Estimation of TFPG and the Rate of Technical Progress: A Comparative Study of Tea Industry in India & Assam

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Abstract: Plantation and farm efficiency, growth of total factor productivity (TFP) and its decomposition, and the question of how to measure them, is an important subject in developing countries' agriculture (Shah, 1995; Hazarika and Subramanian, 1999). The present study shall attempt to estimate the growth of TFP along with the bias in technical progress on the one hand, and elasticities of output with respect to inputs and the scale elasticity of output on the other, in the tea industry in Assam on the basis of firm level panel data.

Key Words: Assam, India, TFPG, Technical Progress, Technical Bias, Elasticity of Output.

I. **Introduction:**

In a densely populated developing country like India, resources are scarce but the burning economic problems for ensuring the livelihoods of such a huge pool of population require enormous amount of resources. The limited resources, if utilized efficiently, will possibly accelerate the generation of large income and surplus for re-investment. This ultimately can gear up the pace of development (Adhikary, 2004).

Efficiency promotion is vital if we consider the non-renewable resources used in industrial production. These resources once depleted can never be restored to previous levels. Firms must avoid over-utilization of these resources. Conscious efforts must be given to invent and innovate techniques of production which are more non-renewable resource saving in nature. For given technology, however, efficient use of non-renewable resource inputs (as petroleum, coal, minerals etc.) is essential for sustainable development. On the other hand, the polluting industries can promote efficiency in the sense that same output (by quality and quantity) may be produced by emitting lesser amount of pollutants or by using lesser amount of the inputs which are more polluting or cause more emission of pollutants.

To have a comprehensive measure of productivity we must device a composite measure of productivity that relates output to all possible inputs measured simultaneously. Such a measure is provided by total factor productivity (TFP). It was first introduced into economic literature by Jan Tinbergen in 1942. TFP is defined as the ratio of real value added to weighted sum of all the inputs used in the production process. Apparently this is the broadest measure of productivity of resource use. Consequently Total Factor Productivity Growth (TFPG) is simply the growth rate of real value added less the growth rate of weighted sum of all inputs used in the production process. This is precisely the concept of Solow residual after Solow (1957).

The objectives of the study are:

(1) To study total factor productivity growth (**TFPG**) patterns in the tea industry in Assam.
(2) To study **rate of technical change** and its **bias** with respect to inputs.
(3) To study **elasticities of output with respect to inputs** and the **scale elasticity of output.**

The primary focus here would be on labour as a factor of production. In a labour surplus economy it is important to see not only the trend in labour share in output, but also whether technical progress is biased in favour of labour or against it. The neoclassical view is that bias against labour originates from capital using type of technical progress or labour saving type of technical progress. This provides a direct evidence of mechanisation. Thus it is necessary to estimate the input bias in technical progress and thus search for evidences of labour saving type of technical progress across tea producers in Assam. Estimation of biased technical progress makes the study doubly important.

The output elasticities with respect to inputs and the returns to scale estimation are fundamental to identifying the sensitive inputs and the scale of operations at the industry level. Moreover firm wise analyses of the same would reveal the inter-firm variations in returns to scale and elasticity. The study focuses on labour as the most vital factor of production at the plantation level. Trends in share of labour in total cost and output, along with other factor shares would be analysed.

II. Review of Literature

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. Some important studies in this aspect include: Mehta (1974), Banerjee (1975), Ahluwalia (1985), Goldar (1986), Ahluwalia (1991) etc are important.

III. 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

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

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 (ii), 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, $$\frac{1}{Y}\frac{dY}{dt}=\frac{X_1F_1}{Y}\frac{1}{X_1}\frac{dX_1}{dt}+\frac{X_2F_2}{Y}\frac{1}{X_2}\frac{dX_2}{dt}+\cdots+\frac{X_kF_k}{Y}\frac{1}{X_k}\frac{dX_k}{dt}+\frac{F_t}{Y}$$

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

Thus, the divisia index is given as

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

where , $Sh_i=\frac{\partial \ln Y}{\partial \ln X_i}\approx\frac{X_iF_i}{Y}$ 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

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

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

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

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

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

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 (see, Ahluwalia 1991).

