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Productivity Growth in Organized Manufacturing in Telangana

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Abstract

This paper makes an attempt to estimate Total Factor Productivity (TFP) growth by using both growth accounting approach and production function approach.Kendrick, Solow and Tornqvist-Theil indices are used to estimate TFP. TFP growth is also calculated by estimating Cobb-Douglas production function, Constant Elasticity of Substitution (CES) production function and Translog production function.The study covers the time-period from 1980-81 to 2012-13. Analysis and estimates are carried out for sub-period representing post-reforms from the year 1990-91 to 2012-13. In order to explain the study of labour productivity and its determinants and impacts on the other variables, annual data on value added, capital, employment, labour payment, profit are taken for organized manufacturing for the period 1990-91 to 2008-09.

All the three indices show positive TFP growth in the organized manufacturing in the Telangana state and across most of the districts, however, the magnitude of TFP growth estimated are not equal. The Solow index shows negative TFP growth in Hyderabad, Warangal and Khammam districts, while, TFP growth is negative for Rangareddy, Warangal and Khammam if estimated by Kendrick index. The estimates from Theil-Torquist index are positive for the study period for all the districts. Similarly, Cobb-Douglas production function, CES production function and Translog production functions for the organized manufacturing are estimated for Telanagana state and each district. The estimated C-D production function and CES production function shows no TFP growth in Telangana organized manufacturing and a negative TFP growth in case of Khammam (reverse is the case for rest of the districts). The Translog production function, otherwise, estimates a negative TFP growth for Telangana during the study period while a positive TFP growth in the post-reform period.

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1. Introduction

The path of manufacturing growth in India has been a subject of enquiry and strong debates (Balakrishnan, 2010). Equally significant has been the efforts to establish the close and eventual sources of its growth. Transformations in policy atmosphere, capability to attract factor inputs and its competent use have been central to such analysis. However, majority of such studies has examined economy wide trends or industry wide patterns (Tendulkar *et al.* 2006). As manufacturing activity in India has region specific characteristics and is subjected to a number of state level legislations, regional analysis assumes importance. However, only restricted efforts exist on regional industrial growth in India, particularly in the wake of changes in economic policies since 1991(Trivedi *et al.* 2011).

Against this background, the objectives of the paper are to

(i) To examine trends in labour productivity, capital intensity and capital output ratio in the organised manufacturing sector in Telangana state using data from the Annual Survey of Industries for the period 1980-81 to 2012-13.

(ii) To analyse the patterns of total factor productivity (TFP) growth in the organised manufacturing sector of the state using data from the Annual Survey of Industries for the period 1980-81 to 2012-13.

The paper consists of six sections including the introduction and summary. Section 2 gives a brief explanation of the Methodology used in the estimation of TFP growth. A detailed explanation to the methodology is given in Appendix 1 and Appendix 2. Section 3 gives details of database, variables used and the time period taken into consideration. The results from the estimation is presented in detail in section 4 and section 5 compares the manufacturing situation in Telangana and that of in India. Section seven presents a brief summary of the findings.

2. Methodology

In this paper, TFP growth is estimated by using both growth accounting approach and production function approach. Growth accounting approach demands the decomposition of output growth into contributions of input growth. The difference between the output growth and the weighted sum of input growth is termed as residual which is also known as technical change or TFP growth. Three indices namely, Kendrick Index, Solow index and Tornqvist-Theil index are used in the paper to estimate TFP growth. Production function is the mathematical formulation of outputs in relation to the inputs. TFP growth is also calculated by estimating Cobb-Douglas production function, Constant Elasticity of Substitution (CES) production function and Translog production function.[1]

3. Database, period of study and Variables used

Annual survey of Industries (ASI) is the prime source of data for organized manufacturing sector in India. The data for the newly formed Telangana state is assimilated for this study from the ASI reports prepared by Directorate of Economics & Statistics, Government of Andhra Pradesh, Hyderabad. The data for the 10 districts in Telangana is collected from these reports. The study covers the time-period from 1980-81 to 2012-13. Also in the study, analysis and estimates are carried out for sub-period representing post-reforms from the year 1990-91 to 2012-13.[2] In order to explain the study of labour productivity and its determinants and impacts on the other variables, annual data on value added, capital, employment, labour payment, profit are taken for organized manufacturing grouped for the period 1990-91 to 2008-09.

Output: ASI provides data on both value added and value of output at current prices. The ASI provides two measures of value added namely, net value added and gross value added. In this study the net value added (NVA) has been taken as the proxy for the output variables.

Employment: There are various measures provided by ASI to represent the employment variable. The concepts are namely, number of workers, total person engaged, man-days per worker, man-days per employee. The man-days concepts are very extensive and in a sense they represent the true picture of the labour employment but due to unavailability of data at disaggregated industry level, these concepts have not been used as the proxy for the employment. The total person engaged includes both waged workers and non-waged workers and is more than the waged workers. In this study total person engaged is used to represent the employment variable.

Capital: In the ASI, there are different types of capital such as fixed capital, productive capital, working capital, invested capital and physical working capital. The fixed capital in the ASI is given in book value. So the fixed capital does not really represent the value of fixed capital used in the production process at present. To avoid this undervaluation of capital, the capital stock by applying the Perpetual Inventory Accumulation Method (PIAM) has been calculated. To generate the series on net capital stock by PIAM the following steps have been followed:

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[1] Details of the methodology is given in Appendix-1.

[2] The data for the year 2011-12 is not published. So to maintain the gap in the data, proxies are estimated (assuming no disturbance in trend) by using the compound annual growth rate where the initial period is 2010-11 and the end period is 2012-13.

1. The average age of a machine is 25 years and of transport equipment is 20 years for manufacturing industry (National Accounts Statistics- Sources & Methods, 2007). So for fixed capital stock the average life in the study is taken to be 25 years as the weight of transport equipment is negligible. So the benchmark year for the estimation should be 1955-56. But due to lack of availability of data, 1980-81 is taken as the benchmark year. The fixed capital for 1980-81 at book value from ASI is adjusted for price changes by using WPI deflator for machinery at 2004-05 prices. This provides the benchmark capital stock (K0).

2. Gross investment in fixed capital is computed for each year by subtracting the book value of the fixed assets in the previous year and adding to that figure the reported depreciation in fixed assets in the current year. To obtain real gross investment series, the gross fixed investment series is deflated by the WPI deflator for machinery at 2004-05 prices.

Fixed capital at book value in year t is FC_t and D_t is the reported depreciation in that year. Then, the gross investment in year t, denoted by It, is obtained as below:-

$$I_t = FC_t - FC_{t-1} + D_t$$

Real gross investment is calculated as: $Real\ I_t = {}^{I_t}/_{R_t}$

Where R_t = deflator at period 't'

Real net investment in fixed assets is derived by subtracting economic depreciation (a proportion of fixed capital stock at the previous period) from real gross investment in fixed assets. The rate of depreciation (assumed to be in equal rate throughout the life of the machinery) is taken as 4 per cent, as the estimated life of the machinery is 25 years ((National Accounts Statistics- Sources & Methods, 2007).

Starting from the benchmark fixed capital stock and adding the real net investment in fixed assets for successive years, the net fixed capital stock series is constructed.

Capital Stock at period 't': $K_t = K_{t-1} - (0.04 * K_{t-1}) + Real\ I_t$

The calculated series on the capital stock is used to represent capital in this study.

Labour Compensation: ASI provides data on factor payment to labour on three different concepts such as wages to worker, total emoluments, provident funds & other expenses and above all labour compensation. In the ASI reports for Andhra Pradesh, provident funds & other expenses are not recorded. So for Telangana, total emoluments are taken as proxy for the labour compensation.

Profit: Profits is the factor payment to the use of capital. Profit is calculated as the gross value added less of labour compensation and depreciation.

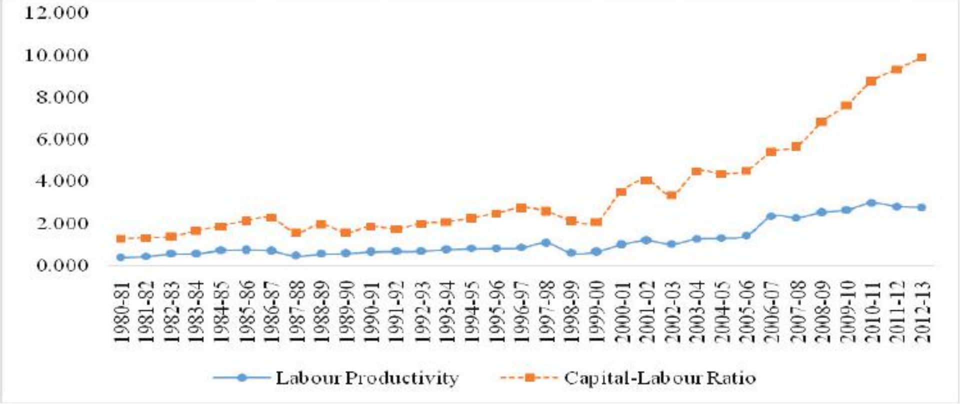
Deflators: Wholesale Price Index (WPI) deflator for manufactured products with base year 2004-05 is used to deflate variables like value added, output; and the WPI deflator for machineries at 2004-05 prices are used to adjust inflation in the calculation of capital stock.

4. Results from the estimates

4.1 Trends in labour productivity, capital intensity and capital-output ratio

The labour productivity and capital intensity of the registered manufacturing sector in the state show increasing trends for the period 1980-81 to 2012-13. It can be clearly seen from the figure below that the increase in labour productivity is much lower in comparison to the increase in capital intensity. The trends suggest a positive relationship between capital intensity and labour productivity. The positive relationship is called the 'technological progress function' by Kaldor which relate the growth in labour productivity and growth in capital intensity i.e. capital-labour ratio for the manufacturing sector. The labour productivity for the manufacturing sector in Telangana was 0.40 lakh rupees per person in 1980-81 which increased significantly to 2.76 lakh rupees per person engaged in 2012-13. The capital-labour ratio also increased from Rs. 1.29 lakh per person to Rs. 9.91 per person in 2012-13. The data also shows clearly that both labour productivity and capital intensity increased faster after 1999-2000.

Fig. 1 Trends of labour productivity and capital intensity in Telangana (values in lakh rupees per person engaged)



Source: estimated from ASI.
Base Year: 2004-05

The labour productivity and capital intensity trends in districts of Telangana, in general, demonstrate increasing trends during 1980-81 to 2012-13; but the pattern they follow, the rates at which they grow differ from district to district. The trends show that productivity and capital intensity rise, gather pace in the districts in the second half of the introduction of reforms in 1990-91. The pattern also shows there is an increasing divergence between labour productivity and capital-labour ratio. The capital-labour ratio in every district increased significantly except in few districts like Nizamabad, Karimnagar, Adilabad, Warangal, Khammam and Nalgonda. The labour productivity trend in these districts is quite flat indicating a very slow growth.The trends in these district hint at existence of labour intensive but high value added manufacturing in these sectors. The high value added and high labour intensity pulls down the productivity level together; and the low capital-using techniques keep the capital intensity in check. Labour productivity in Rangareddy and Medak has increased steadily while in Hyderabad, the increase is quite slow. Though capital-labour ratios in these three districts are high, still there is increasing divergence between capital intensity and labour productivity. This may hint at the labour productivity not being carried along with the capital intensity in these districts. The phenomenon of strong capital-deepening and capital inefficiency in these districts are highlighted in these graphs (Ahluwalia, 1991:52).

After analyzing the trends of labour productivity and capital intensity, (Fig.1) the growth rates of the variables involved are examined. Table 1 presents the growth rate of the different factor inputs and also the ratios involved for the time period 1980-81 to 2012-13. The growth rate for the sub-period 1990-91 to 2012-13 is also estimated to look into the progress that took place after the implementation of reforms. There are two ways of decomposing the output growth, one, as the sum of productivity growth and employment growth; and second as the weighted sum of factor input growth (labour and capital) and the residual. In this subsection, the first kind of decomposition is carried out. The other one is carried out in the next subsection which deals with growth accounting approach.

