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The Non-Parametric Approach of Measuring TFPG: A Study of Tea Industry in Assam

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Abstract: ***Over the years a significant number of studies have been conducted on spatial and inter-temporal variations in manufacturing sector performance and productivity all around the world including India. However, systematic panel data studies on productivity analysis and efficiency analyses, including TFPG, in the tea industry in Assam are rare. This paper makes an to examine the performance of tea producers by using a composite measure factor productivity growth over the period 2012 – 2022.***

Keywords: Assam, Tea Industry, Productivity Growth, TFPG, Performance Analysis

1. Introduction

Total Factor Productivity Growth (TFPG) provides a measure of performance of production units. TFPG is an index of change in output net of changes in inputs over the same period of time. Alternatively, TFPG is output growth less the sum total of inputs share weighted input growth. A TFPG series can be computed over a period of time by constructing a suitable index that captures the total factor productivity of a production unit.

This description of TFPG essentially implies that it is a residual measure – that is, the part of output growth that cannot be accounted for by factor share weighted input growth. This residual actually captures the combined effects of factors (not production inputs) such as change (or improvement) in technology, better capacity utilization, learning by doing, improved input quality, more efficient use of inputs etc.

Productivity growth and productivity differential has been one of the most popular areas of applied economic research as it is based on the well-defined analytical framework of the standard neoclassical economic theory of the production function. But the primary weakness of this approach of measuring performance of production units through productivity growth is that it does not allow for the distinction between changes in technology and those in the efficiency with which a known technology is applied to production.

That is technological progress and efficiency of factor use cannot be disentangled. But productivity across firms in an industry may vary due to technological differences, due to differences in efficiency in the process of production and due to differences in the environment in which the production unit or firm operates. The traditional methodology of measuring productivity based on the standard definition of production function implicitly assumes that maximum output is attained by firms or production units for given levels of inputs. That is, output maximization is an implicit assumption. This is overcome in the efficiency adjusted TFPG measure where output growth of the firm is decomposed into technical progress, contributions of input growth and change in technical efficiency by adopting a frontier approach. TFPG is a composite measure of technological change and changes in the efficiency with which known technology is applied to production (Ahluwalia 1991). Therefore, TFPG is the combined result of technical progress and technical efficiency change with which the factors are used to produce output. These two components of TFPG are analytically distinct and may have quite different policy implications (Nishimizu and Page 1982). High rate of technical progress, on the one hand, can co-exist with the deteriorating technical efficiency performance. On the other hand, relatively low rates of technical progress can co-exist with improving technical efficiency performance. As a result, specific policy actions are required to address the different sources of variations in productivity. The technical change component of TFP growth captures shifts in 'best practice' techniques production frontier over time and can be interpreted as providing a measure of innovation. This decomposition of TFP growth into technical efficiency improvement (catching up) and technological advance is, therefore, useful in distinguishing innovation or adoption of new technology by 'best practice' firms from the diffusion of new advance technology which leads to improved technical efficiency amongst firms, i.e.; 'catching up'. Coexistence of high rate of technical progress and a low rate of change in technical efficiency may reflect failures in achieving technological mastery or effective diffusion of best technical practices. It may also reflect high levels of technological dynamism in an industry with rapid obsolescence rates for technology.

The objective of the study is to study total factor productivity growth (**TFPG**) patterns in the tea industry in Assam. It is an attempt to examine the performance of tea producers by using a composite measure factor productivity growth over the period 2012 – 2022

2. Review of Literature

Over the years a significant number of studies have been conducted on spatial and inter-temporal variations in manufacturing sector performance and productivity all around the world including India. However, systematic panel data studies on productivity analysis and efficiency analyses, including TFPG, in the tea industry in Assam are rare (Hazarika and Subramanian 1999).

