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# Econometric Analysis of Efficiency in Indian Cement Industry

Sarbapriya Ray
Dept. of Commerce, Shyampur Siddheswari Mahavidyalaya,
University of Calcutta, West Bengal, India.
Tel:+91-33-9433180744,E-mail:sarbapriyaray@yahoo.com

**Abstract:**

This article tries to assess total factor productivity performance and efficiency growth pattern for cement industry in India for the period, 1979-80 to 2008-09. Malmquist Data Envelopment Analysis (DEA) has been adopted to estimate different performance measures viz. productivity growth, technological change, and technical efficiency change for the entire period. We have observed that there is an accelerating trend in productivity during post-reform period. Industry also experienced increase in technological progress along with stagnation in technical efficiency. It was found in this study that the increasing technical change along with non- responding technical efficiency change were the main ingredients responsible for accelerating productivity change in India's cement industry. Moreover, the results allow us to conclude that gross mark up and growth in output, foreign direct investment (FDI) variables have significant positive impact on total factor productivity growth but openness impacted negatively which is beyond our expectation. In this sector, there is an urgent need to improve both technical efficiency and technological progress.

**Key words:** Cement, India, Industry, Total Factor Productivity, Malmquist Index, technical change, efficiency change.

## 1. Introduction:

In recent years, the factors affecting economic growth in developing countries have been receiving growing attention. Productivity has long been accepted as an engine of economic growth and determinants of international competitiveness. A higher growth in output due to growth in total factor productivity is preferred to an input driven growth as inputs are subjected to diminishing return. Since the advent of gradual economic liberalization from the 1980s and the overhauling of the *license raj* regime in the 1991-92, Indian economy has been on a higher growth trajectory. Indian industries also have been witnessing profound changes in the basic parameters governing its structure and functioning with economic reforms initiated in 1991.Dramatic and substantial changes have taken place that encouraged competition in the industry by gradual dismantling of licensing rule, reduction in tariff rates, removal of restriction on import of raw materials and technology, price decontrol, rationalization of customs and excise duty, enhancement of the limit of foreign equity participation etc. India's annual growth rate accelerated from a moderate rate of 3.5 percent till 1980s to over 7 percent per annum by 2005. The rising growth pathway has been attributed to extensive reforms in trade as well as industrial policies and supplemented by extensive changes in rules and regulations governing the financial sector. The emphasis on gradualism and evolutionary transition rather than rapid restructuring (Ahluwalia, 1994) as the underlying feature of India's economic reforms and consequent growth momentum has led to large number of research engagements with Indian economy both in India and abroad trying to analyze the underlying growth trends brought about by economic policy reforms.

Impact of economic reforms on manufacturing productivity has been a subject of research inquiry but the findings are controversial and inconclusive. Although there exists voluminous empirical research work regarding nexus between trade liberalization and factor productivity growth, overviews on the link between liberalization and TFPG find inadequate evidence on this issue. Moreover, it has been found that although there have been a large volume of studies carried on upon productivity growth, relatively a small number of studies have been conducted so far in India regarding sources of productivity growth. The Malmquist index decomposes the total productivity growth into 'efficiency change' and 'technical progress'. TFP can be increased by using its existing technology and factor inputs more efficiently which is termed as 'efficiency change'. The TFP of an industry may enhance if the industry adopts innovations or technological improvements, which is referred to as 'technological change'. Therefore, changes in TFP from one period to the next are the products of both efficiency change and technological progress. Most previous studies conducted in India have failed to consider the sources of such changes in productivity growth. This study has been motivated by the generally neglect of the issue of technical efficiency while considering the appropriateness of the economic reforms in promoting productivity and growth of an economy. Past studies on the impact of trade policy reforms of Indian manufacturing sector also neglected the issue of efficiency. The issue of efficiency is relevant because if inefficiency exists and is ignored, productivity growth no longer tells us anything about technical change. Another motivation for this study is the issue of measurement and aggregation problems that are associated with the use of parametric approach to measuring technical efficiency and TFPG. Tybout (1995) has argued that most of the assumptions upon which residual based methods of measuring total factor productivity growth are unrealistic particularly in developing countries which are characterized by rigidities and distortions. It is against this backdrop that this study employs a non-parametric approach so as to overcome some of these difficulties.