From Table 1, it can be observed that the net value added (NVA) increased in Telangana for the manufacturing sector in the period 1980-81 to 2012-13. The growth of NVA for the entire period of study is 8.31 percent per annum whereas it recorded a higher growth rate of 9.25 percent per annum during the period 1990-91 to 2012-13. Highest growth in manufacturing NVA is estimated in Mahboobnagar district (19 per cent) for 1980-81 to 2012-13 and around 14 percent for 1990-91 to 2012-13. The lowest growth is recorded in Hyderabad (1.2 per cent) for the period 1980-81 to 2012-13 and in Karimnagar (around 3 per cent) in the post reform period.

Table 1: Growth rates of variables and important ratios

	1980-81 to 2012-13						1990-91 to 2012-13					
	Capital Stock	Labour	NVA	Productivity	Capital Intensity	Capital -output ratio	Capital Stock	Labour	NVA	Productivity	Capital Intensity	Capital-output ratio
India	9.31	1.29	7.50	6.13	7.92	1.68	7.64	1.66	7.66	5.91	5.89	-0.02
Telangana	8.48	2.29	8.31	5.88	6.05	0.16	9.59	1.18	9.25	7.98	8.32	0.31
Mahboobnagar	15.85	5.49	19.00	12.81	9.83	-2.64	14.53	6.00	13.94	7.49	8.05	0.52
Rangareddy	12.26	3.97	9.94	5.74	7.98	2.11	11.38	3.93	10.97	6.78	7.18	0.37
Hyderabad	0.72	-3.15	1.24	4.52	3.99	-0.51	5.72	-1.45	4.48	6.02	7.28	1.19
Medak	11.63	3.45	11.22	7.51	7.91	0.37	8.32	2.96	9.40	6.26	5.21	-0.99
Nizamabad	10.99	3.52	6.77	3.14	7.22	3.96	8.08	-0.66	4.04	4.74	8.80	3.88
Karimnagar	10.17	-0.59	6.41	7.04	10.82	3.53	7.55	-1.76	2.90	4.75	9.48	4.52
Adilabad	1.20	0.89	6.89	5.94	0.31	-5.32	1.93	-1.01	8.67	9.77	2.97	-6.20
Warangal	11.49	2.19	8.07	5.76	9.11	3.17	12.27	0.61	3.48	2.86	11.59	8.49
Khammam	9.97	2.22	6.94	4.62	7.58	2.83	10.54	3.39	8.04	4.50	6.92	0.31
Nalgonda	14.73	6.35	14.64	7.79	7.87	0.08	10.87	5.04	12.28	6.89	5.56	-1.25

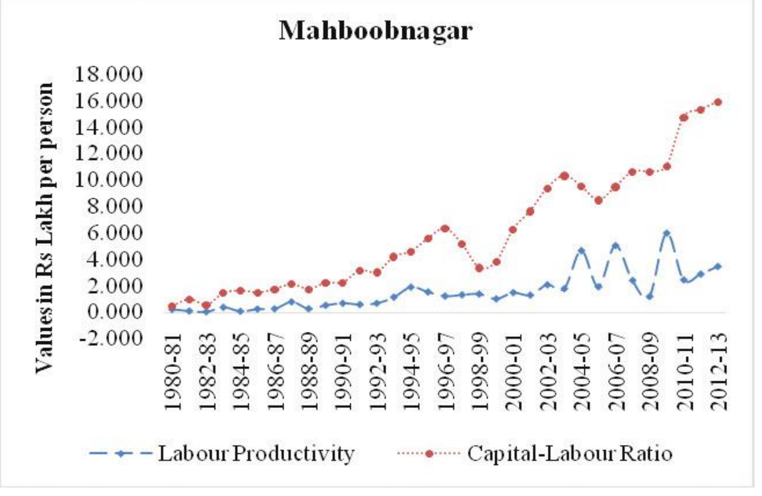
Source: Estimated from ASI

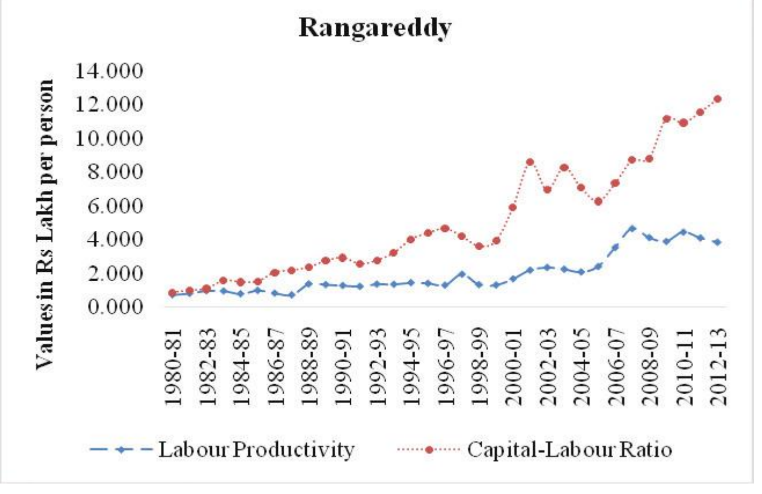
Base year: 2004-05

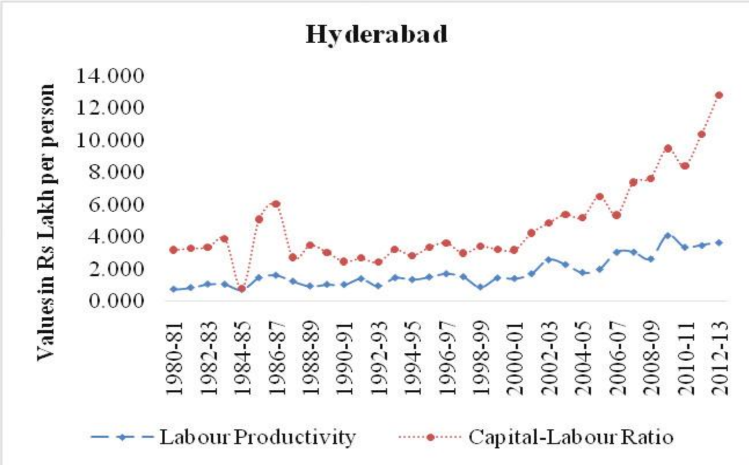
Note: The values are the antilogarithm of the relavant regression coefficient minus one when the equations estimated are of the form $\log Y = a + bT$ and T refers to time.

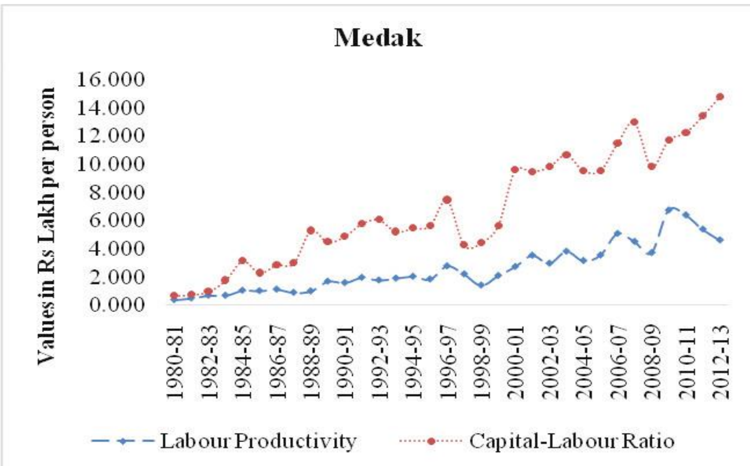
Table 1 also shows a very slow growth in the manufacturing employment in the study period. The employment grew at 2.3 per cent per annum in 1980-81 to 2012-13 and at 1.2 per cent for the period 1990-91 to 2012-13. This figure suggests the employment growth declined significantly during the post reform period. Nalgonda district has the highest employment growth in the period 1980-81 to 2012-13 at 6.4 per cent per annum while Mahboobnagar has the highest growth in employment at 6 per cent for the period 1990-91 to 2012-13. Negative growth in employment is recorded in Hyderabad and Karimnagar during the study period.

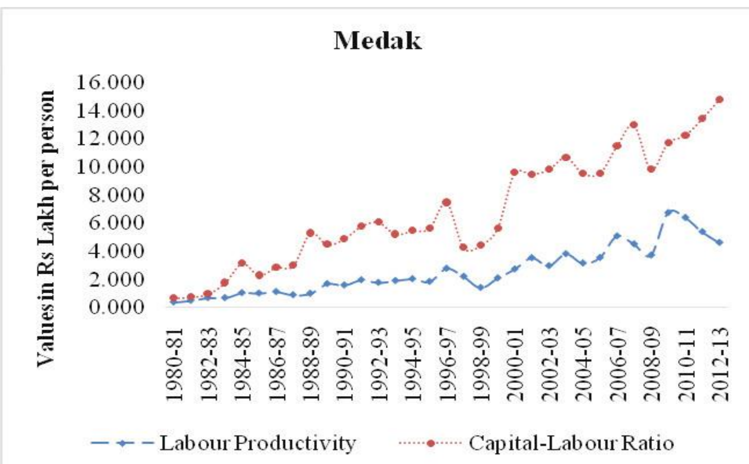
Fig. 2: Trends in labour productivity and capital intensity in different districts

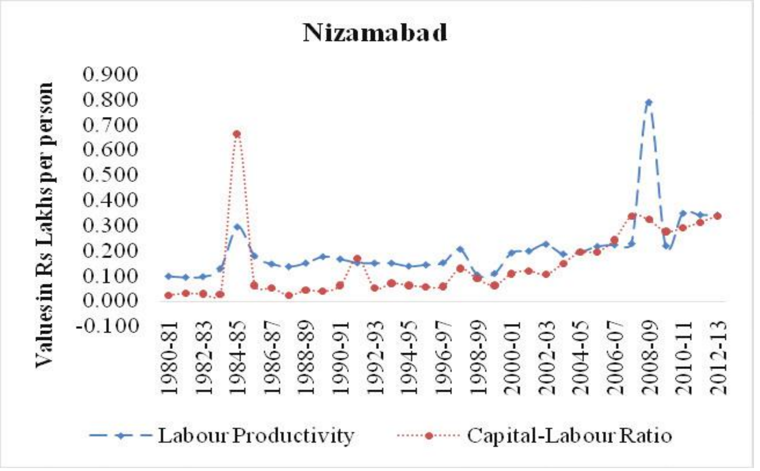


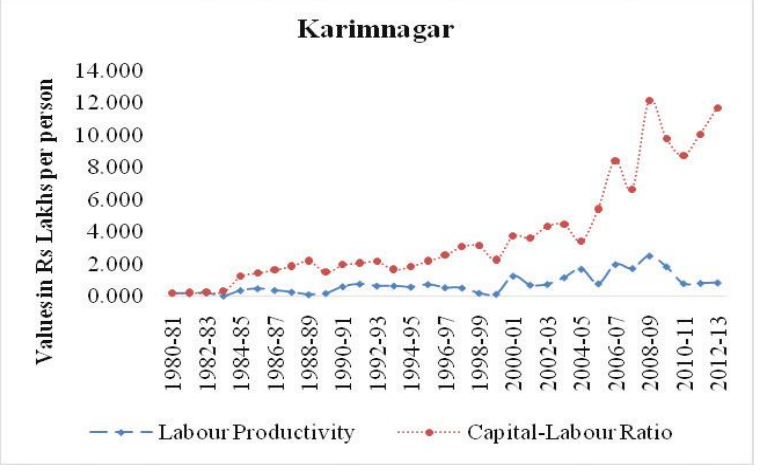


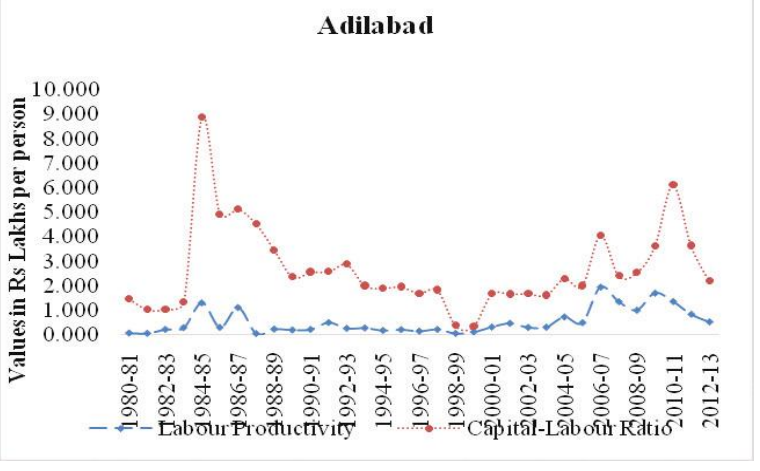

Hyderabad
Values in Rs Lakh per person
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-01
2002-03
2004-05
2006-07
2008-09
2010-11
2012-13
Labour Productivity
Capital-Labour Ratio

