The previous chapter has detailed the analytical tools used for the study. This includes mathematical economic and econometric methods besides the different techniques of measuring TFPG. Data collection methodologies both from primary and secondary sources are also narrated. This chapter presents the empirical results of the study in three sub-sections. Analytical discussions of the results and necessary interpretations are also presented. To start with, descriptive statistics are presented in the form of summary statistics. The TFPG estimates for all Assam, Barak valley region and upper Assam region under alternative methodologies (parametric and non-parametric) are then presented in a systematic order.

Production function estimates along with the rate of technical progress, its input bias and elasticities for all Assam, Barak valley region and upper Assam region are then analysed. Finally stochastic production and cost frontier estimates and estimates of estate level technical efficiency are presented. Selected scatter diagrams are graphically analysed with economic interpretations of each.

4.1 Empirical Results on TFPG Estimates Using Annual Balance Sheet Information (2001-10) at the Estate level

4.1.1 Descriptive Statistics

The summary of the data set used in the present study is presented in this section. Summary statistics include descriptive statistics as minimum, maximum, arithmetic mean, standard deviation and coefficient of variation.

Summary statistics of variables used to estimate all the production functions and further to compute TFPG are presented in table 4.1.1. The descriptive statistics of the variables reported in the data summary include mean, standard deviation, minimum, maximum, coefficient of variation for output, area cultivated or land, wages as a measure of quantity of labour, pesticides and fertilisers, irrigation, and implements. The summary statistics are computed on the basis of ten years data starting 2001. Land has been measured in hectares, wages are deflated by the cost of living index for industrial workers, and pesticides and fertilizers are measured at their cost deflated by the Whole Sale Price Index (WPI of 1993 =100). Similarly, irrigation and implements are valued at their real cost after deflation by WPI. As expected a new WPI series was released by RBI with 2004-05 as base, i.e., with WPI value for 2004-05 as 100. WPIs for all the time points (2001-10) were expressed with reference to 1993-94 as the base year. This was done by splicing which is a rudimentary application of the unitary method.

Table 4.1.1. 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

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

The data analysed at the estate level is purely based on annual balance sheet information on outputs and inputs at the estate level. Output data is taken in real terms, or in terms of real (absolute) quantities expressed in kg per annum. Table 4.1.1 presents summary statistics of data for the plantation sector and as such output is quantity of green leaf in kg. Table 4.1.2 presents the summary statistics for the same variables but only for upper Assam tea estates. The corresponding figures for Barak valley estates are presented in Table 4.1.3.

Table 4.1.2. Summary Statistics of Variables used to Estimate Production function and TFPG of Upper Assam Estates

Variables	Mean	Standard deviation	Min. value	Max. Value	C.V
Output (kg)	1156002.36	608975.42	109936.8	2739507	0.52
Land (hectares)	620.29	312.19	232.965	1593.11	0.50
Wages (Rs)	28166466.03	12374771.89	8593258.112	71361434.58	0.44
Pesticides &fertilizers (Rs)	47456268.14	30630827.57	15064506.77	1680352947	0.65
Irrigation (Rs)	6468466.39	3915288	57615663.6	16418413	0.61
Implements (Rs)	990238.30	921607	146411.991	4476307.082	0.93

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

Table 4.1.3. Summary Statistics of Variables used to Estimate Production function and TFPG for Barak Valley Estates

Variables	Mean	Standard deviation	Min. value	Max. Value	C.V
Output (kg)	1721672.89	1957587.54	198788	8727946	1.13
Land (hectares)	600.78	235.76	190.4	1152.11	0.39
Wages (Rs)	16539099.74	10210722.02	170038.56	37281168.41	0.62
Pesticides & fertilizers(Rs)	6276908.368	7413717.09	96589	33398964.96	1.18
Irrigation (Rs)	1396326.71	2890481	4808	14374037	2.07
Implements (Rs)	1675936.57	3720993	12454	15981352.28	2.22

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

Table 4.1.4 presents the estate wise mean TFPG estimates for both Upper Assam and Barak valley estates for the ten year period 2001 – 10.

Table 4.1.4. Estate Wise mean TFPG Estimates (both Upper Assam - Barak Valley combined)during 2001-10

Estate ID NO.	Solow Divisia Index	Tornqvist Index	Malmquist Index
1	2.28	0.01	-3.69
2	0.33	0.28	-7.39
3	2.27	0.26	-11.08
4	-0.63	0.10	-0.15
5	0.02	0.39	-4.57
6	6.21	7.17	0.25
7	-0.68	0.16	14.78
8	-0.02	0.16	-0.48
9	-0.94	0.20	-2.87
10	-5.26	-2.45	0.99
11	0.71	-1.32	1.47
12	1.31	0.60	17.84
13	3.35	0.16	7.41
14	3.18	2.12	1.11
15	-0.85	-0.98	4.95
16	-0.97	1.14	4.71
17	1.70	0.52	15.45
18	5.76	5.20	0.75
19	-0.44	-1.75	0.05
20	-0.92	-6.11	0.45
21	-0.44	-1.26	-1.35
22	-0.38	-10.67	-2.05
23	9.66	9.62	-2.75
24	-3.04	-14.22	-3.45
25	-0.02	-0.63	-4.15
26	0.70	10.72	-4.85
27	-1.29	-15.01	-1.93
28	2.79	13.88	1.93
29	-4.69	-8.83	-1.80
30	-0.82	-5.80	-1.33
31	-0.91	-10.74	-0.63
Mean	**0.58**	**-0.87**	**0.57**
S.D.	**2.18**	**6.53**	**6.25**

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

In case of Solow Divisia Index the mean TFPG for all estates (n=31) turns out to be 0.58. However in case of measurement by Tornqvist Index the mean TFPG for all estates turns out to be negative at -0.87. The mean TFPG for all estates taken together when Malmquist index is used turns out to be 0.57. The standard deviation captures the variation in TFPG across estates. The standard deviation is more for Tornqvist and Malmquist Indexes but less for Solow index. Thus greater variability in TFPG is observed in case of Tornqvist and

Malmquist Indexes. Moreover double digit values of TFPG are rarely observed. In case of Solow index estate number 10 exhibits a ten year mean TFPG of -5.26 which is the minimum mean TFPG when measured in terms of Solow divisia index. For the same measure estate number 23 exhibits a mean TFPG value of 9.66 which is the highest in the sample in terms of Solow divisia measure. Clearly lesser variability in mean TFPG is observed in terms of Solow measure compared to the two other measures.

In case of Tornqvist measure the highest mean TFPG observed is 13.88 and the lowest is -15.01. The maximum and minimum mean TFPG in terms of Malmquist index turns out to be 17.84 and -11.08. Negative TFPG is exhibited by many estates and the value varies across measures for the same garden. Since all the three measures (first two parametric and the third non-parametric) are based on the same data set for the same estates it is interesting to note the simple correlation coefficients for the measures. The simple correlation coefficient between the Solow measure and the Tornqvist measure is computed at 0.65 which positive as well as statistically significant. The same correlation figure computed for Solow and Malmquist measures turn out to be 0.03 which is positive but close to zero and statistically insignificant. The corresponding correlation figure between Tornqvist and Malmquist index turns out to be 0.09. This shows that the two parametric measures are strongly positively associated while the parametric measures are not associated with the non-parametric measure. However, as there is no evidence of negative association between these two, they cannot be mutually conflicting results.

Estate Wise mean TFPG Estimates (Upper Assam) during 2001-10 are presented in table 4.1.5.

Table 4.1.5. Estate Wise mean TFPG Estimates (Upper Assam) during 2001-10			
Estate ID NO.	Solow Divisia index	Tornqvist Index	Malmquist Index
1	2.28	0.01	-3.69
2	0.33	0.28	-7.39
3	2.27	0.26	-11.08
4	-0.63	0.10	-0.15
5	0.02	0.39	-4.57
6	6.21	5.17	0.25
7	-0.68	0.16	4.78
8	-0.02	0.16	-0.48
9	-0.94	0.20	-2.87
10	-5.26	-2.45	0.99
11	0.71	-1.32	1.47
12	1.31	0.60	17.84
13	3.35	0.16	7.41
14	3.18	2.12	1.11
15	-0.85	-0.98	4.95
16	-0.97	1.14	4.71
17	1.70	0.52	1.45
Mean	**0.71**	**0.39**	**0.87**
S.D.	**2.48**	**1.58**	**6.41**

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

Table 4.1.5 represents Estate Wise mean TFPG Estimates (for Upper Assam) during 2001-10. The samples mean TFPG is 0.71, 0.39 and 0.87 for Solow divisia index, Tornqvist Index and Malmquist index respectively. The standard deviation turns out to be 2.48, 1.58 and 6.41 for three indices respectively. Therefore, all the indices reflect positive TFPG.

Table 4.1.6 shows the estate wise mean TFPG estimates (for Barak Valley) during 2001-10. The sample mean TFPG is 0.43, -2.54 and -1.51 for Solow divisia index, Tornqvist Index and Malmquist index respectively. The standard deviation turns out to be 3.59, 9.39 and 1.92 for three indices respectively. Thus, except Solow divisia index, other indices reflect negative TFPG in the tea industry in Barak Valley.

Table 4.1.6. Estate Wise Mean TFPG Estimates (Barak Valley) during 2001-10			
	Solow Divisia index	Tornqvist Index	Malmquist Index
1	5.76	5.20	0.75
2	-0.44	-1.75	0.05
3	-0.92	-6.11	0.45
4	-0.44	-1.26	-1.35
5	-0.38	-10.67	-2.05
6	9.66	9.62	-2.75
7	-3.04	-14.22	-3.45
8	-0.02	-0.63	-4.15
9	0.70	10.72	-4.85
10	-1.29	-15.01	-1.93
11	2.79	13.88	1.93
12	-4.69	-8.83	-1.80
13	-0.82	-5.80	-1.33
14	-0.91	-10.74	-0.63
Mean	**0.43**	**-2.54**	**-1.51**
S.D.	**3.59**	**9.39**	**1.92**

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

Table 4.1.7. Year Wise mean TFPG Estimates (Upper Assam) during 2001-10			
Year	Solow Divisia	Tornqvist	Malmquist
2002-03	0.73	-0.44	-3.6
2003-04	-6.72	-14.61	-2.8
2004-05	-2.57	-15.54	-1.6
2005-06	1.72	-1.79	-0.6
2006-07	-8.10	-9.16	1.4
2007-08	5.70	4.17	3.8
2008-09	-5.71	8.81	6.6
2009-10	9.25	4.85	9.8
2010-11	-3.21	1.45	13.4
A.M.	**-0.99**	**-2.47**	**2.93**
S.D.	**5.84**	**8.71**	**5.94**

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

Table 4.1.7 presents the year wise mean TFPG estimates only for upper Assam estates over the period 2001-10. The last three columns show the three different measures of TFPG, namely the Solow divisia index, the Tornqvist divisia index and the non-parametric

Malmquist index. Mean TFPG is found for this sample of estates is found to be negative when measured by both Solow and Tornqvist indexes. However the Malmquist measure shows a positive of mean TFPG. The next table, i.e., table 4.1.8 shows the corresponding mean TFPG figures for Barak valley estates. In case of the 14 estates of Barak valley mean TFPG is also found to be negative with only one difference. Apart from the Solow and Tornqvist measures, the Malmquist measure also gives a negative mean.

Year Wise mean TFPG Estimates (Barak Valley) during 2001-10 are presented in table 4.1.8.

Table 4.1.8. Year Wise Mean TFPG Estimates (Barak Valley) during 2001-10

Year	Solow Divisia	Tornqvist	Malmquist
2002-03	0.323	-0.751	0.75
2003-04	-0.643	-3.889	0.05
2004-05	-1.423.	-9.566	-0.65
2005-06	-1.542	-9.421	-1.35
2006-07	-0.974	-11.323	-2.05
2007-08	-0.825	-11.654	-2.75
2008-09	-0.062	-10.99	-3.45
2009-10	0.314	-7.24	-4.15
2010-11	1.024	-2.23	-4.85
A.M.	**-0.30**	**-7.45**	**-2.05**
S.D.	**0.84**	**4.16**	**1.81**

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

Interpretation of the numerical values of both tables 4.1.7 and 4.1.8 needs to done cautiously. In table 4.1.7 for instance, the Solow divisia measure for 2004-05 computed separately for each of the 17 upper Assam estates yield a sample mean TFPG value of -2.57. This is basically the average TFPG computed for the particular year over all the 17 upper Assam estates. Similar interpretation applies to the corresponding figure of table 4.1.8. That is, -1.42 is the average TFPG for the year 2004-05, computed over the entire cross section of 14 Barak valley estates. Quite naturally there are positive and negative TFPG estates in each region and also each year. The negative mean for a year just indicates the fact that some of the estates have performed poorly in terms of TFPG and further that negative quantities have dominated over the positive ones. In this context it is worth noting that negative TFPG is something that has commonly been observed in Indian industries (Ahluwalia, 1985 and 1991). As exhibited by table 4.1.8, there seems to be a turnaround in terms of TFPG at the industry level post 2009. For the Solow measure TFPG is found positive and rising during the last two years and in case of Tornqvist measure TFPG is found to be negative but falling in absolute terms, thereby implying a rise in TFPG. This pattern however is not exhibited by the non-parametric measure. For upper Assam estates, fluctuations in TFPG are observed throughout and with a downturn towards the end years. Even here non-parametric and the two parametric measures show slightly conflicting results and seem to be non-associated.

TFPG, irrespective of the method or technique of measurement, is basically a difference between output growth (in a real sense) and the factor share weighted sum of factor growths. Hence both theoretically and practically high output growth at the tea estate level may or may not be associated by high growth of total factor productivity. The converse is also true for obvious reasons. A firm having a high output growth during a period may exhibit high, low or even negative TFPG depending on the factor shares and the factor growth rates over that period. Thus generally speaking, TFPG and output growth rates may not be statistically associated.

Figure 4.1 depicts the scatter diagram between Solow divisia measure of TFPG and the output growth at the tea estate level for the entire sample of 31 estates. For simplicity the arithmetic mean output growth in plotted against the mean TFPG over the ten year study period 2001-10.

As seen in figure 4.1, there is no evidence of any association (positive or negative) between TFPG and output growth at the estate level. The simple Pearsonian product moment correlation coefficient between TFPG and output growth turns out to be 0.0054 which is close to zero.

The size of plantation in any plantation based industry is effectively captured by the area cultivated. This is essentially true for the tea plantations. Larger estates may or may not exhibit high TFPG but it is important to test whether large estates have higher TFPG.