In particular, the study attempts to quantify the sources of productivity growth in India's cement industry. Therefore, the objective of the study is to measure productivity growth by decomposing it into technical change and technical efficiency change in India's cement industry. Specifically, this study tries to quantify the level of technical efficiency and technical change in this particular manufacturing sector and examines the determinants of TFPG.

The paper is structured as follows: the methodology to estimate productivity growth by Malmquist productivity index is depicted in Section 2. The result of productivity growth in India's cement industry is evaluated in Section 3. Section 4 analyses determinants of TFPG and section 5 depicts summary and conclusion.

## 2. Methodology:

*2.1. Description of data and measurement of variables:*

The present study is based on industry-level time series data taken from several issues of Annual Survey of Industries, National Accounts Statistics, *CMIE* and Economic Survey, Statistical Abstracts (several issues), *RBI* Bulletin on Currency and Finance, Handbook of Statistics on Indian Economy, and Office of Economic Advisor, Ministry of Industry etc covering a period of 30 years commencing from 1979-80 to 2008-09. Selection of time period is largely guided by availability of data.[2] In the ASI, the cement industry is conveniently classified under 2 sub-sectors for which consistent data are available, at three and four-digit industrial classification levels. The study uses data from the annual reports of 2 leading sub sectors of the industry comprising of 32 firms to observe their performances since1979-80.The data were also taken from *PROWESS* database (*CMIE)*, which provides balance sheet of the companies registered with the Bombay Stock Exchange. Selection of time period is largely guided by availability of data.

The output in the current model is the modified gross value of output(y) defined as the total output produced by the firm. In order to avoid over estimation due to ignoring contribution of material input on TFP, a third variable of intermediate inputs [material including energy input (Appendix-1)] [3] has been

[2] Till 1988 – 89, the classification of industries followed in ASI was based on the National Industrial classification 1970 (NIC 1970). The switch to the NIC-1987 from 1989-90 and also switch to NIC1998 requires some matching. Considering NIC1987 as base and further NIC 1998 as base, cement industry has been merged accordingly. For price correction of variable, wholesale price indices taken from official publication of CMIE have been used to construct deflators.

[3] Earlier studies that have not treated material including energy as separate factor of production, has failed to pick-up significant economies that are likely to generate in the use of such input. Jorgenson (1988) has observed that in a three input production framework, the contribution of intermediate inputs like material, energy etc. are significant sources of

incorporated in the value-added function as such to obtain gross output. Pradhan and Barik (1999) argued that the gross output, instead of value added, appears to be the appropriate choice of TFPG estimation in India. Generally, TFP growth estimates based on value added terms are over estimated since they ignore the contribution of intermediate inputs on productivity growth (Sharma, 1999). Therefore, modified gross value of output so calculated has been used as a measure of output suitably deflated by wholesale price index of manufactured and material, labour and fixed capital stocks are our aggregate input proxies. Total number of persons engaged in India's cement industry is used as a measure of labor inputs as is reported in ASI which includes production workers and non-production workers like administrative, technical and clerical staff (Goldar, 2004). Deflated gross fixed capital stock at 1981-82 prices is taken as the measure of capital input. The estimates are based on perpetual inventory method (Appendix-A-2) and following the same line as adopted in deflating energy input, the reported series on materials has been deflated to obtain material inputs at constant prices.

To verify the extent to which Indian cement industry is engaged in international trade, we have obtained figure for trade openness [(Import + export)/ Gross total output values of the domestic industries]. Trade openness has been calculated from data available in Statistical Abstract & ASI. FDI incorporates the import of capital goods by the multinational corporations (MNCs) and the transfer of managerial and technical skills resulting from the link between parent companies and local subsidiaries of MNCs. The figures for FDI over our study period have been collected from Handbook of Statistics on Indian Economy, Statistical Abstracts and World Development Report.

This paper covers a period of 30 years from 1979 -80 to 2008-09.The entire period is sub-divided into two phases as pre-reform period (1979 -80 to 1991-92) and post-reform period (1991-92 to 2008-09), sub-division of period being taken logically as such to assess conveniently the impact of liberalization on TFPG .

