function, which is twice differentiable.

iii) Translog Index

The Translog Index (also known as Tornqvist-Theil index) is a superlative index that is consistent with the flexible production function and can be applied to discrete data points (Ahluwalia, 1991). It not only accommodates discrete time analysis, but also imposes fewer *a priori* restrictions on the underlying technology of production. Another advantage of the Tornqvist-Theil index is that it accounts for changes in quality of inputs. Since current factor prices are used in constructing the weights, quality improvements in inputs are incorporated, to the extent that these are reflected in higher wage and rental rates (Capalbo and Vo, 1988).

The Tornqvist-Theil index provides consistent aggregation of inputs and outputs under the assumptions of competitive behavior, constant returns to scale, Hicks-neutral technical change, and input-output separability. However, Caves, Christensen and Diewert (1982) have shown that Tornqvist-Theil indices are also superlative under very general production structures, i.e., nonhomogeneous and nonconstant returns to scale, so they should provide consistent aggregation across a range of production structures (Antle and Capalbo, 1988).

The function takes the form:

$$TFPG = \left(\ln Q_t - \ln Q_{t-1}\right) - \sum_{i=1}^{n} 1/2\left(s_{i.t} - s_{i.t-1}\right)\left(\ln X_{i.t} - \ln X_{i.t-1}\right) \tag{14}$$

where TFPG represents total factor productivity growth, Q denotes output, X_i factors of production and s_i share of factors of production in total output at current prices. Most of the recent studies in the Indian context have used the discrete approximation of the translog production function in the form of TLI (see for example, Ahluwalia, 1991; Balakrishnan and Pushpangadan, 1994; Rao, 1996a; Pradhan and Barik, 1998; Trivedi *et al*., 2000; Goldar and Kumari, 2003 among others).

The above equation is based on a more general neo-classical production function for which the elasticity of substitution need not be infinite, equal to unity or even constant. However, the technical change is assumed to be of Hicks-neutral type. Further, if factors are paid their marginal products, TFPG measured gives the difference between the growth of real output and the rate of growth of factor and raw-material inputs.

Assumptions of Growth Accounting Approach (GAA)

In order to obtain unbiased estimates of TFPG using GAA, the assumptions of constant returns to scale, perfect competition and full capacity utilization are necessary. If these assumptions are violated, the TFPG estimates would be biased. The problem is aggravated when there is a change in policy environment. This is because the same factors that could lead to changes in TFPG could also change the degree of market power (price-cost margins) and the returns to scale parameter (Srivastava and Sengupta, 2000). The authors find that these assumptions do not hold in the Indian case, thus the traditional estimates of TFPG are pro-cyclical.

Production Function and Growth Accounting Approaches: A Comparison

It has been well documented in the literature (Rao, 1996a) that both PFA and GAA assume a well-behaved production function and a stable production function over time. The widely accepted advantage of the production function approach is that the assumptions of constant returns to scale and perfect competition need not be imposed. The estimates of parameters of the production function directly provide information about the factor shares. Moreover, if flexible functional forms are used, returns to scale or homotheticity property of production functions can be directly tested for. In this sense, the PFA scores over the GAA.

One of the major disadvantages of using PFA is the problem of identification of production function due to the simultaneity in determination of input intensities and output levels. The semi-parametric approach developed by OP and LP helps in overcoming the simultaneity problem to a certain extent. The problems of autocorrelation and multicollinearity encountered in the use of PFA vitiate the empirical estimates obtained by this approach. The massaging of the data to take care of these statistical problems renders it difficult to interpret the empirical results. The assumption of 'well-behaved' production function takes away flexibility and the ability of TL production function to approximate a non-homothetic production structure. A further drawback of the econometric approach is the greater difficulty of explaining the econometric methodology to a range of users, as well as the difficulty in replicating and producing productivity estimates on an ongoing basis. The limitation of GAA is that, if the share of capital is treated as a residual, it implies the assumption of constant returns to scale. Moreover, if output elasticities are proxied by the observed factor shares, it implies the assumption of a competitive market structure. Further, the use of a functional form other than CD production function in GAA can yield different results as it would be difficult to equate output elasticites with factor income shares.

