A Comparative Analysis Between Two Parametric Non-Frontier Approaches to the Measurement of Total Factor Productivity Growth for Indian Paper and Paper Products Industry

Pinki Bera
Ph.D. Scholar, Department of Economics, Vidyasagar University
Midnapore, West Bengal, India

Mihir Kumar Pal
Professor of Economics, Department of Economics, Vidyasagar University
Midnapore, West Bengal, India

Abstract

In this study we have examined Total Factor Productivity Growth (TFPG) from two parametric *non-frontier approaches (production function approach and cost function approach) for the Indian paper and paper products industry over the period 1980-81 to 2016-17. We have chosen paper and paper products industry (2-digit level of NIC2008) at all-India level, because, its energy intensity is the highest among the manufacturing industries, according to Annual Survey of Industries (ASI) data. Here, we have considered the most general specification, Trans-log form of production function as well as cost function. Results shows that TFPG declined in the post reform period, highlighting the fact that liberalisation process has its adverse impact on productivity growth. This may be due to decreasing capacity utilisation and fall in the agricultural growth rate in the Indian economy in the liberalised era. Energy intensity of this manufacturing industry is found to be decreasing after liberalization era. But in the absolute amount, it is quite high in the post-reform period compared to other industries. We may think that after liberalization, they have used sophisticated machinery, eco-friendly technology in the production process and hence energy intensity of this industry shows a declining tendency. Decreasing energy intensity, quite significantly, would decrease the level of pollution generated by the manufacturing industry. So, interestingly enough, this may lead us to conclude that the growth of this manufacturing industry is in line with the basic essence of sustainable development.*

Keywords: *Total Factor Productivity, Energy intensity, Trans-log Cost function, Trans-log Production function, Sustainability.*

JEL Classification: *D24, L6, O33.*

1. Introduction

Productivity is the average measure of the efficiency of production. It is a ratio of output to input(s) or factor(s) of production used in the production process. The ratio of output to one input factor measures single factor productivity and the ratio of an index of aggregate output to an index of aggregate inputs measures total factor productivity (TFP). TFP is defined as residual factor in growth, which takes the form of invention, innovation and diffusion. Empirically, they are used synonymously but there is a conceptual difference between them. Total factor productivity (TFP) measures the efficiency of a productive process or a production unit (Balakrishnan, 2004). In the existing literature, single-factor productivity is not considered a true measure of productivity as it does not denote overall changes in the productive capacity of a firm. Total factor productivity tries to overcome this limitation by measuring changes in

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production due to changes in all inputs, such as labour, capital, technology, capacity utilisation and quality of factors of production (Kathuria, Raj & Sen, 2013). It can be theoretically established that the use of cost function rather than a production function for estimating the trans-log form[30] has several advantages. Cost functions are homogeneous in prices regardless of the homogeneity properties of the production function, because a doubling of all price will double the costs but will not affect factor ratios. In production function estimation, high multi-collinearity among the input variables often causes problems. Since there is usually little multi-collinearity among factor prices, this problem does not arise in cost function estimation. In this respect, this study focuses on estimating total factor productivity using transcendental logarithmic specification of production function as well as cost function approach. We have compared the estimates of TFPG from both the approaches and have tried to explain the differences in results obtained. So, we may think that the analysis builds upon a place in the existing literature of the manufacturing industries in India. Several studies in recent times have attempted to analyse the productivity of manufacturing industries from production function approach or cost function approach separately. Very few works have been done in a comparative analysis of the estimates of TFPG between cost function and production function approach. In this work, we also estimate the energy intensity of paper and paper products industry. Energy intensity (EI) indicates the value of energy consumption per unit of value of output. There may be either an increase in energy intensity or decrease in energy intensity. The remainder of the article is organised as follows: The second section reviews the literature on TFP and EI and research gap; the third section describes objectives of our study; in section four we discuss the database and methodology; productivity growth and energy intensity estimates are presented under Results and Discussion in section five; Casual relation between TFPG and Energy intensity are shown in section six and the last section concludes the article.