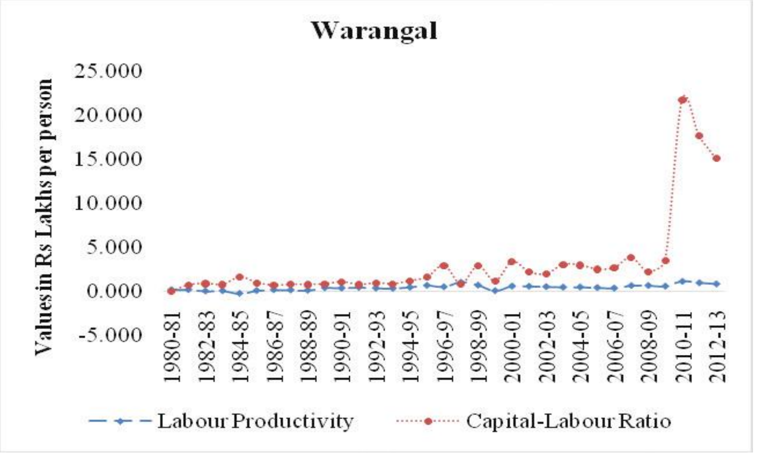

Medak
Values in Rs Lakh per person
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-01
2002-03
2004-05
2006-07
2008-09
2010-11
2012-13
Labour Productivity
Capital-Labour Ratio

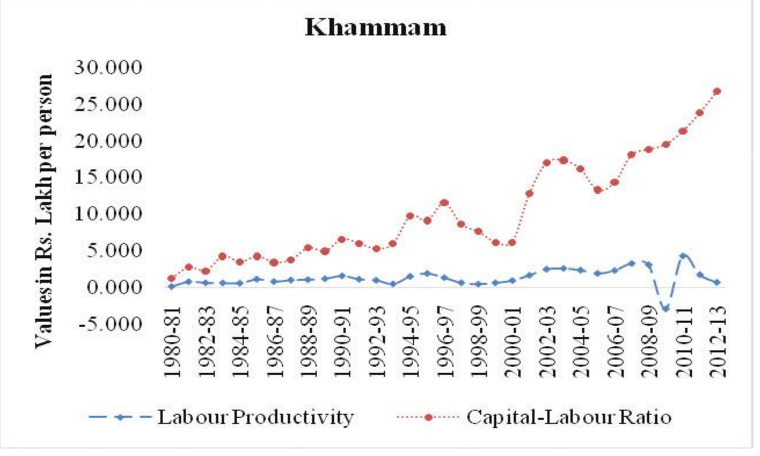

Medak
Values in Rs Lakh per person
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-01
2002-03
2004-05
2006-07
2008-09
2010-11
2012-13
Labour Productivity
Capital-Labour Ratio

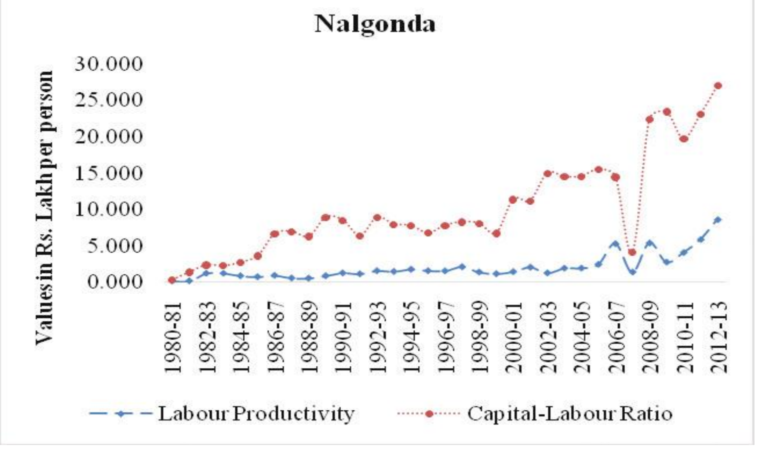

Nizamabad
Values in Rs Lakhs per person
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-0.100
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-01
2002-03
2004-05
2006-07
2008-09
2010-11
2012-13
Labour Productivity
Capital-Labour Ratio


Karimnagar
Values in Rs Lakhs per person
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-01
2002-03
2004-05
2006-07
2008-09
2010-11
2012-13
Labour Productivity
Capital-Labour Ratio


Adilabad
Values in Rs Lakhs per person
10.000
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-01
2002-03
2004-05
2006-07
2008-09
2010-11
2012-13
Labour Productivity
Capital-Labour Ratio







Source: estimated from ASI.
Base Year: 2004-05

The growth in labour productivity is around 6 per cent per annum for the period 1980-81 to 2012-13. But the growth rate accelerated after 1990-91 as it grew at 8 percent per annum. The high NVA growth along with low employment growth in the period resulted in the much faster productivity growth. Highest productivity growth is estimated in Mahboobnagar district at 13 per cent in the period 1980-81 to 2012-13 and lowest productivity growth is recorded in Nizamabad (3.1 per cent) for 1980-81 to 2012-13 (Table-1).

The other factor input, capital stock, grew at 8.5 per cent per annum during the period 1980-81 to 2012-13 but the rate of growth increased to 9.6 per cent in the post reform period. Rangareddy and Medak, being industrially developed, the capital base must have been stronger. Still these two districts maintained high growth rate of capital stock which hinted at high capital accumulation and high capital intensive industrialization in the districts. The high growth of capital intensity shows 'more machines to work with'. The high growth in the capital intensity is one of the causes of productivity growth (Table-1).

Capital-output ratio increased at 0.2 per cent per annum for the state as a whole. Capital-output ratio is the inverse of the capital productivity. The capital output ratio for Telangana remained almost stagnant for the entire period of study. The positive capital-output ratio or a negative capital productivity growth is because of the growing share of the capital-intensive manufacturing (Raj, 1976). The growth of capital-output ratio can be decomposed as the growth of capital intensity less of growth of labour productivity. Negative growth in capital output ratio is observed in Mahboobnagar, Hyderabad and Adilabad district for the period 1980-81 to 2012-13. In the above districts, share of capital intensive manufacturing declined during the period. Likewise negative growth in capital-output ratio is recorded in Medak, Adilabad and Nalgonda for the period 1990-91 to 2012-13 (Table-1).

4.2 Sources of Growth: Increase in factor inputs or Total Factor Productivity (TFP) growth

4.2.1 Growth Accounting Estimates of TFP growth

As mentioned in the earlier section, the second way of looking at growth is the decomposition of growth into the weighted growth of factor inputs and the residual. The residual actually, is the crux of the analysis in the productivity measurement. The residual is called the 'total factor productivity growth'.

Table 2: TFP estimates from growth accounting approach

Districts/State/ India	Solow Index		Kendrick Index		Tornqvist-Theil Index	
	1980-81 to 2012-13	1990-91 to 2012-13	1980-81 to 2012-13	1990-91 to 2012-13	1980-81 to 2012-13	1990-91 to 2012-13
Mahboobnagar	0.50	0.29	0.90	6.25	0.16	0.14
Rangareddy	0.01	0.01	-0.34	1.71	0.09	0.09
Hyderabad	-0.03	0.03	0.37	6.14	0.01	0.05
Medak	0.04	0.03	0.31	0.48	0.11	0.08
Nizamabad	0.00	0.08	2.19	-0.22	0.07	0.02
Adilabad	0.32	0.26	-0.46	-0.45	0.02	0.07
Karimnagar	0.28	-0.01	5.39	5.03	0.07	0.07
Warangal	-0.02	-0.17	-0.51	0.24	0.05	0.04
Khammam	-0.08	-0.18	-0.73	-0.42	0.03	-0.01
Nalgonda	0.24	0.13	2.34	2.15	0.19	0.15
Telangana	**0.02**	**0.02**	**0.35**	**3.30**	**0.08**	**0.08**
India	**0.03**	**0.25**	**5.42**	**1.18**	**0.08**	**0.07**

Source: Estimated from ASI
Base year: 2004-05
Note: The growth rates are average annual growth rate

The TFP growth for organized manufacturing in Telangana is estimated using three most popular indices of growth accounting method and is presented in Table 2. The estimates show positive TFP growth in the manufacturing sector in the period 1980-81 to 2012-13. The estimates also show the pace of TFP growth remained almost equal in the post-reform period also. It is interesting to observe that the magnitude of TFP growths differ according to the index used though the variables used are the same.

The TFP growth estimation is also carried out for all the districts. Mahboobnagar, Medak, Karimnagar and Nalgonda districts are found to have high TFP growth in registered manufacturing. The Translog index is estimated to be 0.2, 0.1, 0.1 and 0.2 for the above mentioned districts for the period 1980-81 to 2012-13. TFP growth in Hyderabad is the lowest among them (0.01) but the growth accelerated in the post reform period in Hyderabad.

The Solow's index and Kendrick's index show positive TFP growth while the estimates from the Kendrick index show very high TFP growth for Telangana manufacturing. TFP growth in Adilabad is estimated to be highest by Solow index while it is highest in Karimnagar if estimated by Kendrick index. High TFP growth is estimated in Nalgonda and Mahboobnagar during the period of study.

4.2.2 Production Function Estimates of TFP growth

Another dominant method of estimating TFP growth is the Production function approach. In this study, three types of production functions viz. Cobb-Douglas production function, CES production function and Translog production function are estimated for the period 1980-81 to 2012-13 and 1990-91 to 2012-13.