**2.2. Econometric specification:**

Malmquist TFP Index:

Productivity change over time is an indicator of the performance of an industry. In order to assess the performance of the Indian cement industry, the Malmquist (output-based) productivity index (MPI) will be used to measure the productivity change and to decompose this productivity change into the technical change index (TECHCH) and the technical efficiency change index (EFFCH). And technical efficiency changes was further decomposed into pure technical efficiency (PEEFCH) and scale efficiency (SECH) components using the Data Envelopment Analysis (DEA) framework of Färe *et al* (1994).

Data Envelopment Analysis is a linear-programming methodology where we use input and output data for Decision Making Units (DMU). In our study, each sector is a Decision Making Unit (DMU). The DEA methodology was initiated by Charnes et al. (1978) who built it on the frontier concept started by Farell (1957). The methodology used in this paper is based on the work of Fare et. al. (1994) and Coelli et. al.(1998). We have used the DEA- Malmquist Index to calculate the total factor productivity growth in Indian cement industry. The Malmquist TFP Index measures change in total output relative to input. This idea was developed by a Swedish statistician Malmquist (1953). It is a suitable methodology because of following reasons (Mahadevan, 2001). First, the data envelopment analysis approach is an improvement over Translog index approach. In Translog approach, technical inefficiency is ignored and it calculates only technical change which is wrongly interpreted as TFP growth. But, in the literature of DEA productivity, total factor productivity growth (TFPG) is composed of technical change and technical efficiency. Second, DEA also identifies the sources of TFP growth which will help the policy makers to identify the specific source of low TFP growth. Another advantage of nonparametric nature of DEA is that it reveals best practice frontier rather than central tendency properties of frontier. In DEA, there is also no need to estimate any production function. It only requires data input and output quantities and price data is not needed to

output growth.

determine appropriate weights as is necessary with either econometric or index number approaches (Lambert and Parker 1998). This Malmquist productivity index can be decomposed into efficiency change, technical change and total factor productivity growth. Total factor productivity growth is geometric mean of efficiency change and technical change. We have used the DEAP 2.1 software developed by Coelli (1996) to compute these indices.

Following Fare et al. (1994) among others, the output oriented Malmquist productivity change index will be adopted for this study. Output orientation refers to the emphasis on the equi-proportionate increase of outputs, within the context of a given level of input. The output based Malmquist productivity change index may be formulated as:

$M_j^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = [D_j^t(y^{t+1}, x^{t+1}) / D_j^t(y^t, x^t) \text{ X } D_j^{t+1}(y^{t+1}, x^{t+1}) / D_j^{t+1}(y^t, x^t)]^{1/2}$ -------------------(1)

Where M is the productivity of most recent production point (xt+1,yt+1) relative to earlier production point($x^t$,$y^t$).D's are output distance functions. Thus, a value greater than unity will indicate positive factor productivity growth between two periods. Following Fare et.al(1994), an equivalent way of writing this index is :

$M_j^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = D_j^{t+1}(y^{t+1}, x^{t+1}) / D_j^t(y^t, x^t) \text{ X}[D_j^t(y^{t+1}, x^{t+1}) / D_j^{t+1}(y^{t+1}, x^{t+1}) \text{X} D_j^t(y^t, x^t) / D_j^{t+1}(y^t, x^t)]^{1/2}$ ------------------------------------------------------------------------------------------ ----------------------- (2)

In equation (2),the ratio outside the brackets is equal to the change of technical efficiency between t and t+1. In other words, it represents the change in the relative distance of the observed production from the maximum potential production. The components inside the bracket of equation (2) is the geometric mean of the two productivity indices and represent the shift in production technologies (technical change) between time t and t+1.

That is:

Technical Efficiency change (EFFCH)= $D_j^{t+1}(y^{t+1}, x^{t+1}) / D_j^t(y^t, x^t)$ -----------------------------------------(3)

Technical change (TECHCH)= $[D_j^t(y^{t+1}, x^{t+1}) / D_j^{t+1}(y^{t+1}, x^{t+1}) \text{ X } D_j^t(y^t, x^t) / D_j^{t+1}(y^t, x^t)]^{1/2}$-------------(4)

Efficiency change in equation (3) can further be decomposed as the product of two components- pure efficiency change and scale efficiency change as follows (Fare et.al,1994):