According to Hulten (2000), the econometric approach to productivity measurement can be treated as complimentary to the growth accounting and index number approaches. The argument is based on several reasons. First, the output and input series constructed by using the index number approach can be used as variables in estimating productivity using the econometric approach, thus "the question of whether or when to use econometrics to measure productivity change is really a question of which stage of the analysis index number procedures should be abandoned" (Hulten, 2000). Second, the relative simplicity of the growth accounting and index number approaches can be used to help interpret the richer results of the econometric approach. Finally, by merging the different approaches, econometrics can be used to help explain TFP. In summary the "potential richness and testable set-up [of the econometric approach] make them a valuable complement to the non-parametric, index number methods that are the normal tool for productivity statistics" (Schreyer and Pilat, 2001).

2.2.5 Frontier Approach: Stochastic Frontier *versus* Data Envelopment Approaches

This section concentrates on frontier approaches that are used to estimate TFP growth. The frontier approach assumes that there exists an unobservable function (the production frontier or best-practice function) corresponding to the set of maximum attainable output levels for a given combination of inputs. The advantage of this approach is that it decomposes the changes in TFP into technological progress and technical efficiency change; the former associated with changes in the best-practice production frontier, and the latter with other productivity changes, such as learning by doing, improved managerial practice, and changes in the efficiency with which a known technology is applied. This distinction is essential for policy formulation, especially in developing countries, where identifying TFP growth with technological progress can miss the fact that technical efficiency change seems to be the most relevant component of the total change in TFP (Nishimizu and Page, 1982) and therefore, the introduction of new technologies without having realized the full potential of the existing ones might not be meaningful. The two main approaches in frontier method for the estimation of TFP growth are the stochastic frontier approach (SFA) – the parametric approach and the data envelopment analysis approach (DEA) – the non-parametric approach.

The Stochastic Production Frontier

The stochastic production frontier (SPF) method is credited to Meeusen and van den Broeck (1977) and Aigner, Lovell, and Schmidt (1977). They proposed a single-equation cross-sectional stochastic production frontier model which assumes that establishment i uses the input vector Xi to produce a single output Yi based on the following equation:

$$Y_i = f(X_i, \beta)\exp(\vartheta_i - u_i) \qquad i = 1,2,....,N \tag{15}$$

The error term in the model is comprised of two components, a traditional symmetric random noise component (ϑ_i) and a new one-sided inefficiency component (u_i). The ϑ account for measurement error and other random factors that are beyond the control of firms such as weather, strikes, luck and so on and are independently and identically distributed with mean zero and constant variance, σ_ϑ^2 . The u_i that captures technical inefficiency is a combined outcome of non-price and organizational factors that constrains a firm from achieving their maximum possible output from the given set of inputs and technology. The u_is are non-negative and assumed to be independently and identically distributed. Thus, when the firm is fully technically efficient (TE=1), u takes the value of 0 and when the firm faces constraints (0<TE<1) u takes a value less than 0. The magnitude of u specifies the 'efficiency gap", that is how far a firm's given output is from its potential output. Both the ϑ_i s and u_is are assumed to be independent of the regressors.

The direct estimates of the SPF model can be obtained by maximum likelihood method or generalized least square method. The crucial issue as regards the estimation of stochastic production frontier is assigning a proper functional from to the inefficiency term 'u'. The empirical models tend to differ primarily in their assumption relating to the inefficiency term u, and different studies have experimented with u taking on various distributions and produced different results. This remains a serious methodological problem of this approach.

The model was originally defined for the analysis of cross-sectional data, but various models to account for panel data have also been introduced, by Pitt and Lee (1981), Cornwell *et al.* (1990), Kumbhakar (1990), and Kumbhakar *et al.* (1991). Early studies using the stochastic frontier approach assumed that u was time-invariant, namely $u_{it} = u_i$. Later, Battesse and Coelli (1992) proposed a time-varying model for the technical efficiency effects in the stochastic production frontier for panel data. But all these models are based on the assumption that Hicks-neutral technology underlies the shifts of the production function. In other words, they considered only parallel shifts of the production frontier over time (where innovation improves the marginal productivity of all inputs equally). This is very much similar to the production coefficients of the average response function of the non-frontier approach that remains constant with the exception of the intercept term. Of late, the assumption on the underlying technology is relaxed to allow for non-neutral shifts in the production frontier such that the marginal rate of technical substitution at any input combination changes over time. This stems from the argument of Kalirajan and Shand (1994) who mentioned that a producer might obtain different levels of output from the same amount of input using different production methods. In reality, neutral shift is a special case whereas the more general case is non-neutral shift of the production frontier. They proposed the stochastic varying coefficients frontier approach so as to incorporate non-neutrality into the frontier approach.