Table 3: TFP growth estimates from production function approach

India/State/ Districts	Cobb-Douglas production function		CES production function		Translog production function	
	1980-81 to 2012-13	1990-91 to 2012-13	1980-81 to 2012-13	1990-91 to 2012-13	1980-81 to 2012-13	1990-91 to 2012-13
India	**0.05**	**0.08**	**0.08**	**0.08**	**0.165**	**-0.621**
Telangana	**0.00**	**0.00**	**0.00**	**0.00**	**-0.208**	**1.364**
Mahboobnagar	0.10	0.01	0.16	0.02	-1.311	-1.994
Rangareddy	0.09	0.06	0.05	0.06	0.464	0.267
Hyderabad	0.03	0.02	0.02	0.01	0.097	-0.078
Medak	0.05	0.03	0.05	0.03	0.206	0.581
Nizamabad	0.02	0.02	0.00	0.01	0.037	0.087
Adilabad	0.04	0.04	0.04	0.06	-0.694	-0.575
Karimnagar	0.05	0.07	0.06	0.07	-0.110	0.072
Warangal	0.08	0.02	0.07	0.03	0.038	0.104
Khammam	-0.05	-0.04	-0.05	-0.01	0.736	1.634
Nalgonda	0.04	-0.03	0.05	-0.03	0.288	-1.215

Source: Estimated from ASI

Base year: 2004-05

Note: The growth rates are average annual growth rate

Cobb-Douglas Production Function:

The estimates of C-D production function for Telangana shows no TFP growth in the manufacturing sector during the period 1980-81 to 2012-13 and for the post-reform period. The estimate though is an insignificant one. The TFP estimates for the registered manufacturing in Mahboobnagar, Adilabad and Nalgonda districts show insignificant TFP growth. The TFP growth in Rangareddy is found to be 0.09 per cent and is significantly different from zero. Khammam shows a negative TFP growth during the period of study. The estimates also conclude at operation of constant returns to scale in Telangana organized manufacturing in the post reforms period (Table-3).

Translog Production function

The estimated Translog production function for Telangana manufacturing for the period concludes a negative of 0.02 per cent in TFP growth. Highest TFP growth is estimated in Khammam district for the period 1980-81 to 2012-13. TFP growth is estimated to be negative in Mahboobnagar, Rangareddy, Hyderabad, and Medak. This result confronts the estimated TFP growth in the Cobb-Douglas specification. For the period 1990-91 to 2012-13, the estimated TFP growth for Telangana manufacturing is 1.6 per cent. In this period, Khammam also registered the highest TFP growth in the state. Mahboobnagar and Nalgonda districts have negative TFP growth. The TFP growth estimated in this specification is much higher than that of the estimated from Cobb-Douglas specification. The estimated Translog production function for the period 1980-81 to 2012-13 hint at capital using bias in Hyderabad and Nizamabad; and a labour using bias in case of Khammam. As the homotheticity condition for Telangana manufacturing is not fulfilled, the operation of constant returns to scale is absent (Table-3).

CES production function

The TFP growth estimated for Telangana in CES specification is '0' which resembles the C-D production function. The TFP estimates show positive and significant TFP growth in Mahboobnagar, Rangareddy, Hyderabad, Medak, Karimnagar and Warangal. Khammam registered a negative TFP growth during the period 1980-81 to 2012-13. In the other districts, the TFP coefficients are estimated to be insignificant. The scale parameter for the Telangana manufacturing is estimated to be 0.9, hinting at operation of diminishing returns in the sector; while in Nizamabad, Karimnagar and Khammam, the estimates show operation of increasing returns to scale. The estimated elasticity of substitution is -1.2 for the period 1980-81 to 2012-13. A negative elasticity of substitution is a very complicate measure to interpret as it is affected by a variable from outside the model. A simple interpretation of this situation is that the factors are close complements of each other. It is estimated that the elasticity of substitution is greater than one in case of Karimnagar, Adilabad and Khammam. Here the capital is being substituted rapidly for labour. So the distribution pattern in the manufacturing sector in these districts will move towards capital and the capital share will increase over the period. In other districts (except Hyderabad), share of labour is expected to increase over the period as the elasticity of substitution is less than one (Table-3).

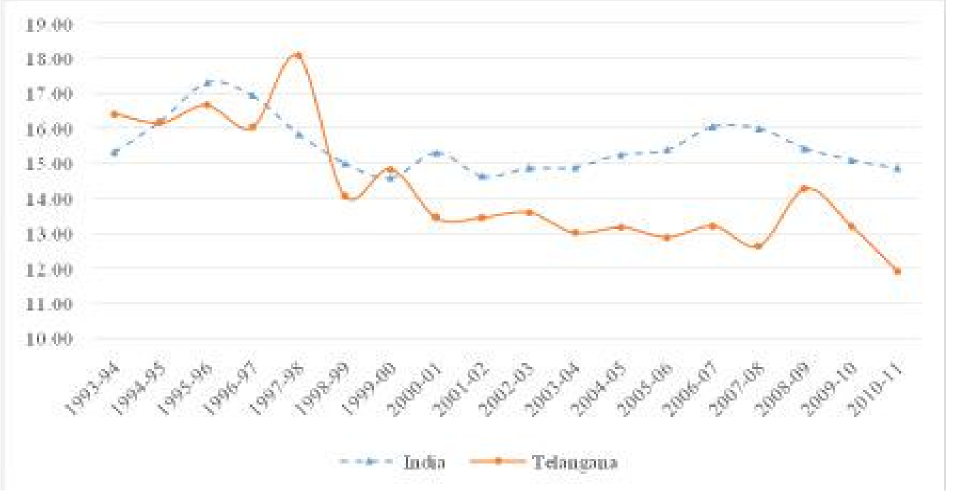
5. Comparison: Telangana's manufacturing vs. Indian manufacturing

Telangana as a newly formed state must have a comparison of performance of manufacturing sector between India and itself to facilitate policy formation for the specific state.

5.1 Share of manufacturing sector

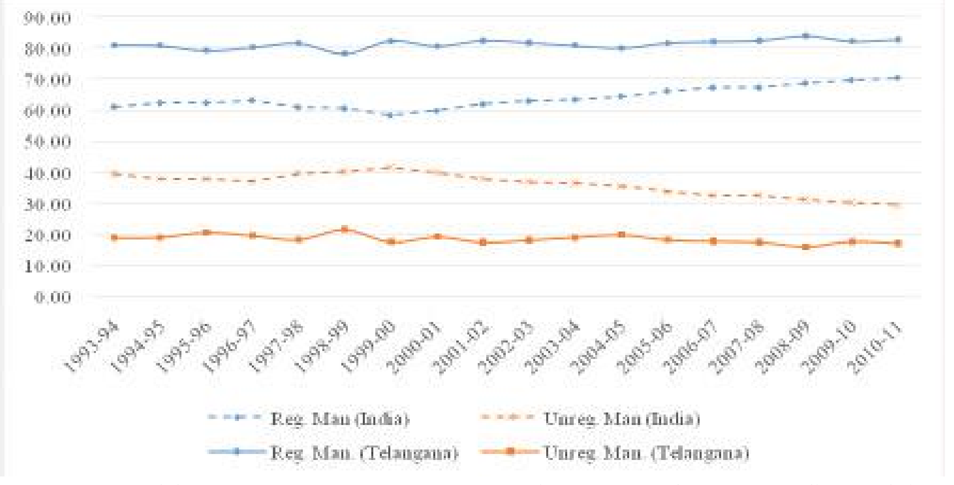
Figure 3 clearly suggests a fall in the share of manufacturing in Telangana state GDP. The share was 16.4 per cent in the year 1993-94 and had declined to 11.9 per cent during 2010-11. There are some ups and downs in the share but overall the trend suggests a decline. In comparison to Telangana manufacturing, share of India's manufacturing sector remains almost stable for the period of study. There is a marginal decline in the share from 15.32 per cent in 1993-94 to 14.87 per cent in 2010-11.

Figure 3: Share of Manufacturing in GDP



Source: Estimated from NAS, CSO, MOSPI; Directorate of Economics and Statistics, Andhra Pradesh.

Figure 4: Registered and Unregistered division in Manufacturing



Source: Estimated from NAS, CSO, MOSPI; Directorate of Economics and Statistics, Andhra Pradesh.

Figure 4 represents the composition of manufacturing GDP in Telangana and India. In Telangana, 82.8 per cent of the manufacturing sector is registered during 2010-11. The trend shows the share of registered manufacturing and unregistered manufacturing in Telangana remained almost stable for the period 1993-94 to 2010-11. In case of India, 61.2 per cent of the manufacturing GDP comes from registered manufacturing in the year 1993-94 which has increased to 70.38 per cent in the year 2010-11. So there is an equal fall in the share of unregistered manufacturing in India. The composition of manufacturing shows a higher per centage of registered manufacturing operates in Telangana when compared to India.

5.2 Growth rates

Table 4 gives a comparison of growth achieved by the manufacturing sector in Telangana and India. It can be seen that the manufacturing sector grew at a faster rate in India rather than in Telangana. The growth rate for the period 1993-94 to 2010-11, was 7.19 for India and 6.98 for Telangana. In the first half of the post-reforms, Telangana manufacturing grew at 6.9 per cent per annum in comparison to around 7per cent per annum at the all India level. However, second half of reforms saw a higher growth of manufacturing in Telangana than in India.

Table 4 also shows the growth in registered and unregistered manufacturing in Telanagana and India for the period of study. The growth rate estimates indicate higher growth in the registered manufacturing in comparison to unregistered manufacturing for the period 1993-94 through 2010-11 and also for the sub periods. The growth rate of registered manufacturing in Telangana is 7.5 per cent in comparison to 8 per cent in India. In the second half of the period of study, registered manufacturing in Telangana gathered pace so also the case for India. Unregistered manufacturing shows a slow growth during the period of study. It is interesting to see that the growth rate of unregistered manufacturing is slower than that of India's during the different sub-periods of the study.

Table 4: Growth rate of manufacturing sector

Period	India/ State	Manufacturing	Registered Manufacturing	Unregistered Manufacturing
1993-94 to 2010-11	India	7.19	7.95	5.70
	Telangana	6.98	7.52	4.91
1993-94 to 1999-2000	India	6.97	6.94	6.88
	Telangana	6.94	7.23	5.89
2000-01 ton 2010-11	India	8.72	9.93	6.43
	Telangana	9.76	10.77	5.81

Source: National Accounts Statistics, CSO, MOSPI; Directorate of Economics and Statistics, Andhra Pradesh

Base Year: 2004-05 price

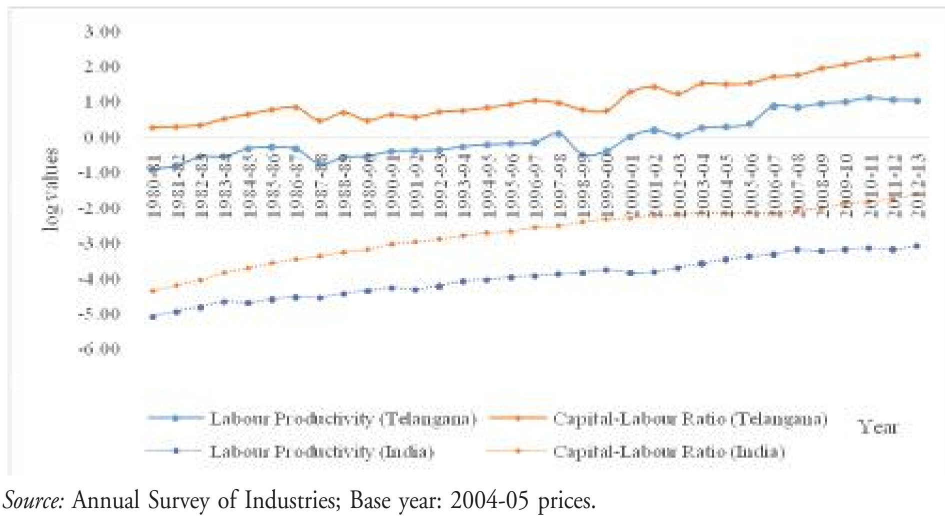
Note: The values are the antilogarithm of the relevant regression coefficient minus one when the equations estimated are of the form logY = a + bT and T refers to time

5.3 Trends and growth of labour productivity and capital intensity in organized manufacturing

The trend in labour productivity and capital intensity for organized manufacturing both in case of India and Telangana are increasing for the period 1980-81 to 2012-13 (Fig-5). The labour productivity for organized manufacturing in Telangana is 0.40 lakh rupees per person engaged in comparison to 0.006 lakh rupees per person engaged in India. Labour productivity increased to 2.76 lakh rupees per person engaged in Telangana and to 0.05 lakh rupees per person engaged in India in the year 2012-13. The value of capital intensity for Telangana also increased from 1.29 lakh rupees per person engaged to 9.91 lakh rupees per person engaged. The comparative figures for India was 0.01 lakh rupees per person engaged in 1980-81 and 0.20 lakh rupees per person engaged in 2012-13.