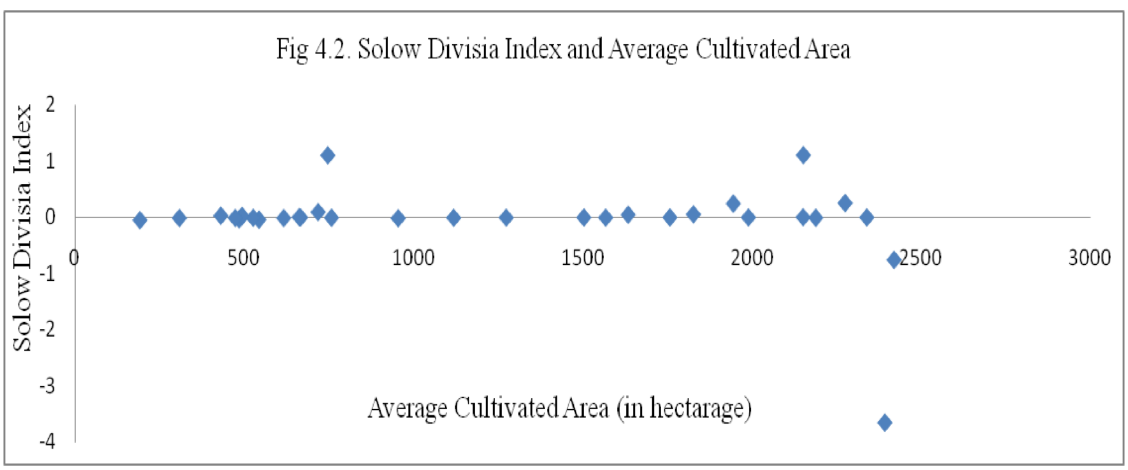
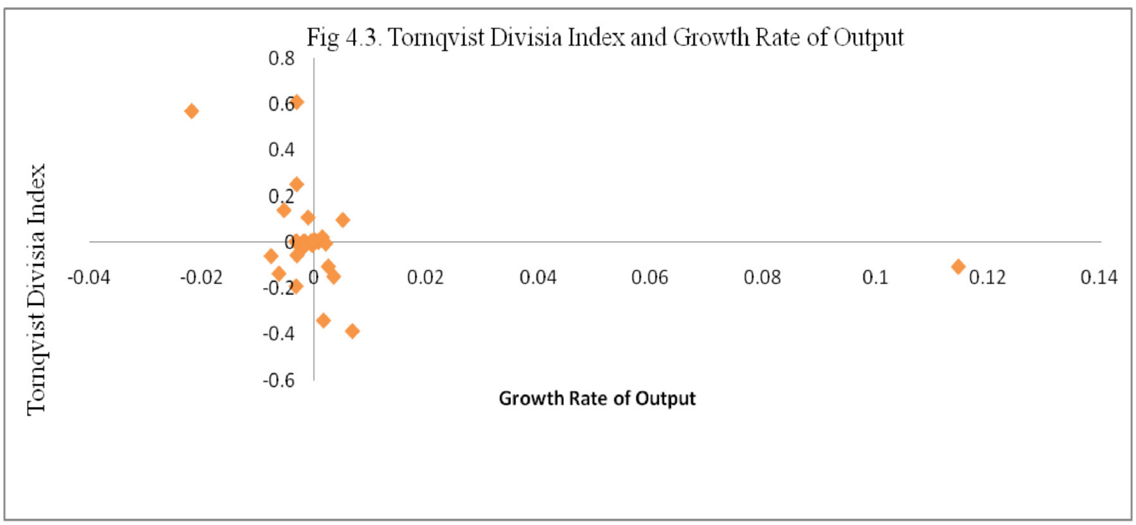


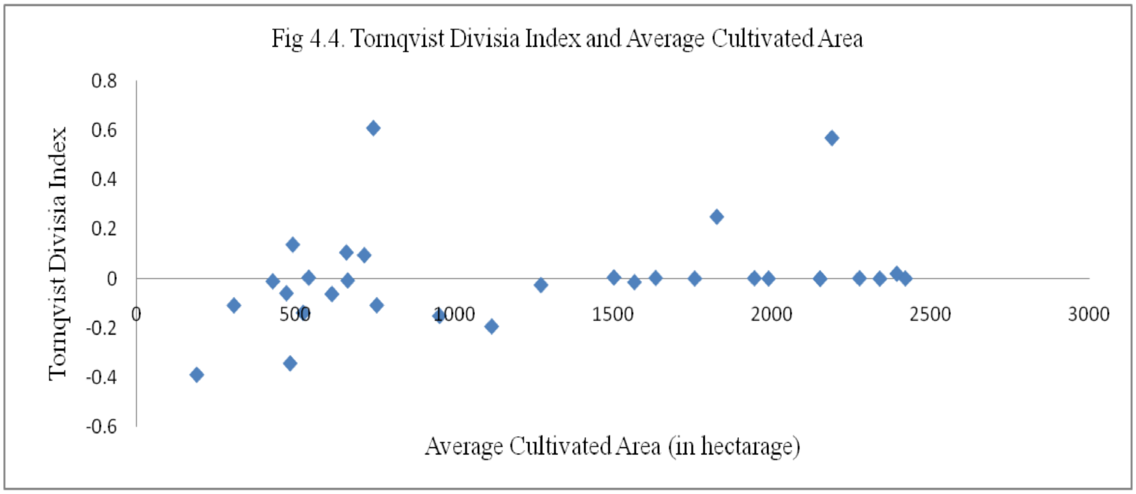
Figure 4.2 depicts the scatter diagram between average Solow divisia index of TFPG and the average area cultivated at the tea estate level over the ten year study period. Clearly no pattern is observed from the scatter and estates of different sizes are observed to exhibit

positive, zero and negative TFPG. The simple correlation coefficient between TFPG and area cultivated turns out to be 0.097 which is statistically insignificant. Thus there is no pronounced association between area cultivated and TFPG among the sample of tea estates in Assam for the period 2001-10.

The scatter diagram between TFPG as measured by the Tornqvist Index and growth rate of output (both averaged over the 10 year period) is shown in figure 4.3. Even in this case no clear pattern of any positive or negative association is observed from the scatter. Moreover the simple correlation coefficient between the two is -0.078 which is negative but is statistically insignificant.



The scatter diagram between TFPG as measured by Tornqvist divisia index and the average area cultivated is presented in figure 4.4. Even in this case there is no observed association between TFPG and area cultivated which is basically size of the plantation.



The frequency distributions for the three different TFPG measures of all 31 sample estates are presented in tables 4.1.9, 4.1.10 and 4.1.11 respectively. Refer to table 4.1.9 which shows the frequency distribution of TFPG of all estates when measurement is done using Solow divisia Index. It is clear that a large number of tea estates (i.e., 54.84 percent of the total sample estates) have TPFG value between -1.26 and 0.74 which is poor. Roughly 32 percent of the estates have a TFPG value of 0.74 or more. In fact just three estates have exhibited a TFPG value of 4.74 to 10.74. In other words just around 10 percent of the estates are found to be performing well in terms of TFPG.

Table 4.1.9. Frequency Distribution of TFPG across Estates for Solow Divisia Index		
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	2.18	

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

Table 4.1.10. Frequency Distribution of TFPG across Estates using Tornqvist Divisia Index		
Class Interval	Absolute Frequency	Relative Frequency (%)
(-15.01) - (-11.01)	2	6.45
(-11.01) - (-7.01)	3	9.68
(-7.01) - (-3.01)	2	6.45
(-3.01) - (0.99)	17	54.84
(0.99) - (4.99)	2	6.45
(4.99) - (8.99)	2	6.45
(8.99) - (12.99)	2	6.45
(12.99) - (16.99)	1	3.23
Mean TFPG	-0.87	
Minimum TFPG	15.01	
Maximum TFPG	13.88	
Standard Deviation	6.53	

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

Table 4.1.10 shows the frequency distribution of TFPG of all estates when measurement is done using Tornqvist divisia Index. There exists a similarity in the distributions of TFPG across estates in table 4.1.10 compared to that in table 4.1.9. However the range of TFPG values observed in table 4.1.10 is slightly dissimilar. Coincidentally 54.84 percent of estates have TFPG values in between -3.01 and 0.99. This is somewhat similar to the observation in table 4.1.9, which shows that the same percentage of estates (that is, 54.84 percent), have TFPG value in between -1.26 and 0.74 in case of the Solow measure. This striking similarity of over concentration of estates in a particular class or range of TFPG values is further observed in case of the TFPG distribution for the Malmquist measure.

Table 4.1.11. Frequency Distribution of TFPG across Estates using Malmquist Index

Class Interval	Absolute Frequency	Relative Frequency (%)
(-11.08) - (-7.08)	1	3.23
(-7.08) - (-3.08)	5	16.13
(-3.08) - (0.92)	15	48.39
(0.92) - (4.92)	5	16.13
(4.92) - (8.92)	2	6.45
(8.92) - (12.92)	0	0
(12.92) - (16.92)	2	6.45
(16.92) - (20.92)	1	3.23
Mean TFPG	0.57	
Minimum TFPG	-11.08	
Maximum TFPG	17.84	
Standard Deviation	6.25	

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

In table 4.1.11 it is observed that around 48 percent of estates have TFPG value in between -3.08 and 0.92. This is again a high concentration of firms (or estates) within a particular range or class of TFPG values. Admittedly this is not a surprising observation.

It is quite possible that a group of estates in a region (either upper Assam or Barak valley) having similar sizes of plantations (in terms of area), staff strength (both permanent and casual), factory, machinery and equipment and also growing similar varieties of tea may have relatively small differences in yield of green leaf per hectare, and input requirements per hectare. If input and output variations are small across a particular group of estates, they are also expected to exhibit TFPG values (over a period) that do not vary much across each other. This is simply because TFPG is the difference between real output growth and the sum of the factor share weighted input growths. This can explain such over-concentration of estates in a particular class interval of TFPG.

Bivariate Correlation Analyses are presented in table 4.1.12.

Table 4.1.12. Bivariate Correlation Analysis

	TFPG	IC	MC	WS	WFS	DEP	W	PF	I	IMP	H	Y
TFPG	1											
IC	-0.17	1										
MC	0.05	0.24	1									
WS	-0.12	0.10	0.48	1								
WFS	-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					
PF	-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			
IMP	-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;
WFS = Welfare sundries; DEP = Depreciation
IMP. = Implements; Y= Output;
W = Wage; P = Pesticides and fertilisers;
H = Hectare I = irrigation

Pair wise ordinary correlation coefficients between all variables considered for estimation of the production functions and TFPG are presented in Table 4.1.12. Variable names and their abbreviations are given below the table. TFPG is seen to be negatively correlated with almost all variables except area under cultivation (H). Immature cultivation is positively associated with mature cultivation, wages, area under cultivation and output which are expected. Mature cultivation is found to be strongly positively associated with workers sundries, welfare sundries, implements and area under cultivation and output. Interestingly workers' sundries and welfare sundries are positively associated with output. Generally variables as workers sundries and welfare sundries are taken as welfare expenses on tea estate workers. Both these variables are found to have positive association with output. One explanation could be that workers health and fitness levels are vital for efficient estate maintenance and obviously on plucking. Plucking efficiency depends not only on experience of the workers but also on their physical capability.

In the present study wages are taken as a measure of labour quantity. Arguably in the plantation sector (tea included) labour quantity is perhaps the most important variable factor that can influence both TFPG and efficiency. Output and wages are strongly positively associated which is natural. A strong positive correlation is also observed between area under cultivation and mature cultivation which is also expected. Area and output are also positively associated. Labour quantity negatively influences TFPG as the correlation coefficient between the two is found negative. This may imply that firms with higher growth rate of labour have lower TFPG. This apparently is not surprising as because TFPG is real output growth minus the sum of all factor share weighted input growths. Labour is also a factor and so if labour recruitment surpasses some threshold limit then over a particular period, labour share may rise (as a percentage of output), or labour growth rate may rise or both, thereby resulting in low and even negative TFPG. Thus excess growth rate of labour may result in lower TFPG across estates.

In the plantation sector during certain years and seasons rejection of old bushes, maintenance of immature cultivation and the gradual transition from immature to mature cultivation may require excessive labour or work force. Moreover complete rejection of old bushes and replanting new saplings (i.e., developing an immature cultivation) requires enormous labour effort. The labour requirement goes down once the young bushes have grown to become mature bushes. All estates do not require such heavy labour effort at the same time even if they are located in the same agro-climatic zone. During this phase of transition the labour bill may overshoot and output may not expand fast due to limited plucking. After a season or two this picture is supposed to change dramatically when immature cultivation has been transformed to mature cultivation so that sufficient plucking may be done in each season. As rejection and uprooting of old bushed and developments of immature cultivation by planting fresh saplings are no longer required within a few seasons, labour use is devoted to irrigation, pruning, pesticides, and fertiliser application and finally to plucking.

Thus after this transitionary phase output is expected to grow faster than factor share weighted inputs. Understatedly this industry is plantation based and as such labour, irrigation and pesticides are the most vital inputs for a given soil quality. Regarding good performance in terms of output growth and yield, another vital aspect needs to be observed and that is rainfall. Irrigation in tea estates is sometimes done artificially but to a limited extent. If 500 hectares of mature cultivation is to be watered by artificial means (such as sprinkler irrigation), then that would not be cost effective. Thus tea estates are over dependent on the monsoon or even occasional rainfall during other times of the year. The early summer rains and late winter rains are most important for development of fresh buds. These buds are supposed to appear in spring, i.e., during March – April each year. If there is low or scanty rainfall during the spring season in the districts of Assam where the tea estates are most concentrated, then the summer tea is most likely to be affected as because the first plucking of the year is done just before the summer sets in. Quite naturally if there is an under rainfall during the monsoons then the autumn tea is likely to be affected. In the plantation sector poor performance in terms of yield and TFPG may occur during adverse weather conditions. Thus TFPG may turn out to be negative or low during drought like years despite applications of all inputs in their correct proportions.

Ordinary Least Square Estimates of the Cob-Douglas Production Function (Both Upper Assam - Barak Valley combined) are presented in table 4.1.13.

Table 4.1.13. Ordinary Least Square Estimate of the Cob-Douglas Production Function (Both Upper Assam and Barak Valley)

coefficients of	Estimated value	t ratio	Sig.
Constant	7.558	16.873	0.000
Land	0.997	13.401	0.000
Wages	0.074	1.373	0.171
P&F	-0.085	-1.382	0.168
Irrigation	0.017	0.575	0.568
R square : 0.488; adjusted R^2=0.479; F =52.689			
Output Elasticity w.r.t Land	= 0.997		
Output Elasticity w.r.t wages	= 0.074		
Output Elasticity w.r.t pesticides & fertilizers	= -0.085		
Output Elasticity w.r. t Irrigation	= 0.017		
Scale Elasticity of output	= 1.003		

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

As is evident from the OLS estimate of the Cobb-Douglas production function (Both Upper Assam - Barak Valley combined), all factors influence output positively (except pesticides which plays a negative role in determining output). However negative influence of pesticides is not evident from the cross correlation results in table 4.1.12. Moreover all Inputs are not statistically significant. Only the area under cultivation is statistically significant while labour, pesticides and fertilizers and irrigation are not. Labour plays an insignificant role in determining estate level output in Assam. This is an unexpected finding. Output is more sensitive with respect to area under cultivation. The scale elasticity of output turns out to be

1.003 representing the case of Constant Returns to Scale (CRS) which is tested to be statistically insignificant.

Ordinary Least Square Estimates of the Cob-Douglas Production Function (Upper Assam) are presented in table 4.1.14.

Table 4.1.14. Ordinary Least Square Estimate of the Cob-Douglas Production Function(Upper Assam)

coefficients of	**Estimated value**	**t ratio**	**Sig.**
Constant	7.837	17.889	0.000
Land	1.025	8.998	0.000
Wages	0.024	0.124	0.902
P & F	-0.180	-1.209	0.228
Irrigation	0.055	1.275	0.204
R square : 0.552; adjusted R^2=0.541; F =50.861			
Output Elasticity w.r.t Land		=1.025	
Output Elasticity w.r.t wages		=0.024	
Output Elasticity w.r.t pesticides & fertilizers		=-0.180	
Output Elasticity w.r. t Irrigation		=0.055	
Scale Elasticity of output		=0.924	

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

The OLS estimate of the Cobb-Douglas production function (Upper Assam) in table 4.1.14 shows almost the same picture as is found in case of sample of entire Assam. The only difference is that in case of Upper Assam the scale elasticity of output is 0.924 whereas in case of entire Assam it is 1.003.

The OLS estimate of the Cobb-Douglas production function (Barak Valley) in table 4.1.15 reflects that land and wage influence output positively while pesticides & fertilizers and irrigation play a negative role in determining output. Among all Inputs only the area under cultivation is statistically significant while labour, pesticides and fertilizers and irrigation are not. The scale elasticity of output turns out to be 1.281 indicating the case of increasing returns to scale.

Table 4.1.15. Ordinary Least Square Estimate of the Cob-Douglas Production Function(Barak Valley)			
coefficients of	**Estimated value**	**t ratio**	**Sig.**
Constant	5.523	4.185	0.000
Land	1.292	5.924	0.000
Wages	0.143	1.744	0.087
P & F	-0.021	-0.218	0.828
Irrigation	-0.133	-1.871	0.067
R square :0.466 ; adjusted R^2=0.425; F =11.148			
Output Elasticity w.r.t Land	= 1.292		
Output Elasticity w.r.t wages	= 0.143		
Output Elasticity w.r.t pesticides & fertilizers	=-0.281		
Output Elasticity w.r.t Irrigation	= -0.871		
Scale Elasticity of output	=1.281		

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

The most commonly observed statistical finding of tables 4.1.13, 4.1.14 and 4.1.15 is that area under cultivation or land is the most significant factor for the production of green leaf. Although practically labour is perhaps the single most important factor of production in tea plantation, its statistical significance in ordinary regression analysis is very small. This is slightly unexpected but can be logically explained. In plantations as tea the most vital factor that potentially explains output fluctuations across estates is the size of mature cultivation relative to the total cultivated area of the garden. It is mature cultivation from where plucking is done. The level of plucking in an entire season determines the seasonal green leaf output. Labour may turn out to be insignificant if it does not vary significantly across firms and output fluctuations are little affected by labour quantity fluctuations. On the other hand area under cultivation can explain to a large extent the variations in output across firms or estates.

The transcendental logarithmic production functions are estimated separately for all Assam, Upper Assam and Barak valley estates with the help of panel data on 31 estates over the ten year period 2001-10. These results are presented in tables 4.1.16, 4.1.17 and 4.1.18 respectively. The estimates of parameters of a translog production function do not have any direct interpretation; rather the elasticities of output with respect to inputs are important. In a time varying translog production function the rate of technical progress and its direction of bias is also important.