The Data Envelopment Analysis Approach

The data envelopment analysis (DEA) approach proposed by Charnes, Cooper and Rhodes (1978) rests on the individual firm framework of Farrell (1957). Unlike traditional methods that look for the average path through the middle points of a series of data, DEA looks for a best practice frontier within the data. Using a nonparametric linear programming technique, DEA constructs a production frontier from observed input-output data without imposing a functional form on either technology or deviations from it. This implies that the programming framework lends naturally to the construction of frontier technology without requiring the assumption of cost minimization or profit maximization, which makes it superior to its counterparts.

Unlike the parametric estimation, the deterministic estimation has a single one sided error component where u is greater than zero represents technical inefficiency. As the deterministic method does not account for statistical errors, all deviations from the frontier constitute technical inefficiency. Thus it can be expected that TFP growth from non-parametric estimation would be lower than that estimated parametrically. Under the DEA methodology, TFPG is estimated as the changes in Malmquist productivity index.

The Malmquist Productivity Index

Malmquist productivity indexes were first introduced into the literature by Caves, Christensen, and Diewert (1982) and were empirically applied by Fare, Grosskopf, Norris and Zhang (FGNZ) (1994). FGNZ (1994) developed a non-parametric approach for estimating the Malmquist indexes, and showed that the component distance function could be derived using a DEA-like linear program method. This method constructs best practice frontier for each time period for each technology category. Comparing each unit to the best-practice frontier provides a measure of its catching up in efficiency to that frontier and a measure of shift in the frontier (or technological progress). Then, the Malmquist indexes, which measure the change in TFP, are calculated as a product of these two components.

The Malmquist productivity index is defined by using distance functions. The Malmquist TFP index measures the TFP growth change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Following Färe *et al.* (1994), the output-oriented Malmquist TFP change index between period s (the base period) and period t (the terminal period) is given by

$$m_0(y_s, x_s, y_t, x_t) = \frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} \left[\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)} \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)} \right]^{1/2} \quad \text{------------ (16)}$$

where the notation $d_0^s(y_t, x_t)$ represents the distance from the period t observation to the period s technology. A value of m_0 greater than one indicates positive TFP growth from period s to period t while a value less than one indicates a TFP growth decline. Note that while the product of the efficiency change and technical change components must by definition equal the Malmquist index, those components may be moving in opposite directions. For instance, a Malmquist index of 1.25 (which signals a productivity gain) could have an efficiency-change components less than one (say, 0.5) and a technical change component greater than one (say, 2.5).

The term inside the bracket is the geometric mean of the shifts in technology observed in period s and period t or the frontier effect which tells us how far the efficient frontier itself has shifted over time due to the use of better technology and equipment. The term outside the bracket measures the output-oriented measure of Farrell technical efficiency between period s and period t or the catching up effect indicating how far the unit has moved towards the efficient frontier due to the better use of technology and equipment. In other words, TFP growth can be decomposed as,

TFP Growth = Technical Efficiency Change (Catching up Effect) × Technical Change (Frontier Effect)

The TFP estimation requires solving of four LPs for each unit of analysis. The LPs are:

$$\begin{aligned} \left[d_0^t(y_t, x_t)\right]^{-1} &= \max_{\phi\lambda} \phi, \\ st \qquad -\phi y_{it} + Y_t\lambda &\geq 0, \\ x_{it} - X_t\lambda &\geq 0, \\ \lambda &\geq 0, \end{aligned}$$

$$
\begin{aligned}
\left[d_0^s(y_s, x_s)\right]^{-1} &= \max\nolimits_{\phi\lambda} \phi, \\
st \qquad\qquad -\phi y_{is} + Y_s\lambda &\geq 0, \\
x_{is} - X_s\lambda &\geq 0, \\
\lambda &\geq 0, \\
\left[d_0^t(y_s, x_s)\right]^{-1} &= \max\nolimits_{\phi\lambda} \phi, \\
st \qquad\qquad -\phi y_{is} + Y_t\lambda &\geq 0, \\
x_{is} - X_t\lambda &\geq 0, \\
\lambda &\geq 0,
\end{aligned}
$$

and

$$
\begin{aligned}
\left[d_0^s(y_t, x_t)\right]^{-1} &= \max\nolimits_{\phi\lambda} \phi, \\
st \qquad\qquad -\phi y_{it} + Y_s\lambda &\geq 0, \\
x_{it} - X_s\lambda &\geq 0, \\
\lambda &\geq 0,
\end{aligned}
$$

where y_{it} is a MX1 vector of output quantities for the *i*-th unit in the *t*-th year;

x_{it} is a KX1 vector of input quantities for the *i*-th unit in the *t*-th year;

Y_t is a NXM matrix of output quantities for all N units in the *t*-th year;

X_t is a NXK matrix of input quantities for all N units in the *t*-th year;

λ is a NX1 vector of weights and ϕ is a scalar.