The capital stock grew at 9.3 per cent per annum in India for the period 1980-81 to 2012-13 and at 7.7 per cent in the period 1990-91 to 2012-13. The capital stock for Telangana grew at 9.6 per cent per annum for the period 1990-91 to 2012-13. Both India and Telangana maintained a slow growth rate in employment and even slower in the post reform period. The net value added in the Telanaga organized manufacturing increased more rapidly than that of India. The growth in labour productivity is 6.1 per cent per annum in case of Indian organized manufacturing and 5.9 per cent per annum for the Telangana manufacturing. The higher productivity growth is the corresponding result of the growth rate of employment. The labour productivity growth for Telangana (9.3) in the post reform period is higher than that of India. The capital intensity growth for Telangana organized manufacturing is faster in the post reform period. It grew at 8.3 per cent per annum in comparison to 5.98 per cent in India.

Figure 5: Labour productivity growth and capital intensity growth in organised manufacturing



Source: Annual Survey of Industries; Base year: 2004-05 prices.

5.4 Total factor productivity growth

The TFP growth for Indian manufacturing and Telangana manufacturing is estimated for the period 1980-81 to 2012-13 using both growth accounting and production function approach. The growth accounting approach is carried out by estimating Solow index, Kendrick Index and the Tornqvist-Theil index. The estimated indices show a positive TFP growth for India as well as Telangana. The estimated TFP growth by translog index came out to be almost same for India as well as Telangana. The Solow index concludes a 0.03 per cent TFP growth and 0.08 per cent TFP growth is estimated by the translog index. The Kendrick index shows higher TFP growth for the Indian as well as Telangana organized manufacturing. (Refer to Table 2)

The C-D production function estimated for India for the period 1980-81 to 2012-13 concludes a TFP growth in India. The TFP growth is 0.05 per cent for the period 1980-81 to 2012-13 and 0.08 per cent for the period 1990-91 to 2012-13. During the same period, the estimated C-D production function shows no TFP growth for Telangana manufacturing. The estimates also show operation of increasing returns to scale in Indian manufacturing for the post reform period whereas constant returns to scale is operating in Telangana. (Refer to Table 3 and Table A1 and A2)

The translog production function estimated for Indian manufacturing for the period 1980-81 to 2012-13 shows a TFP growth of 0.1 per cent. In the post reform period, the TFP growth is estimated to be a negative of 0.3 per cent. The estimated Translog production function for Telangana manufacturing concludes a negative of 0.02 per cent for the period 1980-81 to 2012-13 and 1.6 per cent TFP growth for post reform period. Estimates also show no Hicks-neutrality and no homotheticity for both Indian ad Telangana manufacturing. (Refer to Table 3 and Table A3 and A4)

The CES production function estimate concludes a TFP growth of 0.08 per cent for the Indian manufacturing for the entire period of study as well as post reforms period. The estimates for Telangana show no TFP growth in its manufacturing sector. The scale parameters show operation of increasing returns to scale for India whereas presence of diminishing returns to scale for Telangana manufacturing. The elasticity of substitution is estimated to be 1.1 for the entire period of study and 1.1 for the post reforms period. The estimates hint at an increasing share of capital in the value added for the Indian manufacturing. But no such conclusion can be made from the estimates for Telangana as the factor substitution is affected by some factor outside the model. (Refer to Table 3 and Table A5 and A6)

6. Summary

The paper discusses the trends and growth of different productivity measures for organized manufacturing in Telangana state as well as for different districts in the state. The labour productivity trend shows an upward movement across the districts and the state during 1993-94 to 2010-11. Total factor productivity growth is also estimated using the growth accounting and production function approach. Solow index, Kendrick index and Tornqvist-Theil index are used to estimate the TFP growth using growth accounting approach. All the indices show positive TFP growth in the organized manufacturing in the Telangana state and across most of the districts, nevertheless, the magnitude of TFP growth estimated are not equal. The Solow index shows negative TFP growth in Hyderabad, Warangal and Khammam districts while TFP growth is negative for Rangareddy, Warangal and Khammam if estimated by Kendrick's index. The estimates from Theil-Torquist index are positive for the study period for all the districts. Similarly, Cobb-Douglas production function, CES production function and Translog production functions for the organized manufacturing are estimated for Telanagana state and each districts. The estimated C-D production function and CES production function shows no TFP growth in Telangana organized manufacturing and a negative TFP growth in case of Khammam (reverse is the case for rest of the districts). The Translog production function, otherwise, estimates a negative TFP growth for Telangana during the study period while a positive TFP growth in the post-reform period.

The empirical analysis shows that the TFP growth among districts is significantly different from each other. In some districts, the TFP growth is positive in the entire study period from 1980-81 to 2012-13 but, when only the post-reform period is considered, it became negative. In some districts, it is the other way round. Districts like Mahboobnagar registered negative TFP growth in both the periods (Fig.6 and 7).

In Hyderabad, growth in capital stock is very slow and the employment growth is also negative. As the output growth is very low, corresponding productivity growth remained low. The growth in capital intensity is also found to be slower in Hyderabad compared to other districts. (Fig. 6 and 7).This results in slow process of capital accumulation affecting the TFP growth in Hyderabad. As growth rate of productivity could not keep up pace with the growth of capital intensity, capital-output ratio grew at a very slow rate. The discrepancy in the ratios indicates a strong capital-deepening phenomenon, but,at the same time, it also highlights the capital inefficiency resulting in negative TFP growth. Hyderabad is characterized by the presence of few large and medium industries like tobacco and beverages, electrical machinery, paper products, non-electrical machineries, metal products and repairing works. The flow of investment in these sectors is very low and the value added from this sector is also low. Further, the employment generation capacities of these industries are also very limited. Again after the reforms, Hyderabad became a major IT hub and a large chunk of investment flew into this sector. As a consequence, growth in the capital stock is very slow for the entire period. Fall in employment combined with slow rise in the capital stock contributed to increase in capital intensity. The capital stock declined further and became very low at the start of reforms period. It is only in the post reform period, the capital stock increased gradually. The tilted feature of Hyderabad manufacturing towards the low NVA sectors added pressure on the NVA growth. So the capital output ratio grew slowly in the district.

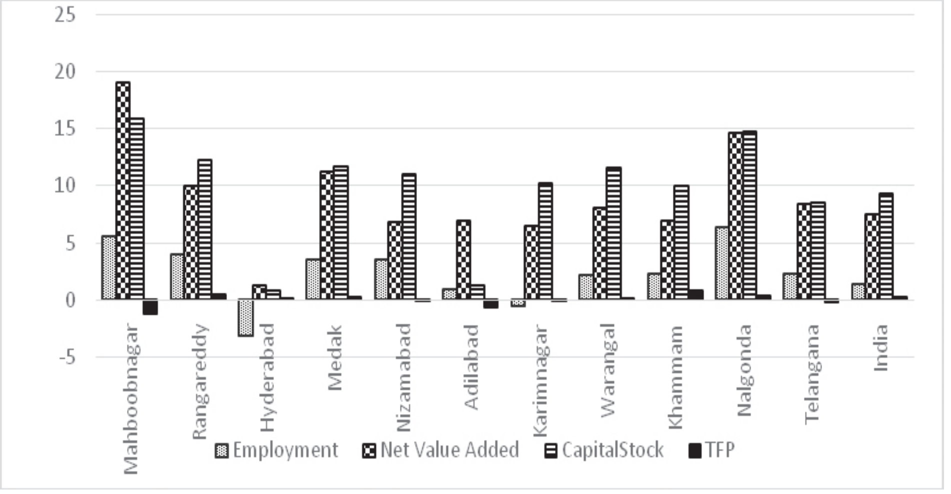
The TFP growth is negative for Adilabad, Karimnagar and Mahboobnagar for the entire period of study and became negative for Mahboobnagar, Adilabad and Nalgonda during post reform period. The growth in the capital-output ratio is negative for Adilabad for the study period as well as for the sub-period. It is also negative for the Nalgonda district in the post-reform period (fig. 6 and 7).This shows inefficient use of the capital and hence negative TFP growth in these districts. For Mahboobnagar district, TFP estimates are found to be negative as estimated by the translog production function and positive as estimated by Tornqvist-Theil index. The Tornqvist-Theil index considers only the autonomous TFP growth while translog production function takes into consideration the biases in the use of factor inputs and also the rate of change in TFP. Mahboobnagar district is characterized by low capital base and the growth of employment is found to be lower than the growth in the capital stock. The NVA growth is also high. So the mismatch between capital intensity growth and productivity growth is due to inefficient use of capital stock. NVA growth in this district in the post reform period slowed down as the industrial profile of the district became biased towards the low value added industries. Manufacturing sectors in the district are mainly agro-based. So they are either consumer non-durables or intermediate goods. As a result, TFP growth in these sectors is very low.

Rangareddy and Medak are the major industrial districts of the state. Majority of the large industries are situated in these districts. In addition, the industrial profile is also scattered across sectors. In these two districts, capital stock and NVA grew at a very high rate. So the capital intensity and labour productivity increased at almost an equal rate. The capital-output ratio grew at a very low rate. The trend suggests that growth in capital stock resulted in increase in the value added and the employment growth remained almost stable throughout (fig. 6 and 7). The low discrepancy suggests efficient use of capital in these two districts and hence, higher TFP growth. The industrial profile of these two districts is much tilted towards pharmaceuticals, high technical manufacturing, automobile industry and plastic products and is high in value addition. Major industries in the chemical sector, metallic products sector are being set up with huge investment. So they will continue to dominate the manufacturing sector in the state with high TFP growth.

The districts are ranked with respect to their NVA growth during the period of study from 1980-81 to 2012-13. Highest growth is found in Mahboobnagar, followed by Nalgonda district. Hyderabad ranked last among the districts. In terms of employment growth, Nalgonda comes first and is followed by Mahboobnagar. Hyderabad and Karimnagar recorded a negative employment growth. Mahboobnagar and Nalgonda stand first and second in terms of growth in capital stock. Hyderabad registered lowest growth in capital stock. In the post-reform period also, Mahboobnagar stands first in both NVA growth and capital stock growth. Nalgonda, and Rangareddy come close to the growth rates achieved by Mahboobnagar, while Hyderabad registered lowest growth of NVA and capital stock the post-reform period too. In terms of employment growth, Mahboobnagaris ranked first while Hyderabad achieved a negative growth. The TFP growth is highest in Khammam and Rangareddy during the entire period of study and is well supported by growth of employment, NVA and capital stock. In the post-reform period, TFP growth in Khammam is the highest and Medak has taken over Rangareddy for the second position.Mahboobnagar, in both cases, shows negative TFP growth.