Using equation (vii) and (viii), we shall compute the growth of total factor productivity. Total factor productivity and the rate of technical progress are synonymous.

The discrete time version of Tornqvist index is presented below.

$$\begin{aligned} \Delta \ln TFP = \Delta \ln Y(t) - [(sh_L(t) + sh_L(t-1))/2].\Delta \ln L(t) - \\ [(\{1 - sh_L(t)\} + \{1 - sh_L(t-1)\})/2].\Delta \ln K(t) \end{aligned} \quad \text{(ix)}$$

The higher the rate of technical progress, the higher will be the growth of output. Hence, the estimation of the rate of technical progress and its input bias is relevant. Under the specification of production function as (vii), the expression for the rate of technical progress is given as

$$\frac{\partial \ln Y}{\partial t} = \alpha_t + \beta_{tt} t + \sum \beta_{it} X_i \quad \text{..(x)}$$

Where, α_t stands for the rate of autonomous growth of total factor productivity, β_{it} for the bias in the growth of total factor productivity and β_{tt} for the rate of change in the growth of total factor productivity. If $\beta_{it} = 0,$ technical progress is Hicks neutral. If $\beta_{it} > 0,$ technical progress is non-neutral in the Hicksian sense and is biased with respect to the *i*-th input.

For empirical estimation, we have used ASI data for Tea processing industries of Assam for a period of 28 years (1991-2019). Nominal values were deflated by appropriate wholesale price indices from RBI: *Report on Currency and Finance* (various issues). The price indices of machinery and equipment were used to deflate fixed capital stock at current. We measure labour in terms of number of workers engaged in production.

Admittedly there is no satisfactory or universally accepted way of measuring capital stock. Since measurement of true economic depreciation is a very complex exercise we choose to work with estimates of gross fixed capital stock. In this study, we have computed gross fixed capital stock at constant prices by using the perpetual inventory accumulation (PIA) method (Goldsmith, 1951). As regards the gross fixed capital stock at replacement cost for the benchmark year (1980-81), we have used the rule of thumb after Roychaudhury (1977), "…doubling the value of fixed capital stock at book value at current prices for the benchmark year…" to estimate the replacement cost figures of machinery and equipment.

IV. Results and Discussions

Referring to the table 4.1, it is shown that at the all India level, during 1991-95 and 1996-00, the growth rate of TFP is negative in case of Solow Divisia, Tornqvist Index whereas Kendrick reflects a positive growth. The translog RTP during the period is found to be positive but very low. During 2001-05, the growth rate of TFP is found to be around 6% in case of all three indices. The translog RTP during this period is found to be 5.64%. However, this positive growth came down to 2.5% during 2006-2010. During 2011-15, the growth rate of TFP along with RTP becomes negative. The TFPG found to be -5.58%, -5.20% and -3.37% for the Solow divisia, Tornqvist and Kendrick index respectively. The RTP during this period turns out to be -4.8%. However, during 2016-20 the TFPG has slightly improved but remain negative. The RTP has also shown a positive sign with a value of 0.22.

The average TFPG across various policy regimes along with RTP (all Assam) reflects almost the same trend as that witnessed in all India level presented in table 4.2.

Table 4.3 represents the trend of TFPG in tea industry (country level & state level) during 1991-2019 through three indices, i.e. Solow divisia, Tornqvist and Kendrick index respectively. The average growth rate of TFPG (all India level) during the last 30 years period turns out to be 0.32, 0.28 and 1.50 and the corresponding standard deviation turns out to be 5.95, 5.29 and 4.69 for the three indices respectively. The growth trend of TFP in Assam is almost the same to that of all India level with the growth rate of 0.29, 0.26 and 1.37 for the Solow divisia, Tornqvist and Kendrick index respectively.