2. Brief Survey of Existing Literature

2.1 Studies on Total Factor Productivity Growth:

In this sub-section, we have presented a brief review of literature on the studies on measurement and determinants of productivity in India as well as other emerging and developed economies. There are many studies dealings with the measurement of TFP and TFPG for the Indian manufacturing industries, and due to the different methods used and different approaches of variable construction, there are conflicting results. The literature on measurement of TFP is quite extensive; which is discussed in the following:

Das et al. (2010) have examines the relative contributions of factor accumulation and productivity growth in the different sectors of the Indian economy. The TFP growth measure incorporates contributions of labour-quantity and quality and capital-ICT and non-ICT assets in its measurements. According to Kathuria et al. (2013), growth in productivity is the only plausible route to increase standard of living and therefore, it is considered as a measure of welfare. They used the Levinsohn and Petrin (LP) method along with growth accounting and stochastic production frontier analysis from 1994–1995 to 2005–2006 to check the sensitivity of results. Kumbhakar, Nakamura, and Heshmati (2000) paper dealt with estimation of firm-specific technical change (TC) and firm-specific measures of technological biases (inputs and scale) in estimating TFP growth from a variety of dual parametric models. TC is found to be positive for all years, except those in which output growth rates were negative. The scale

[30] The trans-log form for a single output technology was introduced by Christensen, Jorgenson and Lau (1971). The multiple output case was defined by Burgess (1974) and Diewert (1974a, p. 139)

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component is found to be less than 1% per year. Scale bias is found to be negative, implying an increase in the minimum efficient scale size.

2.2 Studies on Energy Intensity:

According to Government of India, energy intensity in Indian industries, are the highest among the manufacturing sector of developed other emerging economies. Energy consumption per unit of production in the manufacturing of steel, aluminium, cement, paper, textile etc. is much higher in India, even in comparison with some developing countries.

S. Ray (2011) attempts to measure and examine the degree of energy intensity of seven major manufacturing industry of India viz. Paper, Aluminium, Iron & Steel, Fertilizer, Chemical, Glass and Cement, at an industry level. The study observes whether there exists any inter-industry variation in energy intensity and depicts varied energy intensities which are well above the average intensity of the entire aggregate manufacturing industry. Sahu and Sharma (2016) calculated total factor productivity and determine factors related to energy intensity for the pre-existing manufacturing plants in India. The results indicate that most of the industries achieved positive TFP growth except a few. In case of determinants of energy intensity, they found plants with higher TFP and higher output are energy efficient. Papadogonas et al. (2007) to analyse energy intensity of Greek manufacturing firms. The results strongly indicate that when firms are more capital intensive, they are more energy intensive. Goldar (2018) examined the trends in the level of energy use and energy intensity of production in various broad sectors of the Indian economy and at the aggregate economy level and found a downward trend in energy intensity of the Indian economy in the period 1980 to 2010 and upward trend during 2010-2015. Reddy and Ray (2011) study aim to determine the physical Energy Intensity indicators in five industrial sub-sectors and investigated the options for carbon dioxide reduction during 1991–2005. The results show that the combined effect (considering both structural and intensity effects together) on both iron & steel and paper & pulp industries is negative while it is positive for aluminium and textiles. Soni, Mittal, Kapshe (2017) tried to analyse the factors which influence the Energy Intensity of Indian manufacturing industries and how they can be improved to reduce the Energy Intensity. They concluded that reduction in Energy Intensity can be achieved by concentrating on its influencing factors, represented by the explanatory variables, and adopting appropriate measures to optimize them.

2.3 Research Gap:

Our literature review shows that most of the studies have estimated TFPG from production function approach. There is dearth of studies on TFPG using cost function approach. We can make methodological improvement using cost function approach. The cost function approach shows association between firm costs, output, and input prices. We think that the use of cost function rather than production function for estimating productivity growth is of much significance due to the fact that this form can decompose TFPG. Again, we find no study comparing results obtained from production function approach and cost function approach.

3. Objectives of Our Study

The objectives of our study are:

a) To estimate the total factor productivity growth (TFPG) for the Indian Paper and paper products industry by using production function approach and cost function approach over the time period 1980-81 to 2016-17 and to make a comparative analysis between the different estimates of TFPG.

b) To estimate the impact of liberalisation on TFPG using both the parametric non-frontier approaches (cost function approach and production function approach).

c) To estimate energy intensity (EI) of the above - mentioned manufacturing industry during the selected time period to address the issue of sustainability of this Indian manufacturing industry.

d) To access causal relationship between TFPG (production function approach and cost function approach) and energy intensity (EI).

4. Database and Methodology

4.1: Database:

This paper covers a period of 37 years from 1980-81 to 2016-17[31]. The entire period is divided into two phases, the pre-reform (1980-81 to 1990-91) and post-reform period (1991-92 to 2016-17). This is done to incorporate the impact of liberalisation on total factor productivity growth (TFPG) obtained by production function approach and cost function approach.