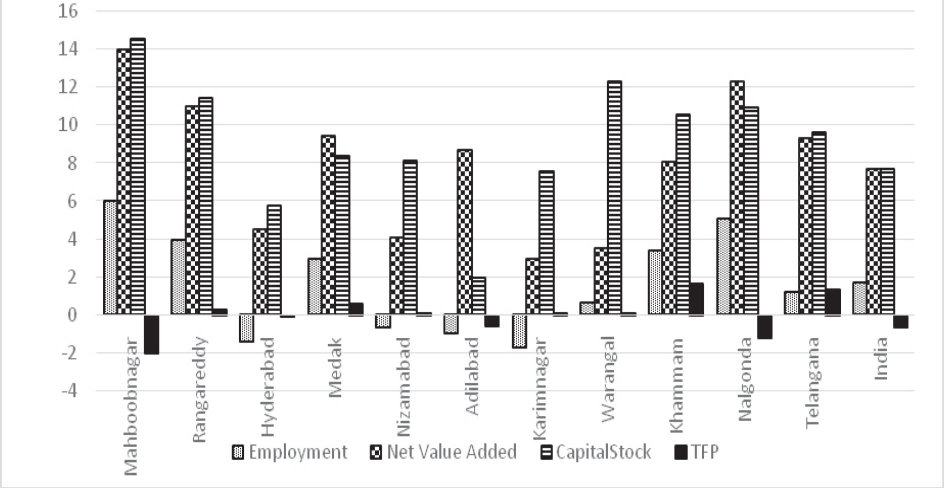
An important conclusion that emerges from the above analysis is that when the growth in capital stock overtakes the growth in NVA, the TFP in those districts reported improvement. Likewise, in districts like Rangareddy and Medak, wherein TFP performance is better, have also recorded high growth in capital stock and NVA. Nalgonda's growth in capital stock declined so also the NVA in the post-reform period. This reflects the inefficient use of capital and thus the decline in TFP growth. Telangana being a power shortage state during the study period negatively affects the manufacturing output. The decline in efficiency in the use of capital in the state, high time spent of the management with the government and regulatory bodies, inverse investment climate negatively impacted the manufacturing growth of the state (Veeramani, 2004:34).

Figure 6: Comparison of Employment, Net value added, Capital stock and TFP growth (1980-81 to 2012-13)



Source: Estimated from Table 1 and Table 2.
Note: TFP growth taken here is the Tornqvist-Theil index

Figure 7: Comparison of Employment, Net value added, Capital stock and TFP growth (1990-91 to 2012-13)



Source: Estimated from Table 1 and Table 2.
Note: TFP growth taken here is the Tornqvist-Theil index.

Table 6 : Correlation matrix among districts for the period (1980-81 to 2012-13)

	Employment	Net Value Added	Capital stock	TFP
Employment	1			
Net Value Added	0.867855	1		
Capital stock	0.830397	0.79005	1	
TFP	-0.08139	-0.42975	0.011485	1

Source: Estimated from Table 1 and Table 2.

Table 7: Correlation matrix among districts for the period (1990-91 to 2012-13)

	Employment	Net Value Added	Capital stock	TFP
Employment	1			
Net Value Added	0.876383	1		
Capital stock	0.749528	0.395372	1	
TFP	-0.28507	-0.48315	-0.18578	1

Source: Estimated from Table 1 and Table 2

The rankings of the districts show the correlation between the variables and their association with TFP growth. The correlation matrix even represents the growth in capital stock and TFP growth. The correlation coefficient between the two is smaller in the post-reform period. The fluctuations in the TFP growth in the post-reform period are high as the growth rate for different districts changes signs. The correlation coefficients between Capital stock, NVA and TFP growth show weak correlation. Thus the capital growth cannot be transformed into NVA growth at the same rate and there is insignificant correlation between capital stock growth and TFP growth (Table 6 Table 7).

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Appendix-1

A.1 Growth accounting approach (GAA)

Growth accounting is applied to time-series data on output and input growth to calculate growth in the residual known as technical change. The residual in the estimation may be due to measurement error, omitted variables, aggregation bias and model specification. The method demands the decomposition of growth in output into contributions of input accumulation and technical change. The application of growth accounting may be incorrect when the method is undertaken without establishing the form of production function underlying the data. The crux of the 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 applications of GAA date back to Tinbergen (1942) and Solow (1957). There are many ways of measuring total factor productivity through GAA but the three indices often used are: (i) Kendrick's arithmetic index (Kendrick, 1961); (ii) Solow's index (Solow, 1957); and (iii) Translog Index (Christensen and Jorgenson, 1973). In this present study, TFP growth is estimated through these indices.

A.1.1 Kendrick's arithmetic index[3]

Kendrick index measures total factor productivity using a distribution equation derived from 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 the absence of technological change. Kendrick index for TFP (At) for the period't' will be:

$$\frac{dA}{A} = \frac{Q_1/Q_0}{(wL_1+rK_1)/(wL_0+rK_0)} - 1 \qquad (1)$$

where 'w' and 'r' denote the factor rewards to labour and capital respectively in the base year '0'.

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 to the assumption that factor rewards are equal to their marginal productivity. Second, technological change is of Hicks-neutral type. The third assumption is that of constant returns to scale. Thus, in the base year, A_0 will be equal to unity by definition.

[3] See, Kendrick (1961).

A.1.2 Solow Index[6]

Solow (1957) used a linear Cobb-Douglas production function to obtain the TFP growth. So the Solow residuals are built on all the assumptions of the linearly homogenous C-D production function, viz., disembodied Hicks-neutral technical progress, a unitary elasticity of substitution and Euler's theorem.

The underlying C-D production function will be

$$Q = AL^{\alpha} K^{\beta} \quad (2)$$

The measure is computed as follows:

$$\frac{\hat{A}}{A} = \frac{\hat{Q}}{Q} - \left(\alpha \frac{\hat{L}}{L} + \beta \frac{\hat{K}}{K} \right)$$

where α and β are marginal productivities of labour and capital which are also the shares of labour and capital in the value added respectively.

$\hat{Q}, \hat{L}, and\ \hat{K}\ represent\ the\ derivatives\ with\ respect\ to\ time\ of\ Q, L, and\ K$

A.1.3 Translog index

The Translog Index (also known as Tornqvist-Theil index) is a superlative index, historically advocated by Tornqvist (1936) and Theil (1965) but introduced into the productivity measurement by Christensen and Jorgenson (1973). The index is consistent with the flexible production function and can be applied to discrete data points (Caves, Christensen & Diewert, 1982: 1411). The Translog index provides consistent aggregation of inputs and outputs under the assumptions of competitive behaviour, constant returns to scale, Hicks neutrality, and input-output separability.

The function takes the form:

$$TFPG = (lnQ_t - lnQ_{t-1}) - \sum \frac{1}{2}(s_{it} - s_{it-1})(lnX_{it} - lnX_{it-1})$$

WhereTFP growth represents total factor productivity growth, Q denotes output, X_i factors of production and si 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 Translog Index (see for example, Ahluwalia, 1991; Balakrishnan and Pushpangadan, 1994; Rao, 1996; Pradhan and Barik, 1998; Trivedi *et al.*, 2000; Goldar and Kumari, 2003).

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[4] Solow (1957: 314).

A.2 Production function approach (PFA)

Production function entails the mathematical relationship between output and factor inputs. The aggregate production function has been employed in neoclassical economics to explain both income distribution and economic growth. TFP is "pure technological progress" disembodied from the labour and capital equipment. After all, by being a residual, the higher the number of direct inputs into production, the less the TFP is. Hence, the TFP estimates can change wildly with changes in the specification of the aggregate production function.

A.2.1 Cobb-Douglas production function[5]

The advancement in defining the relationship of physical production and the amount of the labour and capital is dated back to the progressive introduction of Cobb-Douglas production function. In their seminal paper 'The theory of production (1928)' Cobb and Douglas made an attempt to deal with these questions as a case study of American manufacturing sector for the period 1899-1922.

The estimated production function can be written as in the form

$$V = A\ L^{\alpha} K^{1-\alpha} \tag{5}$$

Equation 5 gives the general form of Cobb-Douglas production function where, V is Output, L and K represent Labour input and Capital input respectively, A refers to the efficiency parameter, and α represents the distribution parameter. This equation represents only the homogenous production function of degree one. This function was first developed upon the assumptions of a first degree homogeneous function of labour, capital and output would approach zero when either of the two inputs approaches zero.

A more generalised form of the equation is used in production theory given as below:

$$V = A\ L^{\alpha} K^{\beta} \tag{6}$$

Equation 6 gives the most common form of Cobb-Douglas production function where, V is Output, L and K represent Labour input and Capital input respectively, A refers to the efficiency parameter, and α and β represent the distribution parameters. This equation represents the homogenous production function of any degree.

These above equations do not give the estimates of Total Factor Productivity growth as Technology is not a factor of production. So when in equation 6, a term for disembodied

[5] See, Cobb and Douglas (1928).

technology is introduced; we get a C-D production function of the form as below:

$$V = A_0 e^{\beta_t t} L^{\beta_l} K^{\beta_k} \tag{7}$$

where V, L, K and t refer to output, labour, capital and time respectively. Technology is assumed to be an exponential function of time ($e^{\beta_t t}$). It is also assumed to be Hicks- neutral. β_l and β_k are the distribution parameters. ($A_0 e^{\beta_t t}$) is the efficiency parameter which is a function of time.

A logarithmic transformation of C-D production function (equation 7) yields a linear equation

$$\log V = a + \beta_l \log L + \beta_k \log K + \beta_t t \tag{8}$$

The OLS estimation of the specification given in equation (8) yields estimates of β_l, β_k, and β_t. While β_t provides a measure of TFP growth, sum of β_l and β_k is a measure of degree of homogeneity.

A.2.2 CES production function

The CES production function allows the elasticity of substitution to take on any value in the range 0 to α. The simplest form of the function depicts constant returns to scale, given as below:

$$V = \gamma[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{\frac{-1}{\rho}} \tag{9}$$

where V, L, K refer to output, labour, and capital respectively. 'γ' refers to the efficiency parameter, δ refers to distribution parameter and ρ refers to the substitution parameter.

The more general form of the CES production function exhibits all the returns to scale according to the value of μ and also represents distribution with sum of distributive parameters not equal to one.

$$V = \gamma[\delta K^{-\rho} + \varphi L^{-\rho}]^{\frac{-\mu}{\rho}} \tag{10}$$

Where V, L, K refer to output, labour, and capital respectively. 'γ' refers to the efficiency parameter; δ and ϕ refer to distribution parameter; ρ refers to the substitution parameter, and μ refers to scale parameter.

The above specifications do not characterise any technical change. So to introduce Hicksian neutral technical change the specification described below is used.

$$V = \gamma_o e^{\alpha t}[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{\frac{-\mu}{\rho}} u^{e_{it}} \quad (11)$$

Applying a logarithmic transformation in equation (11)

$$\ln V = \ln \gamma_0 + \alpha t - \frac{\mu}{\rho}\ln[\delta K^{-\rho} + (1-\delta)L^{-\rho}] + u_{it} \quad (12)$$

where V, L, K refer to output, labour, and capital respectively. 'γ' refers to the efficiency parameter; δ and ϕ refer to distribution parameter; ρ refers to the substitution parameter, and μ refers to scale parameter. If the value of 'μ' is greater than one, then it is increasing returns to scale, for μ equal to one it is constant returns to scale and for diminishing returns to scale the value of μ will be less than one.

Kmenta specification of CES production function (1967)[6] :

An alternative method is proposed by Kmenta (1967) which is linear and can be estimated by least square technique. The approximation to CES production function can be written as:

$$\ln V_{it} = \ln \gamma + \mu\delta \ln K_{it} + \mu(1-\delta)\ln L_{it} - \frac{1}{2}\rho\mu\delta(1-\delta)(\ln K_{it} - \ln L_{it})^2 + \alpha t \quad (13)$$

$$\ln V_{it} = \beta_1 + \beta_2 \ln K_{it} + \beta_3 \ln L_{it} + \beta_4(\ln K_{it} - \ln L_{it})^2 + \alpha t \quad (14)$$

Where $\beta_1 = \ln(\gamma) \beta_2 = \mu\delta \; \beta_3 = \mu(1-\delta) \; \beta_4 = \frac{-1}{2}\rho\mu\delta(1-\delta)$

The estimated parameters of CES production function give an idea about the efficiency parameter, returns to scale parameter, distribution parameter and also the elasticity of substitution parameter. This specification is a development over the Cobb-Douglas production function which is based on a priori assumption like constant returns to scale, unit elasticity of substitution. The CES production function gives the substitution parameter.