Table 4.1.16. Parameter Estimates of Translog Production Function (Upper Assam - Barak Valley combined) using OLS

Variables	Coefficients	Estimated values	t-value
constant	α	8.891	2.989
Ln w	β_w	-0.171	-0.581
Ln p	β_p	-0.999	-2.369
Ln I	β_i	5.486	4.562
Ln H	β_h	0.975	3.014
Time (t)	β_t	-0.508	-0.482
t x t	β_{tt}	-0.005	-0.633
W x t	β_{wt}	-0.324	-0.321
P x t	β_{pt}	0.010	0.109
I x t	β_{it}	0.020	0.414
H x t	β_{ht}	0.104	0.916
W x w	β_{ww}	0.903	0.579
W x p	β_{wp}	-0.857	-0.797
W x i	β_{wi}	0.382	0.185
W x h	β_{wh}	0.173	0.205
P x p	β_{pp}	-0.119	-0.116
P xi	β_{pi}	0.140	0.287
P x h	β_{ph}	-0.585	-0.487
I x i	β_{ii}	0.180	0.365
I x h	β_{ih}	0.018	0.382
H x h	β_{hh}	0.097	0.853
R square = 0.57, F = 3.04			

Source: Author's estimates based on firm level primary data.
Note: W = Wage; P =Pesticides and fertilisers; I = Irrigation; H = Hectare.

Estimates of translog production function (Upper Assam) are presented in table 4.1.17

Table 4.1.17. Parameter Estimates of Translog Production Function (Upper Assam)

Variables	Coefficient	Estimated values	t-value
Ln w	β_w	1.985	1.114
Ln p	β_p	-4.615	-3.055
Ln I	β_i	-.731	-0.753
Ln H	β_h	4.503	2.443
Time (t)	β_t	-0.112	-0.839
T x	β_t^2	0.012	1.051
W x t	β_{wt}	-0.112	1.032
P x t	β_{pt}	-0.056	-0.185
I x t	β_{it}	0.132	1.386
H x t	β_{ht}	-0.135	-0.542
W x w	β_{ww}	-9.195	-0.567
W x p	β_{wp}	0.388	0.033
W x i	β_{wi}	0.202	0.058
W x h	β_{wh}	6.627	0.723
P x p	β_{pp}	-0.758	-0.230
P xi	β_{pi}	0.007	0.002
P x h	β_{ph}	0.760	0.357
I x i	β_{ii}	0.166	0.182
I x h	β_{ih}	-0.443	-0.186
H x h	β_{hh}	37.094	0.606
R Sq. = 0.24		F = 4.433	

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

Note: W = Wage; P =Pesticides and fertilisers; I = Irrigation; H = Hectare.

Estimates of translog production function (Barak Valley) are presented in table 4.1.18.

Table 4.1.18. Parameter Estimates of Translog Production Function (Barak Valley)

Variables	Coefficients	Estimated values	t-value
Ln w	β_w	2.064	1.112
Ln p	β_p	-2.548	-1,506
Ln I	β_i	-1.550	-0.800
Ln H	β_h	6.498	0.926
Time (t)	β_t	0.149	0.419
T x t	β_t^2	-0.033	-0.563
W x t	β_{wt}	0.007	0.269
P x t	β_{pt}	-0.022	-0.693
I x t	β_{it}	0.017	0.696
H x t	β_{ht}	-0.060	-0.851
W x w	β_{ww}	1.953	0.759
W x p	β_{wp}	0.827	-0.534
W x i	β_{wi}	-0.199	0.410
W x h	β_{wh}	4.899	0.719
P x p	β_{pp}	0.363	0.651
P xi	β_{pi}	0.019	0.984
P x h	β_{ph}	-0.099	-0.968
I x i	β_{ii}	0.222	0.984
I x h	β_{ih}	1.854	0.879
H x h	β_{hh}	0.139	0.017
R Sq. = 0.27			F = 3.433

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

Note: W = Wage; P =Pesticides and fertilisers; I = Irrigation; H = Area Cultivated in Hectare

The elasticities of output with respect to inputs and the scale elasticities for all Assam, Upper Assam and Barak valley tea estates are presented in tables 4.1.19. Output elasticity with respect to wages or labour is low in both regions. Output is more than unitary elastic with respect to area under cultivation or land. The value for Barak valley region is slightly higher. Irrigation has low elasticity value in all regions but the value is found to be negative for Barak valley estates. This could be a sample aberration. Higher irrigation expenditure may be associated with lower output only during drought like situations where output is likely to fall even if all inputs are normally applied. However a ten year period is not supposed be drought like and hence more number of Barak valley estates need to be studied before a decisive comment can be made on the negative elasticity of irrigation. Pesticides and fertilizers have negative output elasticity. The absolute value is low and thus whether this is a part of a general pattern or not cannot be said without studying a larger sample of estates of both regions. The Cobb-Douglas scale elasticity of output turns out to be 0.924 for upper Assam which is almost unity which is indicative of constant returns to scale. For Barak valley region estates this value is slightly above unity thereby indicating increasing returns to scale. However the combined data shows indications of constant returns to scale.

Comparison of Elasticities of output with respect to inputs (Cobb-Douglas Production function) is presented in table 4.1.19.

Table 4.1.19. Output Elasticities with respect to Inputs using Cobb - Douglas Production Function

Inputs	Upper Assam	Barak Valley	Upper Assam - Barak Valley combined
Wages	0.024	0.143	0.074
Hectare	1.025	1.292	0.997
Irrigation	0.055	-0.133	0.017
P & F	-0.180	-0.021	-0.085
Scale Elasticity of Output	0.924	1.281	1.003

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

Comparison of TFPG indices between Upper Assam - Barak Valley combined are shown in table 4.1.20.

Table 4.1.20. Comparison of TFPG Across Regions

Measure	Upper Assam	Barak Valley	Upper Assam - Barak Valley combined
Solow	5.41	0.423	0.58
Tornqvist	3.91	-6.83	-2.49
Malmquist	4.63	-1.51	0.89
Translog RTP	0.673	-0.525	-0.797

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

Table 4.1.20 presents the TFPG estimates for both regions separately and as well as on the basis of all estates pooled together. These estimates are presented on the basis of ten years average computed separately for each formula. From the comparison of upper Assam and Barak valley estates it is evident that all measures of TFPG provide higher values for upper Assam. Thus it is perhaps correct to state that upper Assam estates are better performers when it comes to total factor productivity growth. The Barak valley region shows poor performance in terms of Tornqvist, Malmquist as well as the translog measure of technical change.

Table 4.1.21. Comparison of Output Elasticities (Upper Assam - Barak Valley combined)

Elasticity of output with respect to	Translog production Function	Cobb-Douglas production function
Wages	1.099	0.074
Hectare	1.252	0.997
Irrigation	0.207	0.017
Pesticides & Fertilisers	-2.494	-0.085
Scale Elasticity of output	0.064	1.003

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

Table 4.1.21 shows the comparison of output elasticities for translog and Cobb-Douglas functions for all estates pooled together. The translog values are clearly higher in absolute quantity. But one significant difference lies in the labour elasticity as measured by the Translog function vis – a – vis the Cobb Douglas function. Elasticity of labour is beyond unity when measured by the translog function but is near about zero when measured by the Cobb-Douglas function. This may be indicative of the fact that the Cobb-Douglas production function is be an improper specification of the technological relationship between output and inputs. However land is an elastic factor by both measures, translog giving a slightly higher value. Output is not much sensitive with respect to irrigation and has negative elasticity with respect to pesticides and fertilizers. This has been observed before in tables 4.13, 4.14 as well as in table 4.1.15. Somehow it seems that higher applications of pesticides and fertilizers have a derogatory impact on output. A deeper and dedicated study needs to be undertaken in order to clearly understand the inverse or negative impact of higher pesticides and fertilizers on output in the tea estates of Assam and elsewhere in India. Higher pesticide content in tea may be harmful for export growth and even perhaps domestic sales, but exactly how and why total green leaf or estate output may be adversely affected due to higher fertilizer and pesticide use is difficult to understand.

Comparison of Output Elasticities (Upper Assam) is shown in table 4.1.22.

Table 4.1.22. Output Elasticities with respect to Inputs (Upper Assam)

Elasticity of output with respect to	Translog production function	Cobb-Douglas production function
Wages	1.413	0.024
Hectare	0.850	1.025
Irrigation	0.323	0.055
Pesticides & Fertilisers	-1.333	-0.180
Scale Elasticity of output	1.252	0.924

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

Table 4.1.22 presents a comparison between the partial factor elasticities as measured by the OLS estimates of parameters of the translog production function and the Cobb-Douglas production function only for upper Assam estates. Even here it is observed that elasticity of labour as measured by the translog function is much higher than the corresponding value estimated by the Cobb-Douglas function. In fact the latter estimates show near about zero value of labour elasticity. Elasticity of land or area under cultivation is found to be higher for the Cobb-Douglas estimates. Irrigation has low elasticity according to both these production functions. As usual pesticides and fertilizers have negative partial elasticity as per translog estimates as well as according to Cobb-Douglas estimates. For the pooled data (upper Assam and Barak valley combined) translog estimates of scale elasticity of output is found to be very low (0.064) whereas the corresponding figure for upper Assam estates is estimated at 1.252 which is clearly greater than unity. For upper Assam output is elastic with respect to labour according to the translog estimates but labour is inelastic according to Cobb-Douglas estimates. Pesticides and fertilizers have negative partial elasticities which is a finding of table 4.1.21 as well.

Table 4.1.23. Output Elasticities with respect to Inputs (Barak Valley)

Elasticity of output with respect to	Translog production function	Cobb-Douglas production function
Wages	1.047	0.413
Hectare	0.229	1.294
Irrigation	-0.134	-0.387
Pesticides & Fertilisers	-0.562	-0.022
Scale Elasticity of Output	0.571	1.318

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

Table 4.1.23 shows the comparison of input elasticities separately for the translog and Cobb-Douglas production function estimates for Barak valley estates only. Even in this case output is found to be elastic with respect to labour according to the translog estimates but not as far as the Cobb-Douglas estimates are concerned. Moreover the translog estimates give negative elasticity values with respect to irrigation and pesticides and fertilizers and the magnitudes are substantial. As a consequence of these large negative elasticity values the scale elasticity as measures by the translog function is found to be low. The Cobb-Douglas estimates do not reveal such high negative estimates of elasticities and thus the scale elasticity for Cobb-Douglas production function is above unity although the labour elasticity is low. Somehow it appears that estates that spend more on irrigation and pesticides and fertilizers have lower output of green leaf.

Regression Estimates of Rate of Technical Progress (RTP) are presented in table 4.1.24.

Table 4.1.24. Regression Estimates of Rate of Technical Progress (RTP)

Estimated coefficients								Overall Significance and Nature of Technical progress (TP)		
Type	β_t	β_{tt}	β_{wt}	β_{ht}	β_{it}	β_{pt}	R^2	F	D.W. stat.	Type of TP
All Assam combined	0.005 (0.54)	0.006 (0.70)	-0.036 (-0.36)	0.116 (1.02)	0.022 (0.47)	0.011 (0.12)	0.12	0.38	2.25	Neutral
Upper Assam	0.003 (0.073)	-0.003 (-2.89)	-0.035 (-1.80)	-0.135 (1.47)	0.132 (-1.76)	-0.056 (0.89)	0.31	2.086	2.38	Neutral
Barak Valley	0.089 (0.91)	0.0004 (0.006)	0.005 (0.784)	0.013 (0.85)	-0.004 (0.837)	-0.009 (-1.24)	0.16	0.73	2.13	Neutral

Source: Author's estimates based on firm level primary data
Note: Figures in parenthesis are estimated t values.

Table 4.1.24 shows the regression estimates for the rate of technical progress (RTP) as measured by the ordinary least squares estimates of time derivative of the translog production function. This is actually the translog rate of technical change. It is to be noted is that the dependent variable for this regression is the time derivative of the natural logarithm of output in real terms. This table presents results of a panel data regression on the basis of estate level data, i.e., 31 estates over 10 years for the combined sample of upper Assam and Barak valley, 17 estates over the same period for upper Assam, and 14 estates over the same period for Barak valley. As in the previous cases no sophisticated panel data techniques are used. All regressions done so far are basically pooled regressions. The estimates presented in table 4.1.24 represent the OLS estimates of equation number (3.8.1.10). This is already written in the methodology chapter (chapter 3, section 8).

The parameter estimates of the time derivative of the translog production function shown in table 4.1.24 reveal mostly insignificant estimates of the parameters. The Durbin-Watson test statistic is close to 2.0 which is indicative of no first order autoregressive scheme in the errors. The F value is also small thereby indicating that the overall regression is statistically insignificant. The R square vale is 0.12 thereby implying that just 12 per cent of the variation in $d(lnY)/dt$ is explained by the line of linear regression. In case of upper Assam the overall regression is significant at 11.2 per cent but not at 5 per cent level. R-square value is higher at 0.31. Surprisingly, the coefficient of time squared is significant at 1 per cent and moreover the value is negative. Thus for upper Assam estates it is apparent that RTP is declining and the rate of decline is statistically significant. For Barak valley estates this is not true. All coefficients are found to be statistically insignificant in case of Barak valley estates. The overall regression is also insignificant on account of low value of the computed F statistic. Moreover r-square value is just 0.16. For upper Assam estates there seem to be a bias in technical progress against labour and land. This is not true for Barak valley estates. This functional form seems to be an improper representation of the technological relation between growth rates of output and inputs of the model.

The year wise translog rate of technical change is presented in table 4.1.25. Separate estimates are computed for upper Assam and Barak valley estates. The combined RTPs are also computed and shown in the same table. The results are computed on the basis of the estimates of the parameters of the time derivative of the time varying translog production function. These estimated parameters are presented in the previous table. These estimates of RTP are different in many senses compared to the Solow, Tornqvist and Malmquist index measures. Although significant bias with respect to any factor is not observed the RTP is found to be negative for each year for all upper Assam estates and also for all Barak valley estates. Moreover the absolute values are higher for upper Assam compared to Barak valley estates. Thus RTP is found to be lower in upper Assam estates taken as a whole. The reverse phenomenon was observed for the Solow, Tornqvist and Malmquist index measures where it was observed that TFPG was positive for upper Assam estates and negative for Barak valley estates. Moreover according to the figures in table 4.1.25 the Barak valley estates are seen to exhibit rising RTP values although the values themselves are negative. The positive TFPG observed for upper Assam estates are not reflected in the translog rate of technical progress estimates.

Year Wise Rate of Technical Progress (RTP) series during 2002-10 is presented in table 4.1.25.

Table 4.1.25. Year Wise Translog Rate of Technical Progress (RTP)

Year	Upper Assam	Barak Valley	Upper Assam – Barak Valley combined
2002	-0.183	-0.009	-0.113
2003	-0.185	-0.008	-0.114
2004	-0.191	-0.006	-0.117
2005	-0.197	-0.006	-0.121
2006	-0.203	-0.004	-0.123
2007	-0.208	-0.004	-0.126
2008	-0.213	-0.003	-0.128
2009	-0.218	-0.002	-0.132
2010	-0.224	-0.001	-0.134
A.M.	**-0.202**	**-0.004**	**-0.123**

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

Although most of the variables of the RTP regression turned out to be insignificant, the direction and the average quantity of bias were still computed for each input using the estate wise secondary data and the estimated parameters

Direction and amount of bias (Upper Assam - Barak Valley combined) with respect to inputs are presented in table 4.1.26.

Table 4.1.26. Direction and Amount of Bias with respect to Inputs (Both Upper Assam - Barak Valley combined)

Inputs	Direction of Bias	Amount of Bias
Hectare	Positive	0.704
Wages	Negative	-1.125
Irrigation	Positive	0.691
Pesticides & Fertilisers	Positive	0.801

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

Direction and amount of bias (Upper Assam) with respect to inputs are presented in table 4.1.27.

Table 4.1.27. Direction and Amount of Bias with respect to Inputs (Upper Assam)

Inputs	Direction of Bias	Amount of Bias
Hectare	Negative	-0.514
Wages	Negative	-0.594
Irrigation	Positive	1.082
Pesticides & Fertilisers	Negative	-0.715

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

Direction and amount of bias (Barak Valley) with respect to inputs are presented in table 4.1.28.