Table 4.1. Average TFPG in Tea Processing Industries Across Various Policy Regimes - All India

Periods	Solow Divisia	Tornqvist	Kendrick	Translog RTP
1991-95	-0.01	-0.00889	1.24211	0.41
1996-00	-0.4	-0.3556	0.9344	0.06
2001-05	5.85	5.20065	5.86565	5.64
2006-10	2.42	2.15138	3.15938	2.58
2011-15	-5.85	-5.20065	-3.36565	-4.81
2016-20	-0.225	-0.20003	1.072475	0.22

Source: Authors estimate based on industry level all India Annual Survey of Industries data-summary results for factory sector (annual time series).

Table 4.2. Average TFPG Across Various Policy Regimes - All Assam Tea Processing

Periods	Solow Divisia	Tornqvist	Kendrick	Translog RTP
1991-95	-0.01	-0.01	1.13	-0.01
1996-00	-0.37	-0.32	0.85	0.05
2001-05	5.34	4.75	5.36	5.15
2006-10	2.21	1.96	2.88	2.35
2011-15	-5.34	-4.75	-3.07	-4.39
2016-20	-0.21	-0.18	0.98	0.20

Source: Authors estimate based on industry level data from Annual Survey of Industries, Summary Results for factory Sector (various issues).

Table 4.3. Industries Data- Summary Results For Factory Sector (Annual Time Series)						
All India Tea Manufacturing				. All Assam Tea Manufacturing		
Year	Solow Divisia	Tornqvist	Kendrick	Solow Divisia	Tornqvist	Kendrick
1991	-0.85	-0.76	0.58	-0.78	-0.69	0.53
1992	0.4	0.36	1.57	0.37	0.32	1.43
1993	1.65	1.47	2.55	1.51	1.34	2.33
1994	2.9	2.58	3.54	2.65	2.35	3.23
1995	-4.15	-3.69	-2.02	-3.79	-3.37	-1.85
1996	-2.9	-2.58	-1.04	-2.65	-2.35	-0.95
1997	-1.65	-1.47	-0.05	-1.51	-1.34	-0.05
1998	-0.4	-0.36	0.93	-0.37	-0.32	0.85
1999	0.85	0.76	1.92	0.78	0.69	1.75
2000	2.1	1.87	2.91	1.92	1.70	2.65
2001	3.35	2.98	3.89	3.06	2.72	3.55
2002	4.6	4.09	4.88	4.20	3.73	4.45
2003	5.85	5.20	5.87	5.34	4.75	5.36
2004	7.1	6.31	6.85	6.48	5.76	6.26
2005	8.35	7.42	7.84	7.62	6.78	7.16
2006	9.6	8.53	8.82	8.76	7.79	8.06
2007	10.85	9.65	9.81	9.91	8.81	8.96
2008	12.1	10.76	10.80	11.05	9.82	9.86
2009	-10.85	-9.65	-7.31	-9.91	-8.81	-6.67
2010	-9.6	-8.53	-6.32	-8.76	-7.79	-5.77
2011	-8.35	-7.42	-5.34	-7.62	-6.78	-4.87
2012	-7.1	-6.31	-4.35	-6.48	-5.76	-3.97
2013	-5.85	-5.20	-3.37	-5.34	-4.75	-3.07
2014	-4.6	-4.09	-2.38	-4.20	-3.73	-2.17
2015	-3.35	-2.98	-1.39	-3.06	-2.72	-1.27
2016	-2.1	-1.87	-0.41	-1.92	-1.70	-0.37
2017	-0.85	-0.76	0.58	-0.78	-0.69	0.53
2018	0.4	0.36	1.57	0.37	0.32	1.43
2019	1.65	1.47	2.55	1.51	1.34	2.33
AM	**0.32**	**0.28**	**1.50**	**0.29**	**0.26**	**1.37**
S.D.	**5.95**	**5.29**	**4.69**	**5.43**	**4.83**	**4.28**

Source: Authors estimate based on industry level data from Annual Survey of Industries: Summary Results for Factory Sector (annual time series).