DEA and SFA: A comparison

The DEA envelops observed input-output data without requiring *a priori* specification of the functional form. This turns out to be its major advantage because different specifications of the production function under the SFA provide different results and this remains a methodological problem. Another advantage of DEA, as argued in Gong and Sickles (1992), is that the method is more appealing than the econometric method as inefficiency is likely to be correlated with the inputs. Again, DEA allows for the use of nominal and physical values at the same time as inputs and outputs, since its objective is not to estimate the functional parameters but a relative measure of performance (Majumdar, 1996). Another advantage of DEA is that it can estimate even if firm produces multiple outputs, which is a norm in large number of industries, e.g., petrochemicals, power etc. However, DEA is not free from drawbacks, either. These drawbacks, which are in turn the advantages of the SFA, include the following. First, measurement error and statistical noise are assumed to be non-existent. Second, it does not allow for statistical tests typical of the parametric approach.

2.2.6 Comparison of Approaches - GAA, DEA, Regression Analysis (RA) and SFA

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.

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: Rajesh (2006) and own compilations

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.

3. 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.

Most of the empirical studies on productivity in India have focused on the growth in the TFP in manufacturing sector. A number of studies (see for example, Brahmananda, 1982; Ahluwalia, 1991; Dholakia and Dholakia, 1994; Majumdar, 1996; Rao, 1996a; Pradhan and Barik, 1999; 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. It is to be mentioned that turnaround of TFPG in 1980s has remained a matter of contention. 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.

In the post-reform period also, results are ambiguous. 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.

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: 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 PFA-LP - Levinsohn and Petrin methodology.

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.

4. Methodology and Data

4.1 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 (17).

$$\ln Q_i = \beta_0 + \beta_1 \ln K_i + \beta_2 \ln L_i + v_i - u_i \qquad \text{-------------------------- (17)}$$

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 (18) where we modeled the mean of u_i as a function of a host of firm-specific characteristics.

$$U_i = \delta' z_i + \omega_i \qquad \text{----------- (18)}$$

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:

$$TFPG = \left(\ln Q_t - \ln Q_{t-1}\right) - \sum_{i=1}^{n} 1/2\left(s_{i.t} - s_{i.t-1}\right)\left(\ln X_{i.t} - \ln X_{i.t-1}\right) \qquad \text{-----------} \ (19)$$

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 (20) separately for each of the 15 major Indian states.

$$\ln Y_{ijt} = A_{it} + \beta_L \ln L_{ijt} + \beta_K \ln K_{ijt} \qquad \text{---------------} \ (20)$$

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.

As mentioned earlier, the estimation of equation (20) using ordinary least squares (OLS) method does not correct for the endogeneity bias generally associated with the production function estimations. 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. We used intermediate inputs as the proxy to address this bias.

4.2 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.[10] 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 Uttrarakhand, Chattisgarh and Jharkhand 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.[11]

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[10] The NSSO conducts surveys on the unorganized manufacturing sector quinquennially. Though the NSSO initiated this survey in 1978-79, a complete firm level dataset was available only from 1994-95. This fits well with our objective too.

[11] 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.

4.2 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 2.2.2).
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.

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.[12]

Capital

The measurement of capital input has been a controversial topic in the theoretical as well as the empirical literature. As mentioned in subsection 2.3, 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

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[12] 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.

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.

5. Results

This section gives the TFPG estimates for different methods employed. Before giving the TFPG estimates, we discuss the basic characteristics of the selected states in terms of GVA, employment and fixed capital.