$D^{t+1}(y^{t+1}, x^{t+1}) = D_j^{t+1}(y^{t+1}, x^{t+1}) / D_j^t(y^t, x^t) \text{ X } [D_j^{t+1}(y^{t+1}, x^{t+1}) / D_j^t(y^t, x^t) \text{ X } D_j^t(y^t, x^t) / D_j^{t+1}(y^{t+1}, x^{t+1})]$ ----------------------------------------------------------------------------------------------------------------------(5)

The ratio outside the brackets in equation (5) represents the pure efficiency change, subject to a distance function ($D_j$) between time t and t+1 and is denoted by PECH hereafter. In other word,

Pure Technological Efficiency Change (PECH)= $D_j^{t+1}(y^{t+1}, x^{t+1}) / D_j^t(y^t, x^t)$ ------------------------------(6)

The components inside the brackets of equation (5) represents effect of optimal size and not economies of scale on productivity and is expressed as SECH which can be readily derived by dividing EFFCH of equation(3) by PECH of equation(6) and would not involve its own contribution of additional distance functions. Therefore, Scale Efficiency Change (SECH) =EFFCH / PECH ---------------------------------(7)

After incorporating equation (5) to (7) in equation (2), we obtain the complete decomposition of MPI .

MPI=(EFFCH) x (TECHCH).

Therefore, we can decompose the total factor productivity growth in following way as well.

MPI = Technical Efficiency Change X Technical change

(Catching up effect) (Frontier Effect)

MPI is the product of measure of efficiency change (catching up effect) at current period *t* and previous period *s* (average geometrically) and a technical change (frontier effect) as measured by shift in a frontier over the same period. Technical efficiency change (Catch up) measures the change in efficiency between current (t) and next (t+1) period, while technological change (innovation) captures the shift in frontier technology. The catching up effect measures that how much a firm is close to the frontier by capturing extent of diffusion of technology or knowledge of technology use. On the other side frontier effect measures the movement of frontier between two periods with regards to rate of technology adoption.

As expressed by Squires and Raid (2004), technological change is the development of new product or development of new technologies that allows methods of production to improve and results in shifting upward of production frontier. More specifically, technological change includes both new production processes, called process innovation and discovery of new products, called product innovation. With process innovation, firms figure out more efficient ways of making existing products allowing output to grow at a faster rate than economic inputs are growing which initiates decline in cost of production over time. As producers gain experience at producing something, they become more or more experience in it .Labour finds new way of doing things so that relatively minor modifications to plant and procedures can contribute to higher levels of productivity.

The DEA-Malmquist TFP Index does not assume that all the firms or sectors are efficient so, therefore any firm or sector can be performing less than the efficient frontier. In this methodology, we will use the output oriented analysis because most of the firms and sectors have their objective to maximize output in the form of revenue or profit. It is also assumed that there is constant return to scale (CRS) technology to estimate distance functions for calculating Malmquist TFP index and if technology exhibits constant return to scale , the input based and output based Malmquist TFP Index will provide the same measure of productivity change.

Another merit of defining the MPI using the output distance function $D^t$ is that the MPI and its corresponding components (EFFCH, PECH,SECH,TECHCH) are all calculated in an index form and have a threshold value of one. In other words, if a derived value is equal to one, it indicates that an industry's performance remains unchanged in that performance measure. A value greater than one represents an improvement and a value less than one indicates a decline. The product of index components of TECHCH, PECH and SECH amounts to final MPI.

To determine the final MPI, a close examination of equation (2) and (5) reveal that we have to compute TECHCH, EFFCH and PECH and then derive SECH by dividing EFFCH by PECH .Each output distance function corresponds to one particular output oriented DEA linear programming .Among TECHCH, EFFCH and PECH, there are six output distance functions and thus a total of six different DEA models have to be formulated and solved:

$$D^{t+1}(y^{t+1}, x^{t+1}), D^{t+1}(y^{t}, x^{t}), D^{t}(y^{t}, x^{t}), D^{t}(y^{t+1}, x^{t+1}), D_j^{t+1}(y^{t+1}, x^{t+1}), D_j^{t}(y^{t}, x^{t}) \text{-------(9).}$$

It should be mentioned that the returns to scale properties of technology is very important in total factor productivity measurement as far as Malmquist index is concerned. Malmquist index might not correctly measure TFP changes when variable returns to scale (VRS) assumed for the technology as Grifell-Tatjé and Lovell, 1996, illustrated. Therefore, it is important to impose constant returns to scale (CRS) on any technology which is used to estimate distance functions regarding the calculation of Malmquist TFP index.