A.2.3 Transcendental logarithmic (Translog) production function

The Translog production functions are quadratic in logarithms of the inputs. The Translog production function is a flexible functional form not much restricted by the a priori assumptions about technology. It does not assume Hicks Neutrality and constant rate of technological change, and also it allowed a variable elasticity of substitution of the inputs.

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[6] Kmenta (1967: 180)..

$$Log(V) = \beta_0 + \beta_l(LogL) + \beta_k(LogK) + \beta_t T + {}^1/_2\,\beta_{ll}(LogL)^2 + {}^1/_2\,\beta_{kk}(LogK)^2 + \beta_{lk}(LogL)(LogK) + \beta_{lt}(LogL)T + \beta_{kt}(LogK)T + {}^1/_2\,\beta_{tt}T^2$$

Taking the derivative of equation (15) on 't.'

$$\frac{\partial \log V}{\partial t} = \beta_t + \beta_{lt}(\log L) + \beta_{kt}(\log K) + \beta_{tt}\,(T) \qquad (16)$$

Where V, L, K and T represent Value added, Labour, Capital and Time. ($\beta_l + \beta_k$) gives the degree of homogeneity and thus returns to scale. The parameters of the equation (13) give different depiction of the technical change. β_t is the rate of autonomous TFP growth; β_{tt} is the rate of change in TFP growth, and β_{lt} and β_{kt} define the bias in TFP growth. If β_{lt} is positive, and if the share of labour increases and thus there is a labour using bias. If both are zero, then TFP growth is Hicks Neutrality type. The quadratic terms i.e. β_{ll}, β_{kk} and β_{lk}, give the curvature of the production curve. Equation (16) depicts the rate of technological change.

Appendix-2

Choice between alternative measures of total factor productivity

Which index is better?

In the study, TFP is estimated using the growth accounting approach by three indices viz. Solow index, Kendrick's index and the Translog- Divisia index. From the estimates and also theoretical backing, firmly clears Translog-divisia index as the most appropriate index for TFP estimate.

Theoretical consideration

One of the major limitations of the Kendrick Index is that it is based on a linear production function (and hence, an infinite elasticity of substitution between the factors of production) and does not allow for the diminishing marginal productivity of factors of production. Also the imputed assumptions of this index limit its implications.

The implicit assumptions of Hick neutrality, constant returns to scale and unitary elasticity limits its application in the reality. The TFP estimates also become unambiguous when there is small and continuous shift in technology across time and it approaches the Kendrick's index in such situation.

For such problems, there is need for an implicit production function which is twice differentiable. The translog index is also desirable because of its flexible structure of production not like a restricted structure of production followed by other indices. 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 reflected in higher wage and rental rates are incorporated. The translog index provides consistent aggregation of inputs and outputs under the assumptions of competitive behaviour, constant returns to scale, Hicks neutrality, and input-output separability.

Which form of aggregate production function is better?

In the study, TFP is estimated using the aggregate production functions viz. C-D Production function, CES production function and Translog production fucntion. The theoretical implication and the estimated results backs the use of Translog production function.

Theoretical consideration

As elasticity of substitution is a strategic economic indicator for growth and distribution of income, the estimation of the C-D production function with unitary elasticity of substitution may not carry much value for policy. The C-D production function is very restrictive and cannot be used as an economic tool in a vast range of applications.

The CES production function is an advance version of C-D production function and became more empirically viable due to less assumptions. The CES production function is very helpful in case of estimation of elasticity of substitution or scale parameter or distributive parameter. The additive and homogenous nature of the CES production function has been very helpful in statistical formulation in the production theory. The constancy of elasticity of substitution is also a departure from the popularly used C-D production function. But Transcendental logarithmic (Translog) production function take a greater leap forward by not employing the above two characteristics of earlier discussed production function. This makes the Translog production function far more applicable in the real situation.

The Translog production functions are quadratic in logarithms of the inputs. The Translog production function is a flexible functional form not much restricted by the a priori assumptions about technology. It does not assume Hicks Neutrality and constant rate of technological change, and also it allowed a variable elasticity of substitution of the inputs.

So choice of estimation of aggregate production function depends on the objectives of the study. If the objective is to estimate TFP growth or the nature of technological change then the Translog production function should be used. If the researcher intends to look at the factor substitution, scale parameter and distributive aspects it is better to use the CES production function.

Appendix Tables

Table A1: Cobb-Douglas Production Function (1980-81 to 2012-13)

Model: $\log V = a + \beta_k \log K + \beta_l \log L + \beta_t t$

	Intercept	log (K)	log(L)	Time	Adjusted R-squared	F-statistic	D-W Statistics
India	-6.96 (0.01)	0.12 (0.25)	1.03 (0.00)	0.05 (0.00)	0.99	1180.7	0.93
Telangana	-0.22 (0.89)	0.96 (0.00)	-0.02 (0.80)	0.00 (0.78)	0.97	394.96	1.31
Mahboobnagar	6.72 (0.31)	0.78 (0.19)	-0.83 (0.19)	0.10 (0.26)	0.88	77.92	1.95
Rangareddy	3.47 (0.47)	-0.26 (0.17)	0.90 (0.01)	0.09 (0.00)	0.96	240.76	1.10
Hyderabad	-0.20 (0.88)	0.42 (0.00)	0.55 (0.02)	0.03 (0.00)	0.81	45.16	1.85
Medak	0.62 (0.61)	0.38 (0.00)	0.49 (0.00)	0.05 (0.00)	0.97	390.04	1.97
Nizamabad	-0.29 (0.71)	0.25 (0.00)	0.66 (0.00)	0.02 (0.04)	0.88	75.89	2.10
Adilabad	2.10 (0.84)	0.27 (0.57)	0.37 (0.62)	0.04 (0.40)	0.47	10.56	1.41
Karimnagar	-3.64 (0.56)	0.96 (0.08)	0.12 (0.35)	0.05 (0.00)	0.49	11.43	1.78
Warangal	3.23 (0.49)	-0.10 (0.56)	0.56 (0.21)	0.08 (0.01)	0.69	23.62	1.53
Khammam	-2.31 (0.58)	1.22 (0.00)	-0.13 (0.71)	-0.05 (0.07)	0.71	26.80	1.02
Nalgonda	-1.41 (0.52)	0.48 (0.01)	0.53 (0.01)	0.04 (0.18)	0.91	104.55	1.34

Source: Estimated from ASI

Base year: 2004-05

Note: Numbers in parentheses are the p-values.

Table A2: Cobb-Douglas Production Function (1990-91 to 2012-13)

Model: $\log V = a + \beta_k \log K + \beta_l \log L + \beta_t t$

	Intercept	log (K)	log(L)	Time	Adjusted R-squared	F-statistic	D-W Statistics
India	-7.66 (0.00)	-0.47 (0.06)	1.53 (0.00)	0.08 (0.00)	0.98	536.05	1.31
Telangana	0.36 (0.92)	1.02 (0.00)	-0.12 (0.24)	0.00 (0.90)	0.95	144.81	1.32
Mahboobnagar	-3.53 (0.37)	0.60 (0.05)	0.68 (0.06)	0.01 (0.86)	0.82	34.93	2.59
Rangareddy	0.41 (0.94)	0.12 (0.71)	0.77 (0.02)	0.06 (0.11)	0.93	105.02	0.91
Hyderabad	7.91 (0.41)	0.37 (0.42)	-0.16 (0.76)	0.02 (0.34)	0.71	19.34	2.11
Medak	-0.06 (0.98)	0.56 (0.05)	0.37 (0.01)	0.03 (0.10)	0.93	102.62	1.94
Nizamabad	3.27 (0.67)	0.29 (0.15)	0.33 (0.55)	0.02 (0.07)	0.43	6.56	2.56
Adilabad	23.30 (0.02)	-0.40 (0.53)	-0.98 (0.25)	0.04 (0.40)	0.20	2.81	2.02
Karimnagar	0.98 (0.88)	0.59 (0.33)	0.04 (0.75)	0.07 (0.00)	0.65	14.49	1.60
Warangal	8.48 (0.10)	0.10 (0.56)	-0.05 (0.90)	0.02 (0.25)	0.27	3.67	1.89
Khammam	-2.73 (0.74)	1.19 (0.00)	-0.07 (0.95)	-0.04 (0.34)	0.58	10.66	0.93
Nalgonda	-8.04 (0.05)	1.21 (0.00)	0.42 (0.00)	-0.03 (0.44)	0.89	58.45	1.72

Source: Estimated from ASI

Base year: 2004-05

Note: Numbers in parentheses are the p-values.

Table A3: Translog Production Function (1980-81 to 2012-13)

Model: $Log(V)= \beta_0+\beta_l\,(LogL)+\beta_k\,(LogK)+\beta_t\,T+1/2\,\beta_{\mu}\,(LogL)^2+1/2\,\beta_{kk}(LogK)^2+\beta_{lk}\,(LogL)(LogK)+\beta_{lt}\,(LogL)T+\beta_{kt}\,(LogK)T+1/2\,\beta_{tt}\,T^2$

	intercept	Log (L)	Log (K)	T	log(L)^2	log(K)^2	log(L)* log(K)	log(L)	log(K) *T	T^2 *T	Adj R-sq	F-stat	D-W Stat
India	**-716.58 (0.01)**	**103.11 (0.00)**	**-17.26 (0.27)**	**0.81 (0.51)**	**-4.10 (0.00)**	**-0.88 (0.14)**	**2.41 (0.04)**	**-0.14 (0.09)**	**0.12 (0.27)**	**-0.004 (0.44)**	**0.99**	**913.38**	**2.34**
Telangana	**365.93 (0.13)**	**-4.22 (0.79)**	**-51.82 (0.15)**	**4.22 (0.16)**	**-1.26 (0.03)**	**0.61 (0.66)**	**2.87 (0.07)**	**-0.17 (0.17)**	**-0.15 (0.45)**	**0.01 (0.31)**	**0.97**	**118.29**	**1.69**
Mah.nagar	346.65 (0.01)	-23.60 (0.26)	-58.70 (0.00)	9.62 (0.00)	-1.31 (0.36)	0.92 (0.42)	5.35 (0.06)	-0.52 (0.14)	-0.61 (0.04)	0.06 (0.01)	0.92	43.54	2.94
Rangareddy	-105.19 (0.57)	9.92 (0.27)	11.78 (0.70)	-2.37 (0.52)	-1.33 (0.10)	-1.40 (0.31)	1.72 (0.24)	-0.05 (0.67)	0.28 (0.38)	-0.02 (0.40)	0.96	95.67	1.54
Hyderabad	71.27 (0.04)	16.83 (0.17)	-26.71 (0.01)	0.92 (0.16)	-1.96 (0.06)	0.04 (0.79)	2.31 (0.01)	-0.14 (0.03)	0.06 (0.06)	0.00 (0.07)	0.84	19.16	2.18
Medak	-69.44 (0.52)	8.10 (0.44)	6.13 (0.64)	-0.98 (0.62)	-0.51 (0.46)	-0.42 (0.32)	0.29 (0.77)	0.00 (0.98)	0.09 (0.40)	-0.01 (0.50)	0.97	109.73	2.08
Nizamabad	-74.11 (0.16)	4.39 (0.42)	11.86 (0.04)	-1.16 (0.24)	0.20 (0.07)	-0.08 (0.48)	-0.89 (0.12)	0.04 (0.60)	0.08 (0.04)	0.00 (0.25)	0.89	28.89	2.60
Adilabad	-577.49 (0.01)	106.83 (0.00)	6.73 (0.84)	1.50 (0.56)	-2.78 (0.00)	2.62 (0.23)	-5.33 (0.05)	0.40 (0.15)	-0.59 (0.14)	0.03 (0.12)	0.60	6.36	1.81
Karimnagar	268.06 (0.55)	8.51 (0.84)	-66.18 (0.17)	5.16 (0.06)	0.11 (0.64)	3.96 (0.04)	-0.98 (0.77)	0.02 (0.82)	-0.49 (0.10)	0.01 (0.19)	0.47	4.21	1.91
Warangal	-131.18 (0.05)	31.52 (0.00)	-5.86 (0.67)	1.00 (0.58)	-1.39 (0.12)	0.46 (0.16)	-0.25 (0.86)	-0.01 (0.95)	-0.08 (0.34)	0.00 (0.92)	0.86	21.49	1.78
Khammam	-608.75 (0.00)	86.12 (0.00)	49.88 (0.02)	-8.78 (0.00)	-0.42 (0.77)	0.93 (0.32)	-7.95 (0.02)	0.80 (0.01)	0.20 (0.14)	-0.03 (0.01)	0.80	14.64	1.44
Nalgonda	-122.48 (0.55)	20.65 (0.36)	7.22 (0.75)	-2.28 (0.51)	-1.04 (0.24)	-0.29 (0.28)	-0.15 (0.96)	0.18 (0.42)	0.07 (0.72)	-0.01 (0.62)	0.91	38.57	1.69

Source: Estimated from ASI
Base year: 2004-05
Note: Numbers in parentheses are the p-values.