Ever since the celebrated contributions of Solow and Swan in the field of macroeconomic growth in 1957, and the consequent development of empirical growth accounting methods during the 1960s and 1970s industrial economists in the west have taken TFPG measurement at the industry level as a very powerful analytical economic tool for framing credible and effective industrial policies. India is no exception in this regard. Numerous influential studies have been conducted on India's large and small scale industries since the early 1970s. These studies mainly use ASI and CMIE data bases.

One of the most celebrated works on total factor productivity growth in the context of Indian industries was conducted by Ahluwalia (1985). She estimated Solow and Translog indices of TFPG at different levels of industrial disaggregation for the period 1959-60 to 1980-81 with two sub-periods 1958-65 and 1966-80. She made four alternative estimates of TFPG for the entire manufacturing sector and for use based and input based classification of industries. Her study reveals declining TFPG during the first and second sub-periods, interpreted as decline in productivity performance.

3. Methodological Issues

Total factor productivity indices themselves fall into two separate categories: (a) Arithmatic TFP indices [Abramobitz (1956); Kendrick (1961)]; (b) Geometric or Divisia TFP indices [Solow (1957); Jorgenson and Griliches (1967)] depending upon their definitions of I_t. The most important widely used variant of arithmetic indices is Kendrick index. Kendrick index (1961) of TFP is based on a linear production function which assumes infinite elasticity of substitution between factors of production. The Kendrick index is defined as:

$$P_t = \frac{Q_t}{\sum W_{i,0}.X_i} \quad \text{................(i)}$$

Where, $W_{i,0}$ refers to the reward of the input i in the base year.

In order to compute the Geometric or Divisia indices of total factor productivity, we shall proceed as follows. Given the production function

$$Y = F(X_1, X_2, \dots, X_k, t) \quad \text{......(ii)}$$

Under constant returns to scale, the construction of the divisia or the geometric index of total factor productivity that belongs to the growth accounting approach for measuring productivity is based on the following formula

$$DI = \frac{Y_t}{Y_0} \exp\left[- \sum_{i=1}^{k} \int_0^t Sh_i \frac{\dot{X}_i}{X_i} \right] \quad \text{...(iii)}$$

Where, Y is output, X's are inputs, t is time and Sh is the share of input in the value of output. This type of index was used by Abramowitz (1956), Solow (1956), and Jorgenson and Grilliches (1967) in their empirical studies. The logical foundation of this index was developed and enriched by Richter (1966), Gorman (1970), Hillinger (1970) and Hulten (1973).

Based on the production function (2), the total differential is

$$dY = F_1 dX_1 + F_2 dX_2 + \cdots + F_k dX_k + F_t dt$$

Or, $$\frac{dY}{dt} = F_1 \frac{dX_1}{dt} + F_2 \frac{dX_2}{dt} + \cdots + F_k \frac{dX_k}{dt} + F_t$$

Or,

$$\frac{1}{Y}\frac{dY}{dt} = \frac{X_1 F_1}{Y}\frac{1}{X_1}\frac{dX_1}{dt} + \frac{X_2 F_2}{Y}\frac{1}{X_2}\frac{dX_2}{dt} + \cdots + \frac{X_k F_k}{Y}\frac{1}{X_k}\frac{dX_k}{dt} + \frac{F_t}{Y}$$

Or, $$\frac{F_t}{Y} = \frac{1}{Y}\frac{dY}{dt} - \sum_{i=1}^{k}\left[\left(\frac{X_i F_i}{Y}\right)\left(\frac{1}{X_i}\frac{dX_i}{dt}\right)\right]$$

Thus, the divisia index is given as

$$DI = \frac{\dot{Y}}{Y} - \sum_{i=1}^{k} Sh_i \frac{\dot{X}_i}{X_i} \quad \text{.............(iv)}$$

Where, $Sh_i = \frac{\partial \ln Y}{\partial \ln X_i} \approx \frac{X_i F_i}{Y}$ and $\sum_{i=1}^{k} Sh_i = 1$