5.1 Basic Characteristics of Selected states

Table 3 reports the relative positions of 15 selected states in the formal and informal manufacturing sectors in terms of gross value added (GVA), employment (EMP) and fixed capital stock (FK). In 2005-06, the combined shares of 15 selected states (in all India totals) in GVA, EMP and FK were above 93 per cent in the informal manufacturing sector. In the formal manufacturing sector, these states account for above 80 per cent of GVA and more than 93 per cent of total workforce and capital invested. Maharashtra (row 9) is the leading contributor to employment in the formal manufacturing sector followed by Gujarat (row 4). Maharashtra has also contributed heavily to capital formation in the sector along with TN, AP and Gujarat. In terms of share in GVA, UP and Gujarat were the major contributors while the contribution by Maharashtra is found to be very low despite having high share in employment and fixed capital formation. In the informal manufacturing sector, Maharashtra and UP accounted for a major share in GVA and fixed capital stock. The largest contribution in employment in the informal sector came from WB followed by UP. A simple correlation between GVA with EMP and FK gives interesting pattern. For formal manufacturing, increased capital and employment has not resulted in high GVA, as the correlation is only 0.47 and 0.46 only. On the other hand in informal manufacturing, high capital and labour employment is resulting in high GVA (0.93 and 0.74 as the correlation).

Table 3: Relative importance of major states in Indian manufacturing: 2005-06

	State	Expressed as a percentage of All India Total					
		Formal Manufacturing			Informal Manufacturing		
		GVA	EMP	FK	GVA	EMP	FK
1	AP	6.1	6.4	11.0 (3)	5.3	8.1	6.1
2	Assam	0.9	1.4	1.4	1.6	1.7	0.7
3	Bihar	9.2	6.2	2.5	3.9	6.6	3.7
4	Gujarat	10.1 (2)	14.4 (2)	9.6	7.2	5.1	7.1
5	Haryana	3.0	4.5	4.2	3.1	1.5	6.1
6	Karnataka	1.8	7.8	6.5	6.4	5.4	5.7
7	Kerala	2.4	1.6	3.8	3.9	3.8	5.0
8	MP	7.3	5.3	3.8	3.8	6.0	4.5
9	Maharashtra	5.5	19.5 (1)	13.7 (2)	15.7 (1)	8.0	16.5 (1)
10	Orissa	0.9	2.4	1.7	2.2	5.6	1.1
11	Punjab	4.0	2.3	4.6	2.6	1.6	4.2
12	Rajasthan	4.1	2.6	3.2	4.3	3.6	4.4
13	TN	8.0 (3)	8.7 (3)	15.0 (1)	9.4	9.2 (3)	11.2 (3)
14	UP	10.4 (1)	6.4	7.6	14.4 (2)	14.9 (2)	12.1 (2)
15	WB	6.8	4.1	6.1	9.6 (3)	15.1 (1)	6.5
	Total (15 states)	**80.4**	**93.4**	**94.9**	**93.4**	**96.2**	**95.0**

Notes: GVA – Gross Value Added; EMP – Employment; FK – Fixed Capital; Figure in parenthesis is the rank for the particular category.

5.2 Results – Growth Accounting

TFPG estimates for the formal and informal sector obtained using growth accounting (GA) method are presented in Table 4. 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 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 4: 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.

5.3 Results – LP

The estimated CD production function (Table 5) 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. 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.

Table 5: LP estimates (at the four-digit level)

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

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

TFP growth estimates

The TFP reported a marginal increase in the formal manufacturing sector over the period 1994-2005 (Table 6). 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 6, 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.

We noticed a completely different picture with regard to TFP growth in the informal manufacturing sector (Table 7). 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.

Table 6: Total Factor Productivity Growth in the Formal Sector

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
UP	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
WB	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
MP	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
AP	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
TN	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.[13]

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[13] 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 7: Total Factor Productivity Growth in the Informal Sector

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
UP	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
WB	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
MP	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
AP	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
TN	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.

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 8). 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.

Table 8: Industry-wise TFPG estimates (LP) – Formal Sector

Industry	**Period 1 (1994/5 – 2000/1)**	**Period 2 (2000/1 – 2005/6)**	**Combined (1994/5 – 2005/6)**
Food	4.07	4.81	3.31
Tobacco	14.87	6.08	5.41
Textiles	12.86	3.17	3.20
Apparel	6.77	-8.44	1.21
Leather	9.30	-9.72	3.97
Wood	8.57	-4.40	-4.68
Paper	8.82	7.68	9.26
Publishing	8.20	-8.62	2.62
Petroleum	152.30	-22.53	-11.25
Chemicals	10.68	-10.61	-6.73
Rubber	12.82	-2.71	1.43
Minerals	12.49	12.70	11.28
Basic metal	7.22	8.62	8.69
Metal products	6.09	4.34	6.81
Machinery	6.44	1.25	0.81
Office machinery	3.81	-15.44	-20.63
Electrical machinery	10.25	-9.03	-5.17
Radio & Television	8.54	-19.19	-19.81
Medical, precision inst.	10.32	1.32	3.04
Motor vehicles	8.47	-10.80	-21.92
Transport equipment	13.96	-1.38	3.44
Furniture	8.68	-9.03	4.85
Average	11.34	-1.07	1.11