**3. Empirical results of Malmquist TFP growth:**

In this section, we will discuss the productivity change of cement industry in India, measured by Malmquist Total Factor Productivity (TFPCH) Index and assign the changes in total factor productivity to technological change (TECHCH) and efficiency change (EFFCH). We have also attempted to attribute any change in efficiency (EFFCH) to change in pure technical efficiency (PECH) and /or scale efficiency change (SECH). The summary of annual means of TFPCH, TECHCH and EFFCH for the entire period is presented in table 2.Year 1979-80 being the initial and reference year, the Malmquist TFPCH and its components take an initial score of 1 for the year 1979-80.

[Insert Table-1 here]

The Malmquist result suggests that India's cement industry exhibits positive growth rate of 0.88% during pre-reform period (1980-81 to 1991-92) and the growth rate has further accelerated during the post reform period which is estimated to be 2.22% . Cement sector has exhibited a slight efficiency improvement from -0.39% in pre-reform period to -0.06% during post-reform period which is an indication of efficiency change in positive direction during post-reform period. From table 1, it is apparent that technological changes in cement sector have accelerated also during post- reform period (1991-92 to 2008-09) at 2.22% from a positive growth rate of 0.88% as has been evidenced in pre- reform period.

[Insert Table-2 here]

A summary description of the average performance of each sub sector for the period, 1979-80 to 2008-09 is revealed in Table -2. As mentioned earlier, if the value of the Malmquist index or any of its components is less than unity, this denotes a deterioration in performance, whereas values greater than unity denote improvement in the relevant performance. The last line of table-2 shows that for the entire sample on an average, productivity increased slightly over the 30 years studied. The growth in TFP accelerated during the entire period on an average 0.30%.The improvement in growth is largely due to the effect of technological innovation (TECHCH) which also increased by 0.3% whereas technical efficiency remains stagnated during this time period. This result reveals that acceleration in the industry's TFPG is due to their productivity based frontier capability. On the other side, it can be said that since the technical change is more than unity, it has a favourable effect on the overall TFP growth. The overall technical change in the industry is more than 1 which is a main reason for augmenting the total factor productivity for cement sector. Technical efficiency change is the result of pure technical efficiency change and scale efficiency change. With regards to pure efficiency change, it is one or more than one in most of years. In case of Scale efficiency change, value close to unity shows that in most of the years, industry is operating at optimum scale. Therefore, both Scale efficiency and pure technical efficiency have contributed to the improvement in Technical efficiency.

[Insert Table-3 here]

Table3 above presents that total factor productivity growth during pre-reform period shows positive TFP growth rate which is posted as at 1.06% and in post-liberalization period, it further enhanced to 1.55%. Table 3 displays the average growth rates of EFFCH, TECHCH and TFP(in percentage term) in each sub-sector of India's cement industry. Table 3 illustrates that the overall growth rate of TFP is slightly increasing in the post-reform period (1.55 %) than in the pre-reform period (1.06%). Cement, lime and plaster sector (sub-sector 1) evidenced positive TFP growth in the post-reform period, whereas the same sub-sector (1) had negative TFP growth in the pre-reform period. Only sub sector 2 (Asbestos cement and other cement products) evidenced positive and increasing TFP growth in both periods. In the post-reform period, TECHCH increases abruptly in positive fashion and EFFCH slightly decreases. As a result, since there was increase in TECHCH, it results in a modest increase in TFP. After economic reform, slight efficiency improvement is noticed in sub sector 1 whereas sub sector 2 shows slight decline in efficiency change. But, all sub-sectors display technical progress during post-reforms period.

**4. Determinants of TFPG:**

After calculating the TFP growth in Indian cement industry at sub sectors level, it is our prime objective to determine the determinants which are responsible for TFP growth in the said industry. In our study, we have utilized growth in output and gross mark up as important determinants of TFP growth. Recent literature stresses the importance of foreign sources of capital as determinants of TFP growth.( for instance, Coe and Helpman,1995; Crespo, Martin and Valazquez,2002;Savvides and Zachriadis,2005). Therefore, we have incorporated FDI and trade openness as explanatory variables in our model. We regress the values for growth in TFP measured using Malmquist index on trade openness, FDI, gross mark up and growth in output and subsequently we regress the values for growth in TECHCH and EFFCH on these explanatory variables.