Table 4.1.28. Direction and Amount of Bias with respect to Inputs (Barak Valley)

Inputs	Direction of Bias	Amount of Bias
Hectare	Negative	0.726
Wages	Positive	0.518
Irrigation	Positive	-0.652
Pesticides & Fertilisers	Negative	-0.486

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

Refer to table 4.1.26 the direction and the amount of bias with respect to inputs for the combined data for upper Assam and Barak valley are shown here. Clearly translog rate of technical change is biased in favour of area under cultivation (as captured by the variable 'land'), irrigation and pesticides, but it is biased against labour. This is evident from the signs of the β_{it}'s although all are insignificant in case of the combined (upper Assam and Barak valley) regression of RTP. In case of upper Assam alone (refer to table 4.1.27) the translog rate of technical change is biased against labour, land and pesticides and fertilizers, but is biased in favour of irrigation. In case of Barak valley (refer to table 4.1.28) the translog rate of technical change is biased in favour of labour and land but is biased against irrigation and the combination of pesticides and irrigation. In view of the insignificant t values of the coefficients the technical change is neutral for all Assam and Barak valley. The microeconomic significance of the nature and quantum of bias is more important. Positive bias in factor i (evident from the sign of each β_{it}) implies that technical progress is intensive in the i^{th} factor or is i^{th} factor using. Analogously, a negative bias in factor i (evident from the sign of each β_{it}) implies that technical progress is i^{th} factor saving.

4.2 Empirical Results on TFPG Estimates Using ASI Data (1981-2010) at the Industry Level

The empirical analysis done so far has dealt with estate level input-out data of the plantation sector only. However the factory sector is an equally important sector for the tea industry as because tea processing is done at the processing plants or what is otherwise known as tea factories, which manufacture processed tea.

The same approaches to measurement of total factor productivity growth adopted at the industry level may or may not give results similar to the ones obtained from the analysis of estate level data. In this study industry level might mean the industry data at the state level

(Assam) as well as that at the national level (all India). Hence given the access to both these types of secondary data the study has the opportunity of comparing national level and state level TFPG estimates making use of all the alternative measures. The non-parametric measure of Malmquist is not used for the industry level TFPG measurement for both all India and all Assam data. The industry level analysis is done for the period 1981 – 2010.

In case of tea, the meaning of 'industry' at the state and national levels must be clear. The industry level TFPG analysis is based on secondary time series data obtained from Annual Survey of Industries: *Summary Results for Factory Sector*, Annual Time Series (various issues). Industry level data for tea processing implies secondary data on all tea processing factories operating in the country (or state, as the case may be) during the period under consideration. As per National Industrial Classification 2008, the 5 digit level industrial code (NIC code) for tea processing or manufacturing is 10791. To be precise NIC code 10791 includes "processing and blending of tea including manufacture of instant tea". With the help of the NIC-1998 concordance tables the tea processing industry was marked out or identified for the pre 1998 years at the three digit level of classification and then an uninterrupted time series at the state and national level was formed for the period 1981-2010.

Originally tea processing was classified under manufacturing or processing of ready-made food and beverages, including all types of food processing units that also included coffee and cocoa. The 3-digit classification was actually an aggregation from where isolation of the tea processing or manufacturing industry was difficult.

For the industry level TFPG analysis (using alternative measures), both for the state as well as for the all India level, gross value added is taken as suitable measure of output. Labour, capital and energy are the only three inputs taken to explain gross value added. The value of electricity, fuel and lubricants are clubbed together and renamed as energy. Labour is measured by total wages and emoluments paid to factory workers. Finally capital is measured by gross fixed capital stock. Measurement of real labour time is sometimes a controversial exercise in Indian industries and hence labour quantity in this study is captured by the payments made to all workers and employees. Measurement of true economic depreciation is a complicated exercise. So the study takes gross fixed capital stock as the capital input. Raw materials and intermediate inputs are not considered due to absence of suitable deflators to deflate the nominal quantities. If raw materials are included then final output (and not gross value added) may be taken to compute TFPG series as well as for all production function estimations. However if raw materials are not taken then the logical thing to do is to take gross value added as a proxy for output.

Measurement of gross fixed capital stock is slightly a complicated exercise. The present study uses the perpetual inventory accumulation method of measuring capital stock which is gross fixed capital stock at constant prices. Roychoudhury's (1977) rule of thumb of "doubling the base period value of fixed capital" is done to approximate the replacement cost of plant and machinery for the bench mark year. This figure is deflated by the Whole sale price index (WPI) of machinery and equipment to arrive at a measure of gross fixed capital stock for the benchmark year. The gross fixed capital stock series at constant prices is then computed by the method of perpetual inventory accumulation for the period 1981 to 2009. The WPI series was obtained from RBI Report on Currency and Finance (various issues). The initial base period was 1981 (WPI for 1981=100). The more recent WPI series of 1993 and 2001 as base periods were all converted to the 1981 base period by splicing or what is otherwise a unitary method. This approximation is inevitable to derive an uninterrupted WPI series. The same method was adopted for other price indexes as well. Nominal wages were deflated by the Cost of Living Index for Industrial Workers (CLI). The combined input of electricity, fuel and lubricants (energy in this study) was deflated by the WPI for fuel and lubricants. Separate deflators were thus used for capital stock, labour and energy.

The gross value added which is a proxy for output was deflated by the WPI for all processed or manufactured food articles. All the WPIs are available at Reserve Bank of India: Handbook of Statistics on the Indian Economy (various issues). Uninterrupted time series on the real variables – gross value added, labour, capital stock and energy was arranged for the time period 1981-2009 in order to measure TFPG for tea processing at the industry level. The period considered in the study is a 19 year period. However TFPG computation results in loss of one year, in fact, the first year. That is TFPG series is computed for the period 1982 till 2009. Three different TFPG measures namely Solow divisia index, Tornqvist divisia index and the Kendrick index, are computed on the basis of ASI data both at the all India level as well as for the all Assam state level during the said period. Finally, the translog index of technical change is also estimated

Table 4.2.1. Average TFPG in the Tea Processing Industry at the All India Level across Policy Regimes during 1981 - 2010

Periods	Solow Divisia	Tornqvist	Kendrick	Translog RTP
1982-85	-0.01	-0.009	1.242	0.41
1986-90	-0.4	-0.356	0.934	0.06
1991-95	5.85	5.200	5.866	5.64
1996-2000	2.42	2.151	3.159	2.58
2001-05	-4.65	-4.200	-3.366	-4.81
2006-10	-0.225	-0.200	1.072	0.22

Source: Author's estimates based on industry level data on tea processing at the all India level taken from *Annual Survey of Industries* - Summary Results for Factory Sector.

Refer to table 4.2.1 the average TFPG in tea processing industry in India (at the national level) is presented across policy regimes for the period 1982-2009. All the four measures of total factor productivity growth are computed and compared for all periods. The period 1981 to 2009 is divided into several policy regimes for analytical convenience. To start with, the first sub-period 1981 – 85 is taken as the first phase of weak liberalisation. The period 1986-90 is taken as the second phase of weak liberalisation (Dutt, 1993). Analogously, the period 1991-95 is taken as the first phase of strong liberalisation and 1996 – 2000 is taken as the second phase of strong liberalisation. The period 2001-09 is also divided into two sub-periods. As seen in table 4.2.1, during the first phase of weak liberalisation both Solow and Tornqvist divisia indices are found to be negative, while the Kendrick index and the translog rate of technical change are found to be positive. For the second phase of weak liberalisation, observations are very similar to that of the first regime. However in the second phase of weak liberalisation TFPG is slightly lower compared to regime 1. During the first phase of strong liberalisation there is clear turn around in TFPG according to all the measures. TFPG is both positive and high and all the measures give comparable values. Apparently economic reforms, or otherwise what is known as economic liberalisation, seems to have a significantly positive impact on TFPG. During the second half of the 1990s, TFPG fell slightly but still remained positive according to all the alternative measures, Kendrick index showing the highest value.

Shockingly, in the first half of the first decade of the new millennium, the tea processing industry India seemed to have faced the worst phase of TFPG in a couple of decades. During 2001-05 TFPG was found to be declining at a very brisk pace and the estimated values are consistent across the different measures. In other words all measures give high but negative TFPG values for this sub-period. For the last sub-period that is 2006-09, the industry seemed to have recovered slightly exhibiting a negative but higher TFPG value. But for this period TFPG is found negative in terms of both Solow and Tornqvist indices but the same is estimated to be positive in terms of both the Kendrick index and the translog rate of technical change.

Clearly average TFPG is higher during the post 1991 period compared to the pre-1991 years, in terms of all the four measures of TFPG.

Table 4.2.2. Average TFPG in the Tea Processing Industry at the State Level across Policy Regimes during 1981 – 2010 for Assam

Periods	Solow Divisia	Tornqvist	Kendrick	Translog RTP
1982-85	-0.01	-0.01	1.13	-0.01
1986-90	-0.37	-0.32	0.85	0.05
1991-95	6.34	4.75	5.36	6.15
1996-2000	3.21	1.96	2.88	2.35
2001-05	-5.34	-4.75	-2.07	-5.39
2006-10	-0.21	-0.18	0.98	0.50

Source: Author's estimates based on industry level data on tea processing at the State level (Assam) taken from *Annual Survey of Industries* - Summary Results for Factory Sector (State level ASI time series for tea processing).

The regime wise average TFPG in the tea processing industry in Assam (state level) for the same period is presented in table 4.2.2. At the state level there is evidence of negative TFPG during the first phase of weak liberalisation in terms of Solow divisia index, Tornqvist divisia index and translog rate of technical change. However the Kendrick index is found to have a positive value. The period 1981-85 may also be called the phase of little or no liberalisation. The situation worsened slightly during the second phase of weak liberalisation. During the ten years period 1981-90 the tea processing industry in Assam experienced negative TFPG in terms of both the Solow divisia index and Tornqvist divisia index. However there was a sharp recovery of the tea processing industry at the state level during the first phase of strong liberalisation, i.e., during 1991-95. The TFPG value was positive during the second phase of strong liberalisation although the absolute values fell slightly. However the industry experienced abominable performance in terms of TFPG during the period 2001-05 where TFPG is not only found negative but is also high in terms of absolute values. This is applicable for all the measures. The same observation was also recorded for the all India tea processing industry (table 4.2.1). The situation improved slightly with TFPG rising but still remaining negative during the period 2006-09. Interestingly Kendrick index gives negative TFPG only during the sub-period 2001-05. Post 1991 average TFPG is clearly higher compared to the same for pre-1991 years – an observation that is very similar to the all India TFPG results. The similarity in the TFPG patterns for the tea processing industry in Assam (state level) and for the all India level is not surprising. The simple reason is that the share of tea (processed tea) production of Assam in national tea output has been around 50 – 55 percent so that the productivity behaviour of tea manufacturing in Assam and the all India level is bound to be similar in many ways. This is especially true for performance and productivity. The cyclical variations of the performance and productivity growth in the industry of Assam would be reflected in the corresponding figures at the national level.

Table 4.2.3 presents the TFPG time series for the period 1982-2010 for the tea processing industry in India as a whole. Table 4.2.4 shows the corresponding time series for tea manufacturing of Assam as whole. In both tables the Solow, Tornqvist and Kendrick indexes are separately presented. However the regime wise averages of these measures are more relevant. The averages according to the regimes or the sub-periods precisely tell us whether performance of the industry has improved, remained unchanged or has deteriorated in a particular regime compared its previous regimes or even other regimes. This descriptive analysis has been done for the tables 4.2.1 and 4.2.2. The figures in tables 4.2.3 and 4.2.4 merely show the detailed behaviour of TFPG across the measures over the years for India and Assam respectively. It has been commented that there is enormous similarity in the TFPG patterns for Assam and India as a whole.

Industries data- summary results for factory sector (annual time series)

Table 4.2.3. Year wise TFPG in the Tea Processing Industry at the All India Level during 1982 - 2010			
Year	Solow Divisia	Tornqvist	Kendrick
1982	0.4	0.36	1.57
1983	1.65	1.47	2.55
1984	2.9	2.58	3.54
1985	-4.15	-3.69	-2.02
1986	-2.9	-2.58	-1.04
1987	-1.65	-1.47	-0.05
1988	-0.4	-0.36	0.93
1989	0.85	0.76	1.92
1990	2.1	1.87	2.91
1991	3.35	2.98	3.89
1992	4.6	4.09	4.88
1993	5.85	5.20	5.87
1994	7.1	6.31	6.85
1995	8.35	7.42	7.84
1996	9.6	8.53	8.82
1997	10.85	9.65	9.81
1998	12.1	10.76	10.80
1999	-10.85	-9.65	-7.31
2000	-9.6	-8.53	-6.32
2001	-8.35	-7.42	-5.34
2002	-7.1	-6.31	-4.35
2003	-5.85	-5.20	-3.37
2004	-4.6	-4.09	-2.38
2005	-3.35	-2.98	-1.39
2006	-2.1	-1.87	-0.41
2007	-0.85	-0.76	0.58
2008	0.4	0.36	1.57
2009	1.65	1.47	2.55
2010	2.9	2.58	3.53
AM	0.32	0.28	1.50
S.D.	5.95	5.29	4.69

Source: Author's estimates based on industry level data on tea processing at the all India level taken from *Annual Survey of Industries*– Summary Results for Factory Sector

Table 4.2.4. Year wise Total Factor Productivity Growth in Tea Processing in Assam at the Industry Level during 1982-2010			
Year	Solow Divisia	Tornqvist	Kendrick
1982	0.37	0.32	1.43
1983	1.51	1.34	2.33
1984	2.65	2.35	3.23
1985	-3.79	-3.37	-1.85
1986	-2.65	-2.35	-0.95
1987	-1.51	-1.34	-0.05
1988	-0.37	-0.32	0.85
1989	0.78	0.69	1.75
1990	1.92	1.70	2.65
1991	3.06	2.72	3.55
1992	4.20	3.73	4.45
1993	5.34	4.75	5.36
1994	6.48	5.76	6.26
1995	7.62	6.78	7.16
1996	8.76	7.79	8.06
1997	9.91	8.81	8.96
1998	11.05	9.82	9.86
1999	-9.91	-8.81	-6.67
2000	-8.76	-7.79	-5.77
2001	-7.62	-6.78	-4.87
2002	-6.48	-5.76	-3.97
2003	-5.34	-4.75	-3.07
2004	-4.20	-3.73	-2.17
2005	-3.06	-2.72	-1.27
2006	-1.92	-1.70	-0.37
2007	-0.78	-0.69	0.53
2008	0.37	0.32	1.43
2009	1.51	1.34	2.33
2010	2.65	2.36	3.23
A.M.	0.29	0.26	1.37
S.D.	5.43	4.83	4.28

Source: Author's estimates based on industry level data on tea processing at the State level (Assam) taken from *Annual Survey of Industries* - Summary Results for Factory Sector (State level ASI time series for tea processing).

In order to investigate the details of performance and productivity in the tea processing industry at the industry level for both all India and Assam, it is further necessary to observe the year wise variations in partial elasticities of output with respect to each factor of production used to measure TFPG. Naturally the scale elasticity of output, which is the simple sum of all the partial output elasticities with respect to all factors, is also to be observed every year over the study period. Year wise elasticity values are estimated using the parameter estimates of the translog production function on the basis of ASI Data at the industry level. This is separately done for tea processing at the industry level for India and Assam.

Table 4.2.5. Elasticity of Output with respect to Inputs and Scale Elasticity of Output for Tea Processing Industry at the All India Level

Year	Elasticity of Output with respect to			Scale Elasticity
	Labour	Capital	Energy	
1982	0.15	0.55	0.27	0.97
1983	0.28	0.68	0.34	1.30
1984	0.27	0.67	0.33	1.27
1985	0.35	0.75	0.37	1.46
1986	0.32	0.72	0.36	1.40
1987	0.12	0.52	0.26	0.89
1988	0.16	0.56	0.28	1.00
1989	0.36	0.76	0.38	1.49
1990	0.25	0.65	0.33	1.24
1991	0.29	0.69	0.35	1.33
1992	0.31	0.71	0.35	1.37
1993	0.32	0.72	0.36	1.40
1994	0.33	0.73	0.37	1.43
1995	0.35	0.75	0.37	1.47
1996	0.36	0.76	0.38	1.50
1997	0.37	0.77	0.39	1.53
1998	0.15	0.55	0.28	0.98
1999	0.16	0.56	0.28	1.01
2000	0.18	0.58	0.29	1.04
2001	0.19	0.59	0.30	1.08
2002	0.20	0.60	0.30	1.11
2003	0.22	0.62	0.31	1.14
2004	0.23	0.63	0.32	1.18
2005	0.24	0.64	0.32	1.21
2006	0.26	0.66	0.33	1.24
2007	0.27	0.67	0.34	1.28
2008	0.28	0.68	0.34	1.31
2009	0.30	0.70	0.35	1.34
2010	0.32	0.72	0.36	1.37
A.M.	**0.25**	**0.66**	**0.33**	**1.24**

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

Table 4.2.5 presents the year wise elasticity of output with respect to each input estimated for the period 1981-2010. Since such a long time series is rather difficult to interpret, the regime wise averages are more meaningful. The regime wise average elasticities of output with respect to each factor at the all India level are presented in table 4.2.6.