The divisia index (iv) that shows the rate of technical change is defined as the difference between the rate of growth of output and the weighted average of rates of growth of inputs, the weights being the shares of inputs in the value of output. For the economic time series data, Solow (1957) computed the divisia index by using the formula

$$DI_t = \left(\frac{\dot{Y}}{Y} - \frac{\dot{X}_k}{X_k}\right) - \sum_{i=1}^{k-1} Sh_i \left(\frac{\dot{X}_i}{X_i} - \frac{\dot{X}_k}{X_k}\right) = \left(\frac{\Delta Y}{Y} - \frac{\Delta X_k}{X_k}\right) - \sum_{i=1}^{k-1} Sh_i \left(\frac{\Delta X_i}{X_i} - \frac{\Delta X_k}{X_k}\right) \quad \text{......(v)}$$

Equation (v) gives the Solow residual measure of total factor productivity growth. For the present study where we have only two inputs, namely, capital (K) and labour (L), Solow residual for annual time series data, is

$$DI_t = \left(\frac{\Delta Y}{Y} - \frac{\Delta L}{L}\right) - (1 - Sh_L)\left(\frac{\Delta K}{K} - \frac{\Delta L}{L}\right) \quad \text{....(vi)}$$

Where, Sh_L is the share of labour.

Contrasted with the divisia index Solow used, Tornqvist index is another important variant of the divisia index. Under the specification of a translog production function under constant returns to scale, Diewart (1976) proved that the Tornqvist index is the exact measure of technical change.

Thus, if there is a transcendental logarithmic production function as

$$\ln Y = \alpha_0 + \alpha_t t + 0.5.\beta_{tt} t^2 + \sum_{i=1}^{k} \alpha_i \ln X_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln X_i \ln X_j + \sum_{i=1}^{k} \beta_{it} t \ln X_i \quad \text{.......(vii)}$$

The Tornqvist approximation of the divisia index as introduced by Jorgensen and Grilliches (1967), can be written as

$$\overline{DI}_t = \ln\left(\frac{Y_t}{Y_{t-1}}\right) - \sum_{i=1}^{k} \overline{Sh}_i \ln\left(\frac{X_{i,t}}{X_{i,t-1}}\right) \quad \text{.... (viii)}$$

Where, $\overline{Sh}_i = \frac{1}{2}\left[Sh_{i,t} + Sh_{i,t-1}\right]$. The average rate of technical change, $\overline{DI}_t$, is also called translog index of technical change.

It should be noted that the translog measure of the total factor productivity growth is not significantly different from the Solow residual measure under two conditions. First, the elasticity of substitution is not significantly different from one. Second, variation in the growth rates of inputs over time is not significant (Ahluwalia 1991).

Malmquist TFP index, first defined in a consumer index by Malmquist (1953), and then proposed as a productivity index by Calves et. al. (1982).

Caves, Christensen and Diewert (1982) defined the Malmquist productivity index (output based) as the ratio of two (output) distance functions. Distance functions are functions represents of multiple-output, multiple-input technology, which require data only on input and output quantities.

Suppose that for each time period t=1, 2... T the production technology S^t is given. The technology $S^t = \{(X^t, Q^t): X^t \text{ can produce } Q^t\}$, describes all feasible pairs of input-output vectors. It is assumed that the constant returns to scale prevail so that output based technical efficiency equals the input-based technical efficiency index. Following Shephard (1970) and Fare (1988), the output distance function at point t is defined as:

$$D_0\,((X^t, Q^t) = \inf\{\theta: (X^t, Q^t)\,/\theta)\epsilon S^t\,\} \quad \text{........(ix)}$$
$$=[\sup\{\theta: (X^t, \theta Q^t)\,/\theta)\epsilon S^t]^{-1} \quad \text{..................(x)}$$

This function is homogeneous of degree+1 in outputs and it is the reciprocal of output based Farrell (1957) measure of technical efficiency. It completely characterize the technology in the sense that $(X^t, Q^t)\epsilon\ S^t$ if and only if $D_0\,((X^t, Q^t) \le 1$.