$$TFPG_{it} = \beta + \sum_{t=1}^{30} a_1 OPEN + \sum_{t=1}^{30} a_2 FDI + \sum_{t=1}^{30} a_3 GO + \sum_{t=1}^{30} a_4 GMUP + DUMLIB$$

$$TECHCH_{it} = \beta + \sum_{t=1}^{30} a_1 OPEN + \sum_{t=1}^{30} a_2 FDI + \sum_{t=1}^{30} a_3 GO + \sum_{t=1}^{30} a_4 GMUP + DUMLIB$$

$$EFFCH_{it} = \beta + \sum_{t=1}^{30} a_1 OPEN + \sum_{t=1}^{30} a_2 FDI + \sum_{t=1}^{30} a_3 GO + \sum_{t=1}^{30} a_4 GMUP + DUMLIB$$

Trade Openness ratio (OPEN) =[Import+ Export] / Gross total output values of the domestic industries

GO represents growth in output and FDI is the gross foreign direct investment.

Gross-mark-up (GMUP)=Gross value added minus total emolument / Gross output

DUMLIB =Dummy variable of the post liberalization period (taking value one for 1991-92 and onward and zero for earlier years).

Helpman (1991) and Eaton& Kortum (2001) hypothesized that direct import of capital and intermediate goods is a channel of transmission of foreign technology and consequently eventual growth in TFP. In our study, trade openness has a significant negative value, implying that high levels of imports and exports negatively impacted TFP growth over the entire study period. Negative coefficients of openness only explain -0.0143% of the growth in TFP.This means that trade openness is not the main factor affecting TFP. On the other hand, FDI has significant positive impact on TFP growth. This means that FDI is crucial for capital accumulation as well as it guarantees productivity growth. Externally developed technology and production methods coupled with foreign policy initiatives have been a more important determinant of productivity growth. FDI played positive role in technology change but negligible role in efficiency change. Openness has a significant negative value for efficiency change but is insignificant in explaining technical change.

[Insert Table-4 here]

Significant positive association between GM and TFPG is noticed in our estimate in table-4 implying that with the increase in TFPG, gross mark up enhances. Similar significant association is observed between gross mark-up and efficiency change but gross mark up has insignificant negative impact on technological changes. A significant positive relationship between output growth and TFP growth is evident from our analysis which indicates that with the growing degree of output, productivity is gradually increased. The coefficient of liberalization dummy is found to be negative and statistically insignificant equation-1 .This variable, when incorporated into the equation along with other explanatory variables, captures the net effect of all factors connected with economic reforms other than those which are directly included in the equation.

**5. Summary and conclusions:**

This study attempted to examine the sources of productivity growth in India's cement industry over the sample period 1979-80-2008-09 by applying Malmquist productivity index. The result suggests that there is an accelerating trend in productivity growth during post-reform period. TFP growth is mainly contributed by technical change and not by efficiency change. Moreover, Gross mark up and growth in output, FDI variables have significant positive impact on total factor productivity growth but openness impacted negatively which is beyond our expectation. The present study makes important contribution to the literature on growth empirics in India.

There are some limitations in the study which should be addressed in further research. First, improvement in the research regarding productivity growth in India's cement sector may be achieved through adopting a better measure of capital, which should properly reflect the flow of capital input adjusted by the quality of its stock. In this case, replacement value of capital stock corrected for capital utilization should be chosen for more convincing analysis. Second, number of employees should be adjusted by labor quality to have an accurate measure of labor input. Finally, the results of TFP growth and technical progress could be significantly improved if more data is available and included in computation procedure.

The research suggests that the cement industry in India must augment total factor productivity and attempts should be made to present a stable pattern to the productivity growth. In this sector, there is an urgent need to improve both technical efficiency and technological progress. Development of a comprehensive plan for modernization of all existing cement plants, especially mini plants should be given priority in order to be competitive in global perspective.