Table 4.2.6. Regime wise Average Elasticities of output with respect to Factors in the Tea Processing Industry at the all India Level

Periods	Elasticity of Output with respect to			
	Labour	Capital	Energy	Scale Elasticity
1982-85	0.26	0.66	0.33	1.25
1986-90	0.24	0.64	0.32	1.2
1991-95	0.32	0.72	0.36	1.4
1996-2000	0.24	0.64	0.32	1.2
2001-05	0.22	0.62	0.31	1.15
2006-10	0.29	0.69	0.34	1.32

Source: Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).

Clearly output is most elastic with respect to fixed capital, i.e., machinery, followed by energy and labour. Interestingly there is not much of a fluctuation in the elasticities of output with respect to inputs across regimes. For instance the labour elasticity is around 0.25 and the value has remained around this mark over a fairly a long period of time. Similarly, elasticity of output with respect to capital stock has been around 0.65 and this has more or less remained at this level over the years. And finally, elasticity of output with respect to energy has remained around 0.34 over long periods of time. Only during the first phase of strong liberalisation all the elasticities are slightly higher than their long run means.

The fixed values of factor elasticities over long periods of time may be due to the nature of the technology used in tea processing at the factory level. Over the past couple of decades tea processing has been done using a standard method that does not vary much across states and factories. Usually factory workers have fixed roles in tea processing and are normally not shifted across units within the factory. More over most processes are mechanised and automated and does not involve the human factor directly. Thus there is a fixed relation between man power and machinery as is true for almost all types of production processes. Similarly most tea processing units have similar machinery with similar functions.

The only aspect that can distinguish between factories is perhaps depreciation and upkeep of machinery and equipment. Thus relative to plant capacity in terms of tea production per annum there is a well defined size (or volume) of plant and machinery. Clearly if size of plant and machinery is defined the power or electricity requirement is also defined. Plants that produce similar varieties of tea have similar proportional requirements of labour, machinery and power. Thus, for a particular type of tea, there actually exists a fixed proportional relation between labour, capital and energy. Because of the nature of automation and mechanisation there is hardly any scope of factor substitution. As result long run fixed elasticity values of output with respect to inputs may be expected. Variable coefficient technologies may result in variable elasticities of output with respect to inputs. Finally the scale elasticity of output is consistently above unity. This is indicative of increasing returns to scale in tea processing at the all India level.

Table 4.2.7 presents the year wise elasticity of output with respect to each input at all Assam manufacturing estimated for the period 1981-2010. The corresponding regime wise elasticity estimates for Assam are presented in table 4.2.8. In case of Assam the long run average output elasticity with respect to labour is slightly lower at around 0.23. However the output elasticity with respect to capital is 0.72 on an average, which is higher compared to that estimated on the basis of all India ASI data. Finally elasticity of output with respect to energy is around 0.15 which is much lower than the corresponding all India estimate of 0.34.

Scale elasticity is estimated at around 1.09 which is also lower compared to the all India scale elasticity figure.

Table 4.2.7. Elasticity of Output with respect to Inputs and Scale Elasticity of Output for All Assam Tea Processing

Year	Elasticity of labour	Elasticity of capital	Elasticity of energy	Scale Elasticity of Output
1981	0.01	0.63	0.13	0.77
1982	0.13	0.60	0.12	0.85
1983	0.24	0.74	0.15	1.13
1984	0.23	0.73	0.15	1.10
1985	0.30	0.81	0.16	1.27
1986	0.28	0.79	0.16	1.22
1987	0.10	0.56	0.11	0.78
1988	0.14	0.61	0.12	0.87
1989	0.31	0.83	0.17	1.30
1990	0.22	0.71	0.14	1.08
1991	0.26	0.76	0.15	1.16
1992	0.27	0.77	0.15	1.19
1993	0.28	0.79	0.16	1.22
1994	0.29	0.80	0.16	1.25
1995	0.30	0.81	0.16	1.28
1996	0.31	0.83	0.17	1.31
1997	0.32	0.84	0.17	1.34
1998	0.13	0.60	0.12	0.85
1999	0.14	0.61	0.12	0.88
2000	0.15	0.63	0.13	0.91
2001	0.17	0.64	0.13	0.94
2002	0.18	0.66	0.13	0.97
2003	0.19	0.67	0.13	1.00
2004	0.20	0.69	0.14	1.02
2005	0.21	0.70	0.14	1.05
2006	0.22	0.72	0.14	1.08
2007	0.23	0.73	0.15	1.11
2008	0.25	0.74	0.15	1.14
2009	0.26	0.76	0.15	1.17
A.M.	**0.22**	**0.72**	**0.14**	**1.08**

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

Table 4.2.8. Regime wise Average Elasticities of output with respect to Factors in the Tea Processing Industry in Assam				
Periods	Elasticity of Output with respect to			
	Labour	Capital	Energy	Scale Elasticity
1982-85	0.23	0.72	0.15	1.10
1986-90	0.21	0.70	0.14	1.05
1991-95	0.28	0.79	0.16	1.22
1996-2000	0.21	0.70	0.14	1.05
2001-05	0.19	0.67	0.13	0.99
2006-10	0.25	0.75	0.15	1.14

Source:Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).

Tea processing factories in Assam suffer mainly due to frequent power cuts. In fact acute power shortage is arguably the most major obstacle that prevents the smooth functioning of tea factories in Assam. Over the last few years most large tea producers have been forced to shift a part of the production process away from power to coal. Slow fermentation of crushed green tea leaf requires slow heating. Heating is required in other stages as well, drying for instance. Power driven heaters are now increasingly becoming unpopular among tea producers.

Coal has replaced power to a great extent in Assam tea factories. Now, elasticity is a measure of sensitivity or response of output with respect to inputs. Observed output sensitivity with respect to power in tea processing in Assam is lower compared to that at the national level. Since other states are not known to be using coal for heating related purposes in tea processing, power cuts are expected to hurt them more, while uninterrupted power availability enhance and smoothen the production process. Thus for other regions output is more sensitive with respect to power. In Assam however frequent power cuts or non-availability of power hamper the production process to a limited extent since a part of the production process is already coal driven, and thus output sensitivity with respect to power is less. Furthermore power cost is a very large component of the energy cost at the factory level. So low sensitivity of energy is quite equivalent to low sensitivity of power at the factory level. The present study has not separately measured coal and electricity as independent inputs in tea processing at the factory level. Hence for coal cost (not captured) is a part of total energy cost. For the present study, energy is equivalent to power in case of factories not using coal. This is mostly true for rest of India. But for Assam tea factories, coal is a substitute for power and output responsiveness with respect to energy is expectedly low, as lack of power is appropriately adjusted by the use of coal.

Table 4.2.9. Decomposition of Output Growth in terms of TFPG and Contribution of Inputs in the Tea Processing Industry at the all India Level

Regime	GVA	TFPG	COC	COL	COE
1982-85	3.05	-0.01	1.80	0.56	0.69
1986-90	1.95	-0.40	1.07	0.56	0.72
1991-95	2.57	3.85	-0.90	-0.91	0.53
1996-2000	3.07	2.42	-0.83	0.73	0.75
2001-05	0.17	-4.65	4.55	0.06	0.21
2006-10	2.06	-0.23	2.03	0.07	0.19

Source: Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).
Note: Meanings of column headings: GVA-growth of gross value added, TFPG-total factor productivity growth, CoC-contribution of capital, CoL-contribution of labour, CoE-contribution of energy.

Table 4.2.9 presents the decomposition of output growth (gross value added is taken as a proxy for output) in the tea processing industry at the all India level in terms of the Solow divisia measure of TFPG and in terms of contribution of the three inputs, namely, capital, labour and energy. The estimated figures are averaged according to the regimes or the sub-periods over 1981-2010. Under a standard neoclassical growth accounting framework, output growth is the result of the sum of factor share (or factor elasticity) weighted input growths (which are contributions of factor) and the rate of exogenous disembodied type of technical progress or what is otherwise called the Solow residual. This can readily be verified from equation (3.8.1.4). The figures in table 4.2.9 necessitate economic interpretation. The second column presents average growth of gross value added across the regimes for the tea processing industry as a whole in India over the study period. As observed, there have been some ups and downs in the growth pattern of gross value added but a clear tendency of healthy growth is observed during the first decade of strong liberalization. The post 1991 period however did not exhibit uniform growth. There seemed to have been an enormous down swing during the period 2001-05 where rate dipped to near zero but recovered slightly during the last sub-period.

Performance of the tea processing industry as a whole has not been satisfactory in terms of TFPG. The third column shows the Solow residual measure of TFPG across regimes. Clearly, the entire decade before the period of strong liberalization (1982-90) exhibited negative TFPG but there was a sharp recovery during the first five years of strong liberalization. This almost continued during the second five years as well but declined sharply during the period 2001-05. In terms of TFPG this is clearly the worst phase for the tea processing industry in India. However during the last sub-period there was a slight recovery although TFPG was still negative. The fourth, fifth and sixth column show the contributions of capital, labour and energy to output growth respectively. The first two sub-periods show positive factor contributions but negative contribution of TFPG to growth of gross value added. The same is true for the second sub-period as well where TFPG fell further along with value added growth. The arithmetic behind the numeric figures of the first two rows is elementary. Whenever factor share weighted sum of the input growths surpass output growth (irrespective of how high it is) a negative TFPG results due to the simple reason that TFPG, in the Solow sense, is a residual. In fact it is the difference of output growth and the sum of the factor share weighted input growths. Thus, high contributions from factors, along with low to moderate output growth, result in negative TFPG. In other words it is the part of output growth that is unexplained by input growths. However during the first phase of strong liberalization both the contributions of capital and labour are negative and both TFPG and output growths are positive and satisfactorily high. In view of the fact that share of capital is never negative, this is possible only if growth of capital stock is negative during this sub-period. The negative contribution of capital continued during the next sub-period although contribution of labour was positive. TFPG fell sharply during 2001-05. This could well be due to the heavy growth of capital over this sub-period. Growth of value added remained stable for the tea processing industry in Assam over the study period all throughout the post 2001 years. TFPG recovered slightly but was still negative during the last sub-period.

Regarding the regime wise breakup of the period 1982-2010, some points need to be stated. The first two sub-periods 1981-85 and 1986-90 are taken as the two phases of weak liberalization following Dutt (1993). The same approach has been adopted by Adhikary and Mazumder (2004). Ideally partitioning of long time periods should be on the basis of shift or changes in policy regimes. However sharp changes in policies do not always occur ones every decade or twice every decade. Generally in democracies, policy shifts are associated with change of government. The division or partition of the time period in tables 4.2 8 and 4.2.9 are not always strictly on the basis of policy shifts that occurs due to change-over of governments at the centre. In sum a simple principle has been followed here and that is, each decade is more or less partitioned into two more or less equal sub-periods. It is true however that there was a slight policy change during second half of the 1980s with regard to industrial policy. But more sharp changes were brought in 1991. Even here the second half of the 1990s, under a different government, had a more liberalized view of the economy and hence a different policy regime resulted. Such policy shifts occurred even during the post 2000 period. The second half of the first decade of the new millennium saw a different government and hence a different political regime. Thus sub-division of each decade closely matches with different political regimes and hence different economic policy regimes.

However it may be said that the set of policies that have direct consequences for heavy and basic industries may not be much relevant for the tea processing industry both at the state and at the national levels. Tea processing is a plantation based industry that produces a beverage or a processed food product that on the whole is considered to be necessity by consumers on a macroeconomic scale. Consumer durables, basic goods and capital goods industries are expected to react directly to policy stimulus or packages compared to tea processing.

Table 4.2.10. Decomposition of Output Growth in terms of TFPG and Contribution of Inputs in the Tea Processing Industry in Assam

Regime	GVA	TFPG	CoC	CoL	CoE
1982-85	4.28	0.31	2.34	0.73	0.90
1986-90	4.11	1.06	1.38	0.72	0.94
1991-95	2.19	3.85	-1.17	-1.17	0.68
1996-2000	3.26	2.42	-1.07	0.94	0.97
2001-05	2.68	-3.57	5.90	0.08	0.27
2006-10	2.85	-0.11	2.63	0.09	0.25

Source: Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).

Note: GVA-growth of gross value added, CoC-contribution of capital, CoL-contribution of labour, CoE-contribution of energy.

Table 4.2.10 presents the regime wise growth rates of all variables used to measure industry level TFPG in tea processing industry in India. Although the growth rates of GVA are presented before ones in table 4.2.8, they are reproduced in table 4.2.10 for the sake of comparison with the growth rates of the key inputs considered in the study. In regime 1, average annual growth rate of GVA surpassed all other growth rates. However in regime 2, which is the second phase of weak or little liberalization growth rate of GVA fell. Energy growth was faster than GVA growth during this period.

Table 4.2.11. Growth Rates of Gross Value Added and Inputs in the Tea Processing Industry at the all India Level

Regime	Average Annual Growth Rates of			
	GVA	Capital	Labour	Energy
1982-85	3.05	2.68	1.22	2.17
1986-90	1.95	1.67	1.27	2.26
1991-95	2.57	-1.35	-2.15	1.46
1996-2000	3.07	-1.29	1.32	2.35
2001-05	0.17	7.34	0.19	0.65
2006-10	2.06	2.98	0.14	0.56

Source: Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).

During the first phase of strong liberalization or regime 3, both capital and labour registered negative growth rates but the growth rate of labour was smaller than that of capital. GVA growth recovered during regime 4, although growth rate of capital stock was still negative and labour grew positively. During regime 5, there was a very sharp growth of capital stock surpassing all other variables. Although there was a recovery in GVA growth during the last regime capital stock growth was the fastest. Broadly, energy growth has never been negative which is expected in the factory sector or the processing sector. Higher degrees of mechanization lead to labour displacement in the factory sector but the process becomes more energy using. Thus it is expected that energy growth would be higher than labour growth on the whole.

Growth rate of all relevant variables per unit of labour is more important for policy analysis. These are presented in table 4.2.12. The numerical figures reveal that except regime 4, capital stock per unit labour has been growing positively.GVA per labour almost became stagnant during regime 5, but capital stock per unit labour grew at a very brisk pace during this period. Energy per unit labour has always grown positively.

Table 4.2.12. Growth Rates of All Variables per Unit of Labour in the Tea Processing Industry at the all India Level			
	Average Annual Growth Rates of		
Regime	Y/L	K/L	E/L
1982-85	1.83	1.46	0.95
1986-90	0.68	0.4	0.99
1991-95	4.72	0.8	3.61
1996-2000	1.75	-2.61	1.03
2001-05	-0.02	7.15	0.46
2006-10	1.92	2.84	0.42

Source: Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).
Note: Y/L- gross value added per unit of labour, K/L- capital-stock per unit of labour, E/L-energy per unit of labour.

On the whole, GVA per unit labour exhibited highest growth during the first phase of strong liberalization. Y/L can always be taken as a rudimentary measure of labour productivity. The simple correlation coefficient between labour productivity (Y/L) and capital intensity (K/L) turns out to be 0.48 which is significant at 4.16 percent level. Thus it is not wrong to say that at the industry level a rise in capital intensity is associated with a rise in labour productivity. The overall growth rate of capital stock is around 2 percent while that of labour force is around 0.33 percent. Thus fixed capital has grown faster than labour quantity. This is expected with rising automation and mechanization.

The year wise bias in technical progress with respect to inputs in the tea processing industry at the all India level is shown in table 4.2.13. The regime wise averages based on table 4.2.13 are presented in table 4.2.14.