The present study is based on industry level time series data taken from: Several issues of Annual Survey of Industries (ASI) and Energy statistics published by Central Statistical Organization (CSO), RBI Handbook of statistics on Indian Economy published by Reserve Bank of India (RBI).

4.2: Methodology of the Present Study:

In productivity analysis the concept of total factor productivity growth (TFPG) is widely used. There are several approaches to the measurement of TFPG. Here, we consider trans-log measure to estimate TFPG.

4.2.1: Estimation of TFPG through Production Function Approach: The Model

An estimation of TFPG using, trans-log production approach gives a measure of technical progress.

Basically, the concept is to treat output as a function of factors of production, capital (K), labour (L), and energy (E) as well as some unknown influence captured by a proxy variable, time (T).

$$Y = F(K, L, E, T)$$

We may present the trans-log production function below:

$$\ln Y=\alpha_0+\alpha_1\ln K+\alpha_2\ln L+\alpha_3\ln E+\alpha_4 T+\tfrac{1}{2}\beta_1(\ln L)^2+\tfrac{1}{2}\beta_2(\ln K)^2+\tfrac{1}{2}\beta_3(\ln E)^2+\tfrac{1}{2}\beta_4 T^2+\gamma_1\ln K.\ln L$$
$$+\gamma_2\ln K.\ln E+\gamma_3\ln K.T++\gamma_4\ln L.\ln E++\gamma_5\ln L.T++\gamma_6\ln E.T$$

Where Y, K, Land E are output, capital input, labour input and energy input respectively.

T stands for time (proxy for technological progress).

Now, we regress LnY on all the independent variables chosen and then we can estimate TFPG,

$$TFPG = \frac{\partial \ln Y}{\partial T} = \frac{1}{Y}\frac{dY}{dT}$$

4.2.2: Decomposition of TFP through Cost Function Approach: The Model

In cost function approach, TFP change has two components: one part is technical change and other returns to scale. Technical change is reflected through shift in cost function. Returns to scale is represented by the cost-output elasticity.

The growth rate of TFP is defined as: $\dot{TFP}=\dot{Q} - \dot{F}$

[31] Under the time period our considered for our study, there were five different industrial classifications: NIC-70, NIC-1987, NIC-1998, NIC-2004 and NIC-2008. We have made the data comparable keeping in mind the composition of the all-manufacturing industries for several time periods in our study

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Where, rate of change of output is $\dot{Q}$, $\dot{F}$ is rate of change of total factor inputs; it is the proportionate change in the variables over time. In other words, TFPG is the unexplained part of output growth which is not explained by the growth of inputs taken together.
Let us represent the cost function in three explanatory variables, by
$C= F(Q,P_L,P_K,P_E,T)$ ---------------------(1)
Where P_L is the price of labour, P_K is the price of capital, P_E is the price of energy, T the index of technology, which is a simple time function, and Q is the output.
The cost function specified in the study is the Trans-log form, which is more flexible, compared to the alternative functional forms and Trans-log specification of this generalised cost function as given in equation (1) is:
$\ln C (Q, P_L, P_K, P_E, T) =\alpha_0+\alpha_Q \ln Q+\alpha_L \ln P_L+\alpha_K \ln P_K+\alpha_E \ln P_E+\alpha_T \ln T +\beta_{QL} \ln Q.\ln P_L+\beta_{QK} \ln Q.\ln P_K+\beta_{QE}\ln Q.\ln P_E+\beta_{QT}\ln Q.\ln T+\beta_{LK}\ln P_L.\ln P_K+\beta_{LE}\ln P_L.\ln P_E+\beta_{LT}\ln P_L.\ln T+\beta_{KE}\ln P_K.\ln P_E+\beta_{KT}\ln P_K.\ln T+\beta_{ET}\ln P_E.\ln T+1/2\gamma_Q(\ln Q)^2+1/2\gamma_L(\ln P_L)^2+1/2\gamma_K(\ln P_K)^2+1/2\gamma_E (\ln P_E)^2 +1/2\gamma_T (\ln T)^2$
Now, differentiating (1) totally with respect to T, we get,
$TF\dot{P} = -\dot{\theta}+ (1- \eta_{CQ})\, Q$
Where, the proportionate change in cost is the sum of proportionate change in aggregate inputs (the first term on the right side), the cost/output elasticity (a part of the second term) denoted by, η_{CQ}, and the proportionate shift in the cost function (the third term) due to technology denoted by, $\dot{\theta}$.
The coefficients of the above equation are estimated through the regression exercise by SPSS statistical packages. This package automatically excludes the insignificant variables, when we go in for regression exercise.