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**Appendix:**

**Appendix: A-1 Energy Inputs: -** Industry level time series data on cost of fuel of Indian cement sector have been deflated by suitable deflator (base 1981-82 = 100) to get real energy inputs. An input output table provides the purchase made by manufacturing industry from input output sectors. These transactions are used as the basis to construct weight and then weighted average of price index of different sectors is taken. Taking into consideration 115 sector input -output table (98-99) prepared by CSO, the energy deflator is formed as a weighted average of price indices for various input-output sectors which considers the expenses incurred by manufacturing industries on coal, petroleum products and electricity as given in I-O table for 1998-99. The WIP indices (based 1981- 82) of Coal, Petroleum and Electricity have been used for these three categories of energy inputs. The columns in the absorption matrix for 66 sectors belonging to manufacturing (33- 98) have been added together and the sum so obtained is the price of energy made by the manufacturing industries from various sectors. The column for the relevant sector in the absorption matrix provides the weights used.

**Appendix: A-2 Capital Stock: -** The procedure for the arriving at capital stock series is depicted as follows:

First, an implicit deflator for capital stock is formed on NFCS at current and constant prices given in NAS. The base is shifted to 1981-82 to be consistent with the price of inputs and output.

Second, an estimate of net fixed capital stock (NFCS) for the registered manufacturing sector for 1970-71 (benchmark) is taken from National Accounts Statistics. It is multiplied by a gross-net factor to get an estimate of gross fixed capital stock (GFCS) for the year 1970-71. The rate of gross to net fixed asset available from RBI bulletin was 1.86 in 1970-71 for medium and large public Ltd. companies. Therefore, the NFCS for the registered manufacturing for the benchmark year (1970-71) as reported in NAS is multiplied by 1.86 to get an estimate of GFCS which is deflated by implicit deflator at 1981-82 price to get it in real figure. In order to obtain benchmark estimate of gross real fixed capital stock made for registered manufacturing, it is distributed among various two digit industries (in our study, cement industry) in proportion of its fixed capital stock reported in ASI, 1970-71)

Third, from ASI data, gross investment in fixed capital in cement industries is computed for each year by subtracting the book value of fixed in previous year from that in the current year and adding to that figure the reported depreciation on fixed asset in current year. (Symbolically, $I_t = (\beta_t - \beta_{t-1} + D_t) / Pt$) and subsequently it id deflated by the implicit deflator to get real gross investment.

Fourth, the post benchmark real gross fixed capital stock is arrived at by the following procedure. Real gross fixed capital stock (t) = real gross fixed capital stock (t – 1) + real gross investment (t). The annual rate of discarding of capital stock ($D_{st}$) is assumed to be zero due to difficulty in obtaining data regarding $D_{st}$.

**Table – 1: Change in total factor productivity and its components**

| Pre reforms period (1979-80) | | | | | | Post reforms period(1991-92 to 2008-09) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | Components of TFPG | | Components of Technical Efficiency Change | | | | Components of TFPG | | Components of Technical Efficiency Change | | |
| | EFFCH | TECH CH | PECH | SECH | MTFPCH | YEAR | EFFCH | TECHC H | PECH | SECH | MTFPC H |
| 1979-80 | 1 | 1 | 1 | 1 | 1 | 1991-92 | 0.948 | 1.148 | 1.000 | 0.948 | 1.088 |
| 80-81 | 1.000 | 1.060 | 1.000 | 1.000 | 1.060 | 92-93 | 1.036 | 1.029 | 1.000 | 1.036 | 1.066 |
| 81-82 | 1.000 | 0.981 | 1.000 | 1.000 | 0.981 | 93-94 | 1.018 | 0.942 | 1.000 | 1.018 | 0.959 |
| 82-83 | 1.000 | 1.043 | 1.000 | 1.000 | 1.043 | 94-95 | 1.001 | 1.878 | 1.000 | 1.001 | 1.879 |
| 83-84 | 0.983 | 1.014 | 1.000 | 0.983 | 0.997 | 95-96 | 0.986 | 0.907 | 1.000 | 0.986 | 0.894 |
| 84-85 | 0.988 | 1.231 | 0.999 | 0.989 | 1.216 | 96-97 | 1.014 | 0.987 | 1.000 | 1.014 | 1.001 |
| 85-86 | 1.029 | 0.948 | 1.001 | 1.028 | 0.976 | 97-98 | 1.000 | 0.906 | 1.000 | 1.000 | 0.906 |
| 86-87 | 0.993 | 0.869 | 1.000 | 0.993 | 0.862 | 98-99 | 0.982 | 0.965 | 1.000 | 0.982 | 0.948 |
| 87-88 | 1.007 | 1.033 | 1.000 | 1.007 | 1.040 | 99-'00 | 1.017 | 1.013 | 1.000 | 1.017 | 1.030 |
| 88-89 | 0.966 | 0.987 | 1.000 | 0.966 | 0.954 | 00-01 | 1.001 | 0.992 | 1.000 | 1.001 | 0.993 |
| 89-90 | 1.035 | 0.983 | 1.000 | 1.035 | 1.017 | 01-02 | 1.000 | 0.934 | 1.000 | 1.000 | 0.934 |
| 90-91 | 1.000 | 0.881 | 1.000 | 1.000 | 0.881 | 02-03 | 1.000 | 0.989 | 1.000 | 1.000 | 0.989 |
| 91-92 | 0.948 | 1.148 | 1.000 | 0.948 | 1.088 | 03-04 | 1.000 | 1.024 | 1.000 | 1.000 | 1.024 |
| | | | | | | 04-05 | 1.000 | 0.894 | 1.000 | 1.000 | 0.894 |
| | | | | | | 05-06 | 1.000 | 0.989 | 1.000 | 1.000 | 0.989 |
| | | | | | | 06-07 | 0.994 | 0.939 | 1.000 | 0.994 | 0.934 |
| | | | | | | 07-08 | 1.006 | 1.042 | 1.000 | 1.006 | 1.049 |
| | | | | | | 08-09 | 0.987 | 0.833 | 1.000 | 0.987 | 0.822 |
| Mean | 0.9961 | 1.0137 | 1 | 0.9961 | 1.0088 | Mean | 0.9994 | 1.2283 | 1 | 0.9994 | 1.0222 |