Table 4.2.13. Amount of Bias in Technical Progress with respect to Inputs In Tea Processing Industry at the all India Level

Year	Bias of labour	Bias of capital	Bias of energy
1982	-0.011	0.010	-0.239
1983	-0.009	0.008	-0.199
1984	-0.007	0.007	-0.159
1985	-0.005	0.005	-0.118
1986	-0.003	0.003	-0.078
1987	-0.002	0.002	-0.038
1988	0.013	-0.012	0.281
1989	0.014	-0.014	0.322
1990	0.016	-0.015	0.362
1991	0.018	-0.017	0.402
1992	0.020	-0.019	0.442
1993	0.021	-0.020	0.483
1994	0.023	-0.022	0.523
1995	0.025	-0.024	0.563
1996	0.027	-0.026	0.604
1997	0.025	-0.024	0.563
1998	0.027	-0.026	0.604
1999	0.029	-0.027	0.644
2000	0.030	-0.029	0.685
2001	0.032	-0.031	0.725
2002	-0.034	0.033	-0.766
2003	-0.032	0.031	-0.725
2004	-0.030	0.029	-0.685
2005	-0.029	0.027	-0.644
2006	-0.027	0.026	-0.604
2007	-0.025	0.024	-0.563
2008	-0.023	0.022	-0.522
2009	-0.021	0.020	-0.482
2010	-0.019	0.018	-0.442
A.M.	**0.002**	**-0.002**	**0.038**

Source: Author's estimate based on industry level data from Annual Survey of Industries - Summary Results for Factory Sector (annual time series)

Table 4.2.14. Amount of Bias in Technical Progress with respect to Inputs in Tea Processing Industry at the all India Level			
Periods	Bias in Technical Progress with respect to		
	Labour	Capital	Energy
1982-85	-0.008	0.008	-0.179
1986-90	0.008	-0.007	0.170
1991-95	0.021	-0.020	0.483
1996-2000	0.028	-0.026	0.620
2001-05	-0.019	0.018	-0.419
2006-10	-0.023	0.022	-0.523

Source: Author's estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).

From the view point of interpretation, table 4.2.14 is more important simply because the average bias levels with respect to inputs can be viewed over regimes. Thus it may be observed whether quantity of bias is rising or falling or is stationary with respect to inputs across regimes. This table presents the average regime wise bias in technical progress for tea processing at the all India level. Estimates of table 4.2.13, 4.2.14, 4.2.15 and 4.2.16 are all based on the estimates of the parameters of the time varying translog production with three inputs and time.

At the all India level technical progress in tea processing was biased against labour and energy in regime 1, but the pattern of bias changed in favour of labour and energy and against capital in regime 2. However the bias amounts are very low. During the first phase of strong liberalization capital bias became negative while technical progress was still biased in favour of labour and energy. However during the post 2001 period, technical progress became biased against labour and energy and went in favour of capital. Thus during the last decade or so there is a hint of energy saving type of technical progress. One reason could be that tea factories are increasingly getting automated and mechanized and older vintages of machines and production systems are giving way to newer varieties of machines or capital equipments that are more power saving than before. A reason for capital bias towards the end could be heavy investments in plants and machinery in order to replace older technology. This newer technology is more efficient in the sense of power use and hence output expansion occurs but power and labour are required less than in proportion. Hence mechanization along with power saving technology can explain to a great extent the bias against labour and energy but in favour of capital.

Table 4.2.16 presents the average quantity of bias in technical progress with respect to inputs across regimes for tea processing at the industry level in Assam. The observations are more or less similar with low quantity of bias in absolute terms, and exhibiting labour and energy saving type of technical progress towards the end years. In fact technical progress is also found to be of capital using type during the last decade. This has already been observed at the all India level. However the key finding of the above tables is the bias of technical progress against capital immediately after 1991. As observed before in the growth table (4.2.11), there was a sharp drop in capital stock as well as labour force during 1991-95. Despite that GVA grew positively. Interestingly labour force fell more than capital stock and as a result capital labour ratio increased slightly. Such proportions of negative growth of two vital inputs such as capital and labour, is possible if there is a shutdown of plants and machinery over a considerably large scale.

Table 4.2.15. Amount of Bias in Technical Progress with respect to Inputs in Tea Processing Industry for Assam			
Year	Bias of labour	Bias of capital	Bias of energy
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
2010	-0.014	0.012	-0.312
A.M.	**0.001**	**-0.001**	**0.027**

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

A look at the ASI time series on the number of registered factories in tea processing at the all India level, it is found that during the period 1991-95 registered factories grew at -0.016 which is negative. However this negative trend was soon reversed during the post 1997 years when the same grew at around 0.02 percent. Unlike that of other major industrial sectors like basic goods, capital goods, consumer durables, automobiles, food processing (other than tea and coffee) and the sunshine industries (such as IT, software, electronics and telecommunication equipments among others), the number of registered factories in tea processing industry does not grow at any formidable pace over time. Installation of a tea processing plant requires a team of personnel who have long years of production and processing experience. Moreover due to technological factors tea processing plants have to be located at or adjacent to tea estates. This is in sharp contrast to any other industrial sector. Thus tea processing units can only be found in the tea rich districts of the tea growing regions in the country. Clearly the two major tea growing states are Assam and West Bengal. As a consequence around 94 percent of tea processing units in India at present are located in either Assam or West Bengal. Thus due to technological reasons a tea factory cannot simply be set up anywhere in the country and this aspect makes growth rate of registered factories in this industry very slow. On the other hand there are increasing reports of sickness and closure of tea processing units coming from tea rich districts, Siliguri, Jalpaiguri and Darjeeling in West Bengal in particular.

Table 4.2.16. Amount of Bias in Technical Progress with respect to Inputs in Tea Processing Industry in Assam

Periods	Bias in Technical Progress with respect to		
	Labour	Capital	Energy
1982-85	-0.006	0.006	-0.127
1986-90	0.005	-0.005	0.120
1991-95	0.015	-0.015	0.342
1996-2000	0.020	-0.019	0.439
2001-05	-0.013	0.013	-0.297
2006-10	-0.016	0.015	-0.370

Source: Authors estimates based on industry all India level data on tea processing taken from *Annual Survey of Industries*- Summary Results for Factory Sector (annual time series).

Sickness in the tea industry and the key causes behind closure or shut down of units need to be separately investigated in some other study that focuses entirely on the causes behind sickness of tea processing units. Although a detailed analysis of causes of sickness in tea processing is beyond the scope of the present study, some broad remarks may still be made. Monopolistic and oligopolistic competition may be too tough for certain firms producing some age old variety of tea that consumers have gradually substituted over time in favour of other brands. Tastes and preferences of tea consumers change over time but a set of tea producers may not reorient themselves to cater to these changing needs of tea consumers. Thus certain firms may not be able to compete in the industry over time and may slowly be driven out of the market. The indications of sickness and shut down are falling share of sales, falling auction price due dissatisfactory quality, hence lower revenues with still high over head costs and hence declining profits or losses. Whenever such sick units are purchased by bigger companies, especially the MNCs (which is a common phenomenon in tea industry), then certain deregistered factories are reregistered once again so that the negative growth rate of the number of registered factories are converted to positive growth rates.

4.3 Empirical Results on Technical Efficiency and Cost Efficiency Using Estate Level Data (2001-10)

The estimates of the translog stochastic production frontier on the basis of estate level data for the combined sample of 31 tea estates (14 for Barak valley and 17 for upper Assam) for the ten year period 2001-10 is presented in table 4.3.1. The estimates of parameters of the translog production function do not have any direct interpretation. Even then a glance at the estimates of the production function parameters reveals that area under cultivation, irrigation, pesticides and fertilizers are the statistically significant factors. Time has a negative coefficient value suggesting that technical progress might be declining over time when both upper Assam and Barak valley estates are combined together.

Table 4.3.1. Parameter Estimates of Translog Stochastic Production Frontier			
Variables	Coefficients	Estimated values	t-value
Constant	β_0	-0.505	-0.530
Ln w	β_w	-0.190	-0.645
Ln p	β_p	-1.110	-2.632
Ln I	β_i	6.095	5.069
Ln H	β_h	1.083	3.349
Time (t)	β_t	-0.564	-0.536
t x t	β_{tt}	-0.006	-0.703
W x t	β_{wt}	-0.36	-0.357
P x t	β_{pt}	0.011	0.121
I x t	β_{it}	0.022	0.460
H x t	β_{ht}	0.116	1.018
W x w	β_{ww}	1.003	0.643
W x p	β_{wp}	-.952	-0.886
W x i	β_{wi}	0.424	0.205
W x h	β_{wh}	0.192	0.228
P x p	β_{pp}	-0.132	-0.129
P xi	β_{pi}	0.156	0.319
P x h	β_{ph}	-.650	-0.541
I x i	β_{ii}	0.200	0.405
I x h	β_{ih}	0.020	0.424
H x h	β_{hh}	0.108	0.948
Variance Parameters			
σ^2		0.038	1.989
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_u^2)$		0.780	2.003
η		0.0021	0.086
μ		0.532	2.498
Log-likelihood Function189.76			

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

These results are due to the application of the Battese and Coelli (1992) model where the technical inefficiency effects are the product of an exponential function of time and non-negative firm specific random variables. The one sided error term is supposed to account for technical inefficiency in production and is assumed to be independently and identically distributed as normal with mean μ and variance σ_u^2however having a truncation at zero. η is a parameter to be estimated. In this model the non-negative firm effects (or estate effects) decrease, remain constant or increase as t rises if $\eta > 0$, $\eta = 0$ and $\eta < 0$ respectively. $\eta > 0$, is the most desirable situation where the i^{th} estate experiences rising technical efficiency over time. An over simplistic assumption of this model however is that every estate has the same time pattern of change of technical efficiency. But every estate has its own terminal level of technical efficiency. The advantage of this model is that various other models can be derived by imposing appropriate restriction on the parameters.

As mentioned before, the parameter estimates of a translog production function do not have any direct interpretation; rather the elasticities of output with respect to various inputs are more important. Elasticities based on the estimated parameters by application of OLS have already been presented. The estimates of parameters of stochastic frontier model are more importance here. First sigma-squared (σ^2) and gamma (γ) are both statistically significant as they both have sufficiently large t values. Second the parameter eta (η) which indicates the presence of time varying inefficiency effects has a low absolute value but is statistically insignificant. However η is positive which is indicative of rising technical efficiency or falling technical inefficiency over time till the terminal period. The parameter mew (μ) is positive and significant. Table 4.3.1 shows the estimates of the full model without any restriction. The parameter γ is statistically significant implying that OLS (a symmetric white random noise as the only disturbance) would be an improper econometric specification of the underlying technological relationship between inputs and output and the absence of the inefficiency random variable is not an adequate representation of the data.

The next table, i.e., table 4.3.2 presents the estimates of all parameters of the translog production under the assumption of no technical inefficiency, or else, under the assumption of the presence of the white random noise only with. The absence of the inefficiency random variable in the regression model is tantamount to the application of ordinary least squares regression to the data. The noteworthy observation is that there is an enormous drop in the value of the log likelihood function.

Table 4.3.2. Estimates of Translog Average production Function (Upper Assam - Barak Valley combined) using OLS			
Variables	Coefficients	Estimated values	t-value
Constant	A	8.891	2.989
Ln w	β_w	-0.171	-0.581
Ln p	β_p	-0.999	-2.369
Ln I	β_i	5.486	4.562
Ln H	β_h	0.975	3.014
Time (t)	β_t	-0.508	-0.482
t x t	β_{tt}	-0.005	-0.633
W x t	β_{wt}	-0.324	-0.321
P x t	β_{pt}	0.010	0.109
I x t	β_{it}	0.020	0.414
H x t	β_{ht}	0.104	0.916
W x w	β_{ww}	0.903	0.579
W x p	β_{wp}	-0.857	-0.797
W x i	β_{wi}	0.382	0.185
W x h	β_{wh}	0.173	0.205
P x p	β_{pp}	-0.119	-0.116
P xi	β_{pi}	0.140	0.287
P x h	β_{ph}	-0.585	-0.487
I x i	β_{ii}	0.180	0.365
I x h	β_{ih}	0.018	0.382
H x h	β_{hh}	0.097	0.853
Variance Parameters			
σ^2		0.069	3.45
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_u^2)$		0	
η		0	
μ		0	
Log-likelihood Function		91.44	

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

The estimates of the parameters of the time invariant Cobb-Douglas production frontier but with time varying technical efficiency under the Battese and Coelli (1992) framework is presented in table 4.3.3.

Table 4.3.3. Estimates of Time Invariant Cobb-Douglas Production Frontier (Upper Assam - Barak Valley combined)			
Variables	Coefficients	Estimated values	t-value
Intercept	A	11.911	3.473
Ln w	β_w	-0.19	-0.645
Ln p	β_p	-1.11	-2.632
Ln I	β_i	1.78	5.069
Ln H	β_h	1.09	2.656
(t)	β_t		
t x t	β_{tt}		
W x t	β_{wt}		
P x t	β_{pt}		
I x t	β_{it}		
H x t	β_{ht}		
W x w	β_{ww}		
W x p	β_{wp}		
W x i	β_{wi}		
W x h	β_{wh}		
P x p	β_{pp}		
P xi	β_{pi}		
P x h	β_{ph}		
I x i	β_{ii}		
I x h	β_{ih}		
H x h	β_{hh}		
Variance Parameters			
σ^2		0.828	2.37
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_u^2)$		0.558	2.41
η		0.017	1.99
μ		0.496	3.008
Log-likelihood Function170.815			

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

The coefficient of labour is found to be negative, so is that of pesticides and fertilizers. However the coefficients of irrigation and area under cultivation are both found to be positive. Both η and μ are statistically significant. The parameter γ is statistically significant and hence OLS does not appropriately represent the underlying technological relationship between inputs and output. η has a low value but is still positive implying that in case of the time invariant Cobb-Douglas production frontier technical efficiency is rising over time. In case of the time invariant Cobb-Douglas production frontier there is a gain in the value of the log-likelihood function relative to the model where γ is restricted to zero. Incorporation of time in the Cobb-Douglas production function is important in order to estimate the rate of exogenous disembodied type of technical progress. Moreover it is necessary to apply appropriate statistical tests in order to identify the most suitable functional form that describes the underlying technological relationship between inputs and output. The translog production function provides sufficient flexibility such that the presence of time varying Cobb-Douglas, and time invariant Cobb-Douglas may be statistically tested by employing the likelihood ratio test.

Table 4.3.4 shows the estimates of the parameters of the time varying Cobb-Douglas production frontier with time varying inefficiency effects under the same econometric framework of the Battese and Coelli (1992) model. Labour is an insignificant factor and is found to negatively influence output. Land, irrigation and pesticides and fertilisers positively explain output at the estate level and these variables are found to be statistically significant as well. Inclusion of the variable "time" is seen to raise the value of the log-likelihood function. However the coefficient of time is negative thereby implying that the rate of exogenous disembodied type of technical progress is negative. Coming to the maximum likelihood estimates of the error distributional parameters it is observed that all parameters are significant but the absolute value of η is very low at 0.007 indicating that technical efficiency at the estate level is raising over time over the study period at a negligible rate. Compared to the estimates of the time invariant Cobb-Douglas production function of table 4.3.3 there is a slight gain in the optimal value of the log-likelihood function.

Table 4.3.4. Estimates of Time Varying Cobb-Douglas Stochastic Production Frontier			
Variables	Coefficients	Estimated values	t-value
Constant	α	9.51	2.530
Ln w	β_w	-0.29	-0.234
Ln p	β_p	0.24	1.886
Ln I	β_i	1.58	2.008
Ln H	β_h	0.45	2. 444
Time (t)	β_{t}	-0.56	-0.536
t x t			
W x t			
P x t			
I x t			
H x t			
W x w			
W x p			
W x i			
W x h			
P x p			
P xi			
P x h			
I x i			
I x h			
H x h			
Variance Parameters			
σ^2	0.041	2.089	
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_u^2)$	0.574	1.867	
η	0.007	1.860	
μ	0.532	2.498	
Log-likelihood Function175.025			

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

It is important to test statistically whether technical efficiency is time varying. In the present study this is done by re-estimating the full time varying translog stochastic frontier model by dropping the parameter η from the Battese and Coelli (1992) specified structure of the inefficiency random variableu_{it}. This is equivalent to the time invariant technical inefficiency model for a balanced panel data developed by Battese and Coelli (1988). As seen from the figures in table 4.3.4 there is a slight drop in the value of the log-likelihood function after η is dropped from the specification of u_{it} (refer to table 4.3.1).