4.2.3: Method for measuring energy intensity:

Energy Intensity of any industry is defined as a ratio of total energy consumption (in value) to total output production (in value) of that industry. There may be either an increase in energy intensity or decrease in energy intensity in a dynamic framework. Declining energy intensity in any industry indicates efficient use of energy.
Let, Y_{it} be the total output production in an economy, say India, of i^{th} industry at t, t= 1,2, …,n. And E_{it} is the total energy consumption of i^{th} industry in an economy, say India at t, t=1,2, …,n. Then, Energy intensity of i^{th} industry: $I_{it}= E_{it}/ Y_{it}$

4.2.4: Time series econometric tests to assess the nature of the variables

The Stationarity Test (Unit Root Test)
It is suggested that when dealing with time series data, a number of econometric issues can influence the estimation of parameters using OLS. Since standard regression analysis requires that data series be stationary, it is obviously important that we first test for this requirement to determine whether the series used in the regression process is a difference stationary or trend stationary.
To test the stationary of the variables, we use the Augmented Dickey Fuller (ADF) test[32] and Phillips-Perron Unit Root Test[33].

1) Augmented Dickey Fuller (ADF) test
ADF test is mostly used to test for unit root. Following equation checks the stationary of time series data used in this study:

$$\Delta X_t = \beta_1 + \beta_{2t} + \alpha X_{t-1} + \gamma \Sigma\Delta X_{t-1} + \varepsilon_t$$

[32] developed by Dickey and Fuller in 1979
[33] developed by Phillips and Perron in 1988

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Where, ε_t is white noise error term in the model of unit root test, with a null hypothesis that variable has unit root. The test for unit root is conducted on the coefficient of X_{t-1} in the regression. If the coefficient is significantly different from zero (less than zero) then the hypothesis that X contains a unit root is rejected. The null & alternative hypothesis for the existence of unit root in variable X_t is H_0: $\alpha = 0$ versus H_1: $\alpha < 0$. Rejection of the null hypothesis denotes stationarity in the series.
If the ADF test-statistics (t-statistics) is less (in the absolute value) then the Mackinnon critical t-values, the null hypothesis of a unit root cannot be rejected for the time series and hence, one can conclude that the series is non-stationary at their levels. The unit root test, tests for the existence of a unit root in two cases: with intercept only and with intercept and trend. The case of Intercept & trend takes into account the impact of the trend on the series.

2) Phillips-Perron Unit Root Test

Phillips and Perron (1988) developed a number of unit root tests that have become popular in the analysis of financial time series. The Phillips-Perron (PP) unit root tests differ from the ADF tests mainly in how they deal with serial correlation and heteroskedasticity in the errors. The test regression for the PP tests is

$$\Delta X_t = \beta' D_t + \pi X_{t-1} + u_t$$

Where, ut is I(0) and may be heteroskedastic. Under the null hypothesis that $\pi = 0$, the PP test-statistics have the same asymptotic distributions as the ADF t-statistic and normalized bias statistics. One advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error term u_t. Another advantage is that the user does not have to specify a lag length for the test regression.

The Cointegration Test

Nonstationary variables can be used in regression if their linear combination is stationary. In recent research, it has been noted that if a linear combination of integrated variables is stationary, the variables are said to be cointegrated. Although Engle and Granger (1987) were the first to propose the cointegration test, the methods proposed by Stock and Watson (1988), Johanson (1991), and Johansen and Juselius (1990) are more useful in multivariate testing of long-term equilibrium connections. The following phases make up the estimating portion of the Johansen and Juselius approach.