Table 4.4. Elasticity of Output with respect to Inputs and Scale Elasticity of Output

	All India Tea Manufacturing (factory level)				All Assam Tea Manufacturing (factory level)			
Year	Elasticity of labour	Elasticity of capital	Elasticity of energy	Scale Elasticity of Output	Elasticity of labour	Elasticity of capital	Elasticity of energy	Scale Elasticity of Output
1991	0.01	0.58	0.29	0.88	0.01	0.63	0.13	0.77
1992	0.15	0.55	0.27	0.97	0.13	0.60	0.12	0.85
1993	0.28	0.68	0.34	1.30	0.24	0.74	0.15	1.13
1994	0.27	0.67	0.33	1.27	0.23	0.73	0.15	1.10
1995	0.35	0.75	0.37	1.46	0.30	0.81	0.16	1.27
1996	0.32	0.72	0.36	1.40	0.28	0.79	0.16	1.22
1997	0.12	0.52	0.26	0.89	0.10	0.56	0.11	0.78
1998	0.16	0.56	0.28	1.00	0.14	0.61	0.12	0.87
1999	0.36	0.76	0.38	1.49	0.31	0.83	0.17	1.30
2000	0.25	0.65	0.33	1.24	0.22	0.71	0.14	1.08
2001	0.29	0.69	0.35	1.33	0.26	0.76	0.15	1.16
2002	0.31	0.71	0.35	1.37	0.27	0.77	0.15	1.19
2003	0.32	0.72	0.36	1.40	0.28	0.79	0.16	1.22
2004	0.33	0.73	0.37	1.43	0.29	0.80	0.16	1.25
2005	0.35	0.75	0.37	1.47	0.30	0.81	0.16	1.28
2006	0.36	0.76	0.38	1.50	0.31	0.83	0.17	1.31
2007	0.37	0.77	0.39	1.53	0.32	0.84	0.17	1.34
2008	0.15	0.55	0.28	0.98	0.13	0.60	0.12	0.85
2009	0.16	0.56	0.28	1.01	0.14	0.61	0.12	0.88
2010	0.18	0.58	0.29	1.04	0.15	0.63	0.13	0.91
2011	0.19	0.59	0.30	1.08	0.17	0.64	0.13	0.94
2012	0.20	0.60	0.30	1.11	0.18	0.66	0.13	0.97
2013	0.22	0.62	0.31	1.14	0.19	0.67	0.13	1.00
2014	0.23	0.63	0.32	1.18	0.20	0.69	0.14	1.02
2015	0.24	0.64	0.32	1.21	0.21	0.70	0.14	1.05
2016	0.26	0.66	0.33	1.24	0.22	0.72	0.14	1.08
2017	0.27	0.67	0.34	1.28	0.23	0.73	0.15	1.11
2018	0.28	0.68	0.34	1.31	0.25	0.74	0.15	1.14
2019	0.30	0.70	0.35	1.34	0.26	0.76	0.15	1.17
A.M.	**0.25**	**0.66**	**0.33**	**1.24**	**0.22**	**0.72**	**0.14**	**1.08**

Source: Authors estimate based on industry level all India Annual Survey of Industries data- summary results for factory sector (annual time series)

Table 4.4 represents the elasticity of output with respect to labour, capital and energy respectively for all India and all Assam tea manufacturing during 1991-2019. It is observed that the contribution labour, capital and energy turns out to be 0.25, 0.66 and 0.33 respectively. Thus, capital plays a crucial role along with labour and energy in tea industry in India. In case of Assam, the corresponding contribution of capital to total output (0.72) is quite high than the all India level .The contribution of labour and energy turns out to be 0.22 and 0.14 respectively. The scale elasticity of output with respect to the three inputs is greater than the unity (both in India and Assam), reflecting the case of increasing returns to scale.