Table A4: Translog Production Function (1990-91 to 2012-13)

Model: $Log(V)= \beta_0+\beta_l (LogL)+ \beta_k (LogK)+\beta_t T+1/2\ \beta_{\mu} (LogL)^2+1/2\ \beta_{kk}(LogK)^2+ \beta_{lk} (LogL)(LogK)+\beta_{lt} (LogL)T+\beta_{kt} (LogK)T+1/2\ \beta_{tt} T^2$

	intercept	Log (L)	Log (K)	T	log(L)^2	log(K)^2	log(L)* log(K)	log(L)	log(K) *T	T^2 *T	Adj R-sq	F-stat	D-W Stat
India	-477.5 (0.01)	89.99 (0.03)	-38.85 (0.26)	2.48 (0.19)	-3.86 (0.18)	0.17 (0.94)	2.49 (0.59)	0.01 (0.95)	-0.25 (0.47)	0.01 (0.23)	0.99	354.01	2.24
Telangana	-434.85 (0.59)	-3.07 (0.96)	72.93 (0.45)	-6.81 (0.41)	-2.47 (0.06)	-5.54 (0.25)	5.28 (0.43)	-0.34 (0.55)	0.88 (0.24)	-0.03 (0.24)	0.95	46.42	1.88
Mah. nagar	520.80 (0.03)	-90.01 (0.12)	-33.71 (0.13)	9.54 (0.01)	3.24 (0.26)	0.28 (0.88)	3.90 (0.26)	-0.68 (0.12)	-0.46 (0.25)	0.05 (0.08)	0.81	11.67	2.41
Rangareddy	83.00 (0.90)	15.85 (0.21)	-25.71 (0.83)	0.28 (0.98)	-1.38 (0.21)	0.49 (0.93)	1.19 (0.45)	0.06 (0.57)	-0.05 (0.97)	-0.01 (0.93)	0.95	48.92	1.33
Hyderabad	-1845.75 (0.02)	215.51 (0.02)	127.86 (0.38)	-3.91 (0.60)	-6.51 (0.10)	-2.28 (0.73)	-7.09 (0.00)	0.29 (0.02)	0.06 (0.92)	0.00 (0.81)	0.77	9.28	2.12
Medak	-326.12 (0.24)	-35.16 (0.18)	87.43 (0.20)	-4.85 (0.23)	0.17 (0.93)	-4.85 (0.19)	2.67 (0.40)	-0.19 (0.28)	0.57 (0.22)	-0.01 (0.43)	0.92	28.28	2.10
Nizamabad	39.16 (0.95)	44.12 (0.65)	-64.81 (0.26)	1.86 (0.65)	-3.18 (0.45)	0.86 (0.34)	3.83 (0.27)	-0.14 (0.61)	0.00 (0.96)	0.00 (0.59)	0.48	3.24	2.75
Adilabad	-1332.25 (0.20)	131.36 (0.00)	134.30 (0.44)	-6.93 (0.50)	-0.68 (0.68)	-0.42 (0.96)	-12.04 (0.00)	0.87 (0.00)	-0.21 (0.84)	0.02 (0.62)	0.39	2.57	2.30
Karimnagar	9.08 (0.98)	0.75 (0.98)	-8.11 (0.90)	2.87 (0.34)	0.45 (0.28)	1.37 (0.62)	-1.19 (0.64)	0.13 (0.28)	-0.37 (0.13)	0.00 (0.94)	0.67	6.07	2.45
Warangal	-95.79 (0.20)	25.28 (0.06)	-4.45 (0.71)	-0.06 (0.96)	-1.16 (0.26)	0.35 (0.39)	-0.24 (0.85)	0.06 (0.54)	-0.04 (0.70)	0.00 (0.74)	0.45	2.97	1.49
Khammam	-725.35 (0.00)	53.66 (0.04)	107.60 (0.00)	-15.35 (0.00)	6.60 (0.08)	2.44 (0.13)	-17.86 (0.01)	1.60 (0.00)	0.19 (0.24)	-0.05 (0.00)	0.85	14.61	2.11
Nalgonda	252.06 (0.12)	15.15 (0.48)	-60.32 (0.16)	5.22 (0.15)	-1.37 (0.08)	2.46 (0.36)	1.00 (0.64)	0.09 (0.65)	-0.60 (0.20)	0.03 (0.12)	0.92	27.61	1.59

Source: Estimated from ASI, Base year: 2004-05; *Note:* Numbers in parentheses are the p-values.

Table A5: CES Production function (1980-81 to 2012-13)

Model: $\ln V_{it} = \beta_1 + \beta_2 \ln K_{it} + \beta_3 \ln L_{it} + \beta_4 (\ln K_{it} - \ln L_{it})^2 + \alpha t$

	intercept	logK	logL	(logK-logL)^2	Time	Adj R-sq	F-stat	DW stat	y	δ	μ	ρ
India	-10.76 (0.00)	-1.41 (0.00)	2.58 (0.00)	-0.17 (0.00)	0.08 (0.00)	0.99	1625.8	2.02	0.00	-1.20	1.18	-0.11
Telangana	-0.08 (0.96)	0.89 (0.00)	0.03 (0.90)	0.02 (0.81)	0.00 (0.61)	0.97	286.54	1.30	0.93	0.97	0.92	-1.23
Mah. nagar	6.59 (0.34)	0.83 (0.26)	-0.91 (0.04)	-0.27 (0.02)	0.16 (0.09)	0.89	64.28	2.06	728.83	-11.44	-0.07	0.05
Rangareddy	0.91 (0.82)	-0.30 (0.10)	1.19 (0.00)	0.15 (0.01)	0.05 (0.05)	0.96	204.69	1.27	2.48	-0.34	0.89	0.74
Hyderabad	0.30 (0.83)	0.21 (0.02)	0.72 (0.00)	0.09 (0.10)	0.02 (0.01)	0.81	35.44	1.93	1.35	0.22	0.93	-1.16
Medak	0.95 (0.65)	0.39 (0.00)	0.45 (0.03)	-0.02 (0.84)	0.05 (0.05)	0.97	282.83	1.99	2.58	0.46	0.85	0.16
Nizamabad	-3.29 (0.10)	1.37 (0.03)	-0.09 (0.81)	0.22 (0.04)	0.00 (0.99)	0.89	62.76	2.41	0.04	1.07	1.28	4.56
Adilabad	1.97 (0.87)	0.28 (0.65)	0.38 (0.64)	0.00 (0.98)	0.04 (0.57)	0.45	7.65	1.40	7.14	0.42	0.65	-0.04
Karimnagar	-3.07 (0.63)	0.82 (0.13)	0.21 (0.18)	0.08 (0.34)	0.06 (0.00)	0.48	8.41	1.80	0.05	0.80	1.03	-0.93
Warangal	2.86 (0.60)	-0.12 (0.40)	0.62 (0.27)	0.02 (0.66)	0.07 (0.01)	0.68	17.19	1.53	17.53	-0.25	0.50	0.22
Khammam	-4.48 (0.61)	1.73 (0.18)	-0.45 (0.41)	-0.13 (0.66)	-0.05 (0.09)	0.71	20.09	0.98	0.01	1.35	1.28	-0.43
Nalgonda	-0.80 (0.83)	0.53 (0.01)	0.41 (0.41)	-0.03 (0.77)	0.05 (0.34)	0.90	76.03	1.38	0.45	0.56	0.94	0.29

Source: Estimated from ASI; Base year: 2004-05;
Note: Numbers in parentheses are the p-values

Table A5: CES Production function (1980-81 to 2012-13)

Model: $\ln V_{it} = \beta_1 + \beta_2 \ln K_{it} + \beta_3 \ln L_{it} + \beta_4 (\ln K_{it} - \ln L_{it})^2 + \alpha t$

	intercept	logK	logL	(logK-logL)^2	Time	Adj R-sq	F-stat	DW stat	y	δ	μ	ρ
India	-11.62 (0.00)	-1.65 (0.00)	2.87 (0.00)	-0.23 (0.00)	0.08 (0.00)	0.99	539.66	2.17	0.00	-1.35	1.22	-0.12
Telangana	1.14 (0.75)	0.82 (0.18)	0.02 (0.97)	0.04 (0.78)	0.00 (0.90)	0.95	103.50	1.28	3.12	0.98	0.84	-5.93
Mahboobnagar	-5.02 (0.22)	1.73 (0.03)	-0.40 (0.60)	-0.35 (0.10)	0.02 (0.67)	0.82	26.72	2.71	0.01	1.30	1.33	-1.35
Rangareddy	1.49 (0.75)	-0.82 (0.25)	1.69 (0.01)	0.28 (0.15)	0.06 (0.05)	0.94	83.37	1.07	4.45	-0.94	0.87	0.35
Hyderabad	6.56 (0.56)	0.86 (0.47)	-0.55 (0.39)	-0.11 (0.60)	0.01 (0.66)	0.70	13.99	2.19	705.78	2.77	0.31	-0.15
Medak	-0.28 (0.90)	0.73 (0.56)	0.21 (0.87)	-0.04 (0.90)	0.03 (0.13)	0.93	72.97	1.94	0.76	0.78	0.94	0.52
Nizamabad	1.06 (0.90)	1.46 (0.14)	-0.56 (0.51)	0.27 (0.19)	0.01 (0.49)	0.44	5.38	2.67	2.90	1.61	0.91	0.59
Adilabad	25.93 (0.02)	-1.47 (0.25)	-0.14 (0.91)	0.25 (0.30)	0.06 (0.27)	0.18	2.19	2.12		0.91	-1.61	4.06
Karimnagar	3.11 (0.64)	0.37 (0.55)	0.07 (0.52)	0.12 (0.49)	0.07 (0.00)	0.64	10.71	1.71	22.32	0.84	0.44	-4.00
Warangal	8.55 (0.11)	-0.07 (0.84)	0.10 (0.86)	0.05 (0.55)	0.03 (0.17)	0.24	2.73	1.82	5161.90	-1.96	0.03	0.47
Khammam	-4.81 (0.58)	4.71 (0.15)	-3.84 (0.24)	-0.77 (0.28)	-0.01 (0.71)	0.60	8.82	1.02	0.01	5.38	0.88	-0.07
Nalgonda	-6.52 (0.12)	0.49 (0.81)	1.07 (0.60)	0.14 (0.75)	-0.03 (0.44)	0.88	41.81	1.82	0.00	0.32	1.57	-0.85

Source: Estimated from ASI; Base year: 2004-05;
Note: Numbers in parentheses are the p-values