Note: Estimates are without outliers

On the contrary we observed a consistent decline in TFP in majority of the industries in the informal sector (Table 9). 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 (shaded in the table), 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.

Table 9: Industry-wise TFPG estimates (LP) – Informal Sector

Industry	Period 1 (1994/5 – 2000/1)	Period 2 (2000/1 – 2005/6)	Combined (1994/5 – 2005/6)
Food	-4.86	-0.03	-12.40
Tobacco	-2.51	-0.37	-7.04
Textiles	-1.34	-1.74	-8.12
Apparel	-11.79	-	-18.45
Leather	-4.35	-3.45	-13.07
Wood	-6.21	-1.28	-15.63
Paper	-4.64	-2.83	-5.64
Publishing	-7.81	-0.49	-9.82
Petroleum	-0.97	2.62	-5.08
Chemicals	-5.36	0.07	-3.83
Rubber	-2.41	-0.25	-4.18
Minerals	4.49	-0.55	-10.45
Basic metal	1.67	-1.46	-5.34
Metal products	-3.84	-1.20	-6.84
Machinery	-1.23	-0.12	-7.33
Office machinery	-8.29	-	-6.24
Electrical machinery	-6.90	0.63	-10.56
Radio & Television	-0.40	-3.26	-0.81
Medical, precision inst.	-0.58	-7.44	-6.50
Motor vehicles	2.87	-	13.76
Transport equipment	3.40	-0.42	-10.92
Furniture	-1.79	-0.48	-12.45
Average	**-3.0**	**-0.6**	**-9.4**

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

5.4 Results – SFA

This sub-section discusses the parameter estimates and levels of technical efficiency obtained by estimating the stochastic frontier production function. 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 10. 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.

Table 10: SFA estimates (without correction), 1990

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

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 11 and the relative efficiency scores in Table 12.

Table 11: Region-wise absolute efficiency scores, 1990-2006

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
UP	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
WB	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
MP	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
AP	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
TN	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 12: Region-wise relative efficiency scores, 1990-2006

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
UP	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
WB	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
MP	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
AP	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
TN	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