Let X_t be an (n x 1) vector of variables with a sample of T. Assuming the X_t follows I(1) procedure, estimating the vector error correction representation is required to determine the number of cointegrating vectors:

$$\Delta X_t = A_0 + \prod X_{t-p} + \sum_{i=1}^{p-1} A_i \, \Delta X_{t-i} + \varepsilon_t \qquad (1)$$

The vectors Xt and Xt-i are I(0) variables in the preceding equation, while the vector X_{t-i} is I(1). As a result, the rank of Π matrix determines the long-run equilibrium relationship among Xt. If the rank of Π, say r, is zero, Eq. (1) reduces to a p-th order VAR model with no cointegrating link between the variables in level. If $0<r<n$, on the other hand, there are nxr matrices of α and β, such that

$$\prod = \alpha\beta' \quad (2)$$

Where β is cointegrating vector; hence, $\beta' X_t$ is I(0) although X_t are I(1) and the strength of cointegration relationship is measured by α's. In this framework, we have to estimate (A0, A1, . . .,A_{p-1}, Π, Ω) through maximum likelihood procedures, such that 'Π' can be written as in (2). To estimate all these parameters, we have to follow two-step procedures. In the first step, regress ΔX_t on ΔXt-1, . . .,ΔXt-p+1 and obtain the residuals u_t . In the second step, regress Xt-

1 on ΔXt-1, ΔXt-2, . . .,ΔXt-p+1 and obtain the residuals $\hat{e}_t$. From the obtained residuals $\hat{u}_t$ and $\hat{e}_t$, find the variance–covariance matrices.

Granger causality test

A time series X is said to Granger-cause Y if it can be shown, usually through a series of t-tests and F-tests on lagged values of X (and with lagged values of Y also included), that those X values provide statistically significant information about future values of Y.

Granger defined the causality relationship based on two principles:

1. The cause happens prior to its effect.
2. The cause has unique information about the future values of its effect.

Given these two assumptions about causality, Granger proposed to test the following hypothesis for identification of a causal effect of X on Y:

$P[Y(t+1) \in A \,|I(t)] \neq P[Y(t+1) \in A \,|I_{-X}(t)]$

where P refers to probability, A is an arbitrary non-empty set, and I(t) and $I_{-X}(t)$ respectively denote the information available as of time t in the entire universe, and that in the modified universe in which X is excluded. If the above hypothesis is accepted, we say that X Granger-causes Y.

5. Results and Discussion

In this section, we have presented the estimates of total factor productivity growth and its components using production function approach and cost function approach under three inputs-labour, capital, energy, and one output framework and also try to make comparison between the pre-reform as well as post-reform period. Before estimating TFPG and EI, we use two tests to check for the presence of unit roots for all the individual time series variables.
All-time series data for the variables must be stationary in order to analyse time series econometrics. The estimated t-statistics under OLS regression fail to converge to their real values as sample size grows if the time series data of the variable is not stationary. To check the stationarity of the variables, we conducted two types of unit root tests: Augmented Dickey–Fuller (ADF) test and Philips–Perron (PP) test.

To test the Unit root of the time series variables, we considered the following hypothesis
Null hypothesis: Time series variable has unit root (not- stationary)
Alternative hypothesis: Time series variable has no unit root (stationary)
If the P value is less than 5%, we can reject null hypothesis and accept alternative hypothesis. If the P value is more than 5%, we cannot reject null hypothesis rather we accept null hypothesis.

Each variable is tested in their level and first difference with intercept only as well as trend & intercept for both the test, ADF test as well as PP test. The result shows that the null hypothesis of unit roots cannot be rejected at conventional significance levels for all the variables and therefore it can be concluded that all series are stationary at first difference i.e., all the series are I (1). The results of the unit root test are placed in the appendix to this article.
Our Johansen co-integration Test indicates that there exist 3 co-integrating equations at the 0.05 level and 0.10 level. So, co-integration Test shows that there is meaningful long run relationship among all the variables. Series of all the variables are co-integrated. So, lnC is

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cointegrated with other variables such as lnQ, lnP_K, lnP_L, lnP_E, $(LNQ)^2$, $(LNP_L)^2$, $(LNP_K)^2$, $(LNP_E)^2$ etc.

Table-1: Results of Johansen Co-integration Test

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	Probability
None	0.762928	208.3678	0.0000
At most 1*	0.751493	165.9687	0.0004
At most 2*	0.719875	136.8746	0.0014

Source: Authors' own estimation

To observe the unexplained part of the growth in output (TFPG), we have use two parametric non-frontier approach (production function approach and cost function approach). For both these approach, we have considered Trans-log specification and computed results of TFPG as shown in the table-2 and table-3. We have applied OLS method for obtaining estimated value of co-efficient of different variables.