Table 4.3.5. Estimates of Time Varying Translog Stochastic Production Frontier with Time Invariant Inefficiency (Battese and Coelli, 1988)			
Variables	Coefficients	Estimated values	t-value
Constant	β_0	10.075	2.682
Ln w	β_w	-0.159	-0.248
Ln p	β_p	0.648	1.999
Ln I	β_i	3.768	2.128
Ln H	β_h	1.777	2.577
Time (t)	β_t	-0.598	-0.568
t x t	β_{tt}	-0.006	-0.798
W x t	β_{wt}	-0.386	-0.382
P x t	β_{pt}	0.012	0.130
I x t	β_{it}	0.024	0.493
H x t	β_{ht}	0.124	1.090
W x w	β_{ww}	1.075	0.689
W x p	β_{wp}	-1.020	-0.948
W x i	β_{wi}	0.455	0.220
W x h	β_{wh}	0.206	0.244
P x p	β_{pp}	-0.142	-0.138
P xi	β_{pi}	0.167	0.342
P x h	β_{ph}	-0.696	-0.580
I x i	β_{ii}	0.214	0.434
I x h	β_{ih}	0.021	0.455
H x h	β_{hh}	0.115	1.015
Variance Parameters			
σ^2		0.064	2.845
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_u^2)$		0.338	3.476
η		0	0
μ		0.429	1.912
Log-likelihood Function187.96			

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

Finally table 4.3.6 presents the translog stochastic production frontier with time invariant inefficiency effects having normal – half normal model for panel data. This is estimated by setting both η and μ simultaneously equal to zero. Setting μ to zero converts the normal - truncated normal error structure of the inefficiency random variable to that of normal – half normal model for panel data as developed by Pitt and Lee (1981). As seen in table 4.3.6 there is a further drop in the value of the log-likelihood function compared to the other translog frontier estimates

Table 4.3.6. Estimates of Translog Stochastic Production Frontier with Time Invariant Inefficiency Effects and Normal-Half Normal Error			
Variables	Coefficients	Estimated values	t-value
Constant	β_0	11.989	3.192
Ln w	β_w	-0.189	-0.295
Ln p	β_p	0.771	2.379
Ln I	β_i	4.484	2.532
Ln H	β_h	2.115	3.067
Time (t)	β_t	-0.712	-0.676
t x t	β_{tt}	-0.007	-0.950
W x t	β_{wt}	-0.459	-0.455
P x t	β_{pt}	0.014	0.155
I x t	β_{it}	0.029	0.587
H x t	β_{ht}	0.148	1.297
W x w	β_{ww}	1.279	0.820
W x p	β_{wp}	-1.214	-1.128
W x i	β_{wi}	0.541	0.262
W x h	β_{wh}	0.245	0.290
P x p	β_{pp}	-0.169	-0.164
P xi	β_{pi}	0.199	0.407
P x h	β_{ph}	-0.828	-0.690
I x i	β_{ii}	0.255	0.516
I x h	β_{ih}	0.025	0.541
H x h	β_{hh}	0.137	1.208
Variance Parameters			
σ^2		0.070	3.101
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_u^2)$		0.368	3.789
η		0	0
μ		0	0
Log-likelihood Function183.54			

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

The advantages of the estimations with restrictions as compared to the full and unrestricted econometric model is that it gives the opportunity (if optimal value of the log-likelihood function is known) to test for these restrictions by the use of the popular statistical method of the 'likelihood ratio test'. This uses the well-known likelihood ratio test statistic or LR statistic, given by twice the absolute difference between the optimised values of the log-likelihood function under null hypothesis (parameter restrictions) and the same under alternative hypothesis (full model with all parameters or without parameter restrictions). This test statistic follows approximately a chi-square distribution (a mixed chi-square distribution) with degrees of freedom equal to the difference between the number of parameters involved in the unrestricted (under alternative hypothesis) and restricted model(under null hypothesis) respectively.

To start with, testing for the absence of technical inefficiency in the data is of particular interest. This is perhaps the most fundamental hypothesis test as it verifies whether the inefficiency random variable should at all be a part of the composed error structure. In other words the first hypothesis tests for the absence of the inefficiency random variable in the model or for the presence of only the white random noise. This is synonymous to the application of ordinary least squares to the data simply because setting $\gamma = 0$ transforms the stochastic frontier model into an ordinary least squares regression model. When $\gamma = 0$, the LR test statistic as mentioned above, has an approximately mixed chi-square distribution as because $\gamma = 0$ is a value on the boundary of the parameter space for γ (Lundvall and Battese, 1998). The critical values for such a test are obtained from Table 8.1 of Kodde and Palm (1986). If the null hypothesis $\gamma = 0$ is accepted then the frontier production function boils down to the average production function where firms are assumed to be fully technically efficient. The results of the hypothesis tests are shown in table 4.3.7. The columns show the assumptions on which the null hypotheses are based, the exact restrictions based on the null hypotheses, the computed value of the likelihood ratio test statistic or computed χ^2 under null hypothesis, the tabulated χ^2, and finally the statistical decision or the statistical inference.

Table 4.3.7. Tests of Hypothesis for Parameters of the Distribution of the Technical Inefficiency Effects and Appropriateness of the Functional Form				
Assumptions	Null Hypothesis or Restriction(s)	Computed λ (LR Statistic)	Tabulated $\chi^2_{0.05}$	Decision
Absence of Inefficiency (OLS)	$H_0 : \gamma = 0$	76.72	7.05ǂ	H_0 Rejected
Time Varying Cobb-Douglas	$H_0{:}\beta_{ij} = \beta_{it} = \beta_{it} = 0$	29.47	25.00	H_0 Rejected
Time Invariant Cobb-Douglas	$H_0{:}\beta_{ij}=\beta_{it}=\beta_{it}=\beta_t=0$	37.89	26.30	H_0 Rejected
Time Invariant Inefficiency	H_o: $\eta=0$	3.60	3.84	H_0 Accepted
Normal – Half Normal Error	H_o: $\eta=\mu=0$	12.44	5.99	H_0 Rejected

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

In the case of the first hull hypothesis of no technical inefficiency in the data or absence of the inefficiency random variable from the composed error structure (which is further equivalent to an average production function estimation by use of OLS), it is found that the computed value of the test statistic far exceeds the Kodde and Palm (1986) critical value of 7.05. The null hypothesis of $\gamma = 0$ is rejected andconsequently the traditional translog production function indicating the absence of the inefficiency effects is statistically an inadequate representation of data on the inputs and output of selected tea estates of Assam over the study period. Hence it can be inferred that there is a technical inefficiency effect in the data and variations in observed output are not due to random shocks alone. In other words traditional average production function (OLS regression) would be an improper specification of the underlying technological relation between inputs and output.

Second, it is important to understand the structure of the technical relationship between inputs and output in terms of the most appropriate functional form that can represent the data. Setting the parameters $\beta_{ij} = \beta_{it} = \beta_{tt}=0$ of the full and unrestricted translog production frontier boils it down to a time varying Cobb-Douglas frontier model. The computed value of the LR statistic is clearly greater than the tabulated χ^2value for the relevant degrees of freedom. Thus the null hypothesis of the time varying Cobb-Douglas frontier model is rejected and a time varying Cobb-Douglas production frontier model would be an inappropriate representation of the underlying relationship between inputs and output of the selected tea estates of Assam over the study period.

Third, setting the parameters $\beta_{ij}=\beta_{tt}=\beta_{it}=\beta_t=0$ (of the unrestricted translog model) boils it further down to a time invariant version of the Cobb-Douglas production frontier model. The computed value of the test statistic is once again greater than the corresponding tabulated value for the relevant degrees of freedom. Thus the hypothesis of the time invariant Cobb-Douglas stochastic production frontier model is also rejected by the data at 5 per cent level. Thus both the time varying and time invariant versions of the Cobb-Douglas model are inappropriate functional forms and do not represent the technological relationship exhibited by the data on inputs and output of the selected tea estates of Assam over the period 2001-10.

Fourth, the study adopts the time varying technical inefficiency effects model for panel data following Battese and Coelli (1992) however technical inefficiency effects may or may not be time varying. The fourth hypothesis tests for the absence of time varying technical inefficiency or for time invariant technical inefficiency. Under the restriction $\eta=0$, the computed value of the test statistic (computed χ^2) falls short of the tabulated value for the relevant degrees of freedom and so the fourth hypothesis of time invariant technical inefficiency is accepted at 5 per cent level. Accordingly for the selected tea estates of Assam for the study period, technical inefficiency is not significantly rising over time or is insignificantly rising over time (since estimated $\eta>0$). On the whole the selected tea estates of Assam have not been able to raise their levels of technical efficiency over the study period.

Finally the restriction $\eta=\mu=0$, boils down the inefficiency specification from the Battese and Coelli (1992) time varying model to the time invariant inefficiency effects model with normal – half normal error structure for panel data due to Pitt and Lee (1981). The computed value of the LR statistic or the computed χ^2 is 12.44 which exceed the tabulated value of 5.99. Hence the hypothesis of the Pitt and Lee (1981) specified normal-half normal composed error structure is rejected at 5 per cent level and is therefore not supported by the data. The overall results of statistical tests of hypotheses presented in table 4.3.7 can now be summarised. The translog stochastic production frontier (for panel data) with time invariant inefficiency effects with normal – truncated normal composed error structure may be taken as an appropriate econometric representation of the underlying technological relationship between inputs and output in case of the 31 selected tea estates of Assam over the ten year period 2001-10.

The year wise mean technical efficiency of all the sample tea estates covering upper Assam and Barak valley are presented in table 4.3.8. Mean technical efficiency for each year is basically the arithmetic mean of the technical efficiencies of all 31 tea estates in a cross section for that particular year. One advantage of the primary data set for the present study is that the panel consisting of 31 tea estates over 10 years is a balanced one. As a consequence, the application of the time varying inefficiency effects stochastic frontier model due to Battese and Coelli (1992) gives an opportunity of estimating the technical inefficiencies (or efficiency) for every tea estate for every time point over the 10 year study period. One obvious limitation of this model is that the same time varying pattern of technical efficiency or the same trend of technical efficiency is experienced by all tea estates. As observed from figures in table 4.3.8, there is a slight tendency of a rise in technical efficiency over time over the period 2001-10 for the sample of tea estates taken as a whole. Alternatively, there is a hint of a decline in technical inefficiency over time which desirable.

Table 4.3.8. Year Wise Mean Technical Efficiency for the Combined sample of Upper Assam and Barak Valley Tea Estates

Year	Mean Technical Efficiency (%)
2001-02	70.45
2002-03	70.81
2003-04	71.17
2004-05	71.26
2005-06	71.64
2006-07	72.00
2007-08	72.31
2008-09	72.35
2009-10	72.69
2010-11	73.01
Mean (%)	71.77
Minimum (%)	49.59
Maximum (%)	94.90
Standard Deviation across Estates over time	14.28

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

The average annual exponential rate of growth of annual mean technical efficiency of all sample estates taken together is estimated at 0.4 per cent. This is simply found out by a semi-log curve fitting to the mean technical efficiency figures using discrete time points (1, 2, 3…, and 10) as the independent variable. As the growth rate of technical efficiency is below 1 per cent during the 10 year study period, it may be termed as unsatisfactory. The one desirable aspect however is that technical efficiency has exhibited a rising trend during the study period. Admittedly there exists a substantial variation in estate level technical efficiency in the cross-section. This is expected as because tea estates are likely to vary amongst each other in terms of efficiency levels. Factors that influence the level of technical efficiency at the estate level are not separately considered in the present work. A widely used econometric model that captures the influences of non-input factors on the level of technical efficiency at the estate level is due to Battese and Coelli (1995). This approach has not been used in the present work.

The frequency distribution of mean technical efficiencies for the combined sample (thirty-one to be precise) of Upper Assam and Barak Valley Tea Estates is presented in table 4.3.9. This table is useful in commenting on the relative performance of the sample tea estates. The simple arithmetic mean level of technical efficiency for each sample tea estate for the ten year period was first calculated. The class intervals of percentage technical efficiency are appropriately constructed and absolute as well as relative frequencies are tabulated. The estate level frequency distribution of technical efficiency is vital from the distribution point of view.

Table 4.3.9. Distribution of Estate Wise Mean Technical Efficiency

Class Interval (%)	Frequency	Relative Frequency (%)
45 - 55	5	16.13
55 - 65	4	12.90
65 - 75	7	22.58
75 - 85	10	32.26
85 - 95	5	16.13

Mean Technical Efficiency (%)	71.77
Minimum Technical Efficiency (%)	51.67
Maximum Technical Efficiency (%)	88.57
Standard Deviation of Estate wise Mean Technical Efficiency (%)	12.55

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

It is important to examine whether most of the sample tea estates are concentrated near the production frontier, away from it or are distributed uniformly. This distribution may be captured in terms of the distribution of estate level technical efficiency. Figures in table 4.3.9 are based on the technical efficiency estimates of 31 estates over ten years, or in other words, on 310 pooled observations. The mean technical efficiency for the entire sample of 31 estates (covering upper Assam and Barak valley) over the study period 2001-10, is estimated at 71.77 per cent. Maximum technical efficiency is estimated at 88.57 per cent while the minimum is

51.67 per cent. This is an indication of substantial variations in the level of estate level technical efficiency. The calculated standard deviation of technical efficiency across estates and over time is found to be 12.55. Further, from table 4.3.9, it is evident that more than 48 per cent of producers have technical efficiency in between 75 per cent and 95 per cent. Around 30 per cent of sample tea estates have mean technical efficiency levels ranging between 45 and 65 per cent. Furthermore around 55 per cent of the tea estates are found to have mean technical efficiency of 65 to 85 per cent. Only a few estates are observed to have mean technical efficiencies below 55 per cent and above 85 per cent respectively. On the whole, the distribution of estate level mean technical efficiency is roughly positively skewed with substantial variations between the technically most efficient and the technically most inefficient.

Table 4.3.10. Parameter Estimates of Time Invariant Cobb-Douglas Cost Frontier with Normal-Half Normal Error (Upper Assam)

Variables	Coefficients	Estimated values	t-value
Constant	Ω	10.015	8.98
Ln Q	$1/\vartheta$	0.89	1.25
Variance Parameters			
σ^2		0.23	0.78
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_u^2)$		0.81	0.43
Log-likelihood Function =-1.074			

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

The parameters of the Cobb-Douglas stochastic cost frontier with normal- half normal composed error structure are estimated separately for the 17 sample tea estates of upper Assam and for the 14 sample tea estates of Barak valley. The cost function used for the present study is time invariant although the estimates are based on panel data. More specifically the cost frontier model in the present study is similar to that developed by Schmidt and Lovell (1979).

Table 4.3.10 presents the estimates of parameters of the Cobb-Douglas stochastic cost frontier for the 17 upper Assam tea estates. The dependent variable is the natural logarithm of costs to wage rate ratio at the estate level or total costs of the estate per unit wage or per Rupee wage. Ω is a pure constant and the coefficient of lnQ is actually the inverse of the returns to scale parameter i.e., $1/\upsilon$. Here υ is the sum of all the partial output elasticities with respect to the inputs which equals the returns to scale.

Clearly under increasing returns to scale υ is greater than unity which implies that its inverse is less than unity. The opposite conclusion may be drawn (decreasing returns to scale) if υ is less than unity. Finally $\upsilon = 1$ would result in $1/\upsilon = 1$. Coming to estimates of the time invariant Cobb-Douglas cost frontier for upper Assam tea estates it is found that the constant term is highly significant but the slope coefficient or the coefficient of lnQ is less than unity and is statistically insignificant. The estimated value of $1/\upsilon$ is 0.89 which implies that the returns to scale is 1.124. This is indicative of increasing returns although the coefficient is statistically insignificant. Unlike the estimates of the variance parameters of the stochastic production frontier models, the variance parameters σ^2 and γ in case of the Cobb-Douglas cost frontier are both statistically insignificant. Moreover the optimum value of the log likelihood function is negative.

Almost similar estimates are observed in case of the maximum likelihood estimates of the Cobb-Douglas cost frontier for the 14 Barak valley estates. These results are shown in table 4.3.11.

Table 4.3.11. Parameter Estimates of Time Invariant Cobb-Douglas Cost Frontier with Normal-Half Normal Error (Barak Valley)

Variables	Coefficients	Estimated values	t-value
Constant	Ω	14.298	3.087
Ln Q	$1/\vartheta$	1.089	0.99
Variance Parameters			
σ^2		0.19	0.47
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_u^2)$		0.87	1.02
Log-likelihood Function = -0.8792			

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

The constant or intercept Ω has a comparatively high value and is also statistically highly significant. This is similar to the estimates for upper Assam estates. The estimated coefficient of *lnQ* is 1.089 which is slightly greater than unity implying thereby that the sample tea estates of Barak valley are likely to exhibit constant returns to scale over the study period. Even in this case the coefficient of *lnQ* is statistically insignificant. The estimated variance parameters of the Cobb-Douglas cost frontier (namely σ^2 and γ) for the Barak valley estates are both statistically insignificant. This is similar to the estimates of the same for upper Assam estates. Finally the log-likelihood function at the optimum is also found to be negative. However the advantage of the maximum likelihood estimates of the cost frontier models is that they provide the point estimates of firm level or estate level cost efficiency. The time varying cost efficiency model is not used in the present work and as such the firm wise point estimates are time invariant, or in other words, are fixed quantities for all time for each garden. Consequently, the distribution of estate level cost efficiency (expressed in percentage)along with the descriptive statistics of the distribution are keys to understanding the relative performance of the sample tea estates .