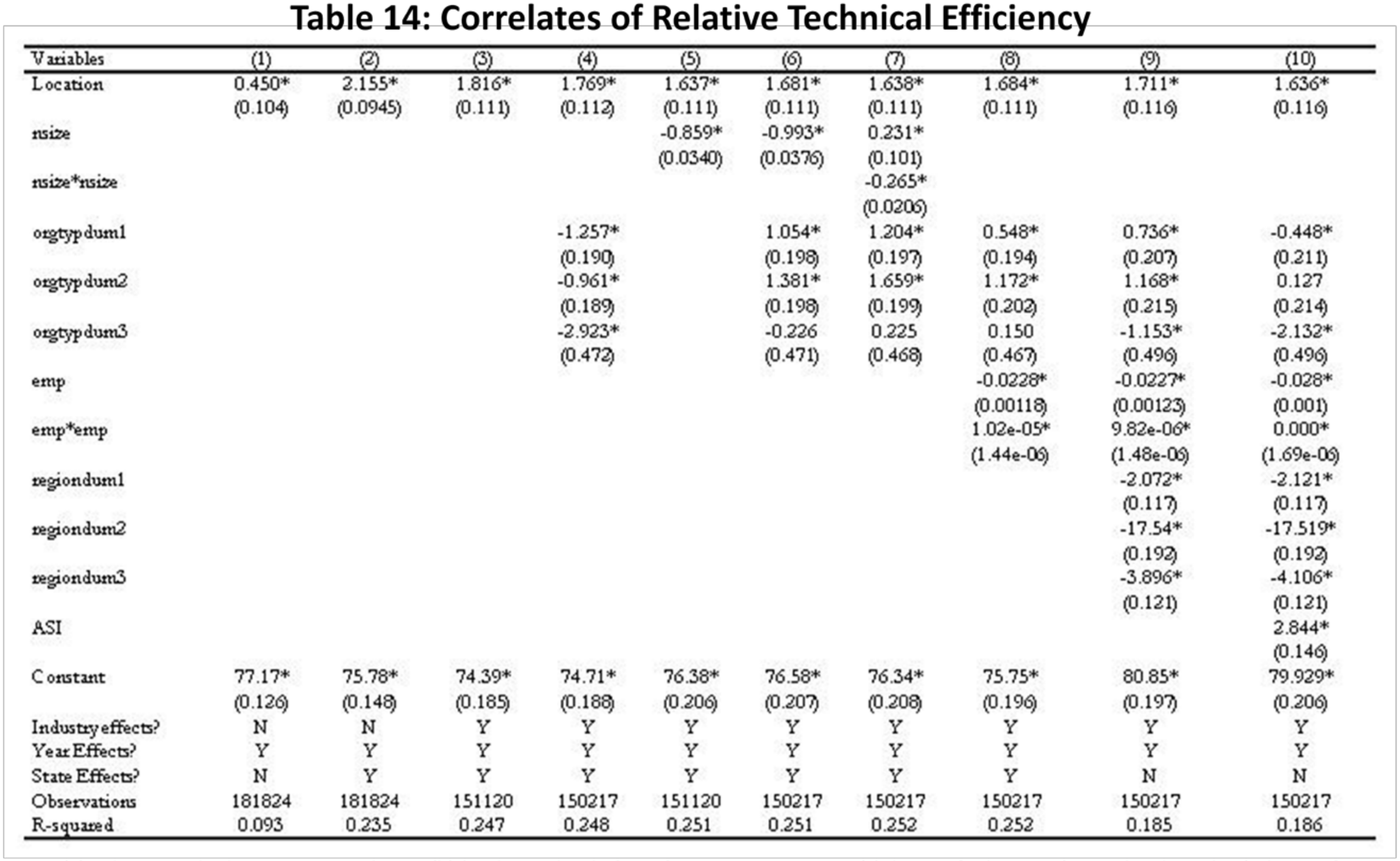
We also examined the factors that determine efficiency levels in formal and informal manufacturing sectors. The firm-specific characteristics included in the efficiency model are size, organization type (pvt. Ltd. /public Ltd. /public sector) , location (rural / urban), region and nature of the firm (formal/informal). We used both absolute and relative technical efficiency as our dependent variables in the model. Tables 13 and 14 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 13: Correlates of Absolute Technical Efficiency

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)		(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
Observations	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+) **a**nd (b) Size measured as No. of workers and square of No. of workers.

Table 14: 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.

5.5 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 15). 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 15: 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	Growth	Decline	Decline	Decline
SFA	Decline	Growth	Decline	Growth

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

6. Conclusion

There is no other issue in explaining economic growth that has generated so much scrutiny than the concept of total factor productivity (TFP) growth. The concept of TFP and its measurement and interpretation has been a fertile ground for researchers after the initial work of Abramovitz and Solow. Different views exist on what constitutes TFP – a measure of technical change or a measure of externality or a measure of ignorance. The concept of TFP gained prominence after the realization that in the long run the input growth is subject to diminishing returns and will be insufficient to generate high output growth. This also resulted in efforts to obtain more accurate estimates of TFP growth for different sectors as well as the economy as a whole.

This paper attempts to provide a review of the different issues in the measurement of TFP including the issue of choice of inputs and outputs. The paper then gives a brief review of the different techniques used to compute TFP growth. The techniques used to estimate TFP growth can be divided into two broad categories – frontier and non-frontier approaches. These approaches are further classified into parametric, semi-parametric and non-parametric techniques. A review of the different studies carried out in India reveals four important points: focus on organized or formal manufacturing; predominant use of real value added as a measure of output -- only in the last few years have productivity studies in India considered the use of gross output as a measure of production; a large number of studies have used the growth accounting approach; and the recent trend is to apply the frontier approach for estimating TFP growth.

Using three different techniques – growth accounting (non-parametric), production function with correction for endogeniety bias (semi-parametric) and stochastic production frontier (parametric) – the paper then computes the TFP growth of Indian manufacturing for both formal and informal sectors from 1989-90 to 2005-06. The results indicate that the TFP growth of the formal and informal sectors has differed greatly over this 16-year period but the estimates are sensitive to the technique used.

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