Table-2: Annual Average Estimates of TFPG (Production function approach)

Period	Technical change (TFPG)
Overall	0.0812***
Pre-liberalisation	0.0812***
Post-liberalisation	0.0418**

Source: Author's own estimation;
*** ** & * represents the level of significance at 1%, 5% and 10% level respectively

From Table-2, we find that for paper and paper products industry, the annual average TFP growth from production function approach for the entire period (1980-81 to 2016-17) is positive and it is 8.12%, which is statistically significant at 1% level. We also observe that after liberalisation rate of growth of TFP has significantly decreased and is statistically significant at 5% level. We also observed that our estimates are robust in nature. The fall in TFPG may be due to decreasing capacity utilisation and fall in the agricultural growth rate in the Indian economy in the liberalised era. Due to the above-mentioned reason, the demand for the manufacturing goods may decrease, affecting the investment behaviour of the business sector and hence adversely affecting the productivity of the concerned manufacturing industry.

Table-3: Annual Average TFPG and its decomposition (Cost function approach)

Period	Shift of the Cost Function ($-\dot{\theta}$)	Cost- Output Elasticity (η_{CQ})	TFPG $[-\dot{\theta}+(1-\eta_{CQ})\dot{Q}]$
Overall	-0.0772	0.2610	-0.0163***
Pre-liberalisation	-0.0543	0.2010	0.0322***
Post-liberalisation	-0.0869	0.2978	-0.0369***

Source: Author's own estimation
***, ** & * represents the level of significance at 1%, 5% and 10% level respectively

Form table-3, we may find that TFPG is sharply declining in the post-liberalisation era, when estimated from the cost function approach. But in the cost function approach TFPG turns out to be negative, when we consider the entire study period, which may be due to the fact that, producers want to minimise cost for a given level of output.

Technological progress in production process is best reflected through a shift of the cost function. The negative or positive sign associated with the parameter implies a shift down or up in the cost of production. From the above table-3, we may conclude that cost function is significantly shifted down in the post-reform period.
Returns to scale parameter indicates the proportionate increase in output for a proportionate increase in all inputs. When the parameter is numerically less than one, it is suggestive of the operation of diminishing returns to scale. We find diminishing return to scale in the entire as well as pre- and post-reform period. The above analysis exhibited that, when diminishing returns to scale operates the growth rate of TFP decreases.

6. Causal Relation between TFPG AND EI

In this section we try to show a causal relation between Total Factor Productivity Growth (TFPG) from both the approaches and energy intensity (EI).

Table-4: Annual Average TFPG and EI

Period	TFPG		EI
	Production function approach	Cost function approach	
Overall	0.0812	-0.0163	0.7268
Pre-liberalisation	0.0812	0.0322	0.7268
Post-liberalisation	0.0418	-0.0369	0.4692

Source: Author's own estimation

Here, we have used Pairwise Granger Causality between TFPG and EI for the Indian paper and paper products industry and the result is presented in the following Table-5. The results reveal that there is a bidirectional causal relationship between EI and TFPG. That implies, EI is the Granger cause of TFPG as well as TFPG is the Granger cause of EI at lag 1 to lag 5.

Table 5: Results of Granger Causality test

Lag	Null Hypothesis	observation	F-Statistics	Probability
1	EI does not Granger Cause TFPG (Cost function approach)	36	0.0968	0.7576
	TFPG (Cost function approach) does not Granger Cause EI		0.54003	0.4676
	EI does not Granger Cause TFPG (Production function approach)		7.1485	0.0116
	TFPG (Production function approach) does not Granger Cause EI		4.6850	0.0378
2	EI does not Granger Cause TFPG (Cost function approach)	35	0.7142	0.4977
	TFPG (Cost function approach) does not Granger Cause EI		0.8769	0.4265
	EI does not Granger Cause TFPG (Production function approach)		2.0636	0.1446
	TFPG (Production function approach) does not Granger Cause EI		2.2104	0.1272

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3	EI does not Granger Cause TFPG (Cost function approach)	34	0.5558	0.6487
	TFPG (Cost function approach) does not Granger Cause EI		0.5503	0.6523
	EI does not Granger Cause TFPG (Production function approach)		1.5497	0.2245
	TFPG (Production function approach) does not Granger Cause EI		0.9092	0.4495
4	EI does not Granger Cause TFPG (Cost function approach)	33	0.4138	0.7969
	TFPG (Cost function approach) does not Granger Cause EI		0.4304	0.7852
	EI does not Granger Cause TFPG (Production function approach)		1.7717	0.1675
	TFPG (Production function approach) does not Granger Cause EI		0.9964	0.4286
5	EI does not Granger Cause TFPG (Cost function approach)	32	1.5747	0.2105
	TFPG (Cost function approach) does not Granger Cause EI		0.3042	0.9048
	EI does not Granger Cause TFPG (Production function approach)		1.1634	0.3596
	TFPG (Production function approach) does not Granger Cause EI		0.5350	0.7474