The frequency distribution of cost efficiency (expressed in percentage) of the sample tea estates of upper Assam is presented in table 4.3.12.

Table 4.3.12. Distribution of Estate Wise Cost Efficiency (Upper Assam)

Class Interval	Frequency	Relative Frequency (%)
45 - 55	3	17.65
55 - 65	2	11.76
65 - 75	3	17.65
75 - 85	5	29.41
85 - 95	4	23.53
Mean Cost Efficiency (%)		72.94
Minimum Cost Efficiency (%)		41.83
Maximum Cost Efficiency (%)		92.45
Standard Deviation of Cost Efficiency (%)		27.33

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

The approach followed here is very similar to that of the presentation of the distribution of estate level technical efficiency. First around 30 per cent of the sample tea estates of upper Assam are found to have cost efficiency between 45 and 65 per cent. Second around 53 per cent of sample tea estates in the upper Assam region have cost efficiency levels in between 75 and 95 per cent which is desirable at least from the industry level standpoint. In other words majority of the sample tea estates of upper Assam have cost efficiency levels beyond 75 per cent. Since cost frontier is a lower contour one has to be cautious regarding economic interpretation of cost efficiency estimates. Finally, the closer the estate to the cost frontier, the higher is the level of cost efficiency. The distribution observed in table 4.52 is suggestive of higher concentration of estates near the cost frontier. Mean cost efficiency of all upper Assam estates taken together is 72.94 per cent. There is a wide observed variation between the minimum and the maximum levels of percentage cost efficiency.

Finally the distribution of estate wise cost efficiency estimates for the sample of Barak valley tea estates is presented in table 4.3.13.

Table 4.3.13. Distribution of Estate Wise Cost Efficiency (Barak Valley)

Class Interval	Absolute Frequency	Relative Frequency (%)
35 - 45	2	14.29
45 - 55	3	21.43
55 - 65	2	14.29
65 - 75	3	21.43
75 - 85	3	21.43
85 - 95	1	7.14
Mean Cost Efficiency (%)	63.57	
Minimum Cost Efficiency (%)	32.21	
Maximum Cost Efficiency (%)	87.09	
Standard Deviation of Cost Efficiency (%)	16.32	

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

The highest and the lowest percentage cost efficiencies at the estate level for Barak valley tea estates are slightly different from the ones observed in table 4.3.12, and as such the class intervals of cost efficiency are adjusted accordingly. First both the highest and the lowest cost efficiency figures for Barak valley estates are lower than the corresponding figures for upper Assam estates. Moreover the mean cost efficiency for Barak valley tea estates turns out to be just 63.57 which is far lower than the corresponding figure for upper Assam estates. However the inter-estates variations in cost efficiency are lower for Barak valley estates. This is evident from the standard deviation of cost efficiency. Coming to the distribution of cost efficiency, around 36 per cent of sample tea estates have cost efficiency in between 35 and 55 per cent. Interestingly around 36 per cent of tea estates have cost efficiency in between 55 and 75 per cent, whereas just around 28 per cent of the sample estates of Barak valley have cost efficiency between 75 and 95 per cent. In fact no tea estate of this region has a cost efficiency level of 90 per cent or more. Thus the distribution of cost efficiency in this region is more even around a lower mean compared to the same for upper Assam tea estates. However just one tea estate is seen to exhibit a cost efficiency of 85 per cent or more. Evidently the estimates of technical efficiency and cost efficiency do not match for the present data set. If allocative efficiency is assumed then u_i of the cost frontier model is closely related to the cost of technical inefficiency. If this is not assumed then the economic interpretation of u_i in a cost frontier is not very clear. In fact both technical and allocative inefficiencies may be possibly involved. Allocative efficiency is not measured in this study and firms are assumed to be perfectly allocatively efficient which in general is not true. Hence the present study refers to the efficiencies measured on the basis of the cost frontier as simply "cost efficiencies" irrespective of whether allocative inefficiency exists or not.

Finally the ordinary least square regression estimates of the Cobb-Douglas cost function for upper Assam and Barak valley tea estates are presented in tables 4.3.14 to 4.3.19. First Cobb-Douglas cost function for the sample of 17 upper Assam tea estates is estimated using ordinary least squares regression. Summary statistics, ANOVA results and the estimates of parameters are presented in separate tables.

Table 4.3.14. Summary Statistics of Cobb-Douglas Cost Function Regression for Upper Assam (2001-10)

Multiple R	0.91
R Square	0.73
Adjusted R Square	0.72
Standard Error	0.004
D.W	1.911

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

The R-square value in table 4.3.14 is 0.73 implying that 73 per cent of the total variation in the log of costs per unit wage rate may be explained by the log of output. The computed value of the Durbin-Watson test statistic is close to 2. So the disturbances are most unlikely to be auto-correlated. The ANOVA results of the cost function regression are presented in table 4.3.15. The computed F value is very high implying that the overall regression is highly significant.

Table 4.3.15. ANOVA Results for Cobb-Douglas Cost Function Regression for Upper Assam (2001-10)

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.00574	0.005746	378.16	1.94E-31
Residual	168	0.00116	1.52E-05		
Total	169	0.00691			

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

Finally the least squares regression coefficients are shown in table 4.3.16. The constant or the intercept is positive and is statistically highly significant. The coefficient of *ln(Q)* is the returns to scale parameter. The estimated value of the slope coefficient is almost unity, implying thereby that the sample of upper Assam tea estates as a whole have experienced constant returns to scale over the period 2001-10. The coefficient of *ln(Q)* is statistically significant as well.

Table 4.3.16. OLS Regression coefficients of Cobb-Douglas Cost Function for Upper Assam (2001-10)

Coefficients	*Estimated Coefficient*	*Standard Error*	*t value*	*P-value*
Constant	7.16	0.008	913.57	4.1E-157
ln (Q)	0.99	0.001	19.45	1.94E-31
Dependent variable = *ln*(C/w)				

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

In case of the OLS estimates of the Cobb-Douglas cost function for Barak valley (refer to table 4.3.17) the R-square and Durbin –Watson values are slightly higher. The computed F statistic is also very high and hence the overall cost function regression is highly significant. Finally the OLS estimates of parameters of the Cobb-Douglas cost function for Barak valley estates are positive and highly significant. The returns to scale parameter which is the inverse of the coefficient of *ln(Q)* (i.e., inverse of 0.918) turns out to be 1.09 which is suggestive of constant returns. These are more or less similar to the observations on OLS estimates of the Cobb-Douglas cost function for upper Assam. One interesting difference between the maximum likelihood estimates of the cost frontier and the OLS regression estimates of the same is that in case of the former only the intercept term is statistically significant whereas the slope coefficient is not. However in case of the OLS estimates, both intercept and slope coefficients are statistically significant.

Table 4.3.17. Summary Statistics of Cobb-Douglas Cost Function Regression for Barak Valley (2001-10)

Multiple R	0.86
R Square	0.76
Adjusted R Square	0.73
Standard Error	0.004
D.W.	2.119

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

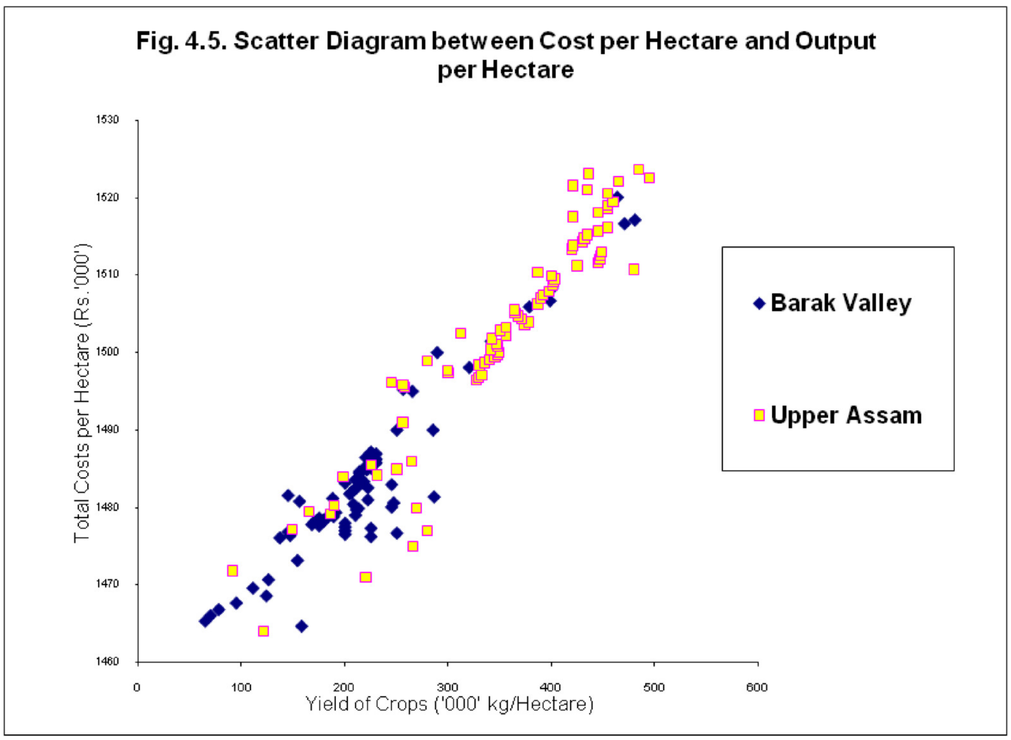
Table 4.3.18. ANOVA Results for Cobb-Douglas Cost Function Regression for Barak Valley (2001-10)

	Df	*SS*	*MS*	*F*
Regression	1	0.003248	0.003248	235.38
Residual	138	0.000993	1.38E-05	
Total	139	0.004241		

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

Table 4.3.19. OLS Regression coefficients of Cobb-Douglas Cost Function for Barak Valley (2001-10)				
Coefficients of	Coefficients	Standard Error	t Stat	P-value
Constant	7.208	0.006	1168.31	9.3E-156
ln (Q)	0.918	0.001	15.34221	2.16E-24
D.W.	2.003	Dependent variable = *ln*(C/w)		

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

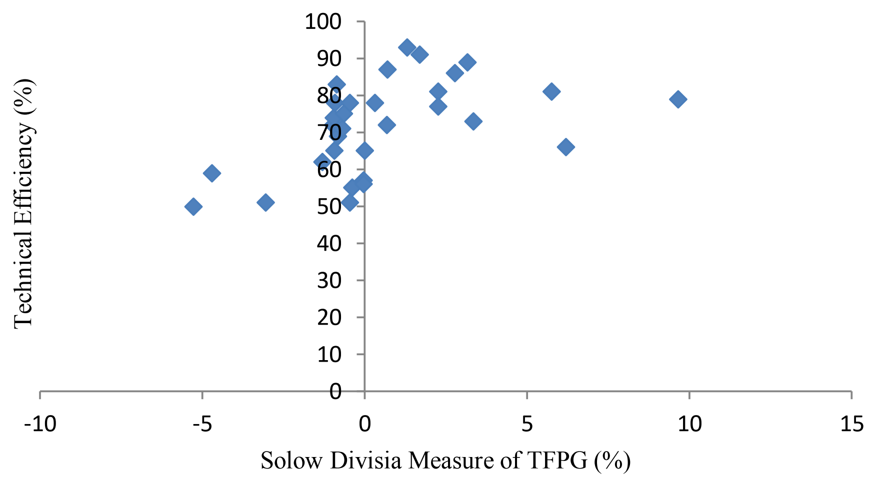


The scatter diagram between costs of plantations per hectare and output per hectare (which is basically the green leaf plucked per annum) is plotted in figure 4.5. Upper Assam estates are represented in red while Barak valley estates are represented in blue. As seen from the scatter there is clear evidence of a strong positive association between cost per hectare and output per hectare in tea plantation for the sample of 31 tea estates. This strong and positive association is not only true for the pooled data for estates of both regions taken together but is also true for the tea estates of the two regions considered separately. The simple correlation coefficient between costs per hectare and output per hectare for the pooled data for both regions turns out to be 0.88 which is highly significant (computed t = 9.37). Thus for the present sample of tea estates higher cost per hectare is directly associated with higher output per hectare. In other words higher the cost per hectare, higher is the output per hectare. Hence from the point of view of the firm (estate manage) spending more per hectare is economically justified as it leads to higher yields.

Higher costs per hectare (compared to others in the sample) may be incurred by some estates owing to several reasons. First some tea estates focus more on the development and cultivation of newer varieties and hence spend more on R&D. R&D in the plantation sector is primarily a part of immature cultivation. Second cost per hectare may rise due to higher irrigation costs. This is possible under moderate to low rainfall conditions where the estate management is forced to arrange for artificial sprinkler irrigation. Generally in Assam, monsoon cultivation is subject to little or no irrigation costs but spring cultivation or the post winter cultivation is done under very low rainfall conditions and consequently for this season irrigation cost is high. On the whole, below average rainfall in a year will lead to high average costs due to higher irrigation costs. Third, many estates reject old bushes and replace them with new ones with the sole objective of raising the quality as well as quantity of green leaf output. In the transition phase it is possible that area under cultivation drops without much of a change in cost levels. This can naturally raise costs per hectare temporarily. Fourth, pests that are extremely harmful from the point of view of growth of fresh buds become increasingly resistant to the standard pesticides used over time. Newer types of pesticides are often required and sometimes in higher doses, in order to combat pest attack. Chewing pests, sucking pests, mite pests, red spider among numerous others are some of the major enemies of tea plants. Thus besides higher irrigation costs, higher pesticide costs also raise the cost per hectare. Fifth, many estates have adopted mechanised processes in cutting, pruning, trimming and even in discarding older plantations. Most mechanised equipments are either diesel or petrol driven and can save a lot of man power and time during the end of a plucking season. But practically if downsizing of staff strength is not done in tandem then cost of mechanisation becomes an additional cost raising the overall cost per hectare. Nevertheless for the present sample of tea estates the available data over the study period shows unmistakably that higher spending per hectare on cultivation related activities lead to higher leaf output per hectare which is a very desirable observation. One surprising observation however that is there is no tendency of flattening of the scatter beyond a certain point. Economically that would tally with the standard neoclassical production behaviour whereby input application raises output but the rate of addition to output declines as inputs are used in higher amounts. This is tantamount to diminishing marginal product. Finally perhaps the most significant observation from the scatter is that upper Assam tea estates in general have higher costs per hectare along with higher output per hectare whereas Barak valley tea estates have lower costs per hectare along with lower output per hectare. Thus theoretically it may be argued that if Barak valley estates spend more on immature cultivation, mature cultivation and R&D along with overall garden maintenance and management (that includes bush health and growth) they are most likely to produce higher output per hectare.

Finally figure 4.6 depicts the scatter diagram between technical efficiency and total factor productivity growth both expressed in percentage. This figure is the key to understanding the association if any, between technical efficiency and total factor productivity growth. The normal – half normal error model for the translog production frontier has been employed to compute percentage technical efficiency for all 31 estates. The Solow divisia index has been employed to compute TFPG for the 31 estates for each of the ten years. The ten year averages are then computed to get the TFPG figures for each of the 31 tea estates.

Fig. 4.6 Scatter Diagram Plotting Technical Efficiency against TFPG



In figure 4.6 average TFPG is plotted against technical efficiency for 31 tea estates. As the scatter shows clearly illustrates, there is a positive association between TFPG and technical efficiency. The simple correlation coefficient between technical efficiency and TFPG turns out to be 0.498 which is statistically significant at 1 per cent level (t = 3.045). Now, theoretically there is no direct correspondence between technical efficiency and TFPG. The former shows the relative position of firms or production units with respect to the production frontier. The original concept of total factor productivity growth is not implicit in the concept and measurement of technical efficiency. TFPG is basically a residual primarily originating from neoclassical growth accounting. However Nishimizu and Page (1982) introduced efficiency change as a source of productivity change in their pioneering work on productivity change in Yugoslavia. The present study has not adopted this approach to TFPG decomposition. Theoretically it is possible for a technically efficient firm to exhibit poor TFPG and conversely a firm exhibiting high TFPG may be technically more inefficient compared to others. For the present sample of tea estates it seems that on the whole the more technically efficient estates have higher TFPG although exceptions may be there. This positive association between the two may or may not be so pronounced once the sample size is raised.