Table 4.5. Amount of Bias of Inputs at All India Tea Manufacturing (factory level)

Year	Bias of labour	Bias of capital	Bias of energy
1991	-0.012	0.012	-0.279
1992	-0.011	0.010	-0.239
1993	-0.009	0.008	-0.199
1994	-0.007	0.007	-0.159
1995	-0.005	0.005	-0.118
1996	-0.003	0.003	-0.078
1997	-0.002	0.002	-0.038
1998	0.013	-0.012	0.281
1999	0.014	-0.014	0.322
2000	0.016	-0.015	0.362
2001	0.018	-0.017	0.402
2002	0.020	-0.019	0.442
2003	0.021	-0.020	0.483
2004	0.023	-0.022	0.523
2005	0.025	-0.024	0.563
2006	0.027	-0.026	0.604
2007	0.025	-0.024	0.563
2008	0.027	-0.026	0.604
2009	0.029	-0.027	0.644
2010	0.030	-0.029	0.685
2011	0.032	-0.031	0.725
2012	-0.034	0.033	-0.766
2013	-0.032	0.031	-0.725
2014	-0.030	0.029	-0.685
2015	-0.029	0.027	-0.644
2016	-0.027	0.026	-0.604
2017	-0.025	0.024	-0.563
2018	-0.023	0.022	-0.522
2019	-0.021	0.020	-0.482
A.M.	**0.002**	**-0.002**	**0.038**

Source: Authors estimate based on industry level all India Annual Survey of Industries data- summary results for factory sector (annual time series)

Table 4.6. Amount of Bias of Inputs at All Assam Tea Manufacturing (factory level)

Year	Bias of labour	Bias of capital	Bias of energy
1981	-0.009	0.008	-0.198
1982	-0.008	0.007	-0.169
1983	-0.006	0.006	-0.141
1984	-0.005	0.005	-0.112
1985	-0.004	0.004	-0.084
1986	-0.002	0.002	-0.055
1987	-0.001	0.001	-0.027
1988	0.009	-0.008	0.199
1989	0.010	-0.010	0.228

1990	0.011	-0.011	0.256
1991	0.013	-0.012	0.285
1992	0.014	-0.013	0.313
1993	0.015	-0.015	0.342
1994	0.016	-0.016	0.370
1995	0.018	-0.017	0.399
1996	0.019	-0.018	0.428
1997	0.018	-0.017	0.399
1998	0.019	-0.018	0.428
1999	0.020	-0.019	0.456
2000	0.022	-0.021	0.485
2001	0.023	-0.022	0.514
2002	-0.024	0.023	-0.542
2003	-0.023	0.022	-0.514
2004	-0.022	0.021	-0.485
2005	-0.020	0.019	-0.456
2006	-0.019	0.018	-0.427
2007	-0.018	0.017	-0.399
2008	-0.016	0.016	-0.370
2009	-0.015	0.014	-0.341
A.M.	**0.001**	**-0.001**	**0.027**

Source: Authors estimate based on industry level all India Annual Survey of Industries data- summary results for factory sector (annual time series)

Tea industry is generally characterised as a labour intensive industry. This has also been observed not only in India but also in Assam as the average amount of bias of labour turns out to be positive (i.e.; 0.002 and 0.001 respectively) during 1991-2019 in table 4.5 and 4.6 respectively. The average amount of bias of in favour of energy turns out to be 0.038 and 0.027 for India and Assam respectively during the same period. However, the tea industry is found to be slightly capital saving in the tea industry in the last three decades.

V. Conclusion of the study

The average TFPG across various policy regimes, the growth trend of TFP in Assam during the 30 years period, along with RTP (all Assam) reflects almost the same trend as that witnessed in all India level. The estimation of elasticity of output with respect to labour, capital and energy respectively for all India and all Assam tea manufacturing during 1991-2019 period reflect that while capital plays a crucial role along with labour and energy in tea industry in India but in case of Assam, the corresponding contribution of capital to total output (0.72) is quite high than the all India level. The scale elasticity of output with respect to the three inputs is greater than the unity (both in India and Assam), reflecting the case of increasing returns to scale.

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