Source: Author's own estimation

For paper and paper products industry, TFPG is found to be sharply declining in the post-liberalisation era, when it is estimated from both production as well as cost function approach. But in the cost function approach TFPG is negative in the overall period, which may be due to the fact that, producers want to minimise cost for a given level of output. On the other hand, Indian paper and paper products industry has become highly energy intensive in our considered time period. The demand for energy is increasing which would increase the output of the paper and paper products industry. Indian Paper and paper products industry use coal and electricity for combustion and outmoded open-hearth furnace in the production process, which may lead to environmental degradation (CO_2, CO, SO_2, H_2S etc.). But energy intensity is declining in the post-reform period compare to pre-reform period. In a sense, it may be stated that, paper and paper products industry should use the green technology as well as sophisticated machines in the production process. Further, green energy sources, such as, wind energy, solar energy, water energy etc may be used which would reduce the pollution (environmental degradation) and lead to overall sustainable development of this industry.

7. Major Findings, Conclusion, Policy Prescription and Scope of the Further Study

In this study, we have tried to estimate EI and TFPG and its components for paper and paper products industry in Indian over the period 1980–1981 to 2016–2017. We have tried to make a comparative analysis between the pre- and post-reform era with respect to the above-mentioned economic variables. In this study, TFPG has been obtained by production function approach and cost function approach. From this study, we may reach at the following conclusions:

- Both augmented Dickey Fuller (ADF) Test and Phillips Perron Test showed that the data of all the variables are stationary at first difference.
- Co-integration test showed that there is long run dependency between all the pairs of variables.
- The growth of productivity shows sharp decrease from pre- to post-reform period.

- There is technological upgradation in the production process over the time period considered for this study.
- Further it may be noted that liberalisation process had its adverse impact on TFPG for this industry.
- The results reveal that there is a bidirectional causal relationship between EI and TFPG.
- If the government takes proper policy prescriptions to reduce the energy consumption by using modern technology, then we can curb the cost of production and reduce environmental emission and thereby pollution.
- Hence, as a policy measure to improve TFPG of this Indian manufacturing industries, it is imperative to focus on measures, such as ensuring environmental governance, upgrading the industrial structure and use of green technology in the production process.

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Appendix

Results of unit root for paper and paper products industry

	ADF		PP	
	INTERCEPT	INTERCEPT & TREND	INTERCEPT	INTERCEPT & TREND
LNQ	-7.8360 (0.0000) ***	-7.8782 (0.0000) ***	-8.6283 (0.0000) ***	-17.8611 (0.0000) ***
LNC	-7.0176 (0.0000) ***	-6.9106 (0.0000) ***	-7.1662 (0.0000) ***	-7.0484 (0.0000) ***
LNVC	-7.4092 (0.0000) ***	-7.3005 (0.0000) ***	-7.7179 (0.0000) ***	-7.6001 (0.0000) ***
LNL	-6.5359 (0.0000) ***	-6.4574 (0.0000) ***	-6.5528 (0.0000) ***	-6.4574 (0.0000) ***
LNK	-9.5498 (0.0000) ***	-9.4179 (0.0000) ***	-27.8744 (0.0001) ***	-30.5511 (0.0000) ***
LNE	-4.7107 (0.0000) ***	-5.1236 (0.0010) ***	-4.6696 (0.0006) ***	-5.0773 (0.0012) ***
LNPL	-6.1675 (0.0000) ***	-6.0766 (0.0001) ***	-6.1629 (0.0000) ***	-6.0746 (0.0001) ***
LNPK	-5.8644 (0.0000) ***	-5.9004 (0.0001) ***	-5.8760 (0.0000) ***	-5.9219 (0.0001) ***
LNPE	-6.1823 (0.0000) ***	-6.0866 (0.0001) ***	-6.2852 (0.0000) ***	-6.1755 (0.0001) ***
LNQ.LNPL	-6.0248 (0.0000) ***	-6.0867 (0.0001) ***	-6.0272 (0.0000) ***	-6.0864 (0.0001) ***
LNQ.LNPK	-6.0643 (0.0000) ***	-6.0490 (0.0001) ***	-6.1111 (0.0000) ***	-6.0996 (0.0001) ***
LNQ.LNPE	-5.8595 (0.0000) ***	-5.7993 (0.0002) ***	-5.8794 (0.0000) ***	-5.8158 (0.0002) ***
LNQ.LNT	-3.1267 (0.0360) **	-7.0498 (0.0000) ***	-7.0244 (0.0000) ***	-8.2508 (0.0000) ***
LNPL.LNPK	-6.5739 (0.0000) ***	-6.4968 (0.0000) ***	-6.5513 (0.0000) ***	-6.4758 (0.0000) ***
LNPL.LNPE	-1.5232 (0.5100)	-6.1943 (0.0001) ***	-2.6103 (0.1005)	-6.1943 (0.0001) ***
LNPL.LNT	-4.9133 (0.0003) ***	-5.3775 (0.0005) ***	-5.3385 (0.0001) ***	-5.3775 (0.0005) ***
LNPK.LNPE	-7.3072 (0.0000) ***	-7.5002 (0.0000) ***	-7.3072 (0.0000) ***	-7.5476 (0.0000) ***
LNPK.LNT	-5.6093 (0.0000) ***	-5.5265 (0.0004) ***	-5.7853 (0.0000) ***	-5.6650 (0.0002) ***
LNPE.LNT	-4.9763	-5.6548	-4.9737	-5.6677