**Source: estimated by author.**

**Table – 2: Mean efficiency growth rate of Individual sub sector over time (:1979-80 to 2008-09)**

| Sub sector | EFFCH | TECHCH | MTFPCH |
|---|---|---|---|
| 1. Cement, lime and plaster | 0.999 | 0.986 | 0.985 |
| 2. Asbestos cement and other cement products | 1.000 | 1.021 | 1.021 |
| *Mean* | 1.000 | 1.003 | 1.003 |

[Note that all Malmquist index averages are geometric means]

**Table – 3:Growth rate of Malmquist productivity, technical change and technical efficiency change**

| Sub sector | Pre-reform period (1979 -80 to 1991 – 92) | | | Post- reform period (1991 –92 to 2008 –09) | | | Entire period (1979-80 to 2008 – 09) | | |
|---|---|---|---|---|---|---|---|---|---|
| | EFFCH | TECHCH | MTFPCH | EFFCH | TECHCH | MTFPCH | EFFCH | TECHCH | MTFPCH |
| 1.Cement,lime and plaster | -0.78 | -0.60 | -1.36 | -0.09 | 0.53 | 0.44 | -0.05 | -0.15 | -0.18 |
| 2.Asbestos cement and other cement products | 0.069 | 3.49 | 3.48 | 0.01 | 4.26 | 4.28 | 0.04 | 3.27 | 3.28 |
| Mean | -0. 35 | 1. 45 | 1. 06 | -0. 04 | 2. 39 | 2. 36 | -0. 01 | 1. 56 | 1. 55 |

**Source: Own estimate**

**Table – 4: Determinants of TFP, EFFCH, TECHCH**

| Variables | Parameter estimates | | |
|---|---|---|---|
| | MTFPI(Equation-1) | EFFCH(Equation-2) | TECHCH(Equation-3) |
| Intercept | -0.0022<br>(-0.215) | 0.082<br>(0.82) | 0.0792<br>(0.77) |
| Trade Openness | -0.0143<br>(-2.108) | -0.718<br>(-2.54) | -0.726<br>(-0.55) |
| FDI | 0.04<br>(3.16) | 0.0239<br>(1.52) | 0.0213<br>(2.049) |
| Growth in Output | 0.00019<br>( 2.82) | 0.000154<br>(0.066) | -0.0043<br>(-1.87) |
| Gross Mark-up | 0.0783<br>(2.34) | 0.21<br>(2.091) | -0.1109<br>(0.048) |
| Dumlib | -0.9938<br>(-45.44) | 1.11<br>(5.04) | 1.10<br>(5.03) |
| $R^2$ | 0.66 | 0.38 | 0.38 |

**Source: Own estimate**