To define the Malmquist index, mixed time period distance functions must be introduced. In particular,

$$D_0^{t+1}(X^t, Q^t) = \inf\{\theta: (X^t, Q^t)\,/\theta)\epsilon S^{t+1}\} \text{.....(xi)}$$

and

$$D_0^t(X^{t+1}, Q^{t+1}) = \inf\{\theta: (X^{t+1}, Q^{t+})\,/\theta)\epsilon S^t\} \text{....(xii)}$$

The terminology 'mixed period' is used since information from t and t+1 is required to define equations. Again, $D_0^{t+1}\,((X^t, Q^t) \le 1$ if and only if $(X^t, Q^t)\epsilon\ S^{t+1}$, and similarly for $D_0^t(X^{t+1}, Q^{t+1})$. Caves, Christensen and Diewert (1982) defined the output based Malmquist productivity index as:

$$\boldsymbol{M^t} = \frac{D_0^t(X^{t+1}, Q^{t+1})}{D_0^{t+1}(X^t, Q^t)} \text{............................ (xiii)}$$

The present study uses secondary data primarily from Annual Balance Sheet information as per CSO (Central Statistical Organisation) format at the Estate level for the period 2012 – 2022, submitted to the Tea Board of India on an annual basis. The study targets 31 firms, around 17 from upper Assam and the remaining from the three districts of Barak Valley.

4. Results and Discussions

Garden Wise mean TFPG Estimates during 2012-22 are presented in table 4.2. The sample mean TFPG for the period 2012-22 is 0.58, -2.49 and 0.89 for Solow divisia index , Tornqvist Index and Malmquist index respectively . The standard deviation turns out to be 2.18, 10.82 and 7.19 for three indices respectively. The Tornqvist index reflects a negative growth rate of TFPG whereas Solow divisia and Malmquist index indicate very low positive growth rate of output in tea industry in Assam.

Garden wise frequency distribution of TFPG (Solow Divisia Index) is presented in table 4.3.

Refer to table 4.3; it is clear that a large number of tea gardens (i.e., 54.84% of the total sample gardens) have TPFG of -1.26 to 0.74 which is very poor.

Pair-wise correlations of growth rates of all variables are calculated independently in table 4.4. The coefficients between TFPG-MC, TFPG-Dep., and TFPG-H are positive and low and that between TFPG-IC, TFPG-WS, TFPG-Wel.S., TFPG-W, TFPG-P&F, TFPG-Im and TFPG-Y are negative. However, the coefficient correlation between TFPG-P&F, TFPG-WS and TFPG-IC are negatively high and that between TFPG-Y, TFPG-W are negatively low. The correlation coefficient between Im-Wel.S, H-MC and Y-Im are found to be positive and high and that between Y-IC, Y-MC, Y-WS, Y-Wel.S., Y-Dep., Y-W, Y-P&F, Y-I, Y-H are positive but low.

Table 4.1: Summary Statistics of Variables used to Estimate Production function and TFPG

Variables	Mean	Standard Deviation	Minimum	Maximum	C.V.
Output (kg)	1296168.51	1129249.42	109936.8	8727946	0.87
Land (hectares)	615.46	294.73	190.4	1593.11	0.48
Wages (Rs)	6216900.48	7867006.97	859325.81	37281168.41	126.54
Pesticides & Fertilizers (Rs)	5135141.60	4566423.47	96589	33398964.96	0.88
Irrigation (Rs)	832558.51	1504197	4808	14374037	1.81
Implements (Rs)	348831.79	1626394	12454	15981352.28	4.66