	(0.0003) ***	(0.0003) ***	(0.0003) ***	(0.0002) ***
LNQ2	-7.9336 (0.0000) ***	-7.9517 (0.0000) ***	-8.9708 (0.0000) ***	-20.0706 (0.0000) ***
LNPL2	-0.8975 (0.7764)	-7.8354 (0.0000) ***	-3.1431 (0.0324) **	-9.3336 (0.0000) ***
LNPK2	-5.9703 (0.0000) ***	-6.0084 (0.0001) ***	-5.9921 (0.0000) ***	-6.0628 (0.0001) ***
LNPE2	-3.6724 (0.0091) ***	-6.1424 (0.0001) ***	-3.6724 (0.0091) ***	-6.2822 (0.0000) ***
LNL.LNK	-9.6034 (0.0000) ***	-9.4723 (0.0000) ***	-27.9256 (0.0001) ***	-31.0537 (0.0000) ***
LNL.LNE	-5.0802 (0.0002) ***	-5.2314 (0.0008) ***	-5.0834 (0.0002) ***	-5.2314 (0.0008) ***
LNL.T	-6.4980 (0.0000) ***	-6.9297 (0.0000) ***	-6.5214 (0.0000) ***	-6.9673 (0.0000) ***
LNK.LNE	-9.4607 (0.0000) ***	-9.3200 (0.0000) ***	-29.3135 (0.0001) ***	-29.7208 (0.0000) ***
LNK.T	-9.5763 (0.0000) ***	-9.4539 (0.0000) ***	-25.8076 (0.0001) ***	-29.9974 (0.0000) ***
LNE.T	-4.6054 (0.0007) ***	-4.5216 (0.0050) ***	-4.5501 (0.0009) ***	-4.4619 (0.0058) ***
LNL2	-6.5673 (0.0000) ***	-6.4912 (0.0000) ***	-6.5851 (0.0000) ***	-6.4912 (0.0000) ***
LNK2	-9.0813 (0.0000) ***	-8.9716 (0.0000) ***	-22.3599 (0.0001) ***	-26.2906 (0.0000) ***
LNE2	-4.6900 (0.0006) ***	-5.0606 (0.0012) ***	-4.6439 (0.0007) ***	-5.0049 (0.0014) ***
(LNK)2/LNY	-8.9486 (0.0000) ***	-8.8525 (0.0000) ***	-20.5488 (0.0001) ***	-26.0013 (0.0000) ***
LNPL.LNK	-7.9678 (0.0000) ***	-7.9004 (0.0000) ***	-7.9676 (0.0000) ***	-7.9004 (0.0000) ***
LNPE.LNK	-9.5716 (0.0000) ***	-9.4505 (0.0000) ***	-14.2188 (0.0000) ***	-14.1022 (0.0000) ***

Source: Authors' estimates using ASI data, figures in the bracket represents probabilistic value
***, ** & * represents the level of significance at 1%, 5% and 10% level respectively