Table 4.2. Garden Wise mean TFPG Estimates during 2012-22

Garden ID NO.	Solow Divisia index	Tornqvist Index	Malmquist Index	Garden ID NO.	Solow Divisia index	Tornqvist Index	Malmquist Index
1	2.28	0.01	-3.69	17	1.70	0.52	15.45
2	0.33	0.28	-7.39	18	5.76	5.20	0.75
3	2.27	0.26	-11.08	19	-0.44	-1.75	0.05
4	-0.63	0.10	-0.15	20	-0.92	-6.11	0.45
5	0.02	0.39	-4.57	21	-0.44	-1.26	-1.35
6	6.21	7.17	0.25	22	-0.38	-10.67	-2.05
7	-0.68	0.16	24.78	23	9.66	9.62	-2.75
8	-0.02	0.16	-0.48	24	-3.04	-34.22	-3.45
9	-0.94	0.20	-2.87	25	-0.02	-0.63	-4.15
10	-5.26	-2.45	0.99	26	0.70	10.72	-4.85
11	0.71	-1.32	1.47	27	-1.29	-15.01	-1.93
12	1.31	0.60	17.84	28	2.79	13.88	1.93
13	3.35	0.16	7.41	29	-4.69	-38.83	-1.80
14	3.18	2.12	1.11	30	-0.82	-5.80	-1.33
15	-0.85	-0.98	4.95	31	-0.91	-10.74	-0.63
16	-0.97	1.14	4.71	Mean	0.58	-2.49	0.89

Source: Author's estimates based on firm level primary data.

Table 4.3: Frequency Distribution of TFPG

Class Interval	Absolute Frequency	Relative Frequency (%)
(-5.26) - (-3.26)	2	6.45
(-3.26) - (-1.26)	2	6.45
(-1.26) - (0.74)	17	54.84
(0.74) - (2.74)	4	12.90
(2.74) - (4.74)	3	9.68
(4.74) - (6.74)	1	3.23
(6.74) - (8.74)	1	3.23
(8.74) - (10.74)	1	3.23

Mean TFPG (%) 0.58
Minimum TFPG (%) -5.26
Maximum TFPG (%) 9.66
Standard Deviation of Garden 2.18
Wise TFPG (%)
Source: Author's estimates based on firm level primary data

Table 4.4: Bivariate Correlation Analysis

	TFPG	*IC*	*MC*	*WS*	*Wel.S*	*Dep*	*W*	*P&F*	*I*	*Im*	*H*	*Y*
TFPG	1											
IC	-0.17	1										
MC	0.05	0.24	1									
WS	-0.12	0.10	0.48	1								
Wel.S	-0.03	-0.04	0.49	0.49	1							
Dep.	0.14	0.18	0.30	0.02	0.23	1						
W	-0.29	0.25	-0.17	-0.13	0.12	0.24	1					
P&F	-0.06	0.10	0.18	-0.07	-0.005	0.10	0.15	1				
I	-0.13	0.06	0.07	-0.04	0.01	-0.09	0.36	0.03	1			
Im	-0.20	0.16	0.33	0.25	0.65	0.28	0.25	0.26	0.002	1		
H	0.08	0.29	0.74	0.39	0.39	0.37	0.14	0.31	0.006	0.49	1	
Y	-0.33	0.33	0.10	0.33	0.33	0.16	0.48	0.10	0.22	0.51	0.36	1

Source: Author's estimates based on firm level primary data.

Note: TFPG = Total Factor Productivity Growth;
IC = Immature Cultivation;
MC = Matured cultivation;
WS = Workers sundries;
Wel. S = Welfare sundries;
Dep. = Depreciation
Im. = Implements;
Y= Output;
W = Wage;
P =Pesticides and fertilisers;
H = Hectare
I = irrigation

5. Conclusion of the Study

Garden Wise mean TFPG Estimates during 2012-22 are estimated by using three different indices. The Tornqvist index reflects a negative growth rate of TFPG whereas Solow divisia and Malmquist index indicate very low positive growth rate of output in tea industry in Assam.

From Bivariate correlation analysis, it is clear that pesticide and fertilizers; mature cultivation and labour are pair wise highly positively correlated. The study concludes that inputs have grown at a very high rate; as a result the growth rate of TFP is very low.

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